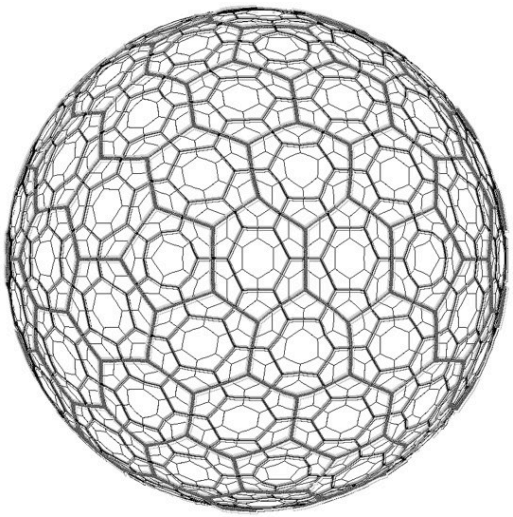
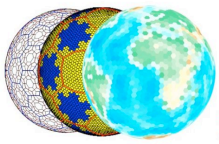


DGGRID version 6.1

User Documentation for
Discrete Global Grid Generation Software

Kevin Sahr



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DGGRID is provided purely as a research tool. While we believe it performs as described in this documentation, we do not guarantee or warranty **DGGRID** for any specific use or purpose. Users of **DGGRID** must agree to take full responsibility for any damages that may occur through such use and agree not to hold the creators of **DGGRID** liable for any such damages.

DGGRID is fully in the public domain and may be used for any purpose with no restrictions. We do, however, ask that you acknowledge your use of **DGGRID** as applicable.

Credits

DGGRID was entirely written in C++ by Kevin Sahr with the following exceptions:

- **DGGRID** uses a (slightly modified) version of Alan Murta's General Polygon Clipping (GPC) library. See http://www.cs.man.ac.uk/aig/staff/alan/software/ for more details.

- Lian Song wrote the original versions of some of the spherical trigonometry routines and the original implementation of the ISEA projection.

- The gnomonic projection code is adapted from Gerald Evanden's PROJ.4 library. See http://everest.hunter.cuny.edu/mp/software.html for more details.

- **DGGRID** uses George Marsaglia's multiply-with-carry "Mother-of-all-RNGs" pseudo-random number generation function.

- Jesse Williamson ported the code to gcc 4.x and added the KML output support.

- The Fuller projection code was written in **R** by Denis White and then ported to C++ by James Scharmann.

The **DGGRID** specifications were developed by (in alphabetical order): A. Ross Kiester, Tony Olsen, Barbara Rosenbaum, Kevin Sahr, Ann Whelan, and Denis White.

DGGRID version 6.1 was released May 28, 2013

www.discreteglobalgrids.org

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1. Introduction

DGGRID is a software package designed to generate icosahedral discrete global grids (DGGs) [Sahr et al., 2003]. The current beta version of **DGGRID** supports two operations. A single execution of **DGGRID** can either generate a user a user-specified DGG, or output a table of grid characteristics for the specified DGG.

DGGRID is designed to be run from the Unix command line. **DGGRID** requires a single command line argument, the name of a "metafile," which is a text file that describes the actions that **DGGRID** is to perform in that run. Thus **DGGRID** is executed by typing at the command line:

```
dggrid metaFileName.meta
```

The metafile consists of a series of key-value pairs that tell **DGGRID** how to proceed. The format of this metafile is described in the next section. The rest of the sections in this documentation give more detail on setting up metafile parameters to control the execution of **DGGRID**.

2. Metafile Format

Metafiles are text files in which each line is either a comment, a blank line, or a key-value pair that designates the value of a parameter for **DGGRID**. Blank lines are ignored by **DGGRID**. Lines beginning with '#' are comments and are also ignored by **DGGRID**.

A parameter is specified by a single line of the form:

parameterName value

Parameter names are not case sensitive. A parameter can be of one of five types. The five parameter types, with a description of their legal values, are:

1. **boolean**. Legal values are **TRUE** and **FALSE** (case sensitive).
2. **integer**. Any integer is a legal value.
3. **double**. Any real number, specified in decimal form, is a legal value.
4. **string**. The remainder of the line following the parameter name is interpreted as the value.
5. **choice**. Legal values consist of one of a finite set of keywords specific to that parameter. The values of choice parameters are not case sensitive but by convention are usually written in all capital letters.

Some parameters are only used for specific operations or when specific other parameter conditions prevail. All parameters have a default value which is used if no value is specified. Detailed information on each parameter is given in the following sections and in **Appendix A**. Repeating a parameter specification within the same metafile over-writes the previously specified value; the last value given for a particular parameter will be used.

Note that a number of parameters from previous versions of **DGGRID** are still active in the code but are not described in this documentation; that is because those parameters have not been fully integrated with the new features in this beta release. Those parameters will be fully restored in a future release.

See the example metafiles that come with the **DGGRID** source code distribution for examples of parameter specification.

3. General Parameters

The version 6.0 beta version of **DGGRID** has 2 distinct modes of operation. The operation is specified using the **choice** parameter `dggrid_operation`. The allowable values for this parameter are: `GENERATE_GRID` (the default), which tells **DGGRID** to performs grid generation, and `OUTPUT_STATS`, which tells **DGGRID** to output a table of grid characteristics. **Sections 5** and **6** describe the parameters that control the `GENERATE_GRID` operation, while **Section 7** describes the `OUTPUT_STATS` operation. Additional operation modes (similar to those found in **DGGRID** version 4.3b) will appear in a future release.

All operation modes require the specification of a single DGG. The parameters for specifying a DGG are described in **Section 4**.

For all operations the **integer** parameter `precision` (default 7) specifies the number of digits to the right of the decimal place **DGGRID** is to use when outputting floating point numbers.

The **integer** parameter `verbosity` is used to control the amount of debugging information which is output by **DGGRID**. Valid values are from 0 to 3. The default value, 0, gives minimal output, such as the value of all parameter settings. It is not recommended that you increase this value.

4. Specifying the DGG

Background

As described in [Sahr et al., 2003], a DGG system can be specified by a set of independent design choices. The first design choice is the desired base polyhedron; **DGGRID** can generate DGGs that have an icosahedron as their base polyhedron. The remaining primary design choices are:

1. The orientation of the base polyhedron relative to the earth.
2. The hierarchical spatial partitioning method defined symmetrically on a face (or set of faces) of the base polyhedron. This usually includes specifying the cell topology and an *aperture*, which determines the area ratio between cells at sequential resolutions.
3. The transformation between each face and the corresponding spherical surface.
4. The resolution (or degree of recursive partitioning).

The current version of **DGGRID** supports DGGs that use either the Icosahedral Snyder Equal Area (ISEA) projection [Snyder, 1992] or the icosahedral projection of R. Buckminster Fuller [1975] (as developed analytically by Robert Gray [1995] and John Crider [2008]). **DGGRID** can generate grids with cells that are triangles, diamonds, or hexagons. Grids with a triangle or diamond topology must use an aperture of 4, while hexagon grids can use an aperture of 3, 4, or a mixed aperture sequence consisting of some number of aperture 4 resolutions followed by aperture 3 resolutions down to the desired resolution. **DGGRID** can also generate the **Superfund_500m** DGG (see **Appendix D**), which is a mixed aperture hexagonal grid that uses the Fuller projection and a condensed hierarchical indexing.

Detailed information about the parameters that specify each of the DGG design choices are given below, along with a discussion on specifying the spherical earth radius. Appendix **C** gives a table of DGGs which can be generated by **DGGRID**; the table lists the parameters for each DGG and the corresponding characteristics of each resulting grid.

Preset DGG Types

DGGRID provides a number of preset DGG types for your use. A preset type can be chosen by specifying one of the following values for the **choice** parameter `dggs_type`:

`CUSTOM` (default) - indicates that the grid parameters will be specified manually (see below)
`SUPERFUND` - the **Superfund_500m** grid (see **Appendix D**)
`ISEA4T` - ISEA projection with triangle cells and an aperture of 4
`ISEA4D` - ISEA projection with diamond cells and an aperture of 4
`ISEA3H` - ISEA projection with hexagon cells and an aperture of 3
`ISEA4H` - ISEA projection with hexagon cells and an aperture of 4
`ISEA43H` - ISEA projection with hexagon cells and a mixed sequence of aperture 4 resolutions followed by aperture 3 resolutions

`FULLER4T` - FULLER projection with triangle cells and an aperture of 4
`FULLER4D` - FULLER projection with diamond cells and an aperture of 4
`FULLER3H` - FULLER projection with hexagon cells and an aperture of 3
`FULLER4H` - FULLER projection with hexagon cells and an aperture of 4
`FULLER43H` - FULLER projection with hexagon cells and a mixed sequence of aperture 4 resolutions followed by aperture 3 resolutions

Each preset grid type sets appropriate values for all of the parameters that specify a DGG. The default values for each preset grid type are given in **Appendix B**. These default preset values can be overridden by explicitly setting the desired individual parameters in your metafile (see below). Note that all preset grid types have a default resolution of 9; a desired DGG resolution can be specified using the parameter `dggs_res_spec` (see below).

Manually Setting DGG Parameters

The following parameters are used to describe a specific DGG instance.

1. Specifying the orientation: The orientation of a DGG base icosahedron relative to the earth can be specified explicitly, randomly determined, or set so that a specified point is maximally distant from icosahedron vertices, by setting the **choice** parameter `dggs_orient_specify_type` to `SPECIFIED`, `RANDOM`, or `REGION_CENTER` respectively.

If `dggs_orient_specify_type` is set to `SPECIFIED` the DGG orientation is determined by the location of a single icosahedron vertex and the azimuth from that vertex to an adjacent vertex. The **double** parameters `dggs_vert0_lon` and `dggs_vert0_lat` are used to specify the location of the vertex, and the **double** parameter `dggs_vert0_azimuth` to specify the azimuth to an adjacent vertex; all or these parameters are in decimal degrees. Note that the default DGG placement, which is symmetrical about the equator and has only a single icosahedron vertex falling on land, is specified by:

```
dggs_vert0_lon 11.25
dggs_vert0_lat 58.28252559
dggs_vert0_azimuth 0.0
```

If `dggs_orient_specify_type` is set to `RANDOM` the orientation of the DGG is randomly determined. All parameter values (including the randomly generated values for a vertex location and azimuth used to orient the grid) will be output for your information to the file specified by the **string** parameter `dggs_orient_output_file_name`. Some control over the random specification of the grid orientation is afforded by the **choice** parameter `rng_type` and the **integer** parameter `dggs_orient_rand_seed`. The **choice** parameter `rng_type` indicates which pseudo-random number generator to use. A value of `RAND` indicates that the C standard library `rand`/`srand` functions should be used. A value of `MOTHER` (the default) indicates that George Marsaglia's "Mother-of-all-RNGs" function should be used. The seed value for

DGGRID to use to initialize the pseudo-random number sequence can be set using the **integer** parameter `dggs_orient_rand_seed`.

If the current operation involves only a small region on the earth's surface it is often convenient to orient the grid so that no icosahedron vertices occur in the region of interest. Such an orientation can be specified by setting `dggs_orient_specify_type` to `REGION_CENTER` and then specifying the center point of the region using the **double** parameters `region_center_lon` and `region_center_lat` (both in decimal degrees).

All operations require that at least one DGG be specified. A single DGG may be used by setting the **integer** parameter `dggs_num_placements` to 1 (the default). Alternatively, you may perform the desired operation on multiple DGGs by setting `dggs_num_placements` to the desired number. If the grid orientation is randomly chosen, this will perform the desired operation on multiple randomly oriented grids. The parameters for each grid will be output to a separate file based on the value of `dggs_orient_output_file_name`, with an additional suffix indicating the grid number (0001 to 000*n* where *n* equals the value of `dggs_num_placements`). This suffix will also be used to designate the corresponding output files (as specified in the particular operation being performed). Note that if `dggs_orient_specify_type` is set to any value other than `RANDOM` all of the grids generated will have exactly the same orientation.

2. Specifying the hierarchical spatial partitioning method: The hierarchical partitioning method used to generate the DGG is specified by choosing a grid topology and aperture (defined as the ratio of areas between cells in a given DGG resolution and the next finer resolution). The topology is specified using the **choice** parameter `dggs_topology` with one of the values: `HEXAGON` (default), `TRIANGLE`, or `DIAMOND`.

DGGRID can create grids that are produced using a single aperture, as well as hexagon grids produced using a mixed aperture of some number of aperture 4 resolutions followed by aperture 3 resolutions. The type of aperture is specified using the **choice** parameter `dggs_aperture_type` with a value of either `PURE` (default) or `MIXED43`. If a PURE aperture type is specified then the desired aperture is specified with the **integer** parameter `dggs_aperture`. The valid values for aperture are dependent on the chosen topology. **DGGRID** can create `HEXAGON` DGGs with an aperture of 3 or 4, and `DIAMOND` and `TRIANGLE` DGGs with an aperture of 4.

If a `MIXED43` aperture type is specified then the parameter `dggs_aperture` is ignored. Instead, the **integer** parameter `dggs_num_aperture_4_res` (default 0) specifies the number of resolutions which use aperture 4; the remaining grid resolutions up to the desired grid resolution (see the next subsection) are generated using aperture 3. Note that the parameter `dggs_num_aperture_4_res` is ignored with `PURE` aperture grids. Only `HEXAGON` topology grids may use the `MIXED43` aperture type.

3. Specifying the projection: The regular polygon boundaries and points associated with DGG cells are initially created on the planar faces of an icosahedron; they must then be inversely

projected to the sphere. The desired projection to use for this is specified by the **choice** parameter `dggs_proj`. The valid values are `ISEA`, which specifies the Icosahedral Snyder Equal Area projection [Snyder, 1992], or `FULLER`, which specifies the icosahedral Dymaxion projection of R. Buckminster Fuller [1975] (as developed analytically by Robert Gray [1995] and John Crider [2008]). The ISEA projection creates equal area cells on the sphere at the expense of relatively high shape distortion, while the Fuller projection strikes a balance between area and shape distortion. See Gregory et al. [2008] for a more detailed discussion of these trade-offs.

