

Satellite-Based Measures for Tracking Atmospheric CO₂ and CH₄ At National, Subnational and Urban Scales

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Overview

The code in this replication package constructs the analysis file from the data sources on the World Bank Development Data Hub and local data using R. A main script runs all of the code to generate the data for the 11 figures and 2 tables in the World Bank Policy Research Working Paper entitled, “Satellite-Based Measures for Tracking Atmospheric CO₂ and CH₄ At National, Subnational and Urban Scales” (No. X). The replicator should expect the code to run for about 30 minutes and require approximately 6GB of data.

Data Availability

Some data are not included in the reproducibility package, but almost all data are available and the code automates its download. The Exclusive Economic Zone data must be downloaded from [marineregions.org](https://www.marineregions.org). Georeferenced files related to the NDLSA boundaries are not included.

Data Sources

- EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database, a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA), and comprising IEA-EDGAR CO₂, EDGAR CH₄, EDGAR N₂O, EDGAR F-GASES version 2024 European Commission, JRC (Datasets). The complete citation of the EDGAR Community GHG Database is available in the ‘Sources and References’ section. https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/EDGAR/datasets/v80_FT2022_GHG
- Flanders Marine Institute (2023). Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 12. Available online at <https://www.marineregions.org/>. <https://doi.org/10.14284/632> Access 2025-09-15. License CC-BY.
- Functional Urban Areas. Schiavina, M., Moreno-Monroy, A., Maffenini, L., & Veneri, P. (2019). Ghsl-oecd functional urban areas. European Commission, Joint Research Centre (JRC) technical report-public release of GHS-FUA. Luxembourg: Publications Office of the European Union. https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_FUA_UCDB2015_GLOBE_R2019A/V1-0
- World Bank Official Boundaries. <https://datacatalog.worldbank.org/search/dataset/0038272/World-Bank-Official-Boundaries>
- World Bank Income Classification. <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>

Instructions for Replicators

New users should follow these steps to run the package successfully: - Users must first have access to all data files if they are not included in the reproducibility package. They should go to the mentioned links, download the listed files, and place them in the local folder. - Download the Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones data from marineregions.org and name the respective shapefiles with the basename `Global_Wells_EEZs_ISO3s` and place them in the “gis” folder

- `s2s_ghg__trend_wp__main.R`
- Ensure all required software and dependencies are installed as listed in the Requirements section.
- Run the `s2s_ghg__trend_wp__main.R` file.
- Note that these scripts are already called in the main R script: - `s2s_ghg_load_edgar.R` downloads via API EDGAR data - `s2s_ghg_load_FUA.R` downloads via API FUA data - `s2s_ghg_load_wb_inc_class.R` downloads via API WB Income classification data. - `s2s_ghg_load_wb_gad_adm0.R` downloads via API GAD administrative level 0 polygons - `s2s_ghg_load_wb_gad_adm0_lines.R` downloads via API GAD administrative level 0 lines - `s2s_ghg_load_wb_gad_adm1.R` downloads via API GAD administrative level 1 polygons - `s2s_ghg_load_wb_gad_adm2.R` downloads via API GAD administrative level 2 polygons

