

CS Description

Benjamin Auer

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1 Introduction

The GEOS-IT native grid is a c180 equidistant gnomonic cubed-sphere grid which is essentially 6 identical faces that wrap a sphere, with 180x180 grid cells per face. The grid used in GEOS is constructed as follows. A cube is inscribed in a sphere and let us imagine in Cartesian space the z-axis goes through the center of two faces of cube. Since the cubed can be arbitrarily rotated around the z-axis we know the longitudes of cube corners are separated by 90° . Likewise by simple geometry we know the corners of the cube are at a latitude given by $\alpha = \pm \sin^{-1}(\frac{1}{\sqrt{3}})$. Using this information we can see that the west edge on one face cube parallel to the z-axis will be defined by a line of constant longitude defined by $(\theta_0, -\alpha), (\theta_0, \alpha)$ and the east edge will the same shifted by 90° . The choice of θ_0 is arbitrary. The interior points of the east and west edges are then constructed by computing a constant spacing in latitude for the appropriate resolution. The north and south edges of the face are computed by mirroring the east and west edges across a plane defined by the center of the sphere and the two diagonal corners of the face. This can be done for all 4 equatorial faces of the cube which defines the 6 faces. The grid on each face is defined by great circles that connect opposite edges of each face and is where the gnomonic part or the name comes from. The edges of each face are equally spaced along the sphere, hence the equidistant part of the name. Each face is identical in terms of the cell sizes for a given index on the face and results in a much more uniform grid cell size that a traditional Lat-Lon grid for example. Note that the literature maybe confusing as they also define an equidistant cubed sphere grid as that obtained by defining an evenly spaced rectilinear grid on each face of the inscribed cube and project those points to the sphere. This is not the grid used by GEOS as it results in a less even size of the cells than the procedure described here.

The orientation of the faces used in GEOS can be seen in Figure 1. Note that faces 3 and 6 are both centered over the poles and the other 4 faces wrap around the globe with the equator bisecting the center of those faces. The N-S lines on the equatorial faces are all constant longitude. The left or west edge of face 1 is a line of constant longitude of -55° and each of edges of the equatorial faces is spaced by 90° . The u-v arrows denote how each face is locally indexed; in other

words the u direction denotes increasing values of Xdim and the v direction denotes increasing values of Ydim. Also note that this implies the indexing on each face does not line up depending on the face. In other words grid cell (1,1) on face 1 is not adjacent to grid cell (180,1) on face 5. Rather it is adjacent to grid cell (180,180) on face 5 for example.