4. Specifying the resolution: The desired DGG resolution can be specified using one of three methods chosen using the **choice** parameter `dggs_res_specify_type` with one of the following values:

`SPECIFIED` (default) - the desired resolution is explicitly specified by setting the value of the integer parameter `dggs_res_spec` (default 9).

`CELL_AREA` - the desired resolution is set to the DGG resolution whose cell area is closest to the area specified by the **double** parameter `dggs_res_specify_area` (in square kilometers).

`INTERCELL_DISTANCE` - the desired resolution is set to the DGG resolution whose intercell distance is closest to the distance specified by the **double** parameter `dggs_res_specify_intercell_distance` (in kilometers).

If `CELL_AREA` or `INTERCELL_DISTANCE` is specified, then the desired area or intercell distance (as applicable) is rounded up or down to the nearest grid resolution based on the value of the **boolean** parameter `dggs_res_specify_rnd_down`; a value of `TRUE` indicates round down, a value of `FALSE` indicates round up. The chosen resolution is always output by **DGGRID** for your information. The calculation of cell areas and intercell distances uses the value specified for the earth radius (see **Subsection 5** below).

If the `dggs_type` is specified to be `SUPERFUND` then the only supported value for `dggs_res_specify_type` is `SPECIFIED`, and the maximum resolution is 9.

DGGRID will attempt to generate grids up to a maximum resolution of **35** (except in the case of `SUPERFUND` grids, which have a maximum resolution of 9). However, the maximum resolution which can be successfully generated by **DGGRID** is a function of the specified grid topology, projection, the size of data types on the machine on which **DGGRID** is compiled and executed, and the location of the generated grid region relative to the faces of the underlying icosahedron. When generating very high resolution grids the user should be aware that even if **DGGRID** reports success the indexes and output cell geometries should be checked by the user to make sure that they are not degenerate.

5. Specifying the earth radius: The **choice** parameter `proj_datum` specifies a datum that **DGGRID** will use to determine the spherical radius of the earth. The legal values for this parameter are given below, along with the earth radius that they indicate:

`WGS84_AUTHALIC_SPHERE` (default): 6371.007180918475 km

`WGS84_MEAN_SPHERE`: 6371.0087714 km
`CUSTOM_SPHERE`: the earth radius (in kilometers) will be read from the double parameter `proj_datum_radius`

Note that the earth radius is *not* used in the process of generating grid geometries in geodetic coordinates; such generation is performed on a unit sphere. The radius is only used in determining the grid resolution (when `dggs_res_specify_type` is not `SPECIFIED`) and in generating grid statistics in kilometers.

5. Controlling Grid Generation

Specifying the value `GENERATE_GRID` for the **choice** parameter `dggrid_operation` will tell **DGGRID** to create all, or some portion of, the specified DGG (see the previous section). The choice parameter `clip_subset_type` controls the amount of the grid that will be generated. Setting the parameter `clip_subset_type` to `WHOLE_EARTH` will generate the entire earth at the specified resolution.

To generate just a portion of the earth you must specify one or more files containing polygons which **DGGRID** will use to determine the portion of the grid to generate. **DGGRID** supports two clipping file formats: ARC/INFO Generate files and ESRI Shapefiles. To specify a clipping file format, set the parameter `clip_subset_type` to `AIGEN` for ARC/INFO Generate files or to `SHAPEFILE` for ESRI Shapefiles.

The ARC/INFO Generate file format is a text file format that provides a way to create clipping regions manually, using just a text editor. For reference, the ARC/INFO Generate polygon file format consists of a text file containing a series of polygons. Each polygon is described by an entry of the form (assuming *n* vertices, in clockwise order):

```
integerPolygonID centerPtLon centerPtLat
vert1Lon vert1Lat
vert2Lon vert2Lat
     ...
vertnLon vertnLat
vert1Lon vert1Lat
END
```

The *centerPtLon* and *centerPtLat* values in the first line of the polygon description can be omitted when creating **DGGRID** clipping files.

To indicate the end of the file the last polygon is followed by an extra:

```
END
```

For example, the following ARC/INFO Generate file would specify a single triangular clipping polygon in southern Oregon:

```
1
-122.7083 42.1947
-121.5000 42.5000
-122.5688 42.4300
-122.7083 42.1947
END
END
```

Though both the ARC/INFO Generate and ESRI Shapefile formats support holes, **DGGRID** does not. Therefore holes in the clipping files will be interpreted by **DGGRID** as regular polygons.

If `clip_subset_type` is set to `AIGEN` or `SHAPEFILE` then the string parameter `clip_region_files` should be set to a space-delimited list of file names containing polygons to use for clipping. These polygons must be specified using geodetic (latitude/longitude) coordinates. Limitations in **DGGRID** require that each clipping polygon be no more than approximately 60° of great circle arc in extant in any direction. The exact limitation is determined by the relationship between each polygon and the underlying icosahedron; **DGGRID** will let you know if a polygon is too large for the grid generation you are attempting. In that event you must break the polygon into smaller polygons before using it in a clipping file.

Intersections between the clipping polygons and the DGG cells are performed in the specified DGG projection space, with the great circle arcs between adjacent vertices in the original clipping polygons transformed into straight lines on the projection plane. If adjacent vertices in the original clipping polygons are too far apart this may result in an inaccurate representation of the region boundary in the clipping space. This effect can be minimized by introducing additional points into the great circle arcs before projection. Setting the double parameter `geodetic_densify` to some arc length (in decimal degrees) will cause **DGGRID** to introduce extra points into each edge arc so that no two vertices are more than the specified distance apart. Setting `geodetic_densify` to `0.0` (the default) indicates that no such densification is to be performed.

Note that a single execution of **DGGRID** can take several hours, depending on the resolution of the grid being generated and the number and complexity of the clipping polygons. You can control the frequency of feedback during grid generation by setting the integer parameter `update_frequency`. The value of this parameter specifies the number of cells that will be tested for inclusion before outputting a status update. The default value is `100000`.

6. Specifying Generated Grid Output

The grid cells generated by a **DGGRID** run with the value `GENERATE_GRID` specified for the **choice** parameter `dggrid_operation` can be output as cell boundaries, cell center points, or both. All DGG output from **DGGRID** is given in geodetic (longitude/latitude) coordinates in decimal degrees.

The **choice** parameters `cell_output_type` and `point_output_type` specify the desired output file format for cell boundaries and cell points respectively. Each of these parameters may have the following values:

> `NONE` - indicates that no output of that type will be performed
> `AIGEN` - indicates that the cell/point output should be in ARC/INFO Generate file format
> `SHAPEFILE` - indicates that the cell/point output should be in ESRI Shapefile format.
> `KML` - indicates that the cell/point output should be in KML (Google Earth) format

The file name prefix to use for the boundary or point output file is specified using the **string** parameter `cell_output_file_name` or `point_output_file_name` respectively. **DGGRID** will add the appropriate file suffix to the specified prefix name, depending on the chosen file format.

DGG output files created by **DGGRID** can be quite large, depending on the size of the region being generated and the resolution of the grid. The generated cell boundaries and/or points can be output across multiple files by setting the **integer** parameter `max_cells_per_output_file` to the maximum number of cells to output to a single file. Setting the parameter to 0 (the default) will cause **DGGRID** to output all cells to a single file, no matter how large. If `max_cells_per_output_file` is greater than 0, output files are distinguished by appending a "_1", "_2", etc. to each output file name.

Since cell boundaries are only true regular polygons in the chosen projection space it may be desirable to introduce additional points into the cell edges to better preserve the boundary shape after inverse projection to longitude/latitude coordinates. The number of additional points to introduce into each edge is specified by the **integer** parameter `densification`. A value of 0 (the default) indicates that no densification should be performed.

A unique integer cell identifier is output along with each cell boundary or point. The integer identifier type is specified using the **choice** parameter `output_cell_label_type`, which can have one of three values:

`GLOBAL_SEQUENCE` (default when `dggs_type` is not `SUPERFUND`) - the identifier is the appropriate value in a linear sequence 1 to *n*, where *n* is the total number of cells in the whole earth DGG

`ENUMERATION` - the generated cells are numbered from 1 to *n*, where *n* is the total number of cells generated

`SUPERFUND` (preset default when `dggs_type` is `SUPERFUND`) - the identifier is a condensed Superfund_500m index (see **Appendix D**). This value must be (and can only be) used when `dggs_type` is `SUPERFUND`.

When output is to an ESRI Shapefile the cell identifier is stored in a `global_id` field. The ESRI Shapefile format limits integer fields to 32-bit integer size, which is not sufficient for storing the identifiers associated with high resolution DGGs. Therefore **DGGRID** creates the Shapefile field **`global_id`** as a fixed width string with a width specified by the **integer** parameter `shapefile_id_field_length` (default 11).

The color and width of KML output cell boundaries can be controlled using the **string** parameter `kml_default_color` (default `ffffffff` or opaque white) and the **integer** parameter `kml_default_width` (default 4) respectively. KML color values are expressed in 8 digit hexadecimal notation of the form *aabbggrr*, with two hexadecimal digits (`00` to `ff`) each for the alpha, blue, green, and red components.

7. Outputting Grid Statistics

Specifying the value `OUTPUT_STATS` for the **choice** parameter `dggrid_operation` causes **DGGRID** to output a table of grid characteristics for the specified DGG (see **Section 4**). The output table will consist of all grid resolutions from 0 up to and including the specified DGG resolution. The values output for each resolution are the number of cells, the area of a hexagonal cell in square kilometers, the intercell distance in kilometers, and the characteristic length scale (CLS). The CLS is the diameter of a spherical cap of the same area as a hexagonal cell of the specified resolution; this metric was suggested by Ralph Kahn. The calculation of cell areas and intercell distances uses the specified earth radius (see **Section 5.5**). Area and distance values are calculated in the projection plane; the actual values for individual cells will vary based on the characteristics of the chosen projection.

The **integer** parameter `precision` (default 7) specifies the number of digits to the right of the decimal point to output for each floating point value.

Appendix A. DGGRID Metafile Parameters

Parameter Name (Type)	Description	Allowed Values (v)	Default	Notes	Used When
`cell_output_file_name` (**string**)	cell boundary output file name prefix	any	`"cells"`		`cell_output_type` is `AIGEN`, `SHAPEFILE`, or `KML`
`cell_output_type` (**choice**)	cell boundary output file format	`NONE` `AIGEN` `SHAPEFILE` `KML`	`AIGEN`		`dggrid_operation` is `GENERATE_GRID`
`clip_region_files` (**string**)	space delimited list of files that specify grid clipping	any	`"test.gen"`		`dggrid_operation` is `GENERATE_GRID`
`clip_subset_type` (**choice**)	specifies how portion of DGG to generate will be determined	`WHOLE_EARTH` `AIGEN` `SHAPEFILE`	`WHOLE_EARTH`		`dggrid_operation` is `GENERATE_GRID`
`clip_type` (**choice**)	method for determining whether a cell is included by a clipping polygon	`POLY_INTERSECT`	`POLY_INTERSECT`		`dggrid_operation` is `GENERATE_GRID`
`densification` (**integer**)	number of points-per-edge densification to use when generating cell boundaries	$0 \le v \le 500$	`0`	v of `0` indicates no densification	`dggrid_operation` is `GENERATE_GRID`
`dggrid_operation` (**choice**)	specifies the operation to be performed by this run of **DGGRID**	`GENERATE_GRID` `OUTPUT_STATS`	`GENERATE_GRID`		always
`dggs_aperture` (**integer**)	desired DGGS aperture	`3, 4`	`4`		`dggs_aperture_type` is `PURE`
`dggs_aperture_type` (**choice**)	is the aperture sequence constant or mixed?	`PURE` `MIXED43`	`PURE`		`dggs_topology` is `HEXAGON`
`dggs_num_aperture_4_res` (**integer**)	number of aperture 4 resolutions in a mixed aperture sequence	$0 \le v \le 35$	`0`		`dggs_aperture_type` is `MIXED43`
`dggs_num_placements` (**integer**)	number of grid placements to use	$1 \le v$	`1`	if `dggs_orient_specify_type` is not `RANDOM` all placements will be the same	`dggrid_operation` is `GENERATE_GRID`

Parameter Name (Type)	Description	Allowed Values (v)	Default	Notes	Used When
`dggs_orient_output_file_name` (**string**)	name of file for output of multiple DGGS placement parameter values	any	"grid.meta"		`dggs_num_placements` > 1
`dggs_orient_rand_seed` (**integer**)	seed for orientation random number generator	$0 \le v$	77316727		`dggs_orient_specify_type` is `RANDOM`

`dggs_orient_specify_type` (**choice**)	how is the DGG orientation specified?	`RANDOM`
		`SPECIFIED`
		`REGION_CENTER`
			`SPECIFIED`		`dggrid_operation` is `GENERATE_GRID`

`dggs_proj` (**choice**)	projection used by the DGGS	`ISEA` `FULLER`	`ISEA`		all operations
`dggs_res_spec` (**integer**)	specified DGG resolution	$0 \le v \le 35$	9	if `dggs_type` is `SUPERFUND` then $0 \le v \le 9$	`dggs_res_specify_type` is `SPECIFIED`
`dggs_res_specify_area` (**double**)	desired cell area	$1.0 \le v$	100.0		`dggs_res_specify_type` is `CELL_AREA`
`dggs_res_specify_intercell_distance` (**double**)	desired intercell distance	$1.0 \le v$	100.0		`dggs_res_specify_type` is `INTERCELL_DISTANCE`
`dggs_res_specify_rnd_down` (**boolean**)	should the desired cell area or intercell distance be rounded down (or up) to the nearest DGGS resolution?	`TRUE` `FALSE`	`TRUE`		`dggs_res_specify_type` is `CELL_AREA` or `INTERCELL_DISTANCE`