List of Exhibits

Exhibit name	Output filename	Script	Note
Table 1a	<code>tbl01a_SEA_Unweighted_WBADMO2s_ghg_tbl01a_gen_SE_Asia_U</code>	<code>s2s_ghg_tbl01a_gen_SE_Asia_U</code>	Found in tables
Table 1b	<code>tbl01b_SEA_Weighted_WBADMO2s_ghg_tbl01b_gen_SE_Asia_W</code>	<code>s2s_ghg_tbl01b_gen_SE_Asia_W</code>	Found in tables
Table 2	<code>tbl02_SEA_Comparative_Scores_CO2s_ghg_tbl02_gen_SE_Asia_Comp</code>	<code>s2s_ghg_tbl02_gen_SE_Asia_Comp</code>	Found in tables
Figure 1	<code>fig_01_ghg_SE_Asia__</code>	<code>s2s_ghg_fig01_panel</code>	Found in figures
Figure 2	<code>fig_02_SE_Asia_co2_trend1_w</code>	<code>s2s_ghg_fig02_panel</code>	Found in figures
Figure 3	<code>fig_03_SE_Asia_co2_trend2_w</code>	<code>s2s_ghg_fig03_panel</code>	Found in figures
Figure 4	<code>fig_04_SE_Asia_ch4_trend1_w</code>	<code>s2s_ghg_fig04_panel</code>	Found in figures
Figure 5	<code>fig_05_SE_Asia_ch4_trend2_w</code>	<code>s2s_ghg_fig05_panel</code>	Found in figures
Figure 6	<code>fig_06_SE_Asia_*_EEZ_scores</code>	<code>s2s_ghg_fig06_panel</code>	Found in figures
Figure 7	<code>fig_07_ghg_global_CO2_long_trend2s_ghg_fig07_panel</code>	<code>s2s_ghg_fig07_panel</code>	Found in figures
Figure 8	<code>fig_08_ghg_global_CO2_short_trend2s_ghg_fig08_panel</code>	<code>s2s_ghg_fig08_panel</code>	Found in figures
Figure 9	<code>fig_09_ghg_global_CH4_long_trend2s_ghg_fig09_panel_ch4</code>	<code>s2s_ghg_fig09_panel_ch4</code>	Found in figures
Figure 10	<code>fig_10_ghg_global_CH4_short_trend2s_ghg_fig10_panel_ch4</code>	<code>s2s_ghg_fig10_panel_ch4</code>	Found in figures
Figure 11	<code>fig_11_ghg_global_subprov_changes2s_ghg_fig11_adm2_by_WB_region</code>	<code>s2s_ghg_fig11_adm2_by_WB_region</code>	Found in figures
Figure 12	<code>fig_12_ghg_global_subprov_changes2s_ghg_fig12_adm2_by_WBIN</code>	<code>s2s_ghg_fig12_adm2_by_WBIN</code>	Found in figures

Requirements

Computational Requirements

Platform: `x86_64-w64-mingw32/x64` (64-bit) Memory; 256GB

Software Requirements

R version 4.3.1 (2023-06-16 ucrt) Running under: Windows Server 2022 x64

Cran libraries: attached base packages: [1] parallel tools stats graphics grDevices utils datasets methods base

other attached packages: [1] curl_5.0.2 mregions2_1.1.2 lubridate_1.9.3 tibble_3.2.1 tidyverse_2.0.0

[6] forcats_1.0.0 fasterize_1.0.5 basemaps_0.0.8 spatialEco_2.0-2 openxlsx_4.2.5.2

[11] purrr_1.0.2 readxl_1.4.3 ggpattern_1.1.3 exactextractr_0.10.0 readstata13_0.10.1

[16] rgdal_1.6-7 patchwork_1.2.0 ggpubr_0.6.0 colourvalues_0.3.9 XML_3.99-0.14

[21] dplyr_1.1.3 stars_0.6-4 abind_1.4-5 gt_0.10.0 xfun_0.52

[26] modelsummary_1.4.5 ordinal_2023.12-4 RColorBrewer_1.1-3 R.utils_2.12.2 R.oo_1.25.0

[31] R.methodsS3_1.8.2 ggplot2_3.5.1 renv_1.0.5 tidyr_1.3.0 terra_1.8-29

[36] ngeo_0.4.7 foreign_0.8-84 foreach_1.5.2 data.table_1.14.8 readr_2.1.4

[41] Hmisc_5.1-2 stringr_1.5.1 httr_1.4.7 sf_1.0-19 raster_3.6-26

[46] sp_2.1-2

loaded via a namespace (and not attached): [1] rstudioapi_0.15.0 wk_0.9.4 magrittr_2.0.3 magick_2.8.1 farver_2.1.1 rmarkdown_2.25

