How to Read the Vulcan files and information about our grids

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1. Binary files

The files, "vulcan.US.10k.dp.v*Y.Y.ZZZ*.bin2" are binary files representing the continental US carbon emissions in units of tonnes of carbon/hour/gridcell on a 10km x 10km surface grid every hour. The land/ocean boundary on the coastlines includes coastal waters.

The file's version stamp is indicated by the "*Y.Y*" numerical sequence. The precision is denoted by the "*dp*" code indicating that these binary files are written in double-precision form.

The "*ZZZ*" tag indicates the economic sector and has the following key:

TOT: the total emissions (summation of sectors below)
RES: the residential sector emissions
COM: the commercial sector emissions
IND: the industrial sector emissions
UTL: the power production sector emissions
MOB: the onroad mobile sector emissions
NON: the nonroad mobile sector emissions
AIR: the aircraft sector emissions (below 3000 feet)
CEM: the cement production sector emissions

This file contains an array with three dimensions in which the longitude direction has 507 gridcells, the latitudinal direction has 355 gridcells and the time dimension has 8760 timesteps.

When reading this file, the first gridcell is at the northernmost/westernmost corner of the 10km x 10km US grid and moves eastward first, then south (see the fortran write statement below).

The center of the first gridcell is located at:

-137.16 W, 51.95 N (NAD83)

In order link this data file to the grid, use the indices given in the "Grid information" section of this document. Alternatively, you can utilize the results provided on a 0.1 x 0.1 degree grid located on the Vulcan website. In order to understand that grid, please jump to the "0.1deg" section of this document.

Each record is a one hourly timestep containing the entire continental US map in the order listed above.

Time zone: all timesteps are in universal time. This means that there are a few hours before local Jan 1, 12 am that emissions begin. These hours represent "wrapped" emissions - they are copied from the hours at the end of the year.

The fortran program that was used to write the hourly double-precision binary file is as follows:

```
*****************************************************************
      Program Iovulcan
      implicit none

      integer                                    :: i,j,t
```

```fortran
      integer,parameter                                 :: im=507,jm=355,
     ^                                                      hrs=24*365
      real*8,   dimension(:,:,:),     allocatable :: emit
      character(len=90)                               :: ofnam

      ofnam = 'vulcan.output.bin2'

      Allocate(emit(im,jm,hrs)); emit = 0.0

      Open(unit=12,file=trim(ofnam),form='binary')

      Do t = 1, hrs
         Write(12) ((emit(i,j,t),i=1,im),j=1,jm)
      End do
      Close(12)

      Stop
      End
************************************************************
```

ANNUAL VERSIONS OF THESE FILES (naming convention:
"vulcan.US.10k.dp.v*Y.Y.ZZZ*.ann.bin2") ARE IDENTICAL EXCEPT THERE IS
NO TIME INDEX LOOP IN THE WRITE STATEMENT.

The total amount of carbon (summing all sectors) should come to
1541353052.804619 tonnes carbon/year.

Note that Alaska and Hawaii are not included in this gridded
emissions file for the continental United States. A separate gridded
fileset for Alaska is available (see Alaska) on the Vulcan website.
The state of Hawaii is not separately gridded but all summary
information on Hawaii emissions are included in the summary files
(state, county, sector, etc) available on the Vulcan website.

2. NetCDF files

   The files, "vulcan.US.10k.sp.v*Y.Y.ZZZ*.nc" are netCDF files
   representing the continental US carbon emissions in units of tonnes
   of carbon/hour/gridcell on a 10km x 10km surface grid every hour.
   The map projection used is the GCS_North_American_1983 (NAD83). The
   land/ocean boundary on the coastlines includes coastal waters.

   THE ONLY DIFFERENCE BETWEEN THESE FILES AND THE BINARY (HOURLY OR
   ANNUAL) DESCRIPTION IS THAT THESE FILES ARE WRITTEN AS SINGLE
   PRECISION.

3. ascii files

The file, "vulcan.US.10k.sp.v*Y.Y.ZZZ*.csv" is an ascii file representing the continental US carbon emissions in units of tonnes of carbon/hour/gridcell on a 10km x 10km surface grid every hour. The land/ocean boundary on the coastlines includes coastal waters.