`dggs_res_specify_type` (**choice**)	how is the DGGS resolution specified?	`SPECIFIED`
		`CELL_AREA`
		`INTERCELL_DISTANCE`
			`SPECIFIED`		`dggrid_operation` is `GENERATE_GRID`

`dggs_topology` (**choice**)	desired cell shape	`HEXAGON`
		`TRIANGLE`
		`DIAMOND`
			`HEXAGON`		all operations

`dggs_type` (**choice**)	specify a preset DGG type	`CUSTOM`
		`SUPERFUND`
		`ISEA3H`
		`ISEA4H`
		`ISEA43H`
		`ISEA4T`
		`ISEA4D`
		`FULLER3H`
		`FULLER4H`
		`FULLER43H`
		`FULLER4T`
		`FULLER4D`
			`CUSTOM`	see Appendix **B** for preset parameter value details	all operations

`dggs_vert0_azimuth` (**double**)	azimuth from icosahedron vertex 0 to vertex 1 (degrees)	$0.0 \le v \le 360.0$	0.0		`dggs_orient_specify_type` is `SPECIFIED`

Parameter Name (Type)	Description	Allowed Values (v)	Default	Notes	Used When
`dggs_vert0_lat` (**double**)	latitude of icosahedron vertex 0 (degrees)	$-90.0 \le v \le 90.0$	`58.28252559`		`dggs_orient_specify_type` is `SPECIFIED`
`dggs_vert0_lon` (**double**)	longitude of icosahedron vertex 0 (degrees)	$-180.0 \le v \le 180.0$	`11.25`		`dggs_orient_specify_type` is `SPECIFIED`
`geodetic_densify` (**double**)	maximum degrees of arc for a clipping polygon line segment	$0.0 \le v \le 360.0$	`0.0`	`0.0` indicates no densification	`dggrid_operation` is `GENERATE_GRID`
`kml_default_color` (**string**)	color of cell boundaries in KML output	any valid KML color	`ffffffff`		`cell_output_type` is `KML`
`kml_default_width` (**integer**)	width of cell boundaries in KML output	$1 \le v \le 100$	`4`		`cell_output_type` is `KML`
`max_cells_per_output_file` (**integer**)	maximum number of cells output to a single output file	$0 \le v$	`0`	`0` indicates no maximum	`dggrid_operation` is `GENERATE_GRID`

`output_cell_label_type` (**choice**)	output form for generated cell indexes	`GLOBAL_SEQUENCE`
		`ENUMERATION`
		`SUPERFUND`
			`GLOBAL_SEQUENCE`		`dggrid_operation` is `GENERATE_GRID`

`point_output_file_name` (**string**)	cell point output file name prefix	any	`"centers"`		`point_output_type` is `AIGEN`, `SHAPEFILE`, `KML`, or `TEXT`

`point_output_type` (**choice**)	cell point output file format	`NONE`
		`AIGEN`
		`KML`
		`SHAPEFILE`
		`TEXT`
			`NONE`		`dggrid_operation` is `GENERATE_GRID`

`precision` (**integer**)	number of digits to right of decimal point when outputting floating point numbers	$0 \le v \le 30$	`7`		all operations

`proj_datum` (**choice**)	desired earth radius datum	`WGS84_AUTHALIC_SPHERE`
		`WGS84_MEAN_SPHERE`
		`CUSTOM_SPHERE`
			`WGS84_AUTHALIC_SPHERE`		all operations

`proj_datum_radius` (**double**)	desired earth radius	$1.0 \le v \le 10{,}000.0$	`6371.0071809185`		`proj_datum` is `CUSTOM_SPHERE`
`randpts_concatenate_output` (**boolean**)	put random points for multiple DGG placements in a single file?	`TRUE` `FALSE`	`TRUE`		`randpts_output_type` is `AIGEN`, `KML`, `SHAPEFILE`, or `TEXT`

Parameter Name (Type)	Description	Allowed Values (v)	Default	Notes	Used When
`randpts_num_per_cell` (**integer**)	number of random points to generate per cell	$0 \leq v$	`0`		`randpts_output_type` is `AIGEN`, `KML`, `SHAPEFILE`, or `TEXT`
`randpts_output_file_name` (**string**)	random points-in-cell output file name prefix	any	`"randPts"`		`randpts_output_type` is `AIGEN`, `KML`, `SHAPEFILE`, or `TEXT` and `randpts_num_per_cell > 0`

`randpts_output_type` (**choice**)	random points-in-cell output file format	`NONE`
		`AIGEN`
		`KML`
		`SHAPEFILE`
		`TEXT`
			`NONE`		`dggrid_operation` is `GENERATE_GRID`

`randpts_seed` (**integer**)	seed for cell points random number generator	$0 \leq v$	`77316727`		`randpts_output_type` is `RANDOM`
`region_center_lat` (**double**)	latitude of study region (degrees)	$-90.0 \leq v \leq 90.0$	`0.0`		`dggs_orient_specify_type` is `REGION_CENTER`
`region_center_lon` (**double**)	longitude of study region (degrees)	$-180.0 \leq v \leq 180.0$	`0.0`		`dggs_orient_specify_type` is `REGION_CENTER`
`rng_type` (**choice**)	specifies the random number generator to use	`RAND` `MOTHER`	`RAND`	`RAND`: C standard library rand `MOTHER`: George Marsaglia's multiply-with-carry "Mother" function	
`shapefile_id_field_length` (**integer**)	number of digits in Shapefile output cell index strings	$1 \leq v \leq 50$	`11`		`cell_output_type`, `point_output_type`, or `randpts_output_type` is `SHAPEFILE`
`update_frequency` (**integer**)	number of cell inclusion tests to perform between outputting status updates	$0 \leq v$	`100000`		`dggrid_operation` is `GENERATE_GRID`
`verbosity` (**integer**)	amount of debugging output to display	$0 \leq v \leq 3$	`0`		all operations

Appendix B. Default Values for Preset DGG Types

All preset grid types share the following default parameter values:

```
dggs_orient_specify_type:   SPECIFIED
dggs_num_placements:        1
dggs_vert0_lon:             11.25
dggs_vert0_lat:             58.28252559
dggs_vert0_azimuth:         0.0
dggs_res_specify_type:      SPECIFIED
```

The table below gives the values of other parameters that are set by each preset DGG type. In addition to the listed parameters, the preset type `SUPERFUND` also sets the value of the parameter `output_cell_label_type` to `SUPERFUND`.

dggs_type	dggs_ topology	dggs_ proj	dggs_res_ spec	dggs_aperture_ type	dggs_ aperture	dggs_num_ aperture_ 4_res
CUSTOM	HEXAGON	ISEA	9	PURE	4	N/A
SUPERFUND	HEXAGON	FULLER	9	MIXED43	N/A	2
ISEA3H	HEXAGON	ISEA	9	PURE	3	N/A
ISEA4H	HEXAGON	ISEA	9	PURE	4	N/A
ISEA43H	HEXAGON	ISEA	9	MIXED43	N/A	0
ISEA4T	TRIANGLE	ISEA	9	PURE	4	N/A
ISEA4D	DIAMOND	ISEA	9	PURE	4	N/A
FULLER3H	HEXAGON	FULLER	9	PURE	3	N/A
FULLER4H	HEXAGON	FULLER	9	PURE	4	N/A
FULLER43H	HEXAGON	FULLER	9	MIXED43	N/A	0
FULLER4T	TRIANGLE	FULLER	9	PURE	4	N/A
FULLER4D	DIAMOND	FULLER	9	PURE	4	N/A

Appendix C. Characteristics of DGGRID Hexagonal DGGs

This appendix gives a table of characteristics for hexagonal DGGs which can be generated using **DGGRID**. For footnotes refer to the **Notes** following all tables. All measurements assume an earth radius of 6,371.007180918475 km (WGS84 authalic sphere radius).

dggs_aperture_type	dggs_aperture	dggs_num_aperture_4_res	dggs_res_spec	*Number of Cells*[1]	*Hex Area*[2] *(km²)*	*Intercell Distance*[3] *(km)*	*Characteristic Length Scale*[4] *(km)*
any	any	N/A	0	12	51,006,562.172408900	7,053.652431411	8,199.500370102
PURE	3	N/A	1	32	17,002,187.390803000	4,072.428130045	4,678.969871730
PURE	4	N/A	1	42	12,751,640.543102200	3,526.826215705	4,046.359550784
PURE	3	N/A	2	92	5,667,395.796934320	2,351.217477137	2,691.252070913
MIXED43	N/A	1	2	122	4,250,546.847700740	2,036.214065023	2,329.606134509
PURE	4	N/A	2	162	3,187,910.135775550	1,763.413107853	2,016.793927320
PURE	3	N/A	3	272	1,889,131.932311440	1,357.476043348	1,551.867548772
MIXED43	N/A	1	3	362	1,416,848.949233580	1,175.608738568	1,343.748841665
MIXED43	N/A	2	3	482	1,062,636.711925190	1,018.107032511	1,163.585710563
PURE	4	N/A	3	642	796,977.533943889	881.706553926	1,007.607198016
PURE	3	N/A	4	812	629,710.644103813	783.739159046	895.601841648
MIXED43	N/A	1	4	1,082	472,282.983077860	678.738021674	775.574018100
MIXED43	N/A	2	4	1,442	354,212.237308395	587.804369284	671.640874213
MIXED43	N/A	3	4	1,922	265,659.177981296	509.053516256	581.641221645
PURE	3	N/A	5	2,432	209,903.548034604	452.492014449	517.004996903
PURE	4	N/A	4	2,562	199,244.383485972	440.853276963	503.705138958
MIXED43	N/A	1	5	3,242	157,427.661025953	391.869579523	447.731781951
MIXED43	N/A	2	5	4,322	118,070.745769465	339.369010837	387.742109836
MIXED43	N/A	3	5	5,762	88,553.059327099	293.902184642	335.791278011
PURE	3	N/A	6	7,292	69,967.849344868	261.246386349	298.479323187
MIXED43	N/A	4	5	7,682	66,414.794495324	254.526758128	290.801673284
MIXED43	N/A	1	6	9,722	52,475.887008651	226.246007225	258.489198831
PURE	4	N/A	5	10,242	49,811.095871493	220.426638482	251.840270089
MIXED43	N/A	2	6	12,962	39,356.915256488	195.934789761	223.857253119
MIXED43	N/A	3	6	17,282	29,517.686442366	169.684505419	193.865444709
PURE	3	N/A	7	21,872	23,322.616448289	150.830671483	172.324490896
MIXED43	N/A	4	6	23,042	22,138.264831775	146.951092321	167.891995186
MIXED43	N/A	1	7	29,162	17,491.962336217	130.623193174	149.237102476
MIXED43	N/A	5	6	30,722	16,603.698623831	127.263379064	145.398469970
MIXED43	N/A	2	7	38,882	13,118.971752163	113.123003612	129.242937252
PURE	4	N/A	6	40,962	12,452.773967873	110.213319241	125.918597874
MIXED43	N/A	6	6	40,962	12,452.773967873	110.213319241	125.918597874
MIXED43	N/A	3	7	51,842	9,839.228814122	97.967394881	111.927546968
PURE	3	N/A	8	65,612	7,774.205482763	87.082128783	99.491085727
MIXED43	N/A	4	7	69,122	7,379.421610592	84.842252709	96.932021147
MIXED43	N/A	1	8	87,482	5,830.654112072	75.415335742	86.161752971
MIXED43	N/A	5	7	92,162	5,534.566207944	73.475546161	83.945542149
MIXED43	N/A	2	8	116,642	4,372.990584054	65.311596587	74.618231367
MIXED43	N/A	6	7	122,882	4,150.924655958	63.631689532	72.698939167
MIXED43	N/A	3	8	155,522	3,279.742938041	56.561501806	64.621260864
PURE	4	N/A	7	163,842	3,113.193491968	55.106659620	62.959106799
PURE	3	N/A	9	196,832	2,591.401827588	50.276890494	57.441107849
MIXED43	N/A	4	8	207,362	2,459.807203531	48.983697440	55.963638539
MIXED43	N/A	1	9	262,442	1,943.551370691	43.541064391	49.745448088
MIXED43	N/A	5	8	276,482	1,844.855402648	42.421126355	48.465922925
MIXED43	N/A	2	9	349,922	1,457.663528018	37.707667871	43.080814927
MIXED43	N/A	6	8	368,642	1,383.641551986	36.737773080	41.972714145
MIXED43	N/A	3	9	466,562	1,093.247646014	32.655798294	37.309075700
MIXED43	N/A	7	8	491,522	1,037.731163989	31.815844766	36.349432607
PURE	3	N/A	10	590,492	863.800609196	29.027376261	33.163620358
MIXED43	N/A	4	9	622,082	819.935734510	28.280750903	32.310604462
PURE	4	N/A	8	655,362	778.298372992	27.553329810	31.479529382
MIXED43	N/A	1	10	787,322	647.850456897	25.138445247	28.720535685
MIXED43	N/A	5	9	829,442	614.951800883	24.491848720	27.981802402
MIXED43	N/A	2	10	1,049,762	485.887842673	21.770532196	24.872712197
MIXED43	N/A	6	9	1,105,922	461.213850662	21.210563177	24.232950506
MIXED43	N/A	3	10	1,399,682	364.415882005	18.853833935	21.540399769
MIXED43	N/A	7	9	1,474,562	345.910387996	18.368886540	20.986349956
PURE	3	N/A	11	1,771,472	287.933536399	16.758963498	19.147021538
MIXED43	N/A	4	10	1,866,242	273.311911503	16.327899147	18.654532852
MIXED43	N/A	8	9	1,966,082	259.432790997	15.907922383	18.174711681
MIXED43	N/A	1	11	2,361,962	215.950152299	14.513688130	16.581806669
MIXED43	N/A	5	10	2,488,322	204.983933628	14.140375452	16.155298985

