

# Generating variable resolution grids

In CESM v2.2 and later, users can create and use custom variable resolution spectral element grids.

The steps required to create a new grid and use it in CESM include:

- Generating a new grid using SQuadGen or VRM\_Editor. The VRM\_tools for creating new grids are located in [https://github.com/ESMCI/Community\\_Mesh\\_Generation\\_Toolkit](https://github.com/ESMCI/Community_Mesh_Generation_Toolkit). **Note:** new features were added to the linux version of VRM\_Editor on Jan 11, 2022.
- Regridding standard atmosphere and land input datasets to the new grid
- Creating a new CAM case, using the resolution name of your new grid
- Running CAM for at least 1 year to spin-up the land model. This may require some adjustment of the model time step and other parameters to get a functioning and stable simulation
- Setting up inputs for CAM-chem with your new grid (including: [Regridding emissions](#), [Regridding meteorological data](#), [Regridding initial conditions](#))
- Creating a new CAM-chem case, using the resolution name of your new grid

These steps for CESM2.2 are outlined in:

- [VRM\\_tools documents](#)
- a [step-by-step guide](#)
- [video of the 12-Feb-2021 tutorial](#)

The [MUSICA Tutorial Session on 14-Jan-2022](#) provides additional tips and describes updates to the grid generation tools.

See [Tips and FAQ](#) for more guidance.

\*\*\* Updated instructions for CESM3 and derecho coming soon \*\*\*

## Types of grid files

Several types of grid files are used to define the Spectral Element unstructured grids.

### EXODUS

EXODUS II is a data model for finite element analysis. The data files for EXODUS are netCDF files with an established convention for describing data objects. The details of the required dimension, variable, and attributes are available in Shoof and Yarberry, Sandia Report, 1994 <[exodus.pdf](#)>.

The spectral element (SE) grids created by SQuadGen and the VRM\_Editor describe the partitioning of each of the cube faces into NE<sub>x</sub>NE quadrilateral regions. Thus for an ne30 grid, each face is divided into 30x30 = 900 quads, and the total number of elements is 6x(30x30) = 5400. The 3D cartesian coordinate locations of the element corners on the unit sphere are stored in counter-clockwise order.

For future reference, the contents of the EXODUS files created using the VRM\_Editor are augmented with additional information about the editor settings and refinement map used to create the grid.

Note that the EXODUS files only describe the partitioning of the cube elements. The figure shows these elements for a uniform ne30 grid over South America. For use in the spectral element model, these elements are further partitioned with the addition of a specified number of grid points in each element. (e.g. for NP4, each element is supported by a 4x4 set of grid points).

### SCRIP

The Spherical Coordinate Remapping and Interpolation Package(SCRIP) provides software to transform values between spherical grids. The grid information for this package is stored in netCDF files with a prescribed format for cells that span the surface of the sphere. Each cell requires a Latitude, Longitude coordinate of the center, the polygonal region of the cell boundaries, and the enclosed area of the cell.

The Gen\_ControlVolumes.exe program adds a grid of 4x4 Gauss-Legendre-Lobatto (GLL) points to each element in the EXODUS input file.

Since the grid points from neighboring elements overlap, only the smaller set of unique grid points is included in the grid description. For a uniform grid, the number of unique grid points is:

$$N = 6*NE*NE*(NP-1)*(NP-1) + 2$$

The 2 additional points are needed to complete the connection between the cube faces. For each of these unique points, an associated control volume (polygon) is constructed and the corresponding area is calculated.

Zoomed in over South America, the green dots in the figure show the added GLL points relative to the elements from the EXODUS file and the red lines indicate the control volume associated with each point. Additional information about the SCRIP package is available in <[SCRIPusers.pdf](#)>

### LATLON

The LATLON file contains the Latitudes, Longitudes, and Area for each unique grid point. These are the coordinates commonly found in a CESM history file for the SE dycore.

An additional array with connectivity information is also included in this file to simplify the process of graphing results on the unstructured grid. This connectivity array defines the quadrilateral for each set of 4 neighboring grid points. Note that the set of unique grid points is the same as those found in the SCRIP file.

## MESH

The mesh file is analogous to the contents of the SCRIP file, with additional information to optimize the ESMF mapping options. For more information regarding the contents of these files, visit the [earthsystemmodeling.org](http://earthsystemmodeling.org) website.

