**Hestia-SWIFL Fossil Fuel Carbon Dioxide (FFCO2) and Anthropogenic heat (AH) Data Product –Flagstaff testbed**

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**HESTIA-SWIFL DATA PRODUCT FOR FLAGSTAFF TESTBED**

The Hestia-SWIFL Flagstaff testbed FFCO2 and AH data represent emissions due to the combustion of fossil fuels in the city of Flagstaff, Arizona. The spatial extent (bounding box) is defined based on the census Urban Area definition.

The emissions are generated using a bottom-up/engineering approach and are tied to results generated by the Vulcan Project version 4, an effort to quantify space/time-resolved FFCO2 emissions for the entire United States landscape. A large number of data sources are combined to best estimate FFCO2 emissions at fine scales such as air quality emissions data, traffic flow data, building information, sociodemographic information, and fuel statistics. The native spatial resolution of the Hestia FFCO2 emissions data product is a combination of points, lines, and polygons dictated primarily by the underlying data sources and the Vulcan FFCO2 emissions output.

The output made available here includes the point, line, polygon representation in addition to emissions placed onto a regularized 10m x 10m grid, both at annual temporal resolution.

**FAIR USE DISCLAIMER**

The Hestia data product is an estimation of fossil fuel CO2 (FFCO2) emissions at very fine scales in time and space. It should be considered a "climatology" of emissions rather than the "weather" of emissions such that the estimates represent "typical" emissions at a given time and place (average conditions). Hence, it is not appropriate to use the data in comparison to short-term "campaign style" atmospheric measurements (e.g. 5 days of continuous monitoring at a specific location) without consideration of and reference to the mismatch between the measurement and the Hestia estimation approach. Users are encouraged to contact Kevin Gurney for updates and consultation on such potential use.

**SECTORAL COMPOSITION**

In addition to the total FFCO2 emissions, emissions are available for seven individual sectors (Residential, Commercial, Industrial, Onroad, Nonroad, Airport, and Railroad). The FFCO2 emissions are provided for Scope 1 (direct emissions) and Scope 2 (emissions driven by electricity consumption are located at the end-user buildings). Note that Scope 1 Electricity production emission is not provided as there is no emission facilities within the City of Flagstaff (as defined by the census Urban Area).

**DATA FILE NAMES AND FILE STRUCTURE**

The Hestia-SWIFL annual FFCO2 and AH emissions are represented using two formats: vector data (points/lines/polygons) and raster data (10m grid) for the year of 2022. The 10m x 10m gridded FFCO2 and AH emissions are stored in GeoTIFF files and represent the emissions resulting from integration of all point, line, and polygon elements within a gridcell (using area or length proportions for line and polygon elements that straddle gridcells). The annual files contain a 2501-row by 2309-column matrix with double-precision values arranged in row-major order - each row runs longitudinally and each column latitudinally with the first grid cell located at the northwestern corner. The time domain reflects local time. The grid details and projection are provided in Table 1. All the gridded FFCO2 emissions are in units of metric tons of carbon (tC) per gridcell, and AH emissions are in units of metric million British thermal unit (MMBtu).

**Table 1.** 10m x 10m emissions output grid parameters

|  |  |
| --- | --- |
| **Parameters** |  |
| Dimensions | X=2501; Y=2309 |
| Units | 10m |
| Projection | NAD83(2011) / Arizona Central (EPSG:6404) |
| Extent | (xmin, ymin) = (230223.7, 452017.1)  (xmax, ymax) = (253223.7, 477117.1) |

**WKT:**

Coordinate Reference System:

User input: NAD83(2011) / Arizona Central

wkt:

