VULCAN AND HESTIA: QUANTIFICATION OF HIGH-RESOLUTION, BOTTOM-UP FOSSIL FUEL CO2 EMISSIONS FOR THE NATION AND US CITIES

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OUTLINE

• Overview and motivation
• Vulcan methodology
• Hestia methodology
• Applications

• NASA grant NNX14AJ20G (Vulcan)
• NIST grants 70NANB14H321 & 70NANB16H264 (Hestia)
• NSF CAREER award (All)
MOTIVATION

• CO₂ continues to increase
  • ~7 billion tons C year⁻¹ from fossil fuels

• Pressure to reduce CO₂ emissions
  • Paris Agreement
  • > 350 mayors in the U.S. have adopted the Paris Agreement goals
  • > 400 U.S. cities are participating in the EV Purchasing Collaborative
  • > 125 cities have pledged to transition their communities to 100% clean energy.
    – Center for Climate and Energy Solutions

• Urban areas:
  • 54% of global population, 70% of global energy use (IPCC 2014, UN 2015)
  • >80% of US population (2010 US Census)
GURNEY LAB AT NAU

• Quantify fossil fuel CO$_2$ (FFCO$_2$) emissions across spatial scales (scope 1):
  • Global (FFDAS)
  • US (Vulcan v3.0)
  • Cities (Hestia)

• Produce data products
  • Sector-specific
  • Gridded output for modeling
  • State/county/regional output
  • Visualization
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<td>EPA port and shipping lane shapefiles</td>
<td>Flat time structure</td>
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a. Emissions Factors Model  
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c. Federal Highway Administration, Annual Average Daily Traffic  
d. Federal Emergency Management Agency  
e. Continuous Count Stations  
f. Clean Air Markets Division  
g. Department of Energy/Energy Information Administration  
h. Department of Energy Residential Energy Consumption Survey, non-electric energy use intensity  
i. Quick Energy Simulation Tool  
j. Source Classification Code  
k. Los Angeles World Airport, The Operations Network  
l. Department of Energy Commercial Energy Consumption Survey, non-electric energy use intensity  
m. Department of Energy Manufacturing Energy Consumption Survey, non-electric energy use intensity
POINT AND NONPOINT

- Process $n$ (e.g. commercial 10 MMBTU boiler, industrial reciprocating engine)
- Fuel $f$ (e.g. natural gas, bituminous coal)
- $E$ – emissions
- $EF$ – emission factor

\[
E_{n,f}^{CO_2} = \frac{E_{n,f}^{CO}}{EF_{n,f}^{CO}} \cdot EF_{n,f}^{CO_2}
\]

- CO emission factors come from either:
  - Self-reported – submitted by SLTs (found through FIPS/SCC
  - Default – created internally but mostly retrieved from WebFIRE/AP-42 and a few literature

- CO2 emission factors:
  - Carbon coefficients/content, from coal sampling literature, EPA (liquids, gas), DOE and based on fuel sample statistics
POINT AND NONPOINT

Point:
- Temporal allocation (hourly): Industrial surveys of occupancy, production cycles, gives SCC categorized temporal structure

Nonpoint:
- Spatial allocation:
  - FEMA HAZUS general building stock data
  - Block group totals on residential, commercial, and industrial buildings
  - Energy use intensity – DOE survey by Census Division
- Temporal allocation (hourly):
  - eQUEST building energy model
  - Local meteorology, DOE survey data
ELECTRICITY PRODUCTION

• CAMD – stack monitoring CO₂ (hourly)
• DOE/EIA – fuel throughput (monthly)
• NEI – CO reporting (point process, annual)
ONROAD

- Merged HPMS road base and Open Street map
- FFCO₂ at county scale – EPA MOVES
  - County/vehicle class/road class
- California – EMFAC
  - County/vehicle class
  - Use statistics (FHWA) to distribute to road class

<table>
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<tr>
<th>NEI 2011 Road Class</th>
<th>HPMS Road Class</th>
<th>OSM Road Class</th>
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ONROAD

• Spatial allocation:
  • FHWA AADT – VMT on all but local roads
  • Non-local roads – gap-filling using nearest neighbor
  • Local-roads – “flat” spatial distribution within counties

• Temporal allocation:
  • CCS classified by road types
  • Allocated to road segments using inverse distance weighting
NONROAD

- CO\textsubscript{2} from EPA nonroad model in all states except CA
- CA: use CO reporting with CO/CO\textsubscript{2} ratio from other western states
- Temporal distribution: SCC time cycle profiles (if available)
- Spatial distribution: EPA shapefiles (if available)

AIRPORT

- NEI point source w/ spatial correction to center of runway
- Reflects taxi/takeoff/landing (below 3000 ft)
- CO/CO\textsubscript{2} ratio from literature review, categorized by aircraft type/size/class
- Temporal distribution: airport “type” based on OPSNET (daily flight volumes) and AIRNAV datasets (airport class shares)
RAIL

• CO reporting from point (railyard) and nonpoint (rail travel)

• Map to EPA rail basemap, distributing via freight statistics (RITA data)

• Constant emissions in time

CMV

• CO nonpoint reporting

• Spatial distribution: port and shipping distributed with shapefiles

• Constant emissions in time
HESTIA

- Urban FFCO$_2$ estimation embedded within national Vulcan product
- Additional data from local sources
- Codebase depends on city, data sources, unique challenges
- Indianapolis, Salt Lake City, Baltimore, Los Angeles
- Melbourne Australia, Virginia-PA corridor

Cities need to understand and manage their carbon footprint at the level of streets, buildings and communities, urge Kevin Robert Gurney and colleagues.
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\(^n\) Marine Emissions Model
## EXAMPLE: RESIDENTIAL BUILDINGS

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<tr>
<th>RECS building type</th>
<th>Pre-1980 NG NE-EUI (kbtu/ft²)</th>
<th>Post-1979 NG NE-EUI (kbtu/ft²)</th>
<th>Pre-1980 Fuel oil NE-EUI (kbtu/ft²)</th>
<th>Post-1979 Fuel oil NE-EUI (kbtu/ft²)</th>
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<td>Mobile home</td>
<td>52.56</td>
<td>22.90</td>
<td>NA*</td>
<td>NA</td>
</tr>
<tr>
<td>Single-family detached house</td>
<td>24.53</td>
<td>18.00</td>
<td>18.87</td>
<td>7.23</td>
</tr>
<tr>
<td>Single-family attached house</td>
<td>42.56</td>
<td>32.38</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Apartment building with 2-4 units</td>
<td>27.84</td>
<td>42.27</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Apartment building with 5 or more units</td>
<td>17.21</td>
<td>30.85</td>
<td>NA</td>
<td>NA</td>
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APPLICATION: INVERSE MODELING

- Indianapolis Hestia compared to atmospheric CO$_2$ inversion (Lauvaux et al., 2016)
- Biotic respiration prior to persistent ground freeze explains majority of difference
FINAL REMARKS

• Vulcan v3.0 (national) data product to be published soon
  • Gridded down to 1km
  • Hourly available on request

• Hestia available for select cities
  • Indianapolis
  • Salt Lake City
  • Baltimore
  • LA (accepted)
  • Melbourne, Australia (ongoing)
  • Virginia-PA corridor (ongoing)

Please contact Gurney group for data requests and re-gridding!
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geoffrey.roest@nau.edu
kevin.gurney@nau.edu