The cubed-sphere coordinates are not given by a simple formula but the coordinates are included in the cubed-sphere files produced by GEOS for the user. Below is an ncdump of the dimensions and variables in a GEOS cubed-sphere file to demonstrate the file format used by cubed-sphere output. Each variable is indexed with 3 indices in the horizontal (as opposed to 2 in a lat-lon grid file); the face number (nf) and the x (Xdim),y (Ydim) index on the face. The lons and lats are the centers of each cell and the corner_lons and corner_lats are the edges of each cell. Notice that the number of edges on each face is one larger than the number of centers in each direction. Each edge is represented twice by virtue of inclusion in each of the faces it borders.

```

dimensions:
  nf = 6 ;
  ncontact = 4 ;
  Xdim = 180 ;
  Ydim = 180 ;
  orientationStrLen = 5 ;
  lev = 72 ;
  time = UNLIMITED ; // (1 currently)
variables:
  int nf(nf) ;
    nf:long_name = "cubed-sphere face" ;
    nf:axis = "e" ;
    nf:grads_dim = "e" ;
    nf:_Storage = "chunked" ;
    nf:_ChunkSizes = 6 ;
    nf:_DeflateLevel = 2 ;
    nf:_Shuffle = "true" ;
    nf:_Endianness = "little" ;
  int ncontact(ncontact) ;
    ncontact:long_name = "number of contact points" ;
    ncontact:_Storage = "chunked" ;
    ncontact:_ChunkSizes = 4 ;
    ncontact:_DeflateLevel = 2 ;
    ncontact:_Shuffle = "true" ;
    ncontact:_Endianness = "little" ;
  char cubed_sphere ;
    cubed_sphere:grid_mapping_name = "gnomonic cubed-sphere" ;
    cubed_sphere:file_format_version = "2.90" ;
    cubed_sphere:additional_vars = "contacts,orientation,anchor" ;
    cubed_sphere:gridspec_file = "C180_gridspec.nc4" ;

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double Xdim(Xdim) ;
    Xdim:long_name = "Fake Longitude for GrADS Compatibility" ;
    Xdim:units = "degrees_east" ;
    Xdim:_Storage = "chunked" ;
    Xdim:_ChunkSizes = 180 ;
    Xdim:_DeflateLevel = 2 ;
    Xdim:_Shuffle = "true" ;
double Ydim(Ydim) ;
    Ydim:long_name = "Fake Latitude for GrADS Compatibility" ;
    Ydim:units = "degrees_north" ;
    Ydim:_Storage = "chunked" ;
    Ydim:_ChunkSizes = 180 ;
    Ydim:_DeflateLevel = 2 ;
    Ydim:_Shuffle = "true" ;
double lons(nf, Ydim, Xdim) ;
    lons:long_name = "longitude" ;
    lons:units = "degrees_east" ;
    lons:_Storage = "chunked" ;
    lons:_ChunkSizes = 6, 180, 180 ;
    lons:_DeflateLevel = 2 ;
    lons:_Shuffle = "true" ;
double lats(nf, Ydim, Xdim) ;
    lats:long_name = "latitude" ;
    lats:units = "degrees_north" ;
    lats:_Storage = "chunked" ;
    lats:_ChunkSizes = 6, 180, 180 ;
    lats:_DeflateLevel = 2 ;
    lats:_Shuffle = "true" ;
int contacts(nf, ncontact) ;
    contacts:long_name = "adjacent face starting from left side going clockwise" ;
    contacts:_Storage = "chunked" ;
    contacts:_ChunkSizes = 6, 4 ;
    contacts:_DeflateLevel = 2 ;
    contacts:_Shuffle = "true" ;
    contacts:_Endianness = "little" ;
char orientation(nf, ncontact, orientationStrLen) ;
    orientation:long_name = "orientation of boundary" ;
    orientation:_Storage = "chunked" ;
    orientation:_ChunkSizes = 6, 4, 5 ;
    orientation:_DeflateLevel = 2 ;