The fortran program that was used to write the hourly single-precision ascii file is as follows:

```
*******************************************************************

      Program IOvulcan

      implicit none
      integer                              :: i,j,t
      integer,parameter                    :: im=507,jm=355,
     ^                                       hrs=24*365
      real,     dimension(:,:,:),     allocatable :: emitot
      character(len=90)                    :: ofnam

      ofnam = 'output.name.csv'

      Allocate(emittot(im,jm,hrs)); emittot = 0.0

      Open(unit=10,file=trim(ofnam),form='unformatted')

      Do t = 1, hrs
         Write(10,'(5e15.8)') ((emittot(i,j,t),i=1,im),j=1,jm)
      End do
      Close(10)

      Stop
      End
*******************************************************************
```

ANNUAL VERSIONS OF THIS FILE (naming convention: "vulcan.US.10k.sp.v*Y.Y.ZZZ*.ann.csv") ARE IDENTICAL EXCEPT THERE IS NO TIME INDEX LOOP IN THE WRITE STATEMENT.

ALL OTHER INFORMATION IS IDENTICAL TO THE BINARY FILE DESCRIPTION INFORMATION.

4. Grid Information

All geospatial inputs to Vulcan (counties, road networks, point locations, etc.) are aggregated to the 10km x 10km cells that overlay the U.S. This 10km x 10km grid was initially generated in a Lambert Conformal Conic map projection, a meters-unit projection. Furthermore, the Vulcan domain uses the official county/state boundaries which include some oceanic margin.

The Vulcan 10km grid's columns (i=1 to i=507) are indexed left to right starting from the northwestern-most cell and its rows (j=1 to j=355) are indexed top to bottom starting from same. e.g.

```
1-1 | 2-1 | 3-1 etc.
-------------
1-2 | 2-2 | 3-2
-------------
1-3 | 2-3 | 3-3
etc.
```

In order to expedite the transfer of values attached to the grid cells used in Vulcan's 10km x 10km grid to some other grid or geographic framework, we have created the floating point, comma-delimited ASCII file 'vulcangrid.csv'.

In order for the values aggregated to each of these 10km x 10km cells to be re-assigned to overlapping grids of other sizes and/or for the values per cell to be consumable by other modeling applications, the file, "vulcangrid.csv" associates the i-j index of each cell with the latitude/longitude coordinate of the NORTHWEST CORNER of each cell. To wit,

a sample of the first 4 lines of vulcangrid.csv:

```
"i","j","ddX","ddY","ijKey"
"1","1","-137.2570535","51.9691461","1.1"
"1","2","-137.1961117","51.88966934","1.2"
"1","3","-137.135342","51.81013841","1.3
```

"i"
the horizontal (column) index number

"j"
the vertical (row) index number

"ddX"
the longitudinal value, in decimal degrees, of the northwest corner of the cell

"ddY"
the latitudinal value, in decimal degrees, of the northwest corner of the cell

"ijKey"
a concatenation of the i and j values, used internally but potentially of use elsewhere

The map projection of the original grid is defined as follows:

```
name: Lambert Conformal Conic
standard parallels:             33.0, 45.0
central meridian:               -97.0
latitude of projection origin:  40.0
false easting:                  0
false northing:                 0
Geographic Coordinate System:   GCS_North_American_1983
```

In order to generate lat/long coordinates, in decimal degrees, for the NW corners of each cell, this original Lambert Conformal Conic grid was unprojected in ArcGIS to NAD83 and the ddX, ddY columns calculated with ArcGIS' "Calculate Geometry" tool.

Questions or concerns on the Vulcan grid or regridding, contact:
Igor Razlivanov
igor.razlivanov@gmail.com

5. Non-gridded data products

We supply a number of emissions aggregated to other spatial resolutions. We supply information at the both county and state spatial scales with annual time resolution. Should you be interested in some other spatial resolution, please contact:

Kevin gurney
Kevin.gurney@asu.edu

6. 0.1 degree grid

THE 0.1 DEGREE GRID FILES ARE ONLY SUPPLIED TO ASSIST USERS WITH REGRIDDING. WE CANNOT BE HELD RESPONSIBLE FOR REGRIDDING CHOICES (SUCH AS LAND/SEA MASKING, ETC) THAT DO NOT MATCH EXPECTATION. WE ENCOURAGE ALL USERS TO PERFORM THEIR OWN REGRIDDING FROM THE VULCAN 10KM x 10 KM TO WHATEVER GRID THEY USE.

The files, "vulcan.US.1deg.dp.v$Y.Y.ZZZ$.bin2" are binary files representing the continental US carbon emissions in units of tonnes of carbon/hour/gridcell on a 0.1 x 0.1 degree surface grid every hour. They have been transformed from the 10km x 10km Vulcan grid.

All other naming conventions are identical to the 10km x 10km binary file naming conventions noted in section 1 of this document.

