Estimating domestic wastewater emissions to marine environments using a spatial extrapolation approach

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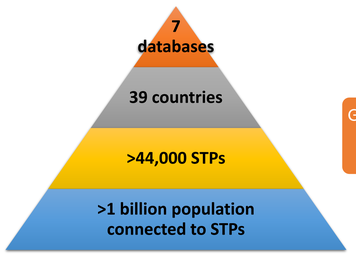
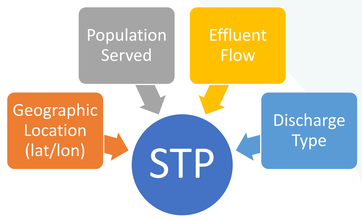
Purpose of Work

- Develop a global dataset on marine emissions from sewage treatment plants (STPs)
- Understand what fraction of the population is discharging directly to marine environments
- Extrapolate marine STP emission estimates to countries where there are limited data
- Enhance current ScenAT global emissions model[1] to refine freshwater/marine estimates

Marine Discharge STP Dataset





Discharge Type	Population Served	% Pop Served
Coastal Water (CW)	141,629,363	13.4%
Estuary	43,874,168	4.2%
Fresh Water	815,075,925	77.3%
Discharges on Land	8,015,365	0.8%
Reuse	10,577,986	1.0%
Other	35,162,358	3.3%
Grand Total	1,054,335,165	100%

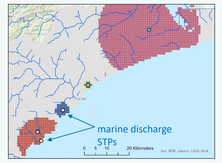
Spatial Allocation of Population to Known STPs

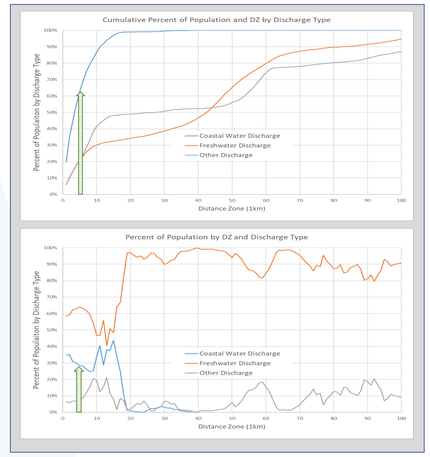
Spatial datasets

- Global population (urban/rural) (1-km grid, Global Rural-Urban Mapping Project[2])
- Global GDP (1-km grid, Gross Domestic Product (GDP) Derived From Satellite Data looking at nighttime luminosity[3])
- Coastline from Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG[4])
- >9,700 Level 2 administrative divisions (called Admin-2) within 100km of coast (ScenAT)

Processing

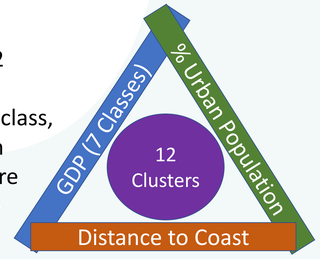
- Spatially allocating the population in each grid cell to an STP location (until the STP served population has been reached)
- Summarize population in each 1-km Distance Zones (DZ) from the coast
- For example, in Brazil (*see charts at right*):
  - 62% of people served by coastal water STPs are within 5 km of the coast (top)
  - In the 4-5km Distance Zone, 28% of connected population are served by coastal water STPs (bottom)
- Determine % of connected population with coastal water (CW) discharge



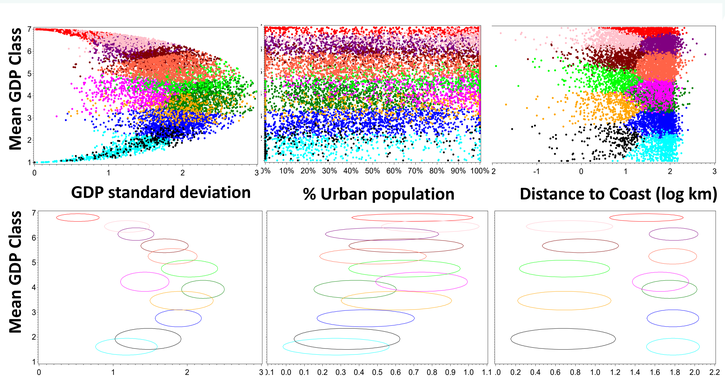


Admin-2 Clustering

- Admin-2 units were grouped into 12 clusters using the statistical method 'K-means clustering' that used GDP class, % urban population, and population centroid distance to coast (i.e., where large populations are relative to the coast) as inputs

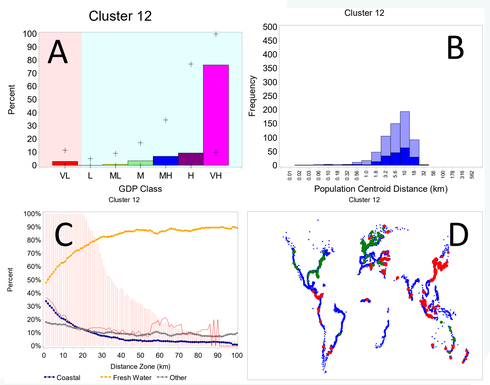


- Achieved good cluster separation as shown in plots below (top row: scatterplot for each Admin-2, bottom row: cluster ellipsoid)
- Clusters represent similar groups of Admin-2 units, with each containing some STPs for extrapolation to other Admin-2 units (without STP data) within the same cluster



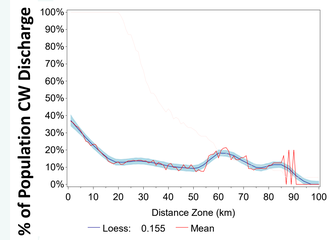
Cluster Analysis

Description for panels in figures below:
A. % of population by GDP class (bars) and rural/urban proportions (red/blue background)
B. Frequency of Admin-2 distance to coast using population centroid. Dark blue bars are Admin-2's with known STP data and light blue without known STPs
C. % of Admin-2s with avg CW discharge by DZ (red line) compared to global average (blue line). Red bars represent number of Admin-2s for that DZ
D. Map of Admin-2s in cluster 12 (green with STP data, red without)



Extrapolation and Next Steps

- Develop a curve to predict %CW discharge using DZ for each cluster
- Use of LOESS (LOcally Estimated Scatterplot Smoothing) without need for parameterization
- Example for Cluster 12:



Predict for an unknown Admin-2:

- Use population in DZ and %CW from LOESS to estimate population connected to coastal discharge STPs
- Sum population for all DZs in Admin-2 to report a single value: % of total population in Admin-2 served by coastal discharge STPs
- This can then be compared to Admin-2s with known STP data for evaluation of the extrapolation method

1. Hodges, J., C. Holmes, R. Vamshi, D. Mao, and O. Price. 2012. Estimating chemical emissions from home and personal care products in China. https://doi.org/10.1016/j.envpol.2011.11.009
2. Center for International Earth Science Information Network - CIESIN - Columbia University, United Nations Food and Agriculture Programme - FAO, and Centro Internacional de Agricultura Tropical - CIAT. 2005. Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4639MPP
3. Ghosh, T., Powell, R., Elvidge, C. D., Baugh, K. E., Sutton, P. C., & Anderson, S. (2010). Shedding light on the global distribution of economic activity. The Open Geography Journal (3), 148-161
4. Wessel, P., and W. H. F. Smith (1996), A global, self-consistent, hierarchical, high-resolution shoreline database, J. Geophys. Res., 101(B4), 8741–8743, doi:10.1029/96JB00104.

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