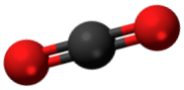
CS486C – Senior Capstone Design in Computer Science

Project Description

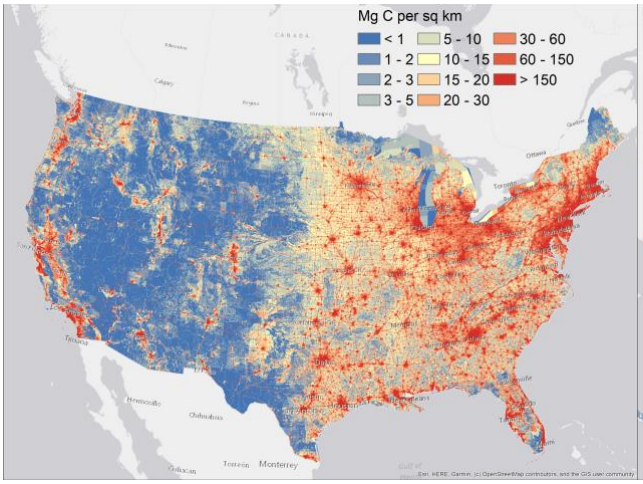
Project Title: Visualizing CO_2 emissions in the United States	
Sponsor Information: 	**Dr. Geoffrey Roest,** Postdoctoral researcher in SICCS geoffrey.roest@nau.edu Prof. Kevin Gurney, Professor in SICCS kevin.gurney@nau.edu

Project Overview:

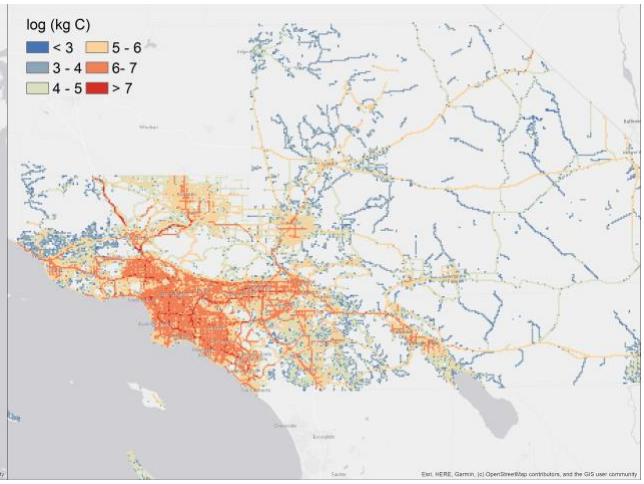
The Earth is warming at an alarming rate and emissions of *greenhouse gases* are largely responsible. Carbon dioxide (CO_2) emissions from human activity are one of the most important drivers of climate change. To address the problem, nations and cities around the world are adopting ambitious goals to reduce their CO_2 footprint. Examples include the *Paris Agreement* of 2015, signed by 195 countries, and the *C40* group, which includes 95 major cities around the world. Cities contribute a large fraction of CO_2 emissions as the global population is increasingly living in urban areas. Here in the United States, cities like Los Angeles are leading the effort to reduce greenhouse gas emissions.

A major problem in enacting or enforcing any emissions improvement plans or commitments is that there has to be a way to measure how you are doing, i.e., how many greenhouse gasses are actually being emitted. Without clear, quantitative, data-driven information on the sources and locations of CO_2 emissions, policy makers have little basis for comparing commitments to actual actions, and thereby documenting positive change (or lack thereof). If one could invent a way to observe/measure this, one could then track this performance over time…and thereby generate clear data on whether emissions at any given locale are going up or down over time.

The Gurney Lab in the NAU School of Informatics, Computing, and Cyber Systems has developed a number of techniques to "measure" emissions for various locales, not by using enormous networks of sensors of some sort, but by indirect means, i.e., by tracking activities that generate emissions. In particular, we use data mining and modeling to quantify CO_2 emissions from fossil fuel combustion ($FFCO_2$) across multiple spatial scales – the entire planet (*FFDAS*), the United States (*Vulcan*), and individual cities (*Hestia*). We utilize data on air quality pollutants, fuel usage, on-road traffic, airport traffic, power plant emissions, and buildings (among other data) to quantify CO_2 emissions and distribute them in space and time. Our final products begin with emissions datasets, which are geographically linked to GIS *shapefiles* (points, polygons, and lines), which are then distributed to regular grids (*raster* data). These grids are used by atmospheric modelers to study atmospheric CO_2 and used to generate visualizations, such as the maps below.