[7] ragg_1.2.5 vctrs_0.6.3 base64enc_0.1-3 rstatix_0.7.2 htmltools_0.5.6 broom_1.0.5

[13] cellranger_1.1.0 Formula_1.2-5 slippymath_0.3.1 KernSmooth_2.23-21 htmlwidgets_1.6.2 httr2_1.2.1

[19] lifecycle_1.0.4 iterators_1.0.14 pkgconfig_2.0.3 Matrix_1.6-1.1 R6_2.5.1 fastmap_1.1.1

[25] digest_0.6.33 numDeriv_2016.8-1.1 colorspace_2.1-0 ggnewscale_0.4.10 textshaping_0.3.6 labeling_0.4.3

[31] fansi_1.0.4 timechange_0.2.0 compiler_4.3.1 proxy_0.4-27 withr_3.0.0 htmlTable_2.4.2

[37] backports_1.4.1 carData_3.0-5 DBI_1.2.3 ggsignif_0.6.4 MASS_7.3-60 rappdirs_0.3.3

[43] ucminf_1.2.1 classInt_0.4-11 units_0.8-5 zip_2.3.0 nnet_7.3-19 glue_1.6.2

[49] nlme_3.1-162 grid_4.3.1 checkmate_2.3.1 cluster_2.1.4 generics_0.1.3 gtable_0.3.4

[55] tzdb_0.4.0 class_7.3-22 hms_1.1.3 xml2_1.3.5 car_3.1-2 utf8_1.2.3

[61] tables_0.9.17 pillar_1.9.0 lattice_0.22-5 tidyselect_1.2.0 pbapply_1.7-2 knitr_1.44

[67] gridExtra_2.3 stringi_1.7.12 evaluate_0.21 codetools_0.2-19 cli_3.6.1 rpart_4.1.19

[73] systemfonts_1.0.4 munsell_0.5.0 Rcpp_1.0.11 scales_1.3.0 e1071_1.7-16 insight_0.19.10

[79] rlang_1.1.5

Memory and Runtime and Storage Requirements

The scripts are run on a computing environment with 256MB memory.

Code Description

The scripts are located in the WP directory for the main along with the figures and tables. The Build_Databases directory includes scripts to build the databases. The data directory has data. The figures_rp directory contains the figures. The gis directory has geospatial data. The Load data directory loads data. The Output_Data directory contains output data. The Output_GIS directory contains output geospatial data. The tables_rp contains tables. The UDF directory has user defined functions.

Folder Structure

Build_Databases

data (databases)

figures_rp (figures)

gis (geospatial data)

Load_data

 R scripts loading data

 EDGAR (process EDGAR data)

local (not public data)

Output_Data
Output_GIS
tables_rp (tables)
UDF (user defined functions)

wp

s2s_ghg__trend_wp__main.R
s2s_ghg__trend_wp_global_libraries.R
s2s_ghg_fig01_panel.R
s2s_ghg_fig02_panel.R
s2s_ghg_fig03_panel.R
s2s_ghg_fig04_panel.R
s2s_ghg_fig05_panel.R
s2s_ghg_fig06_panel.R
s2s_ghg_fig07_panel.R
s2s_ghg_fig08_panel.R
s2s_ghg_fig09_panel_ch4.R
s2s_ghg_fig10_panel_ch4.R
s2s_ghg_fig11_adm2_by_WB_region.R
s2s_ghg_fig12_adm2_by_WBINC.R
s2s_ghg_tbl01a_gen_SE_Asia_Unweighted_CO2_Data.R
s2s_ghg_tbl01b_gen_SE_Asia_Weighted_CO2_Data.R
s2s_ghg_tbl02_gen_SE_Asia_Comp_UnW_and_W_Scores_CO2_Trend_1.R