ClimateClaw: From Natural Language to Reproducible Climate Analysis

Gizem Ekinci[1], Sebastian Willmann[1], Felix Oertel[1], Bianca Wentzel[1], Koketso Molepo[2], Johanna Baehr[3], Kevin Sieck[4], Chao Li[5], Thomas Ludwig[1], Martin Bergemann[1], Jan Saynisch-Wagner[2], Christopher Kadow[1]

Contact:
ekinci@dkrz.de
freva@dkrz.de

[1]Deutsches Klimarechenzentrum, [2]GFZ Helmholtz-Zentrum für Geoforschung,
[3]Universität Hamburg, [4]GERICS - Helmholtz-Zentrum Hereon, [5]Max-Planck Institut für Meteorologie

LLM-based Scientific Assistant

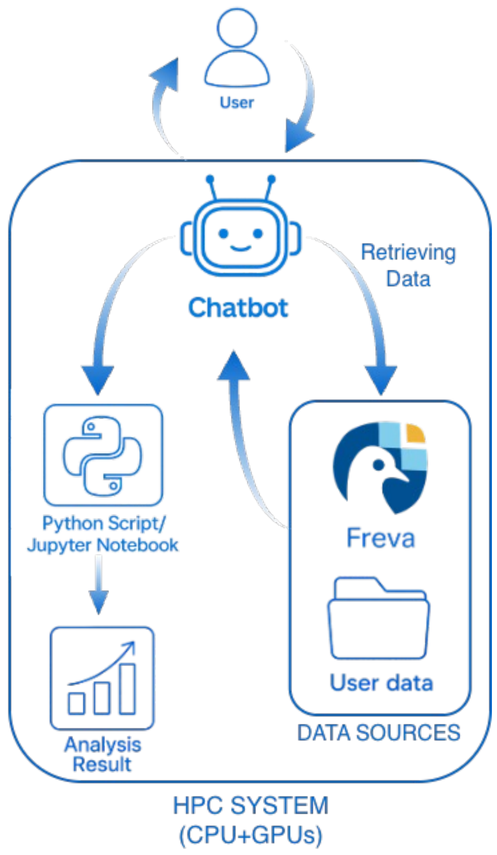
What if researchers could ask…

Annual mean temperature global map plot for the year 2023?

and the assistant would retrieve the correct dataset, write a python script and execute it on HPC, and present and analyze the result.

Natural language interaction → Executable scientific workflow

- Grounded in real climate data
- Reproducible and traceable
- Interactive



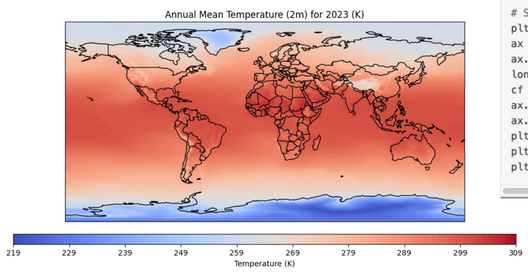
Workflow

To create an annual mean temperature global map plot for the year 2023, I'll:

1. Search for and load ERA5 monthly 2m temperature (tas) data for 2023 using freva_client.databrowser.
2. Calculate the annual mean temperature across all months of 2023.
3. Plot the global annual mean temperature data on a map using matplotlib and cartopy.

