Warming Dashboard Technical Documentation

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About FaIR:
The FaIR (finite amplitude impulse response) model (v1.3 Smith et al., 2018; v2.0.0 Leach et al., 2021) is a reduced complexity climate model also known as a climate model emulator. It contains a small set of equations (six in FaIR v2.0.0) that capture the response of the climate system to changes in greenhouse gas and aerosol emissions. The model includes a large number of parameters which can be calibrated to emulate the emissions responses of full scale global climate models (GCMs), but using a small fraction of the run time and computational resources. Because FaIR is so quick to run, it can be used to evaluate many more scenarios than expensive GCMs can, and can be applied to ensembles of parameters or scenarios to get probabilistic estimates of future warming. FaIR accomplishes this by simulating the pathway from globally averaged emissions to concentrations to radiative forcing to temperature response.

FaIR-calibrate:
In this work, we use a calibrated and constrained ensemble of parameter sets from FaIR-calibrate v.1.4.1 all-2022 (Smith et al., 2024; https://zenodo.org/records/10566813). This parameter set includes 841 ensemble members of 46 parameters derived by calibrating and constraining the FaIR v2.1.3 model using historical emissions and climate observations up through 2022. A new calibration (v.1.5) is expected to be released soon (Chris Smith, personal communication) which will update the parameter sets based on observations through 2024.

Historical emissions inputs to FaIR:
For the historical period, we use the scaled emissions estimates for the period 1750-2022 that were used in the development of the calibrated parameter set described above. These emissions data are from observational and proxy datasets such as the Global Carbon Project, PRIMAP-Hist, Global Fire Emissions Database, and the Community Emissions Data System. The emissions are scaled, as described in section 3.1.2 of Smith et al., (2024). We extend the historical emissions data through 2023 using CO2 emissions observations from the Global Carbon Budget (Friedlingstein et al., 2024) and infilling the other species' emissions using the latest time ratio method from the silicone python package.

Future emissions inputs to FaIR:
For the future period, we use emissions data from the seven scenarios developed by the Network for Greening the Financial System (NGFS, v5) and emissions data from six preliminary CMIP7 scenarios (van Vuuren et al., 2025).

The NGFS scenarios were crafted in consultation with many academic and scientific institutions and aim to capture a range of possible futures. Different storylines of policy ambition are input

into three integrated assessment models (IAMs; GCAM, REMIND, and MESSAGE), which output species specific emissions time series. Of particular interest is the Current Policies scenario, which aims to capture the effect of only policies that are currently in place, excluding pledged but not implemented commitments and future changes in policy ambition.

The Scenario Model Intercomparison Project (ScenarioMIP) within the CMIP framework is tasked with developing plausible future scenarios which can be run by climate models, inform other non-climate science applications, and inform policy decisions. They have recently released emissions data for a set of scenarios proposed to be used in CMIP7. These scenarios span low to medium to high emissions and include overshoot scenarios.

Warming Dashboard:
The Warming Dashboard is a web application built with Shiny for Python which allows users to explore possible warming outcomes from a range of future scenarios. Compared with similar web applications, the Warming Dashboard includes the capability to explore nearer term warming outcomes (not just 2100) and the potential for higher end warming under a given scenario (as opposed to only presenting median projections). In the Dashboard, users can select a year of interest and one or more future scenarios. The following outputs are updated based on user inputs:

- *Median Warming:* the median global warming in the selected year and scenario(s).
- *Probability of Exceeding 1.5°C:* calculated as the percentage of model runs (aka simulations) that exceed 1.5°C warming in the specified year and scenario(s).
- *Probability of Exceeding 2.0°C:* calculated as the percentage of model runs that exceed 2.0°C warming in the specified year and scenario(s).
- *Warming Time Series:* plot displaying the time series of global warming values for the selected scenario(s).The median warming projection is shown as a solid line. 0-100%, 5-95%, and 16-84% confidence intervals on the warming projections are shown as increasingly opaque bands. Horizontal lines mark 0°C, 1.5°C, and 2°C warming. The selected year is indicated by a dashed vertical line for reference.
- *Warming Possibilities:* plot displaying the distribution of warming projections for the selected year and scenario(s). The upper panel shows the warming distribution for each scenario as a boxplot, while the lower panel shows the probability of warming amounts grouped by 0.25°C warming bins.

All warming values are global averages relative to the preindustrial (1850-1900) mean global temperature. Outputs are color coded by scenario. For NGFS scenarios, the number of simulations is 2,523 (841 parameter sets x 3 IAMs). For CMIP7 scenarios, the number of simulations is 841 (based on 841 parameter sets). Both plots on the dashboard are interactive; individual values can be explored by hovering over the plot, users can zoom and pan, and plots can be downloaded as png files.