

pyam: a Python Package for the Analysis and Visualization of Models of the Interaction of Climate, Human, and Environmental Systems

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Software

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Summary

Quantitative model-based scenarios of the human and earth systems play a critical role in the scientific analysis of climate change mitigation options and sustainable development policies. Perhaps the most visible among these projects is the assessment of pathways from Integrated Assessment Models (IAM) and other numerical frameworks by the Intergovernmental Panel on Climate Change (IPCC) in its periodical reports. For the recent *Special Report on Global Warming of 1.5 °C* (SR15, (J. Rogelj et al., n.d.)), a scenario ensemble underpinning the quantitative assessment was compiled and released to facilitate transparency of the assessment and replicability of the findings in the report (Huppmann, Rogelj, Kriegler, Krey, & Riahi, 2018).

Additionally, IAM scenarios (Riahi et al., 2017) serve as one of the main drivers of the Coupled Model Intercomparison Project Phase 6 (CMIP6) (M. J. Gidden et al., 2018; B. C. O'Neill et al., 2016), which informs the global scientific basis for climate change. IAMs are not only limited to global analyses, but also are critical for country-specific policy assessments both domestically as well as in the global context (Rogelj et al., 2016). While great strides have been made to make IAM scenario data publicly available among these different projects, limited effort has been applied so far to develop open tools for their exploration, analysis, and visualization.

Here we present a new tool which aims to fill the current gaps in the IAM toolbox: an open-source analysis and visualization library named **pyam** (Matthew J. Gidden & Huppmann, 2018). **pyam** has been designed since its inception following known best practices in scientific software development, including automatic documentation, unit testing, and continuous integration. At its core, **pyam** is a tool that enables researchers to easily explore, categorize, and visualize scenario data such as the scenario ensembles assessed by the IPCC. Such exploration is enabled via a **pandas.DataFrame**-style interface using a composition design pattern while maintaining sidecar metadata in a single **pyam.IamDataFrame** object.

Critically, **pyam** provides a common mechanism by which scenario data analysis is performed. This allows to easily share such analysis for greater transparency and reproducibility, through, e.g., Jupyter notebooks. In fact, it is already an integral tool used by scientists leading the data analysis of both the IPCC SR15 as well as the ScenarioMIP contribution to CMIP6. The Jupyter notebooks generating the categorization and assessment in the SR15, including figures and tables printed in the report, are based on **pyam** and have been publicly released under an open-source license (Huppmann et al., 2018).

A large suite of examples is available via the [pyam website](#). Here, we provide a small vignette below for interacting with and visualizing the recent SR15 dataset.

```
import pyam

# read all data for three variables at the global ('World') level
# from the *IAMC 1.5 °C Scenario Data*, the database underpinning the IPCC SR15
df = pyam.read_iiasa_iamc15(
    model='*', scenario='*',
    variable=['Emissions|CO2', 'Primary Energy|Coal',
              'AR5 climate diagnostics|Temperature|Global Mean|MAGICC6|MED'],
    region='World'
)

# Categorize these data by their Global Mean Temperature values in 2100
df.categorize(
    'Temperature', 'Below 1.5C',
    criteria={'AR5 climate diagnostics|Temperature|Global Mean|MAGICC6|MED':
              {'up': 1.5, 'year': 2100}},
    color='cornflowerblue'
)

df.categorize(
    'Temperature', 'Below 2C',
    criteria={'AR5 climate diagnostics|Temperature|Global Mean|MAGICC6|MED':
              {'lo': 1.5, 'up': 2, 'year': 2100}},
    color='forestgreen'
)

df.categorize(
    'Temperature', 'Above 2C',
    criteria={'AR5 climate diagnostics|Temperature|Global Mean|MAGICC6|MED':
              {'lo': 2, 'year': 2100}},
    color='magenta'
)

# Temperature data can be plotted directly based on these categories,
# shading areas between lowest and highest values for each category,
# and providing minimum/maximum ranges of final-year data
(df
 .filter(variable='*Temperature*')
 .line_plot(color='Temperature', legend=True,
            alpha=0.5, fill_between=True,
            final_ranges=dict(linewidth=4))
)

# Separately, the other data can be plotted using the temperature categories.
(df
 .filter(region='World')
 .scatter(x='Primary Energy|Coal', y='Emissions|CO2',
          color='Temperature', alpha=0.5, legend=True)
)
```

Executing the above code snippet results in the following figures.