Total emissions for U.S. in 2011



Onroad traffic emissions for Los Angeles in 2011

We have produced our latest version of our dataset for the entire United States and will formally publish it soon. We have also recently published a high-resolution dataset for Los Angeles, one of the largest urban areas in North America. Our data are in the form of "NetCDF" files, a gridded data product often used in atmospheric sciences, or "GeoTiff" files, a raster image with spatial definition.

The Problem

Like many scientific projects, the problem that we have is one of communication and data accessibility. We are producing much-needed datasets that are highly relevant to addressing climate change but these data are in databases or datafiles with specialized technical formats. This means that a select set of trained scientists and collaborators are able to access, download, and use our data for further analysis, but the data remain largely accessible to a broader audience. In particular, policy makers and the general public do not have the resources or technical background to open, understand, and analyze the output that we generate in our group. What is needed is an easily-accessible interface that will allow non-technical users to access and explore what our high-resolution data are revealing about CO_2 emissions.

The Envisioned Solution

This Capstone project will produce a modern, secure web application that provides an interactive graphical interface for exploring our CO_2 emissions findings. Users should access the web app and be presented with a graphical map that visually presents the CO_2 emissions for a selected area, in a way similar to the maps shown above. Controls should allow users to select or scroll the timeframe, with the map view updating accordingly; an advanced feature (e.g., as seen on several weather sites for showing precipitation on radar maps) would allow users to click to "play" a time period, essentially animating the map view to loop through the time period to show changes within that period. Ideally, the product would also be "mobile-friendly", meaning that one could realistically operate the web app on a mobile browser (with the map automatically opening centered on where you are currently standing!), rather than just seeing a shrunken version of the desktop view. Specific features of the product would include:

Level 0 - Minimal viable product:

- The app will allow users to visualize our national-scale products (*Vulcan*), starting with annual/monthly data.
- The app will feature a basemap(s) with layers that can be added on top.
- The layers are based on *raster* (gridded) geospatial data. A user can enable/disable individual layers representing different types of CO_2 emissions sources – e.g., onroad traffic, power plants, etc.
- Users can display emissions information for a location by pointing and clicking on the map or entering a location into a search bar.
- Users can pull up summary statistics such as emissions ranking, sector totals, and per capita averages.

Level 1 – A nicely equipped application:

- Users can adjust color and transparency of layers, to view multiple types of CO_2 sources at a time.
- Users can select multiple grid cells from one or more layers at the same time and view a summary of emissions for the selected grid cells.
- Users can use a slider bar to examine evolution of emissions over monthly timesteps
- Users may instead display our *Hestia* data, which is specific to four cities.

Level 2 – A strong, cutting-edge application:

- The map can display our *vector* shapefile data – e.g. individual road segments (lines), Census blocks (polygons) – and view information about emissions from that object.
- Our hourly emissions can be accessed (large data sets), with animations available. Users can use a slider bar to examine evolution of emissions at these hourly timesteps
- Users may download data in easy-to-use formats (e.g. KML files for Google Earth)

Many users of our app will be members of the general public who are curious about the CO_2 footprint of their neighborhood, their city, and their state. We are also hoping to reach policy makers, who can quantify emissions in their jurisdiction, identify important CO_2 sources and their locations, and develop actionable plans to reduce those emissions.

Knowledge, skills, and expertise required for this project:

- Web/mobile app development [TBD]
- Map development (e.g. Google Maps API, OpenLayers)
- GIS knowledge is desirable but not required

Equipment Requirements:

- There should be no equipment or software required other than a development platform and development software/tools freely available online.

Software and other Deliverables:

- The web application as described above, installed on a server of the client's choice, and tested successfully with real data. Depending on the team's desire, development may occur on a server of the team's choice…or on the target server designated by the client during the requirements acquisition process.
- Must include a complete and clear User Manual for using the web app, preferably integrated as online "readme" or integrated help system within the web app itself.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket, or some other version control repository; and as a physical archive on our server storage space.
- Assistance in getting our app functioning on our [website/on smartphones-TBD]