This file contains a 3D array in which the longitude direction has 650 gridcells, the latitudinal direction has 280 gridcells and the time dimension has 8760 timesteps.

The emissions in this file have been "shuffled" – any emissions that were orphaned in the ocean due to the regridding from our original 10km x 10km grid, are "shuffled" to neighboring land gridcells according to their proportional share. This in an important exercise

for the coastal regions where one wants to maintain the spatial structure of the emissions along populated coastlines.

When reading this file, the first gridcell is at the northernmost/westernmost corner of the 0.1 deg US grid and moves eastward first, then south (see the write statement in sample code below).

The Northwest corner of the first gridcell is located at:

-127.5 W, 51.5 N (NAD83)

Each record is a one hourly timestep containing the entire US map in the order listed above.

Time zone: all timesteps are in universal time. This means that there are a few hours before local Jan 1, 12 am that emissions begin. These hours represent "wrapped" emissions – they are copied from the hours at the end of the year.

The fortran program that was used to write the hourly double-precision binary file is as follows:

```
*********************************************************************
      Program RegridVulcanPtOneHour

      implicit none
      integer                                  :: i,j,t
      integer,parameter                        :: im=650,jm=280,
     ^                                            hours=24*365
      real*8,   dimension(:,:,:),   allocatable :: emit
      character(len=90)                        :: ofnam

      ofnam = 'output.file.bin2'

      Allocate(emit(im,jm,hrs)); emit = 0.0

      Open(unit=12,file=trim(ofnam),form='binary')

      Do t = 1, hours
         Write(12) ((emit(i,j,t),i=1,im),j=1,jm)
      End do

      Close(12)

      Stop
      End
*********************************************************************
```

ANNUAL VERSIONS OF THIS FILE (naming convention: "vulcan.US.1deg.dp.v*Y.Y.ZZZ*.ann.bin2") ARE IDENTICAL EXCEPT THERE IS NO TIME INDEX LOOP IN THE WRITE STATEMENT.

The total amount of carbon (summing all sectors) should come to 1541353052.797615 tonnes carbon/year.

7. Alaska

Hourly emissions for the state of Alaska have been separately gridded on the Vulcan 10km x 10km grid. The naming convention for these files is "vulcan.AK.*". The Alaska fileset conforms to the previous descriptions for [binary](#), [netCDF](#), and [ascii](#) filesets with the important exception of the grid origin and array dimensions for reading the 10km x 10km Alaska files.

The map projection used is:
Projected Coordinate System: NAD_1983_Alaska_Albers

```
Projection:               Albers
False_Easting:            0.000000
False_Northing:           0.000000
Central_Meridian:         -154.000000
Standard_Parallel_1:      55.000000
Standard_Parallel_2:      65.000000
Latitude_Of_Origin:       50.000000
Linear Unit:              Meter (1.000000)
```

Geographic Coordinate System: GCS_North_American_1983

The land/ocean boundary on the coastlines includes coastal waters.

This file contains an array with three dimensions in which the longitude direction has 368 gridcells, the latitudinal direction has 199 gridcells and the time dimension has 8760 timesteps.

When reading this file, the first gridcell is at the northernmost/westernmost corner of the 10km x 10km Alaska grid and moves eastward first, then south (see the fortran write statement below).

The center of the first gridcell is located at:

157.365271 E, 63.923895 N (NAD83)

The fortran program that was used to write the hourly double-precision binary file is as follows:

```
*****************************************************************
      Program Iovulcan
      implicit none

      integer                            :: i,j,t
      integer,parameter                  :: im=368,jm=199,
     ^                                     hrs=24*365
      real*8,   dimension(:,:,:),    allocatable :: emit
      character(len=90)                  :: ofnam

      ofnam = 'vulcan.output.bin2'

      Allocate(emit(im,jm,hrs)); emit = 0.0

      Open(unit=12,file=trim(ofnam),form='binary')

      Do t = 1, hrs
```

```
      Write(12) ((emit(i,j,t),i=1,im),j=1,jm)
    End do
    Close(12)

    Stop
    End
*******************************************************************
```
These files are written to both ascii and netCDF forms, but are not regridded to the 0.1 degree grid. For ascii files, the 'Open' statement would specify the 'unformatted' form.

ANNUAL VERSIONS OF THESE FILES ARE IDENTICAL EXCEPT THERE IS NO TIME INDEX LOOP IN THE WRITE STATEMENT.

The total amount of carbon (summing all sectors) should come to 8004694.998493 tonnes carbon/year.