dggs_ aperture_ type	dggs_ aperture	dggs_ num_ aperture_ 4_res	dggs_ res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
PURE	4	N/A	9	2,621,442	194.574593248	13.776664905	15.739761689
MIXED43	N/A	2	11	3,149,282	161.962614224	12.569222624	14.360265563
MIXED43	N/A	6	10	3,317,762	153.737950221	12.245924360	13.990899092
MIXED43	N/A	3	11	4,199,042	121.471960668	10.885266098	12.436354618
MIXED43	N/A	7	10	4,423,682	115.303462665	10.605281589	12.116473884
PURE	3	N/A	12	5,314,412	95.977845466	9.675792087	11.054537346
MIXED43	N/A	4	11	5,598,722	91.103970501	9.426916968	10.770198923
MIXED43	N/A	8	10	5,898,242	86.477596999	9.184443270	10.493174089
MIXED43	N/A	1	12	7,085,882	71.983384100	8.379481749	9.573510094
MIXED43	N/A	5	11	7,464,962	68.327977876	8.163949573	9.327265801
MIXED43	N/A	9	10	7,864,322	64.858197749	7.953961191	9.087355263
MIXED43	N/A	2	12	9,447,842	53.987538075	7.256844065	8.290902896
MIXED43	N/A	6	11	9,953,282	51.245983407	7.070187726	8.077649087
PURE	4	N/A	10	10,485,762	48.643648312	6.888332453	7.869880469
MIXED43	N/A	3	12	12,597,122	40.490653556	6.284611312	7.180132496
MIXED43	N/A	7	11	13,271,042	38.434487555	6.122962180	6.995449283
PURE	3	N/A	13	15,943,232	31.992615155	5.586321166	6.382339979
MIXED43	N/A	4	12	16,796,162	30.367990167	5.442633049	6.218177124
MIXED43	N/A	8	11	17,694,722	28.825865666	5.302640794	6.058236771
MIXED43	N/A	1	13	21,257,642	23.994461367	4.837896043	5.527268543
MIXED43	N/A	5	12	22,394,882	22.775992625	4.713458484	5.385099341
MIXED43	N/A	9	11	23,592,962	21.619399250	4.592221635	5.246586933
MIXED43	N/A	2	13	28,343,522	17.995846025	4.189740875	4.786754962
MIXED43	N/A	6	12	29,859,842	17.081994469	4.081974787	4.663632823
MIXED43	N/A	10	11	31,457,282	16.214549437	3.976980596	4.543677559
MIXED43	N/A	3	13	37,791,362	13.496884519	3.628422033	4.145451393
MIXED43	N/A	7	12	39,813,122	12.811495852	3.535093863	4.038824493
PURE	4	N/A	11	41,943,042	12.160912078	3.444166226	3.934940188
PURE	3	N/A	14	47,829,692	10.664205052	3.225264029	3.684845679
MIXED43	N/A	4	13	50,388,482	10.122663389	3.142305656	3.590066213
MIXED43	N/A	8	12	53,084,162	9.608621889	3.061481090	3.497724608
MIXED43	N/A	1	14	63,772,922	7.998153789	2.793160583	3.191169964
MIXED43	N/A	5	13	67,184,642	7.591997542	2.721316524	3.109088539
MIXED43	N/A	9	12	70,778,882	7.206466417	2.651320397	3.029118364
MIXED43	N/A	2	14	85,030,562	5.998615342	2.418948022	2.763634255
MIXED43	N/A	6	13	89,579,522	5.693998156	2.356729242	2.692549655
MIXED43	N/A	10	12	94,371,842	5.404849812	2.296110818	2.623293453
MIXED43	N/A	3	14	113,374,082	4.498961506	2.094870437	2.393377471
MIXED43	N/A	7	13	119,439,362	4.270498617	2.040987393	2.331816402
MIXED43	N/A	11	12	125,829,122	4.053637359	1.988490298	2.271838771
PURE	3	N/A	15	143,489,072	3.554735017	1.862107055	2.127446640
MIXED43	N/A	4	14	151,165,442	3.374221130	1.814211016	2.072725690
MIXED43	N/A	8	13	159,252,482	3.202873963	1.767546931	2.019412240
PURE	4	N/A	12	167,772,162	3.040228020	1.722083113	1.967470088
MIXED43	N/A	1	15	191,318,762	2.666051263	1.612632014	1.842422835
MIXED43	N/A	5	14	201,553,922	2.530665847	1.571152828	1.795033102
MIXED43	N/A	9	13	212,336,642	2.402155472	1.530740545	1.748862300
MIXED43	N/A	2	15	255,091,682	1.999538447	1.396580292	1.595584979
MIXED43	N/A	6	14	268,738,562	1.897999385	1.360658262	1.554544266
MIXED43	N/A	10	13	283,115,522	1.801616604	1.325660199	1.514559179
MIXED43	N/A	3	15	340,122,242	1.499653835	1.209474011	1.381817126
MIXED43	N/A	7	14	358,318,082	1.423499539	1.178364621	1.346274826
MIXED43	N/A	11	13	377,487,362	1.351212453	1.148055409	1.311646725
PURE	3	N/A	16	430,467,212	1.184911672	1.075088010	1.228281889
MIXED43	N/A	4	15	453,496,322	1.124740377	1.047435219	1.196688734
MIXED43	N/A	8	14	477,757,442	1.067624654	1.020493697	1.165908200
MIXED43	N/A	12	13	503,316,482	1.013409340	0.994245149	1.135919384
MIXED43	N/A	1	16	573,956,282	0.888683754	0.931053528	1.063723319
MIXED43	N/A	5	15	604,661,762	0.843555282	0.907105508	1.036362844
MIXED43	N/A	9	14	637,009,922	0.800718491	0.883773466	1.009706119
PURE	4	N/A	13	671,088,642	0.760057005	0.861041557	0.983735043
MIXED43	N/A	2	16	765,275,042	0.666512816	0.806316007	0.921211417
MIXED43	N/A	6	15	806,215,682	0.632666462	0.785576414	0.897516550
MIXED43	N/A	10	14	849,346,562	0.600538868	0.765370273	0.874431150
MIXED43	N/A	3	16	1,020,366,722	0.499884612	0.698290146	0.797792489
MIXED43	N/A	7	15	1,074,954,242	0.474499846	0.680329131	0.777272133
MIXED43	N/A	11	14	1,132,462,082	0.450404151	0.662830099	0.757279589
PURE	3	N/A	17	1,291,401,632	0.394970557	0.620702352	0.709148879
MIXED43	N/A	4	16	1,360,488,962	0.374913459	0.604737005	0.690908563
MIXED43	N/A	8	15	1,433,272,322	0.355874885	0.589182310	0.673137413
MIXED43	N/A	12	14	1,509,949,442	0.337803113	0.574027704	0.655823362
MIXED43	N/A	1	17	1,721,868,842	0.296227918	0.537544005	0.614140944
MIXED43	N/A	5	16	1,813,985,282	0.281185094	0.523717609	0.598344367
MIXED43	N/A	9	15	1,911,029,762	0.266906164	0.510246848	0.582954100

dggs_ aperture_ type	dggs_ aperture	dggs_ num_ aperture_ 4_res	dggs_ res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
MIXED43	N/A	13	14	2,013,265,922	0.253352335	0.497122574	0.567959692
MIXED43	N/A	2	17	2,295,825,122	0.222170939	0.465526764	0.531861659
MIXED43	N/A	6	16	2,418,647,042	0.210888821	0.453552754	0.518181422
MIXED43	N/A	10	15	2,548,039,682	0.200179623	0.441886733	0.504853059
PURE	4	N/A	14	2,684,354,562	0.190014251	0.430520778	0.491867522
MIXED43	N/A	3	17	3,061,100,162	0.166628204	0.403158004	0.460605708
MIXED43	N/A	7	16	3,224,862,722	0.158166615	0.392788207	0.448758275
MIXED43	N/A	11	15	3,397,386,242	0.150134717	0.382685136	0.437215575
PURE	3	N/A	18	3,874,204,892	0.131656852	0.358362670	0.409427296
MIXED43	N/A	4	17	4,081,466,882	0.124971153	0.349145073	0.398896245
MIXED43	N/A	8	16	4,299,816,962	0.118624962	0.340164566	0.388636066
MIXED43	N/A	12	15	4,529,848,322	0.112601038	0.331415050	0.378639795
MIXED43	N/A	1	18	5,165,606,522	0.098742639	0.310351176	0.354574440
MIXED43	N/A	5	17	5,441,955,842	0.093728365	0.302368503	0.345454281
MIXED43	N/A	9	16	5,733,089,282	0.088968721	0.294591155	0.336568706
MIXED43	N/A	13	15	6,039,797,762	0.084450778	0.287013852	0.327911681
MIXED43	N/A	2	18	6,887,475,362	0.074056980	0.268772002	0.307070472
MIXED43	N/A	6	17	7,255,941,122	0.070296274	0.261858805	0.299172183
MIXED43	N/A	10	16	7,644,119,042	0.066726541	0.255123424	0.291477050
MIXED43	N/A	14	15	8,053,063,682	0.063338084	0.248561287	0.283979846
MIXED43	N/A	3	18	9,183,300,482	0.055542735	0.232763382	0.265930830
MIXED43	N/A	7	17	9,674,588,162	0.052722205	0.226776377	0.259090711
MIXED43	N/A	11	16	10,192,158,722	0.050044906	0.220943366	0.252426530
PURE	4	N/A	15	10,737,418,242	0.047503563	0.215260389	0.245933761
PURE	3	N/A	19	11,622,614,672	0.043885617	0.206900784	0.236382960
MIXED43	N/A	4	18	12,244,400,642	0.041657051	0.201579002	0.230302854
MIXED43	N/A	8	17	12,899,450,882	0.039541654	0.196394103	0.224379138
MIXED43	N/A	12	16	13,589,544,962	0.037533679	0.191342568	0.218607787
MIXED43	N/A	1	19	15,496,819,562	0.032914213	0.179181335	0.204713648
MIXED43	N/A	5	18	16,325,867,522	0.031242788	0.174572536	0.199448122
MIXED43	N/A	9	17	17,199,267,842	0.029656240	0.170082283	0.194318033
MIXED43	N/A	13	16	18,119,393,282	0.028150259	0.165707525	0.189319897
MIXED43	N/A	2	19	20,662,426,082	0.024685660	0.155175588	0.177287220
MIXED43	N/A	6	18	21,767,823,362	0.023432091	0.151184251	0.172727141
MIXED43	N/A	10	17	22,932,357,122	0.022242180	0.147295578	0.168284353
MIXED43	N/A	14	16	24,159,191,042	0.021112695	0.143506926	0.163955841
MIXED43	N/A	3	19	27,549,901,442	0.018514245	0.134386001	0.153535236
MIXED43	N/A	7	18	29,023,764,482	0.017574068	0.130929402	0.149586092
MIXED43	N/A	11	17	30,576,476,162	0.016681635	0.127561712	0.145738525
MIXED43	N/A	15	16	32,212,254,722	0.015834521	0.124280644	0.141989923
PURE	3	N/A	20	34,867,844,012	0.014628539	0.119454223	0.136475765
MIXED43	N/A	4	19	36,733,201,922	0.013885684	0.116381691	0.132965415
MIXED43	N/A	8	18	38,698,352,642	0.013180551	0.113388189	0.129545355
MIXED43	N/A	12	17	40,768,634,882	0.012511226	0.110471683	0.126213265
PURE	4	N/A	16	42,949,672,962	0.011875891	0.107630195	0.122966880
MIXED43	N/A	1	20	46,490,458,682	0.010971404	0.103450392	0.118191480
MIXED43	N/A	5	19	48,977,602,562	0.010414263	0.100789501	0.115151427
MIXED43	N/A	9	18	51,597,803,522	0.009885413	0.098197052	0.112189569
MIXED43	N/A	13	17	54,358,179,842	0.009383420	0.095671284	0.109303894
MIXED43	N/A	2	20	61,987,278,242	0.008228553	0.089590667	0.102356824
MIXED43	N/A	6	19	65,303,470,082	0.007810697	0.087286268	0.099724061
MIXED43	N/A	10	18	68,797,071,362	0.007414060	0.085041141	0.097159017
MIXED43	N/A	14	17	72,477,573,122	0.007037565	0.082853762	0.094659949
MIXED43	N/A	3	20	82,649,704,322	0.006171415	0.077587794	0.088643610
MIXED43	N/A	7	19	87,071,293,442	0.005858023	0.075592126	0.086363570
MIXED43	N/A	11	18	91,729,428,482	0.005560545	0.073647789	0.084142177
MIXED43	N/A	15	17	96,636,764,162	0.005278174	0.071753463	0.081977920
PURE	3	N/A	21	104,603,532,032	0.004876180	0.068966928	0.078794320
MIXED43	N/A	4	20	110,199,605,762	0.004628561	0.067193001	0.076767618
MIXED43	N/A	8	19	116,095,057,922	0.004393517	0.065464701	0.074793046
MIXED43	N/A	12	18	122,305,904,642	0.004170409	0.063780856	0.072869262
MIXED43	N/A	16	17	128,849,018,882	0.003958630	0.062140322	0.070994961
MIXED43	N/A	1	21	139,471,376,042	0.003657135	0.059727112	0.068237883
MIXED43	N/A	5	20	146,932,807,682	0.003471421	0.058190845	0.066482707
MIXED43	N/A	9	19	154,793,410,562	0.003295138	0.056694094	0.064772678
MIXED43	N/A	13	18	163,074,539,522	0.003127807	0.055235842	0.063106632
PURE	4	N/A	17	171,798,691,842	0.002968973	0.053815097	0.061483440
MIXED43	N/A	2	21	185,961,834,722	0.002742851	0.051725196	0.059095740
MIXED43	N/A	6	20	195,910,410,242	0.002603566	0.050394750	0.057575714
MIXED43	N/A	10	19	206,391,214,082	0.002471353	0.049098526	0.056094784
MIXED43	N/A	14	18	217,432,719,362	0.002345855	0.047835642	0.054651947
MIXED43	N/A	3	21	247,949,112,962	0.002057138	0.044795334	0.051178412
MIXED43	N/A	7	20	261,213,880,322	0.001952674	0.043643134	0.049862031
MIXED43	N/A	11	19	275,188,285,442	0.001853515	0.042520571	0.048579508