The **pyam** user community already spans three continents and multiple scientific domains. New features, e.g., integration with simple climate models, are envisioned for future releases in order to further expand the usability and relevance of the tool. By

region: World variable: AR5 climate diagnostics|Temperature|Global Mean|MAGICC6|MED

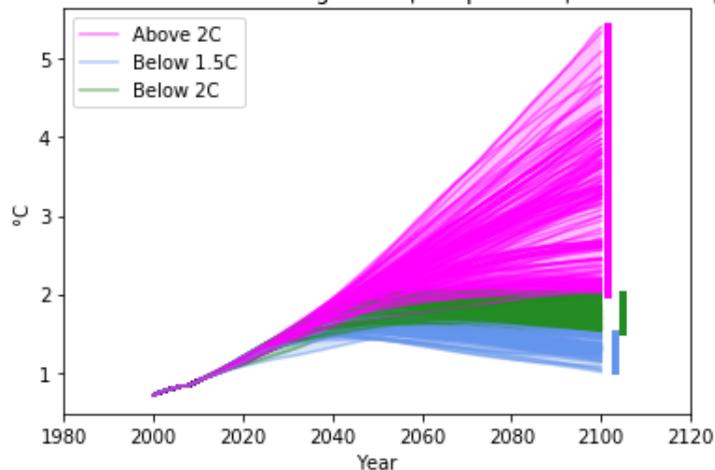


Figure 1: A classic AR5-style line plot, showing various temperature categories, their scenario ranges, and end-of-century outcome ranges.

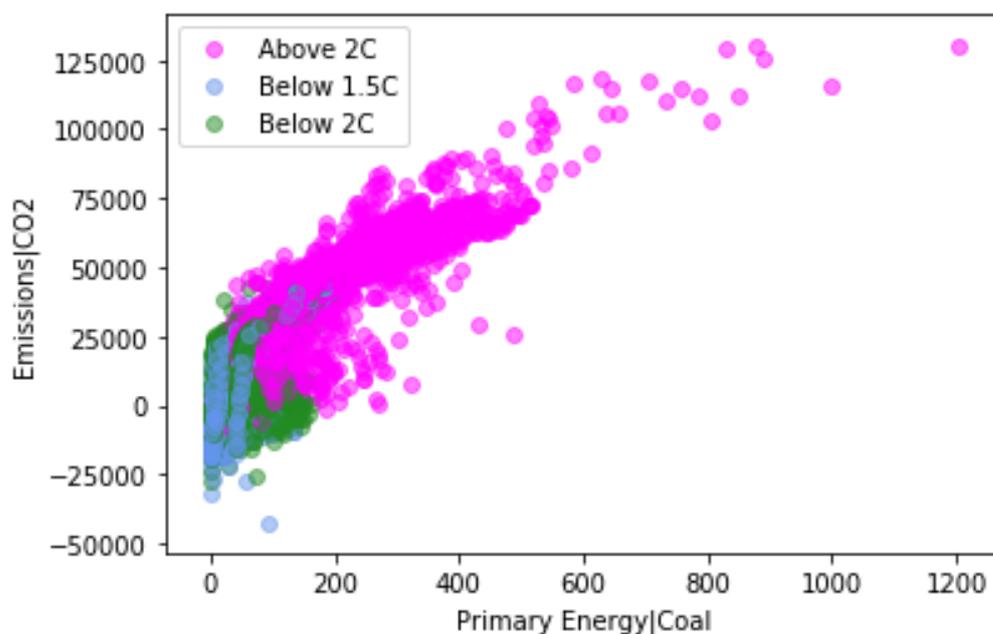


Figure 2: A scatter plot showing scenario values of primary energy from coal vs. CO2 emissions colored based on end-of-century temperature outcomes.

standardizing analysis and visualization work flows in assessment modeling, modelers can more keenly focus on their core competency: developing and performing large-scale models of the interlinked human, environment, and climate systems.

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