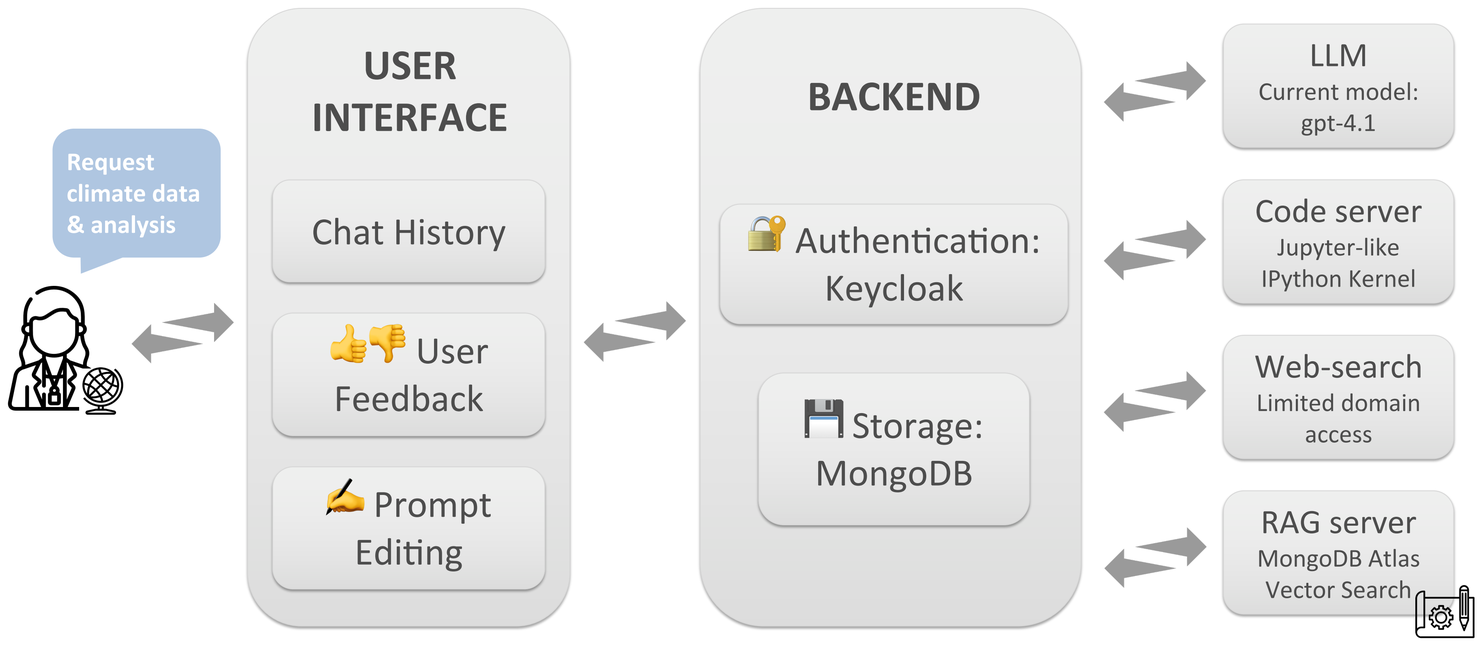
Proceeding to execute these steps.

```python
import freva_client
import xarray as xr
import numpy as np
import matplotlib.pyplot as plt
import cartopy.crs as ccrs
import cartopy.feature as cfeature

# Step 1: Load ERA5 monthly surface air temperature (tas) data for 2023
files = freva_client.databrowser(project='reanalysis', experiment='era5', variable='tas', time_frec
dset = xr.open_mfdataset(list(files), combine='by_coords')

# Step 2: Calculate annual mean
tas_2023 = dset['tas'].mean(dim='time')

# Step 3: Plot global map
plt.figure(figsize=(12,6))
ax = plt.axes(projection=ccrs.PlateCarree())
ax.set_global()
lons, lats = np.meshgrid(dset['lon'], dset['lat'])
cf = ax.contourf(lons, lats, tas_2023, cmap='coolwarm', levels=100, transform=ccrs.PlateCarree())
ax.coastlines()
ax.add_feature(cfeature.BORDERS)
plt.title('Annual Mean Temperature (2m) for 2023 (K)')
plt.colorbar(cf, orientation='horizontal', pad=0.05, aspect=50, label='Temperature (K)')
plt.show()
```



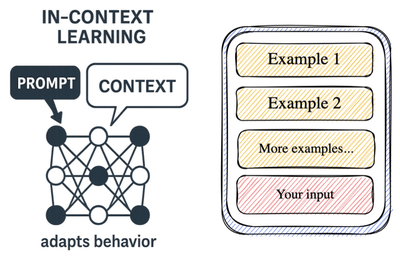
This image shows the global annual mean 2-meter air temperature for 2023, derived from ERA5 monthly data. The map uses a diverging colormap to highlight temperature variations across regions. Coastlines and borders are included for geographic context. If you need further analysis or want this map saved as a file, let me know!