dggs_ aperture_ type	dggs_ aperture	dggs_ num_ aperture_ 4_res	dggs_ res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
MIXED43	N/A	15	18	289,910,292,482	0.001759391	0.041426881	0.047329974
PURE	3	N/A	22	313,810,596,092	0.001625393	0.039818074	0.045491922
MIXED43	N/A	4	21	330,598,817,282	0.001542854	0.038793897	0.044321805
MIXED43	N/A	8	20	348,285,173,762	0.001464506	0.037796063	0.043181785
MIXED43	N/A	12	19	366,917,713,922	0.001390136	0.036823894	0.042071088
MIXED43	N/A	16	18	386,547,056,642	0.001319543	0.035876732	0.040988960
MIXED43	N/A	1	22	418,414,128,122	0.001219045	0.034483464	0.039397160
MIXED43	N/A	5	21	440,798,423,042	0.001157140	0.033596500	0.038383809
MIXED43	N/A	9	20	464,380,231,682	0.001098379	0.032732351	0.037396523
MIXED43	N/A	13	19	489,223,618,562	0.001042602	0.031890428	0.036434631
MIXED43	N/A	17	18	515,396,075,522	0.000989658	0.031070161	0.035497481
MIXED43	N/A	2	22	557,885,504,162	0.000914284	0.029863556	0.034118941
MIXED43	N/A	6	21	587,731,230,722	0.000867855	0.029095423	0.033241354
MIXED43	N/A	10	20	619,173,642,242	0.000823784	0.028347047	0.032386339
MIXED43	N/A	14	19	652,298,158,082	0.000781952	0.027617921	0.031553316
PURE	4	N/A	18	687,194,767,362	0.000742243	0.026907549	0.030741720
MIXED43	N/A	3	22	743,847,338,882	0.000685713	0.025862598	0.029547870
MIXED43	N/A	7	21	783,641,640,962	0.000650891	0.025197375	0.028787857
MIXED43	N/A	11	20	825,564,856,322	0.000617838	0.024549263	0.028047392
MIXED43	N/A	15	19	869,730,877,442	0.000586464	0.023917821	0.027325973
PURE	3	N/A	23	941,431,788,272	0.000541798	0.022988976	0.026264773
MIXED43	N/A	4	22	991,796,451,842	0.000514285	0.022397667	0.025589206
MIXED43	N/A	8	21	1,044,855,521,282	0.000488169	0.021821567	0.024931015
MIXED43	N/A	12	20	1,100,753,141,762	0.000463379	0.021260285	0.024289754
MIXED43	N/A	16	19	1,159,641,169,922	0.000439848	0.020713441	0.023664987
MIXED43	N/A	1	23	1,255,242,384,362	0.000406348	0.019909037	0.022745961
MIXED43	N/A	5	22	1,322,395,269,122	0.000385713	0.019396948	0.022160902
MIXED43	N/A	9	21	1,393,140,695,042	0.000366126	0.018898031	0.021590893
MIXED43	N/A	13	20	1,467,670,855,682	0.000347534	0.018411947	0.021035544
MIXED43	N/A	17	19	1,546,188,226,562	0.000329886	0.017938366	0.020494480
MIXED43	N/A	2	23	1,673,656,512,482	0.000304761	0.017241732	0.019698580
MIXED43	N/A	6	22	1,763,193,692,162	0.000289285	0.016798250	0.019191905
MIXED43	N/A	10	21	1,857,520,926,722	0.000274595	0.016366175	0.018698261
MIXED43	N/A	14	20	1,956,894,474,242	0.000260651	0.015945214	0.018217316
MIXED43	N/A	18	19	2,061,584,302,082	0.000247414	0.015535080	0.017748740
MIXED43	N/A	3	23	2,231,542,016,642	0.000228571	0.014931778	0.017059471
MIXED43	N/A	7	22	2,350,924,922,882	0.000216964	0.014547711	0.016620677
MIXED43	N/A	11	21	2,476,694,568,962	0.000205946	0.014173524	0.016193169
MIXED43	N/A	15	20	2,609,192,632,322	0.000195488	0.013808960	0.015776658
PURE	4	N/A	19	2,748,779,069,442	0.000185561	0.013453774	0.015370860
PURE	3	N/A	24	2,824,295,364,812	0.000180599	0.013272691	0.015163974
MIXED43	N/A	4	23	2,975,389,355,522	0.000171428	0.012931299	0.014773935
MIXED43	N/A	8	22	3,134,566,563,842	0.000162723	0.012598688	0.014393928
MIXED43	N/A	12	21	3,302,259,425,282	0.000154460	0.012274631	0.014023696
MIXED43	N/A	16	20	3,478,923,509,762	0.000146616	0.011958911	0.013662987
MIXED43	N/A	1	24	3,765,727,153,082	0.000135449	0.011494488	0.013132387
MIXED43	N/A	5	23	3,967,185,807,362	0.000128571	0.011198833	0.012794603
MIXED43	N/A	9	22	4,179,422,085,122	0.000122042	0.010910784	0.012465508
MIXED43	N/A	13	21	4,403,012,567,042	0.000115845	0.010630143	0.012144877
MIXED43	N/A	17	20	4,638,564,679,682	0.000109962	0.010356720	0.011832494
MIXED43	N/A	2	24	5,020,969,537,442	0.000101587	0.009954519	0.011372980
MIXED43	N/A	6	23	5,289,581,076,482	0.000096428	0.009698474	0.011080451
MIXED43	N/A	10	22	5,572,562,780,162	0.000091532	0.009449016	0.010795446
MIXED43	N/A	14	21	5,870,683,422,722	0.000086884	0.009205974	0.010517772
MIXED43	N/A	18	20	6,184,752,906,242	0.000082471	0.008969183	0.010247240
MIXED43	N/A	3	24	6,694,626,049,922	0.000076190	0.008620866	0.009849290
MIXED43	N/A	7	23	7,052,774,768,642	0.000072321	0.008399125	0.009595952
MIXED43	N/A	11	22	7,430,083,706,882	0.000068649	0.008183088	0.009349131
MIXED43	N/A	15	21	7,827,577,896,962	0.000065163	0.007972607	0.009108658
MIXED43	N/A	19	20	8,246,337,208,322	0.000061854	0.007767540	0.008874370
PURE	3	N/A	25	8,472,886,094,432	0.000060200	0.007662992	0.008754924
MIXED43	N/A	4	24	8,926,168,066,562	0.000057143	0.007465889	0.008529735
MIXED43	N/A	8	23	9,403,699,691,522	0.000054241	0.007273856	0.008310338
MIXED43	N/A	12	22	9,906,778,275,842	0.000051487	0.007086762	0.008096585
MIXED43	N/A	16	21	10,436,770,529,282	0.000048872	0.006904480	0.007888329
PURE	4	N/A	20	10,995,116,277,762	0.000046390	0.006726887	0.007685430
MIXED43	N/A	1	25	11,297,181,459,242	0.000045150	0.006636346	0.007581987
MIXED43	N/A	5	24	11,901,557,422,082	0.000042857	0.006465649	0.007386967
MIXED43	N/A	9	23	12,538,266,255,362	0.000040681	0.006299344	0.007196964
MIXED43	N/A	13	22	13,209,037,701,122	0.000038615	0.006137316	0.007011848
MIXED43	N/A	17	21	13,915,694,039,042	0.000036654	0.005979455	0.006831493
MIXED43	N/A	2	25	15,062,908,612,322	0.000033862	0.005747244	0.006566193
MIXED43	N/A	6	24	15,868,743,229,442	0.000032143	0.005599417	0.006397302
MIXED43	N/A	10	23	16,717,688,340,482	0.000030511	0.005455392	0.006232754

dggs_ aperture_ type	dggs_ aperture	dggs_ num_ aperture_ 4_res	dggs_ res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
MIXED43	N/A	14	22	17,612,050,268,162	0.000028961	0.005315071	0.006072439
MIXED43	N/A	18	21	18,554,258,718,722	0.000027490	0.005178360	0.005916247
MIXED43	N/A	3	25	20,083,878,149,762	0.000025397	0.004977259	0.005686490
MIXED43	N/A	7	24	21,158,324,305,922	0.000024107	0.004849237	0.005540226
MIXED43	N/A	11	23	22,290,251,120,642	0.000022883	0.004724508	0.005397723
MIXED43	N/A	15	22	23,482,733,690,882	0.000021721	0.004602987	0.005258886
MIXED43	N/A	19	21	24,739,011,624,962	0.000020618	0.004484591	0.005123620
PURE	3	N/A	26	25,418,658,283,292	0.000020067	0.004424230	0.005054658
MIXED43	N/A	4	25	26,778,504,199,682	0.000019048	0.004310433	0.004924645
MIXED43	N/A	8	24	28,211,099,074,562	0.000018080	0.004199563	0.004797976
MIXED43	N/A	12	23	29,720,334,827,522	0.000017162	0.004091544	0.004674565
MIXED43	N/A	16	22	31,310,311,587,842	0.000016291	0.003986304	0.004554329
MIXED43	N/A	20	21	32,985,348,833,282	0.000015463	0.003883770	0.004437185
MIXED43	N/A	1	26	33,891,544,377,722	0.000015050	0.003831496	0.004377462
MIXED43	N/A	5	25	35,704,672,266,242	0.000014286	0.003732944	0.004264868
MIXED43	N/A	9	24	37,614,798,766,082	0.000013560	0.003636928	0.004155169
MIXED43	N/A	13	23	39,627,113,103,362	0.000012872	0.003543381	0.004048292
MIXED43	N/A	17	22	41,747,082,117,122	0.000012218	0.003452240	0.003944165
PURE	4	N/A	21	43,980,465,111,042	0.000011598	0.003363444	0.003842715
MIXED43	N/A	2	26	45,188,725,836,962	0.000011287	0.003318173	0.003790993
MIXED43	N/A	6	25	47,606,229,688,322	0.000010714	0.003232825	0.003693484
MIXED43	N/A	10	24	50,153,065,021,442	0.000010170	0.003149672	0.003598482
MIXED43	N/A	14	23	52,836,150,804,482	0.000009654	0.003068658	0.003505924
MIXED43	N/A	18	22	55,662,776,156,162	0.000009163	0.002989728	0.003415747
MIXED43	N/A	3	26	60,251,634,449,282	0.000008466	0.002873622	0.003283097
MIXED43	N/A	7	25	63,474,972,917,762	0.000008036	0.002799708	0.003198651
MIXED43	N/A	11	24	66,870,753,361,922	0.000007628	0.002727696	0.003116377
MIXED43	N/A	15	23	70,448,201,072,642	0.000007240	0.002657536	0.003036219
MIXED43	N/A	19	22	74,217,034,874,882	0.000006873	0.002589180	0.002958123
PURE	3	N/A	27	76,255,974,849,872	0.000006689	0.002554331	0.002918308
MIXED43	N/A	4	26	80,335,512,599,042	0.000006349	0.002488630	0.002843245
MIXED43	N/A	8	25	84,633,297,223,682	0.000006027	0.002424619	0.002770113
MIXED43	N/A	12	24	89,161,004,482,562	0.000005721	0.002362254	0.002698862
MIXED43	N/A	16	23	93,930,934,763,522	0.000005430	0.002301493	0.002629443
MIXED43	N/A	20	22	98,956,046,499,842	0.000005154	0.002242296	0.002561810
MIXED43	N/A	1	27	101,674,633,133,162	0.000005017	0.002212115	0.002527329
MIXED43	N/A	5	26	107,114,016,798,722	0.000004762	0.002155216	0.002462322
MIXED43	N/A	9	25	112,844,396,298,242	0.000004520	0.002099781	0.002398988
MIXED43	N/A	13	24	118,881,339,310,082	0.000004291	0.002045772	0.002337283
MIXED43	N/A	17	23	125,241,246,351,362	0.000004073	0.001993152	0.002277164
MIXED43	N/A	21	22	131,941,395,333,122	0.000003866	0.001941885	0.002218593
MIXED43	N/A	2	27	135,566,177,510,882	0.000003762	0.001915748	0.002188731
MIXED43	N/A	6	26	142,818,689,064,962	0.000003571	0.001866472	0.002132434
MIXED43	N/A	10	25	150,459,195,064,322	0.000003390	0.001818464	0.002077585
MIXED43	N/A	14	24	158,508,452,413,442	0.000003218	0.001771690	0.002024146
MIXED43	N/A	18	23	166,988,328,468,482	0.000003054	0.001726120	0.001972082
PURE	4	N/A	22	175,921,860,444,162	0.000002899	0.001681722	0.001921358
MIXED43	N/A	3	27	180,754,903,347,842	0.000002822	0.001659086	0.001895497
MIXED43	N/A	7	26	190,424,918,753,282	0.000002679	0.001616412	0.001846742
MIXED43	N/A	11	25	200,612,260,085,762	0.000002543	0.001574836	0.001799241
MIXED43	N/A	15	24	211,344,603,217,922	0.000002413	0.001534329	0.001752962
MIXED43	N/A	19	23	222,651,104,624,642	0.000002291	0.001494864	0.001707873
PURE	3	N/A	28	228,767,924,549,612	0.000002230	0.001474743	0.001684886
MIXED43	N/A	4	27	241,006,537,797,122	0.000002116	0.001436811	0.001641548
MIXED43	N/A	8	26	253,899,891,671,042	0.000002009	0.001399854	0.001599325
MIXED43	N/A	12	25	267,483,013,447,682	0.000001907	0.001363848	0.001558188
MIXED43	N/A	16	24	281,792,804,290,562	0.000001810	0.001328768	0.001518110
MIXED43	N/A	20	23	296,868,139,499,522	0.000001718	0.001294590	0.001479062
MIXED43	N/A	1	28	305,023,899,399,482	0.000001672	0.001277165	0.001459154
MIXED43	N/A	5	27	321,342,050,396,162	0.000001587	0.001244315	0.001421623
MIXED43	N/A	9	26	338,533,188,894,722	0.000001507	0.001212309	0.001385056
MIXED43	N/A	13	25	356,644,017,930,242	0.000001430	0.001181127	0.001349431
MIXED43	N/A	17	24	375,723,739,054,082	0.000001358	0.001150747	0.001314722
MIXED43	N/A	21	23	395,824,185,999,362	0.000001289	0.001121148	0.001280905
MIXED43	N/A	2	28	406,698,532,532,642	0.000001254	0.001106058	0.001263664
MIXED43	N/A	6	27	428,456,067,194,882	0.000001190	0.001077608	0.001231161
MIXED43	N/A	10	26	451,377,585,192,962	0.000001130	0.001049891	0.001199494
MIXED43	N/A	14	25	475,525,357,240,322	0.000001073	0.001022886	0.001168641
MIXED43	N/A	18	24	500,964,985,405,442	0.000001018	0.000996576	0.001138582
MIXED43	N/A	22	23	527,765,581,332,482	0.000000966	0.000970943	0.001109296
MIXED43	N/A	3	28	542,264,710,043,522	0.000000941	0.000957874	0.001094366
MIXED43	N/A	7	27	571,274,756,259,842	0.000000893	0.000933236	0.001066217
MIXED43	N/A	11	26	601,836,780,257,282	0.000000848	0.000909232	0.001038792
MIXED43	N/A	15	25	634,033,809,653,762	0.000000804	0.000885845	0.001012073