PROJCRS["NAD83(2011) / Arizona Central",

BASEGEOGCRS["NAD83(2011)",

DATUM["NAD83 (National Spatial Reference System 2011)",

ELLIPSOID["GRS 1980",6378137,298.257222101,

LENGTHUNIT["metre",1]]],

PRIMEM["Greenwich",0,

ANGLEUNIT["degree",0.0174532925199433]],

ID["EPSG",6318]],

CONVERSION["SPCS83 Arizona Central zone (meters)",

METHOD["Transverse Mercator",

ID["EPSG",9807]],

PARAMETER["Latitude of natural origin",31,

ANGLEUNIT["degree",0.0174532925199433],

ID["EPSG",8801]],

PARAMETER["Longitude of natural origin",-111.916666666667,

ANGLEUNIT["degree",0.0174532925199433],

ID["EPSG",8802]],

PARAMETER["Scale factor at natural origin",0.9999,

SCALEUNIT["unity",1],

ID["EPSG",8805]],

PARAMETER["False easting",213360,

LENGTHUNIT["metre",1],

ID["EPSG",8806]],

PARAMETER["False northing",0,

LENGTHUNIT["metre",1],

ID["EPSG",8807]]],

CS[Cartesian,2],

AXIS["easting (X)",east,

ORDER[1],

LENGTHUNIT["metre",1]],

AXIS["northing (Y)",north,

ORDER[2],

LENGTHUNIT["metre",1]],

USAGE[

SCOPE["unknown"],

AREA["USA - Arizona - SPCS - C"],

BBOX[31.33,-113.35,37.01,-110.44]],

ID["EPSG",6404]]

The gridded raster output files follow a naming convention that indicates the key attributes of the file. For example, the file "SWIFL\_Flagstaff\_annual\_FFCO2\_10m\_2022\_v1.3.tif" indicates the emissions domain (Flagstaff), the time resolution ("annual"), emissions data ("FFCO2" or “AH”), the grid resolution (10m), the data year (2022), and the version number (v1.3). This GeoTIFF file is a multi-layer raster data and includes emission layers for the seven individual sector (AIR, COM, IND, NRD, ONR, RRD, RES), plus total of all sectors per gridcell.

Similarly, a naming convention of the vector output files follow, for example, the file "Airport\_annual\_emissions\_2022.gpkg" indicates the emission sector (e.g., Airport, Commercial, etc), the time resolution ("annual"), and the data year (2022). This GeoPackage file is provided for the seven emission sectors plus Scope 2 emissions, and contains both FFCO2 and AH emissions. Some sectors include additional attributes (facility name, road type, parcel use type etc.). See the Table 2. for the filename reference and descriptions.

**Table 2**. Sector descriptions and vector data details.

|  |  |  |  |
| --- | --- | --- | --- |
| **Sector names (abbreviations)** | **Descriptions** | **Vector data types** | **Additional variables** |
| Airport (AIR) | Aircraft emissions from Landing and Take-Off (up to 3000km) | points, polygons | Facility name |
| Commercial (COM) | Emissions related to commercial activities | points, polygons | Facility name (points), Parcel use, total living area (TFA\_SQFT), building age (yearbuilt) |
| Industrial (IND) | Emissions related to industrial activities | points, polygons | Facility name (points), Parcel use, total living area (TFA\_SQFT), building age (yearbuilt) |
| Nonroad (NRD) | Emissions from off-road vehicles and other mobile sources | points, polygons | Facility name (points) |
| Onroad (ONR) | Vehicle emissions on highways/roadways | lines | Roadtype |
| Railroad (RRD) | Railroad emissions (electricity-driven rails are not included) | points, lines | Facility name (points) |
| Residential (RES) | Emissions related to residential activities | polygons | Parcel use, total living area (TFA\_SQFT), building age (yearbuilt) |
| Scope2 | Emissions from electricity consumptions by residential, commercial, and industrial buildings | polygons | 2020 Census block GEOID |

**Table 3.** Emissions summary (Scope 1)

|  |  |  |
| --- | --- | --- |
| Emission sector | FFCO2 (tC/yr) | AH (MMBtu/yr) |
| Airport | 7,902.0 | 412,536.6 |
| Commercial | 10,308.3 | 840,004.0 |
| Industrial | 48,165.9 | 2,011,423.2 |
| Nonroad | 41.7 | 2,111.9 |
| Railroad | 2,227.1 | 109,260.2 |
| Residential | 13,810.2 | 951,311.6 |
| Onroad | 74,801.3 | 3,854,842.4 |
| Total | 157,256.4 | 8,181,489.9 |

For questions on file formats and updates, please contact Anna Kato and/or Kevin Gurney.