

**Project title:** High-Resolution Integrated Anthropogenic Emission Inventories (CINEI v2.1) for Next-Generation Kilometer-Scale Earth System Models

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**Project Abstract:** Anthropogenic emissions of short-lived species and longer-lived greenhouse gases significantly influence atmospheric composition, air quality, and climate through complex interactions with meteorological and chemical processes at local, synoptic, regional, and global scales. Current emission inventories often lack the spatial resolution and temporal accuracy needed for high-resolution Earth System Modeling, particularly in rapidly changing industrial regions of East Asia, South America, and Africa (Figure 1). This limitation affects the reliability of both climate projections and air quality forecasting in these critical regions. The representativeness of emission inventories in terms of accuracy of emission amounts, category classification, and temporal-spatial resolution is essential for modeling projects on the Levante supercomputer of the German Climate Computing Center (DKRZ).

This project develops CINEI v2.1 (Coupled and Integrated Emission Inventory version 2.1), a next-generation high-resolution (0.1°, kilometer-scale) global anthropogenic emission inventory that integrates high-resolution satellite observations (TROPOMI NO<sub>2</sub>, HCHO) with in-situ ground-based measurements using machine learning techniques. Building upon our published CINEI v1.1 inventory for China (Zhang, Y.: CINEI V1.1: Python code for creating an integrated inventory of anthropogenic emission for China (Version 1), <https://doi.org/10.5281/zenodo.15000795>, 2025a), which provides a foundation for bottom-up emission estimation and regional validation infrastructure, the enhanced version will provide temporally resolved emission estimates with uncertainty quantification for eight major human-activity emission sectors, including power generation, residential, industrial, transportation, agriculture, aviation, shipping, and waste sectors. CINEIv2.1 dataset coordinates community-based efforts from observational and emission communities and serves as a critical foundation for high-resolution weather forecast and climate modeling applications within DKRZ's scope of collaboration. The community project will establish the computational infrastructure on Levante and conduct preliminary development activities:

- Integrating high spatial-temporal resolution observations into emission estimation workflows
- Adapting the emission data to ICON and IFS modeling in the DKRZ scope.
- Numerical experiments focus on chemistry of air quality and chemical and meteorology interaction using WRF-Chem/ICON/IFS over selected test regions.
- Validating the modeling concentration of air pollution with observations

This work is conducted in collaboration with the Max Planck Institute for Meteorology (MPI-M) and ECMWF, and supports the German climate modeling community (Zhang et al., 2025; Pachón et al., 2024), including ICON (ICOsahedral Nonhydrostatic) model and IFS-FESOM (Integrated

Forecasting System coupled to the Finite-volume Sea ice-Ocean Model) development and applications (Pham et al., 2021; Segura et al., 2025). The enhanced inventory will enable more accurate representation of aerosol-cloud-climate interactions and atmospheric chemistry processes at local to synoptic scales, directly benefiting DKRZ's climate modeling activities and contributing to CMIP7 preparations (Dunne et al., 2025).

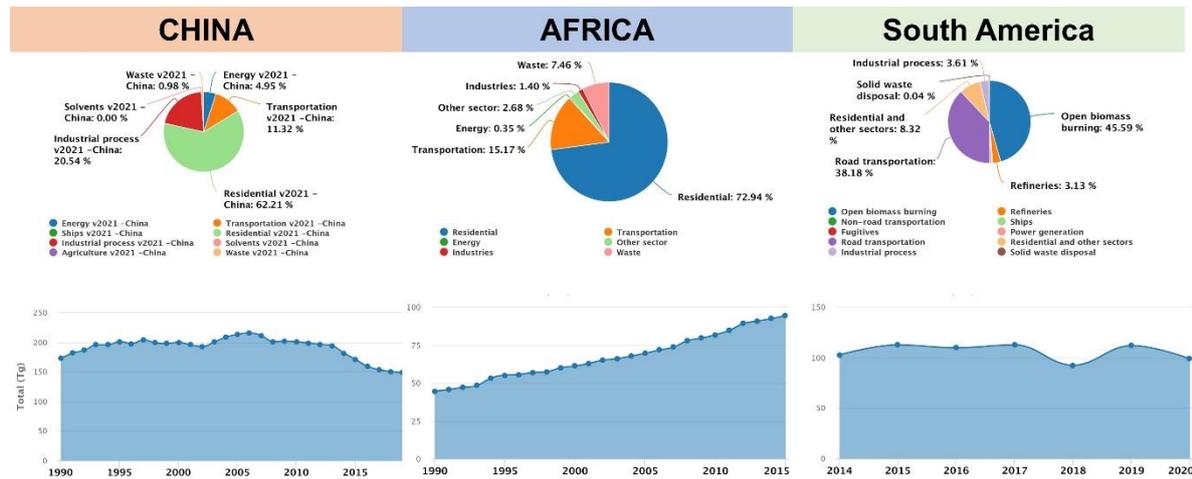


Figure 1. Year-to-year rapid changes of Carbon monoxide emission from anthropogenic sources in China, Africa and South America