dggs_aperture_type	dggs_aperture	dggs_num_aperture_4_res	dggs_res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
MIXED43	N/A	19	24	667,953,313,873,922	0.000000764	0.000863060	0.000986041
PURE	3	N/A	29	686,303,773,648,832	0.000000743	0.000851444	0.000972769
PURE	4	N/A	23	703,687,441,776,642	0.000000725	0.000840861	0.000960679
MIXED43	N/A	4	28	723,019,613,391,362	0.000000705	0.000829543	0.000947748
MIXED43	N/A	8	27	761,699,675,013,122	0.000000670	0.000808206	0.000923371
MIXED43	N/A	12	26	802,449,040,343,042	0.000000636	0.000787418	0.000899621
MIXED43	N/A	16	25	845,378,412,871,682	0.000000603	0.000767164	0.000876481
MIXED43	N/A	20	24	890,604,418,498,562	0.000000573	0.000747432	0.000853937
MIXED43	N/A	1	29	915,071,698,198,442	0.000000557	0.000737372	0.000842443
MIXED43	N/A	5	28	964,026,151,188,482	0.000000529	0.000718405	0.000820774
MIXED43	N/A	9	27	1,015,599,566,684,160	0.000000502	0.000699927	0.000799663
MIXED43	N/A	13	26	1,069,932,053,790,720	0.000000477	0.000681924	0.000779094
MIXED43	N/A	17	25	1,127,171,217,162,240	0.000000453	0.000664384	0.000759055
MIXED43	N/A	21	24	1,187,472,557,998,080	0.000000430	0.000647295	0.000739531
MIXED43	N/A	2	29	1,220,095,597,597,920	0.000000418	0.000638583	0.000729577
MIXED43	N/A	6	28	1,285,368,201,584,640	0.000000397	0.000622157	0.000710811
MIXED43	N/A	10	27	1,354,132,755,578,880	0.000000377	0.000606155	0.000692528
MIXED43	N/A	14	26	1,426,576,071,720,960	0.000000358	0.000590563	0.000674715
MIXED43	N/A	18	25	1,502,894,956,216,320	0.000000339	0.000575373	0.000657361
MIXED43	N/A	22	24	1,583,296,743,997,440	0.000000322	0.000560574	0.000640453
MIXED43	N/A	3	29	1,626,794,130,130,560	0.000000314	0.000553029	0.000631832
MIXED43	N/A	7	28	1,713,824,268,779,520	0.000000298	0.000538804	0.000615581
MIXED43	N/A	11	27	1,805,510,340,771,840	0.000000283	0.000524945	0.000599747
MIXED43	N/A	15	26	1,902,101,428,961,280	0.000000268	0.000511443	0.000584321
MIXED43	N/A	19	25	2,003,859,941,621,760	0.000000255	0.000498288	0.000569291
PURE	3	N/A	30	2,058,911,320,946,490	0.000000248	0.000491581	0.000561629
MIXED43	N/A	23	24	2,111,062,325,329,920	0.000000242	0.000485471	0.000554648
MIXED43	N/A	4	29	2,169,058,840,174,080	0.000000235	0.000478937	0.000547183
MIXED43	N/A	8	28	2,285,099,025,039,360	0.000000223	0.000466618	0.000533108
MIXED43	N/A	12	27	2,407,347,121,029,120	0.000000212	0.000454616	0.000519396
MIXED43	N/A	16	26	2,536,135,238,615,040	0.000000201	0.000442923	0.000506037
MIXED43	N/A	20	25	2,671,813,255,495,680	0.000000191	0.000431530	0.000493021
MIXED43	N/A	1	30	2,745,215,094,595,320	0.000000186	0.000425722	0.000486385
PURE	4	N/A	24	2,814,749,767,106,560	0.000000181	0.000420430	0.000480339
MIXED43	N/A	5	29	2,892,078,453,565,440	0.000000176	0.000414772	0.000473874
MIXED43	N/A	9	28	3,046,798,700,052,480	0.000000167	0.000404103	0.000461685
MIXED43	N/A	13	27	3,209,796,161,372,160	0.000000159	0.000393709	0.000449810
MIXED43	N/A	17	26	3,381,513,651,486,720	0.000000151	0.000383582	0.000438241
MIXED43	N/A	21	25	3,562,417,673,994,240	0.000000143	0.000373716	0.000426968
MIXED43	N/A	2	30	3,660,286,792,793,760	0.000000139	0.000368686	0.000421221
MIXED43	N/A	6	29	3,856,104,604,753,920	0.000000132	0.000359203	0.000410387
MIXED43	N/A	10	28	4,062,398,266,736,640	0.000000126	0.000349964	0.000399831
MIXED43	N/A	14	27	4,279,728,215,162,880	0.000000119	0.000340962	0.000389547
MIXED43	N/A	18	26	4,508,684,868,648,960	0.000000113	0.000332192	0.000379527
MIXED43	N/A	22	25	4,749,890,231,992,320	0.000000107	0.000323648	0.000369765
MIXED43	N/A	3	30	4,880,382,390,391,680	0.000000105	0.000319291	0.000364789
MIXED43	N/A	7	29	5,141,472,806,338,560	0.000000099	0.000311079	0.000355406
MIXED43	N/A	11	28	5,416,531,022,315,520	0.000000094	0.000303077	0.000346264
MIXED43	N/A	15	27	5,706,304,286,883,840	0.000000089	0.000295282	0.000337358
MIXED43	N/A	19	26	6,011,579,824,865,280	0.000000085	0.000287687	0.000328680
PURE	3	N/A	31	6,176,733,962,839,470	0.000000083	0.000283815	0.000324256
MIXED43	N/A	23	25	6,333,186,975,989,760	0.000000081	0.000280287	0.000320226
MIXED43	N/A	4	30	6,507,176,520,522,240	0.000000078	0.000276514	0.000315916
MIXED43	N/A	8	29	6,855,297,075,118,080	0.000000074	0.000269402	0.000307790
MIXED43	N/A	12	28	7,222,041,363,087,360	0.000000071	0.000262473	0.000299874
MIXED43	N/A	16	27	7,608,405,715,845,120	0.000000067	0.000255721	0.000292160
MIXED43	N/A	20	26	8,015,439,766,487,040	0.000000064	0.000249144	0.000284646
MIXED43	N/A	1	31	8,235,645,283,785,960	0.000000062	0.000245791	0.000280814
MIXED43	N/A	24	25	8,444,249,301,319,680	0.000000060	0.000242736	0.000277324
MIXED43	N/A	5	30	8,676,235,360,696,320	0.000000059	0.000239468	0.000273591
MIXED43	N/A	9	29	9,140,396,100,157,440	0.000000056	0.000233309	0.000266554
MIXED43	N/A	13	28	9,629,388,484,116,480	0.000000053	0.000227308	0.000259698
MIXED43	N/A	17	27	10,144,540,954,460,200	0.000000050	0.000221461	0.000253018
MIXED43	N/A	21	26	10,687,253,021,982,700	0.000000048	0.000215765	0.000246510
MIXED43	N/A	2	31	10,980,860,378,381,300	0.000000046	0.000212861	0.000243192
PURE	4	N/A	25	11,258,999,068,426,200	0.000000045	0.000210215	0.000240170
MIXED43	N/A	6	30	11,568,313,814,261,800	0.000000044	0.000207386	0.000236937
MIXED43	N/A	10	29	12,187,194,800,209,900	0.000000042	0.000202052	0.000230843
MIXED43	N/A	14	28	12,839,184,645,488,600	0.000000040	0.000196854	0.000224905
MIXED43	N/A	18	27	13,526,054,605,946,900	0.000000038	0.000191791	0.000219120
MIXED43	N/A	22	26	14,249,670,695,977,000	0.000000036	0.000186858	0.000213484
MIXED43	N/A	3	31	14,641,147,171,175,000	0.000000035	0.000184343	0.000210611
MIXED43	N/A	7	30	15,424,418,419,015,700	0.000000033	0.000179601	0.000205194
MIXED43	N/A	11	29	16,249,593,066,946,600	0.000000031	0.000174982	0.000199916

dggs_aperture_type	dggs_aperture	dggs_num_aperture_4_res	dggs_res_spec	*Number of Cells*[1]	*Hex Area*[2] *(km²)*	*Intercell Distance*[3] *(km)*	*Characteristic Length Scale*[4] *(km)*
MIXED43	N/A	15	28	17,118,912,860,651,500	0.000000030	0.000170481	0.000194774
MIXED43	N/A	19	27	18,034,739,474,595,800	0.000000028	0.000166096	0.000189764
PURE	3	N/A	32	18,530,201,888,518,400	0.000000028	0.000163860	0.000187210
MIXED43	N/A	23	26	18,999,560,927,969,300	0.000000027	0.000161824	0.000184883
MIXED43	N/A	4	31	19,521,529,561,566,700	0.000000026	0.000159646	0.000182394
MIXED43	N/A	8	30	20,565,891,225,354,200	0.000000025	0.000155539	0.000177703
MIXED43	N/A	12	29	21,666,124,089,262,100	0.000000024	0.000151539	0.000173132
MIXED43	N/A	16	28	22,825,217,147,535,400	0.000000022	0.000147641	0.000168679
MIXED43	N/A	20	27	24,046,319,299,461,100	0.000000021	0.000143843	0.000164340
MIXED43	N/A	1	32	24,706,935,851,357,900	0.000000021	0.000141907	0.000162128
MIXED43	N/A	24	26	25,332,747,903,959,000	0.000000020	0.000140143	0.000160113
MIXED43	N/A	5	31	26,028,706,082,089,000	0.000000020	0.000138257	0.000157958
MIXED43	N/A	9	30	27,421,188,300,472,300	0.000000019	0.000134701	0.000153895
MIXED43	N/A	13	29	28,888,165,452,349,400	0.000000018	0.000131236	0.000149937
MIXED43	N/A	17	28	30,433,622,863,380,500	0.000000017	0.000127861	0.000146080
MIXED43	N/A	21	27	32,061,759,065,948,200	0.000000016	0.000124572	0.000142323
MIXED43	N/A	2	32	32,942,581,135,143,800	0.000000015	0.000122895	0.000140407
MIXED43	N/A	25	26	33,776,997,205,278,700	0.000000015	0.000121368	0.000138662
MIXED43	N/A	6	31	34,704,941,442,785,300	0.000000015	0.000119734	0.000136796
MIXED43	N/A	10	30	36,561,584,400,629,800	0.000000014	0.000116655	0.000133277
MIXED43	N/A	14	29	38,517,553,936,465,900	0.000000013	0.000113654	0.000129849
MIXED43	N/A	18	28	40,578,163,817,840,600	0.000000013	0.000110731	0.000126509
MIXED43	N/A	22	27	42,749,012,087,930,900	0.000000012	0.000107883	0.000123255
MIXED43	N/A	3	32	43,923,441,513,525,100	0.000000012	0.000106430	0.000121596
PURE	4	N/A	26	45,035,996,273,705,000	0.000000011	0.000105108	0.000120085
MIXED43	N/A	7	31	46,273,255,257,047,000	0.000000011	0.000103693	0.000118469
MIXED43	N/A	11	30	48,748,779,200,839,700	0.000000010	0.000101026	0.000115421
MIXED43	N/A	15	29	51,356,738,581,954,600	0.000000010	0.000098427	0.000112453
MIXED43	N/A	19	28	54,104,218,423,787,500	0.000000009	0.000095896	0.000109560
PURE	3	N/A	33	55,590,605,665,555,200	0.000000009	0.000094605	0.000108085
MIXED43	N/A	23	27	56,998,682,783,907,800	0.000000009	0.000093429	0.000106742
MIXED43	N/A	4	32	58,564,588,684,700,200	0.000000009	0.000092171	0.000105305
MIXED43	N/A	8	31	61,697,673,676,062,700	0.000000008	0.000089801	0.000102597
MIXED43	N/A	12	30	64,998,372,267,786,200	0.000000008	0.000087491	0.000099958
MIXED43	N/A	16	29	68,475,651,442,606,100	0.000000007	0.000085240	0.000097387
MIXED43	N/A	20	28	72,138,957,898,383,400	0.000000007	0.000083048	0.000094882
MIXED43	N/A	1	33	74,120,807,554,073,600	0.000000007	0.000081930	0.000093605
MIXED43	N/A	24	27	75,998,243,711,877,100	0.000000007	0.000080912	0.000092441
MIXED43	N/A	5	32	78,086,118,246,266,900	0.000000007	0.000079823	0.000091197
MIXED43	N/A	9	31	82,263,564,901,417,000	0.000000006	0.000077770	0.000088851
MIXED43	N/A	13	30	86,664,496,357,048,300	0.000000006	0.000075769	0.000086566
MIXED43	N/A	17	29	91,300,868,590,141,400	0.000000006	0.000073820	0.000084339
MIXED43	N/A	21	28	96,185,277,197,844,500	0.000000005	0.000071922	0.000082170
MIXED43	N/A	2	33	98,827,743,405,431,500	0.000000005	0.000070954	0.000081064
MIXED43	N/A	25	27	101,330,991,615,836,000	0.000000005	0.000070072	0.000080057
MIXED43	N/A	6	32	104,114,824,328,356,000	0.000000005	0.000069129	0.000078979
MIXED43	N/A	10	31	109,684,753,201,889,000	0.000000005	0.000067351	0.000076948
MIXED43	N/A	14	30	115,552,661,809,398,000	0.000000004	0.000065618	0.000074968
MIXED43	N/A	18	29	121,734,491,453,522,000	0.000000004	0.000063930	0.000073040
MIXED43	N/A	22	28	128,247,036,263,793,000	0.000000004	0.000062286	0.000071161
MIXED43	N/A	3	33	131,770,324,540,575,000	0.000000004	0.000061448	0.000070204
MIXED43	N/A	7	32	138,819,765,771,141,000	0.000000004	0.000059867	0.000068398
MIXED43	N/A	11	31	146,246,337,602,519,000	0.000000003	0.000058327	0.000066639
MIXED43	N/A	15	30	154,070,215,745,864,000	0.000000003	0.000056827	0.000064925
MIXED43	N/A	19	29	162,312,655,271,363,000	0.000000003	0.000055365	0.000063255
PURE	3	N/A	34	166,771,816,996,666,000	0.000000003	0.000054620	0.000062403
MIXED43	N/A	23	28	170,996,048,351,724,000	0.000000003	0.000053941	0.000061628
MIXED43	N/A	4	33	175,693,766,054,100,000	0.000000003	0.000053215	0.000060798
PURE	4	N/A	27	180,143,985,094,820,000	0.000000003	0.000052554	0.000060042
MIXED43	N/A	8	32	185,093,021,028,188,000	0.000000003	0.000051846	0.000059234
MIXED43	N/A	12	31	194,995,116,803,359,000	0.000000003	0.000050513	0.000057711
MIXED43	N/A	16	30	205,426,954,327,818,000	0.000000002	0.000049214	0.000056226
MIXED43	N/A	20	29	216,416,873,695,150,000	0.000000002	0.000047948	0.000054780
MIXED43	N/A	1	34	222,362,422,662,221,000	0.000000002	0.000047302	0.000054043
MIXED43	N/A	24	28	227,994,731,135,631,000	0.000000002	0.000046714	0.000053371
MIXED43	N/A	5	33	234,258,354,738,801,000	0.000000002	0.000046086	0.000052653
MIXED43	N/A	9	32	246,790,694,704,251,000	0.000000002	0.000044900	0.000051298
MIXED43	N/A	13	31	259,993,489,071,145,000	0.000000002	0.000043745	0.000049979
MIXED43	N/A	17	30	273,902,605,770,424,000	0.000000002	0.000042620	0.000048693
MIXED43	N/A	21	29	288,555,831,593,533,000	0.000000002	0.000041524	0.000047441
MIXED43	N/A	2	34	296,483,230,216,295,000	0.000000002	0.000040965	0.000046802
MIXED43	N/A	25	28	303,992,974,847,508,000	0.000000002	0.000040456	0.000046221
MIXED43	N/A	6	33	312,344,472,985,068,000	0.000000002	0.000039911	0.000045599
MIXED43	N/A	10	32	329,054,259,605,668,000	0.000000002	0.000038885	0.000044426