    orientation:_Shuffle = "true" ;
int anchor(nf, ncontact, ncontact) ;
    anchor:long_name = "anchor point" ;
    anchor:_Storage = "chunked" ;
    anchor:_ChunkSizes = 6, 4, 4 ;
    anchor:_DeflateLevel = 2 ;

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    anchor:_Shuffle = "true" ;
    anchor:_Endianness = "little" ;
double lev(lev) ;
    lev:long_name = "vertical level" ;
    lev:units = "layer" ;
    lev:positive = "down" ;
    lev:coordinate = "eta" ;
    lev:standard_name = "model_layers" ;
    lev:_Storage = "chunked" ;
    lev:_ChunkSizes = 1 ;
    lev:_DeflateLevel = 2 ;
    lev:_Shuffle = "true" ;
int time(time) ;
    time:long_name = "time" ;
    time:units = "minutes since 2018-02-01 01:30:00" ;
    time:time_increment = 30000 ;
    time:begin_date = 20180201 ;
    time:begin_time = 13000 ;
    time:_Storage = "chunked" ;
    time:_ChunkSizes = 1 ;
    time:_DeflateLevel = 2 ;
    time:_Shuffle = "true" ;
    time:_Endianness = "little" ;
float DELP(time, lev, nf, Ydim, Xdim) ;
    DELP:long_name = "pressure_thickness" ;
    DELP:units = "Pa" ;
    DELP:_FillValue = 1.e+15f ;
    DELP:missing_value = 1.e+15f ;
    DELP:fmissing_value = 1.e+15f ;
    DELP:scale_factor = 1.f ;
    DELP:add_offset = 0.f ;
    DELP:standard_name = "pressure_thickness" ;
    DELP:coordinates = "lons lats" ;
    DELP:grid_mapping = "cubed_sphere" ;
    DELP:vmin = -1.e+15f ;
    DELP:vmax = 1.e+15f ;
    DELP:valid_range = -1.e+15f, 1.e+15f ;
    DELP:_Storage = "chunked" ;
    DELP:_ChunkSizes = 1, 1, 6, 180, 180 ;
    DELP:_DeflateLevel = 2 ;
    DELP:_Shuffle = "true" ;

// global attributes:
:Contact = "http://gmao.gsfc.nasa.gov" ;
:_NCProperties = "version=2,netcdf=4.7.3,hdf5=1.10.6," ;
:History = "Original file generated: Mon Jun 21 02:33:16 2021 GMT" ;

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:Comment = "GMAO filename: d5271_it_sample.qdt_tavg_3hr_glo_C180x180x6_v72.2018-02-01T0130.V01" ;
:Filename = "GEOS.it.asm.qdt_tavg_3hr_glo_C180x180x6_v72.GEOS5271.2018-02-01T0130.V01" ;
:Source = "GEOSadas-5_27_1 experiment_id: d5271_it_sample" ;
:Conventions = "CF-1" ;
:Title = "GEOS-5.27.1 GEOS-IT" ;
:Institution = "NASA Global Modeling and Assimilation Office" ;
:References = "http://gmao.gsfc.nasa.gov" ;
:Format = "NetCDF-4" ;
:SpatialCoverage = "global" ;
:VersionID = "5.27.1" ;
:TemporalRange = "1998-01-01 - ongoing" ;
:ShortName = "DITT3NVQDT" ;
:RangeBeginningDate = "2018-01-31" ;
:RangeBeginningTime = "22:31:30.000000" ;
:RangeEndingDate = "2018-02-01" ;
:RangeEndingTime = "01:31:30.000000" ;
:GranuleID = "GEOS.it.asm.qdt_tavg_3hr_glo_C180x180x6_v72.GEOS5271.2018-02-01T0130.V01" ;
:ProductionDateTime = "Original file generated: Mon Jun 21 02:33:16 2021 GMT" ;
:LongName = "GEOS5271 GEOS-IT 3d time-averaged moisture tendencies" ;
:SouthernmostLatitude = "-90.0" ;
:NorthernmostLatitude = "90.0" ;
:WesternmostLongitude = "-180.0" ;
:EasternmostLongitude = "179.375" ;
:LatitudeResolution = "0.5" ;
:LongitudeResolution = "0.625" ;
:DataResolution = "C180 (72 native layers)" ;
:_Format = "netCDF-4" ;

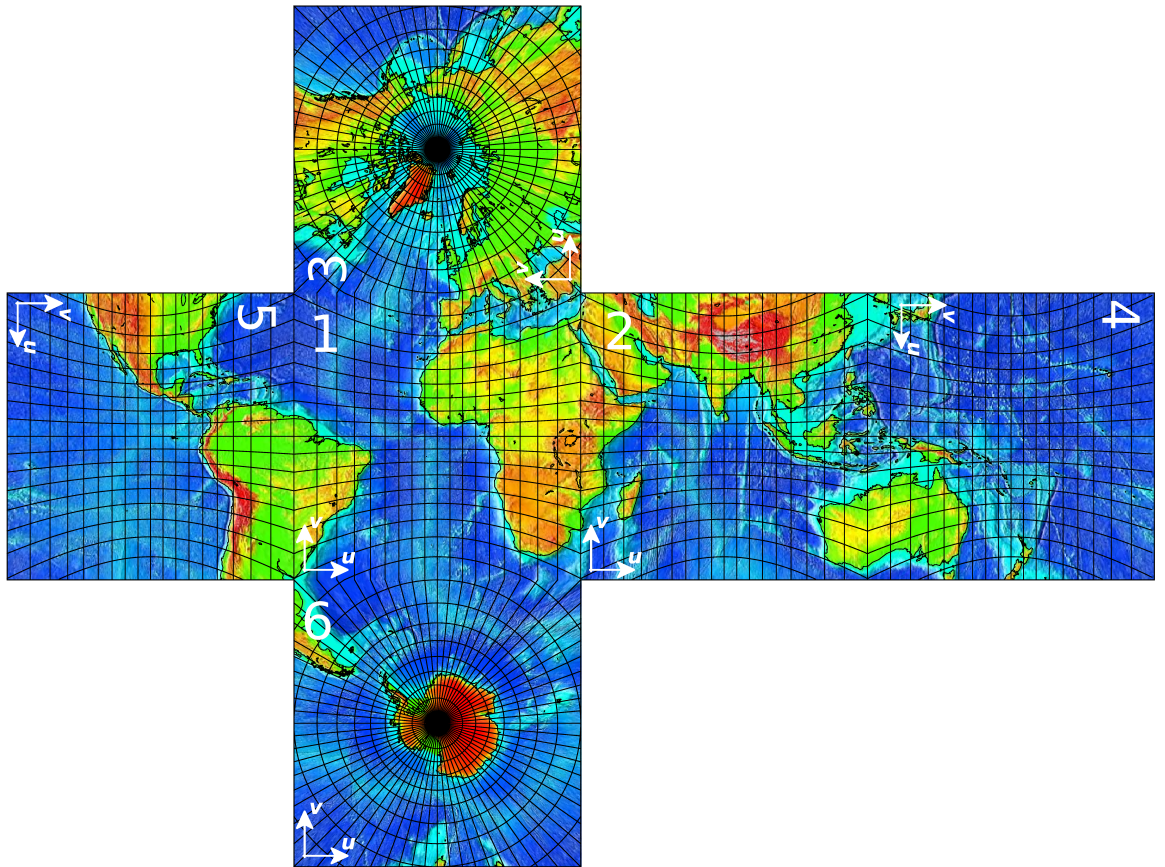


Figure 1: Orientation of the faces in the Cubed-Sphere used by GEOS.