dggs_ aperture_ type	dggs_ aperture	dggs_ num_ aperture_ 4_res	dggs_ res_spec	*Number of Cells[1]*	*Hex Area[2] (km²)*	*Intercell Distance[3] (km)*	*Characteristic Length Scale[4] (km)*
MIXED43	N/A	14	31	346,657,985,428,193,000	0.000000001	0.000037885	0.000043283
MIXED43	N/A	18	30	365,203,474,360,566,000	0.000000001	0.000036910	0.000042170
MIXED43	N/A	22	29	384,741,108,791,378,000	0.000000001	0.000035961	0.000041085
MIXED43	N/A	3	34	395,310,973,621,726,000	0.000000001	0.000035477	0.000040532
MIXED43	N/A	7	33	416,459,297,313,423,000	0.000000001	0.000034564	0.000039490
MIXED43	N/A	11	32	438,739,012,807,557,000	0.000000001	0.000033675	0.000038474
MIXED43	N/A	15	31	462,210,647,237,591,000	0.000000001	0.000032809	0.000037484
MIXED43	N/A	19	30	486,937,965,814,088,000	0.000000001	0.000031965	0.000036520
PURE	3	N/A	35	500,315,450,989,997,000	0.000000001	0.000031535	0.000036028
MIXED43	N/A	23	29	512,988,145,055,171,000	0.000000001	0.000031143	0.000035581
MIXED43	N/A	4	34	527,081,298,162,301,000	0.000000001	0.000030724	0.000035102
MIXED43	N/A	8	33	555,279,063,084,564,000	0.000000001	0.000029934	0.000034199
MIXED43	N/A	12	32	584,985,350,410,076,000	0.000000001	0.000029164	0.000033319
MIXED43	N/A	16	31	616,280,862,983,455,000	0.000000001	0.000028413	0.000032462
MIXED43	N/A	20	30	649,250,621,085,450,000	0.000000001	0.000027683	0.000031627
MIXED43	N/A	1	35	667,087,267,986,663,000	0.000000001	0.000027310	0.000031202
MIXED43	N/A	24	29	683,984,193,406,894,000	0.000000001	0.000026971	0.000030814
MIXED43	N/A	5	34	702,775,064,216,402,000	0.000000001	0.000026608	0.000030399
PURE	4	N/A	28	720,575,940,379,279,000	0.000000001	0.000026277	0.000030021
MIXED43	N/A	9	33	740,372,084,112,753,000	0.000000001	0.000025923	0.000029617
MIXED43	N/A	13	32	779,980,467,213,435,000	0.000000001	0.000025256	0.000028855
MIXED43	N/A	17	31	821,707,817,311,273,000	0.000000001	0.000024607	0.000028113
MIXED43	N/A	21	30	865,667,494,780,600,000	0.000000001	0.000023974	0.000027390
MIXED43	N/A	2	35	889,449,690,648,884,000	0.000000001	0.000023651	0.000027021
MIXED43	N/A	25	29	911,978,924,542,525,000	0.000000001	0.000023357	0.000026686
MIXED43	N/A	6	34	937,033,418,955,203,000	0.000000001	0.000023043	0.000026326
MIXED43	N/A	10	33	987,162,778,817,004,000	0.000000001	0.000022450	0.000025649
MIXED43	N/A	14	32	1,039,973,956,284,580,000	0.000000000	0.000021873	0.000024989
MIXED43	N/A	18	31	1,095,610,423,081,700,000	0.000000000	0.000021310	0.000024347
MIXED43	N/A	22	30	1,154,223,326,374,130,000	0.000000000	0.000020762	0.000023720
MIXED43	N/A	3	35	1,185,932,920,865,180,000	0.000000000	0.000020483	0.000023401
MIXED43	N/A	7	34	1,249,377,891,940,270,000	0.000000000	0.000019956	0.000022799
MIXED43	N/A	11	33	1,316,217,038,422,670,000	0.000000000	0.000019442	0.000022213
MIXED43	N/A	19	31	1,460,813,897,442,260,000	0.000000000	0.000018455	0.000021085
MIXED43	N/A	23	30	1,538,964,435,165,510,000	0.000000000	0.000017980	0.000020543
MIXED43	N/A	4	35	1,581,243,894,486,900,000	0.000000000	0.000017738	0.000020266
MIXED43	N/A	8	34	1,665,837,189,253,690,000	0.000000000	0.000017282	0.000019745
MIXED43	N/A	12	33	1,754,956,051,230,230,000	0.000000000	0.000016838	0.000019237
MIXED43	N/A	16	32	1,848,842,588,950,360,000	0.000000000	0.000016405	0.000018742
MIXED43	N/A	20	31	1,947,751,863,256,350,000	0.000000000	0.000015983	0.000018260
MIXED43	N/A	5	35	2,108,325,192,649,210,000	0.000000000	0.000015362	0.000017551
MIXED43	N/A	9	34	2,221,116,252,338,260,000	0.000000000	0.000014967	0.000017099
MIXED43	N/A	13	33	2,339,941,401,640,300,000	0.000000000	0.000014582	0.000016660
MIXED43	N/A	17	32	2,465,123,451,933,820,000	0.000000000	0.000014207	0.000016231
MIXED43	N/A	21	31	2,597,002,484,341,800,000	0.000000000	0.000013841	0.000015814
MIXED43	N/A	6	35	2,811,100,256,865,610,000	0.000000000	0.000013304	0.000015200
PURE	4	N/A	29	2,882,303,761,517,120,000	0.000000000	0.000013138	0.000015011
MIXED43	N/A	10	34	2,961,488,336,451,010,000	0.000000000	0.000012962	0.000014809
MIXED43	N/A	14	33	3,119,921,868,853,740,000	0.000000000	0.000012628	0.000014428
MIXED43	N/A	18	32	3,286,831,269,245,090,000	0.000000000	0.000012303	0.000014057
MIXED43	N/A	22	31	3,462,669,979,122,400,000	0.000000000	0.000011987	0.000013695
MIXED43	N/A	7	35	3,748,133,675,820,810,000	0.000000000	0.000011521	0.000013163
MIXED43	N/A	11	34	3,948,651,115,268,010,000	0.000000000	0.000011225	0.000012825
MIXED43	N/A	19	32	4,382,441,692,326,790,000	0.000000000	0.000010655	0.000012173
MIXED43	N/A	23	31	4,616,893,305,496,540,000	0.000000000	0.000010381	0.000011860
MIXED43	N/A	8	35	4,997,511,567,761,080,000	0.000000000	0.000009978	0.000011400
MIXED43	N/A	12	34	5,264,868,153,690,690,000	0.000000000	0.000009721	0.000011106
MIXED43	N/A	16	33	5,546,527,766,851,090,000	0.000000000	0.000009471	0.000010821
MIXED43	N/A	20	32	5,843,255,589,769,050,000	0.000000000	0.000009228	0.000010542
MIXED43	N/A	9	35	6,663,348,757,014,770,000	0.000000000	0.000008641	0.000009872
MIXED43	N/A	13	34	7,019,824,204,920,910,000	0.000000000	0.000008419	0.000009618
MIXED43	N/A	17	33	7,395,370,355,801,460,000	0.000000000	0.000008202	0.000009371
MIXED43	N/A	21	32	7,791,007,453,025,400,000	0.000000000	0.000007991	0.000009130
MIXED43	N/A	10	35	8,884,465,009,353,030,000	0.000000000	0.000007483	0.000008550
MIXED43	N/A	14	34	9,359,765,606,561,220,000	0.000000000	0.000007291	0.000008330
MIXED43	N/A	18	33	9,860,493,807,735,280,000	0.000000000	0.000007103	0.000008116
PURE	4	N/A	30	11,529,215,046,068,500,000	0.000000000	0.000006569	0.000007505
MIXED43	N/A	11	35	11,845,953,345,804,000,000	0.000000000	0.000006481	0.000007404
MIXED43	N/A	12	35	15,794,604,461,072,100,000	0.000000000	0.000005613	0.000006412
MIXED43	N/A	16	34	16,639,583,300,553,300,000	0.000000000	0.000005468	0.000006247
MIXED43	N/A	20	33	17,529,766,769,307,200,000	0.000000000	0.000005328	0.000006087

Notes:

[1]At every resolution 12 of the cells are pentagons and the remainder are hexagons.
[2]Assuming an equal area projection. The 12 pentagons have an area exactly 5/6 the area of a hexagon.
[3]Measured in the plane of the projection space.
[4]Characteristic Length Scale (CLS): the diameter of a spherical cap of the same area as a cell of the specified resolution. This metric was suggested by Ralph Kahn.

Appendix D. The Superfund_500m DGG

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Introduction

The **Superfund_500m** grid was commissioned by the US Environmental Protection agency for use in developing its Superfund Emergency Response Atlas. The grid is a hierarchically indexed icosahedral hexagonal discrete global grid (DGG) (Sahr et al. 2003) consisting of approximately 22 hectare hexagons, with approximately 500 meter distance between hexagon centers. This cell size is generated geometrically by creating a mixed aperture sequence of two aperture 4 subdivisions followed by 15 aperture 3 subdivisions.

It is not possible to create a network of equal area, equal shape, and equally spaced grid cells greater than twenty in number on the surface of a sphere. Thus one or more, often two or all three, of these characteristics are distorted to varying degrees across the surface. The approach used here starts with the twenty triangular faces of the icosahedron, creates a regular, equal area, equal shape, and equally spaced network of hexagons of the desired size on one or more of the planar triangles and then projects these cells to the surface of the globe. The distortion characteristics of this approach have been investigated by Kimerling et al. (1999) and Gregory et al. (2008).

Grid characteristics for the 10 addressable **Superfund_500m** resolutions are given in Table 1.

Grid Construction

The cells are generated as regular hexagons (and pentagons) on the surface of an icosahedron, oriented relative to the globe so as to be symmetrical about the equator. The cells are projected to longitude and latitude on a sphere with the authalic WGS84 radius (NAD 83 datum) using the inverse icosahedral projection of R. Buckminster Fuller (1975) as developed analytically by Robert Gray (1995) and John Crider (2008).

The **Superfund_500m** cell identifiers are an instance of Central Place Indexing (CPI). CPI (Sahr, 2011; Sahr & White, in preparation) is a class of hierarchical indexing systems for pure and mixed aperture hexagonal DGGs, where the linear index assigned to each cell is constructed as a path address (Sahr 2008) on a multi-resolution discrete global grid system with the specified aperture sequence. A CPI addressing system was used in the initial design for a sampling system for the EPA's Environmental Monitoring and Assessment Program (White et al. 1992).

Table 1. Superfund_500m DGG Resolutions (see notes after table).

Resolution	# Cells[1]	Hex Area[2] (sq. km)	Intercell Distance[3] (km)	CLS[4] (km)
0	42	12,751,640.5431	3,526.8262	4,046.3596
1	162	3,187,910.1358	1,763.4131	2,016.7939
2	1,442	354,212.2373	587.8044	671.6409
3	12,962	39,356.9153	195.9348	223.8573
4	116,642	4,372.9906	65.3116	74.6182
5	1,049,762	485.8878	21.7705	24.8727
6	9,447,842	53.9875	7.2568	8.2909
7	85,030,562	5.9986	2.4189	2.7636
8	765,275,042	0.6665	0.8063	0.9212
9	2,295,825,122	0.2222	0.4655	0.5319

Table 1 Notes:
[1]At every resolution 12 of the cells are pentagons and the remainder are hexagons.
[2]The 12 pentagons have an area exactly 5/6 the area of a hexagon.
[3]Measured in the plane of the Fuller projection space.
[4]Characteristic Length Scale (CLS): the diameter of a spherical cap of the same area as a cell of the specified resolution. This metric was suggested by Ralph Kahn.

The **Superfund_500m** CPI system was designed to meet two design goals. First, the CPI approach allows the grid to have an intercell spacing of approximately 500 meters, which cannot be achieved with sufficient accuracy using a pure aperture grid system. Second, in order to take advantage of the pre-existing discrete global grid software tool **DGGRID** the cells needed to be hierarchically indexed in such a manner that the Christaller sets of each base cell are each restricted to a single **ij** coordinate system whose axes form two of the edges of a spherical quadrilateral formed by a pair of adjacent icosahedral faces.

These design goals were met by constructing a grid with base cells of valence 5 (i.e., with pentagonal voronoi areas) centered on each of the 12 vertices of an icosahedron and then applying the following aperture sequence:

$$4, 4, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}, 3^{cw}, 3^{ccw}$$

To assign a unique hierarchical index to each cell, as well as to achieve the remaining grid design goals, the generator types ***A-K*** were defined with the following generator string representations:

A: ***A***123456
B: ***C***123***CCC***
C: ***D***123***EED***
D: ***F***123***IK***6
E: ***J***123***GH***6
F: ***D***123***EE***6
G: ***DD***234***E***6
H: ***EE***2***D***456
I: ***E***1***DD***456
J: ***E***1***D***345***E***
K: ***D***123***E***5***D***

Two of the base cells on opposing sides of the icosahedron are assigned generator type ***A***, while the remaining 10 base cells (centered on the remaining 10 icosahedral vertices) are assigned generator type ***B***. Figures 1-3 illustrate the resolution 17 regions corresponding to the resolution 1 grid cells, numbered 10-51 (to avoid leading zeros in indexes). The resolution 0 base tiles centered on the resolution 1 cells labeled 10 and 51 are the two base cells that were assigned generator type ***A***, which generates a single pentagonal cell at all resolutions.

Index Form

The base tiles of the **Superfund_500m** CPI indexes correspond to resolution 1 DGG cells, as illustrated in Figure 1. Base tiles 11-50 each have four hierarchical children at the aperture 4 resolution 2, which are assigned the additional digits 1-4. These resolution 2 cells each have three children at resolution 3, which are assigned the additional digits 1-3; this assignment continues recursively through the aperture 3 resolutions 3-17. The special base tiles 10 and 51 have a single hierarchical child at all resolutions, which is assigned the additional digit 1 at each resolution. In order to reduce the length of indexes, a first order compression is performed by grouping the aperture 3 resolution 3-16 digits into pairs and replacing each pair of digits with a digit value of 1-9.

The assignment of digits has been chosen so that all indexes form integers with the same number of digits, and so that possibly troublesome leading zeros can be avoided, even if redundant leading digits are removed from indexes when working in regions where this is possible.

Thus the full resolution 17 **Superfund_500m** CPI indexes are condensed into indexes with 11 digits, resulting in 10 addressable grid resolutions (see Table 1).

A **Superfund_500m** index at full resolution (resolution 9) has the 11-digit form:

BB499999993

where:

- *BB* is the 2-digit resolution 1 base tile cell with values 10-51,
- *4* is the resolution 2 aperture 4 digit with values 1-4,
- each *9* represent two successive combined aperture 3 digits for resolutions 3-16, with values 1-9 each, and
- the final 3 represents the extra aperture 3 at resolution 17, with values 1-3

Note that the resolution 9 footprint of base tiles 11-50 form approximate spherical diamonds on the surface of the globe, as illustrated in Figure 1. Figures 2 and 3 illustrate the resolution 9 indexing footprints of base tiles adjacent to base tiles 10 and 15 respectively. The hierarchical children at each aperture 3 resolution form a compact triangle; Figure 4 illustrates the pattern formed at resolution 9.

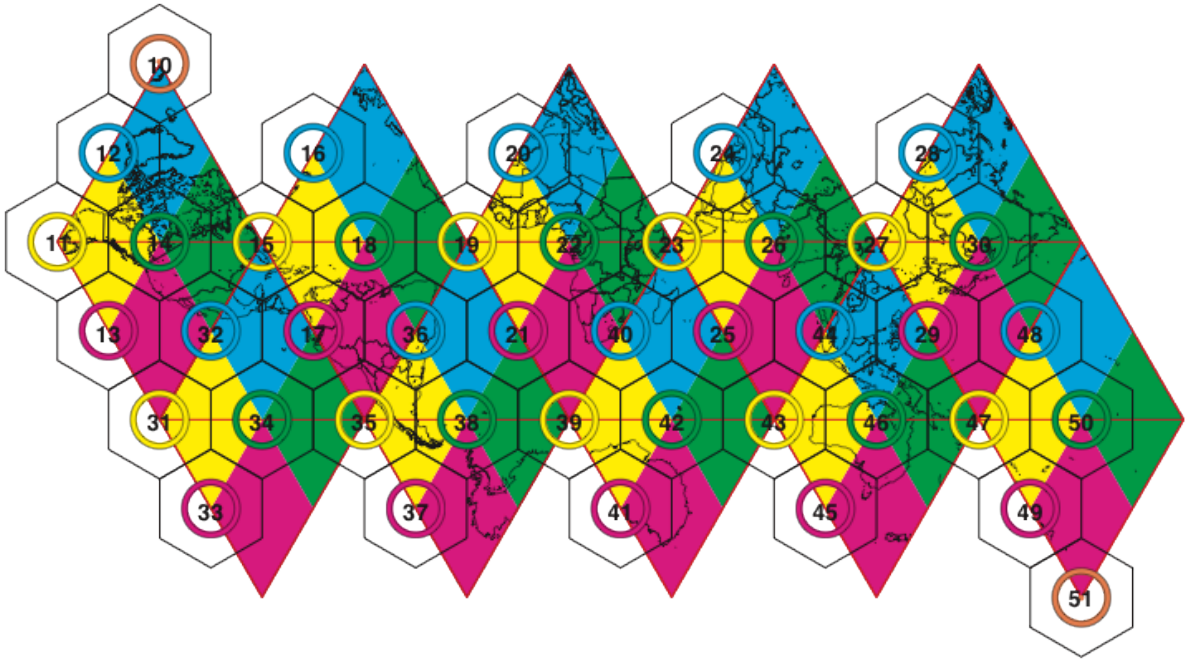

Figure 1. Superfund_500m base tiles on an unfolded icosahedron with corresponding resolution 9 indexing footprints. Cells within the footprint region of a base tile will have that base tile's index as the first two digits of the cell's index. Tiles 10 and 51 index only a single cell at all resolutions, centered on the corresponding base tile. Note that all tiles that are centered on a triangle vertex are actually pentagons on the sphere.

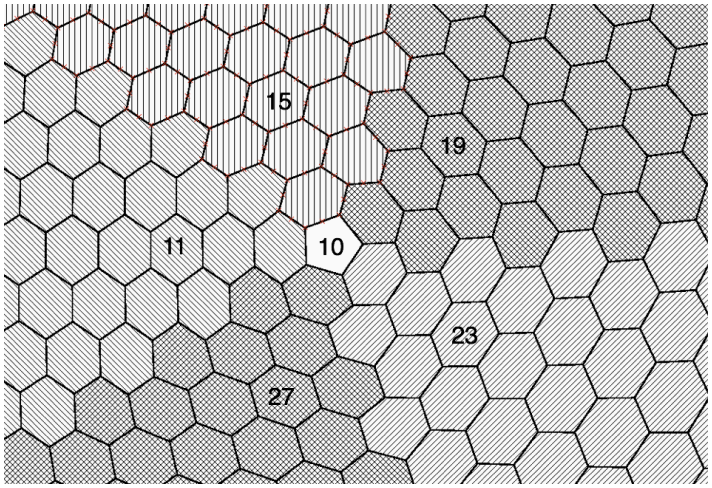

Figure 2. Region around base tile 10 at resolution 9.

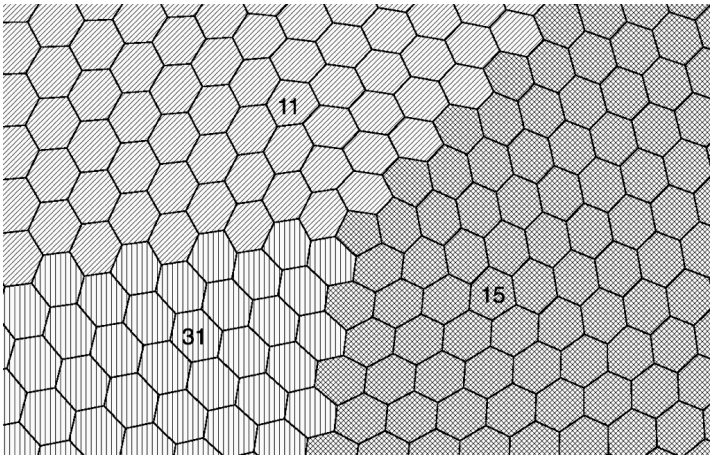

Figure 3. Region around base tile 15 at resolution 9.

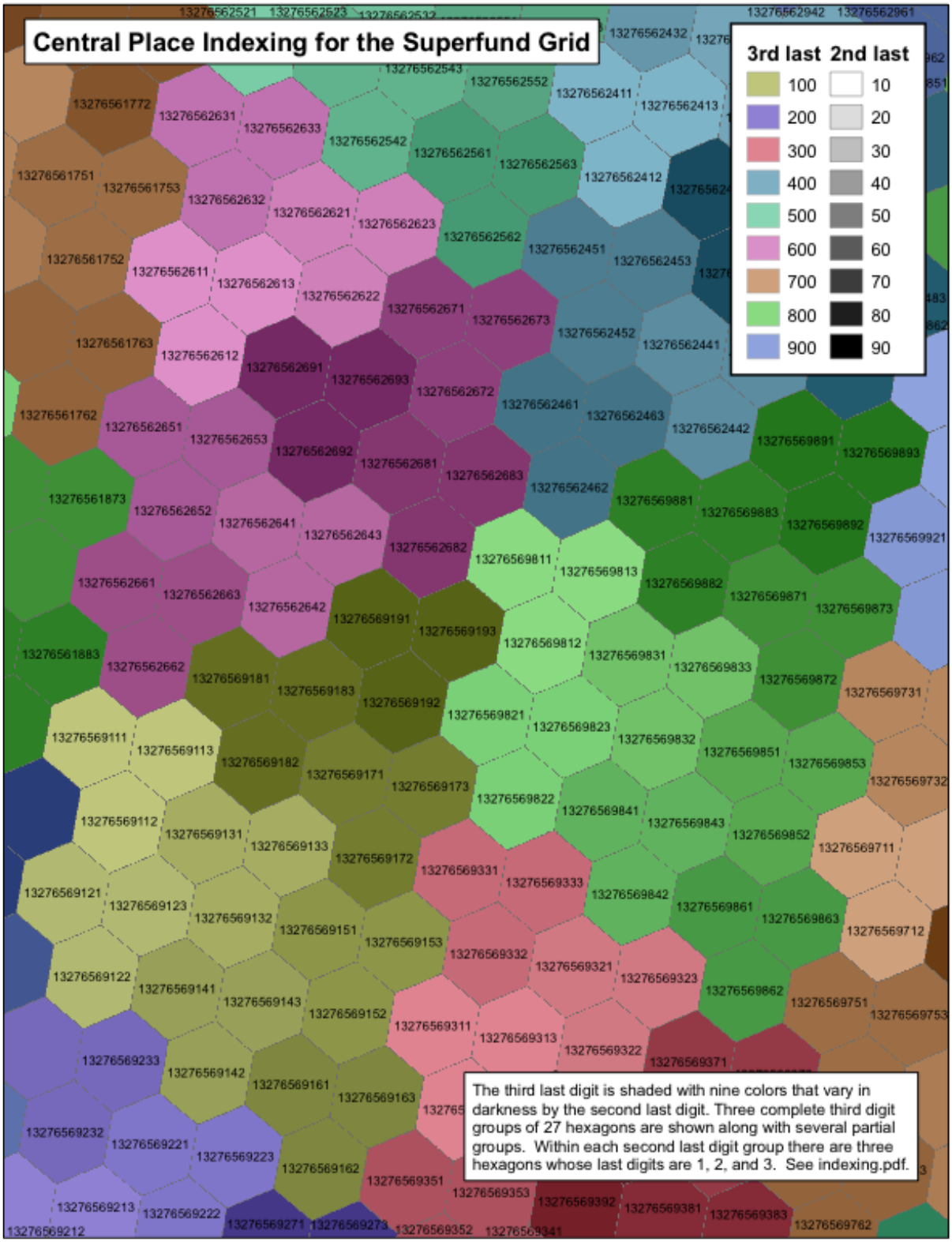

Figure 4. Superfund_500m resolution 9 tiling pattern.

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