Architecture & Methodology



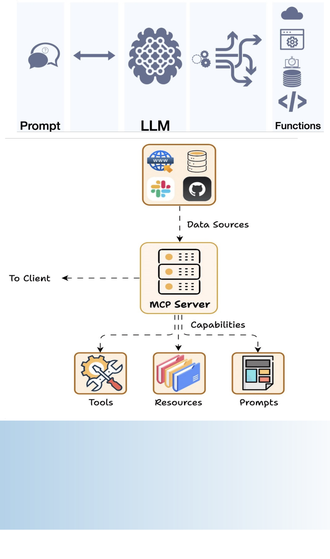
We adapt to scientific domain without fine-tuning:

- In-context learning
- Few-shot prompting



We integrate external tools via Model Context Protocol

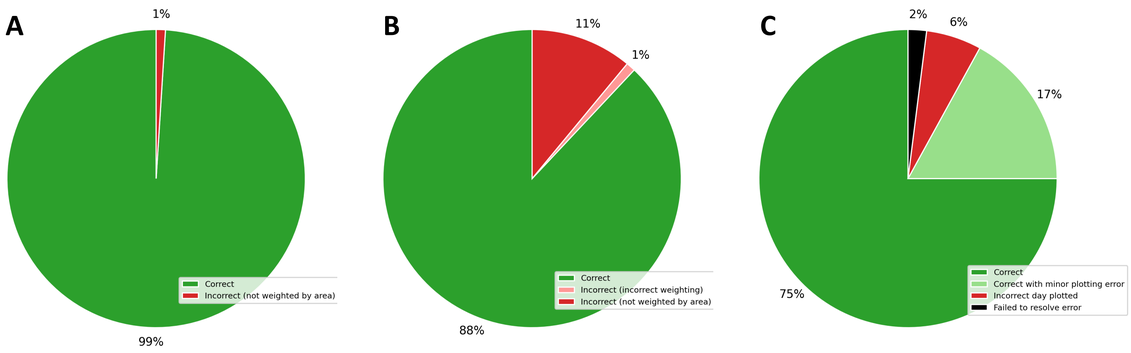
- Standardized tool interfaces
- Mediates communication between model and execution layer
- Enforces structured tool calls



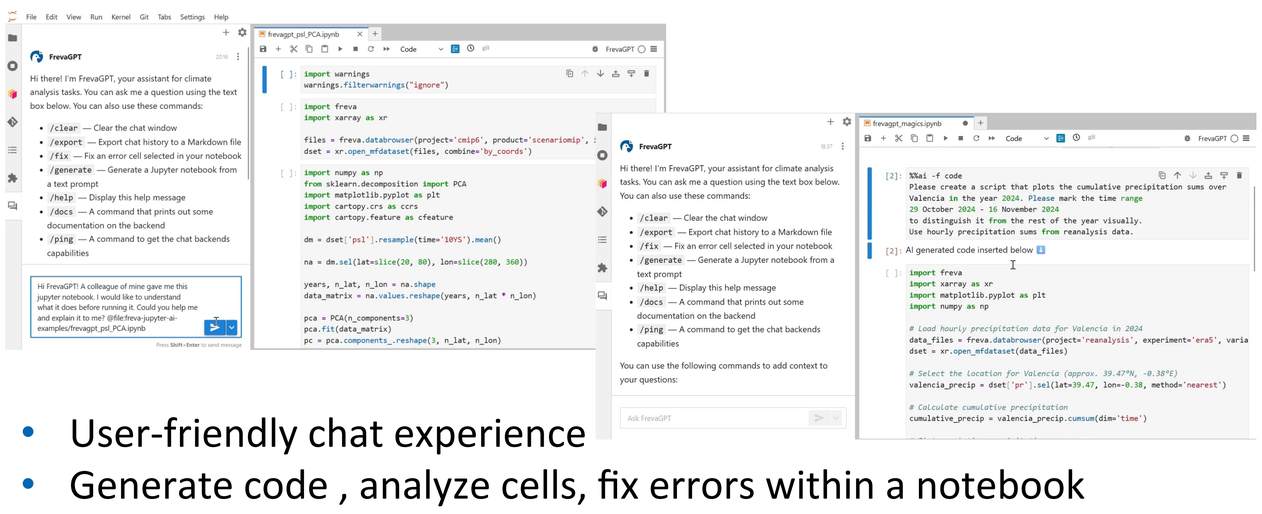
Evaluation

We evaluated ClimateClaw by prompting 100x each with the following tasks of increasing difficulty:

- **A:** What was the global mean temperature between 1961 and 1990?
- **B:** Use the monthly temperature data to generate a yearly time series on the temperature anomaly between 1940 and 2023 inclusive. As reference, use the climatology of 1961 to 1990.
- **C:** For the day the Neumayer III started operations, make a polarstereographic map plot of Antarctica showing sfcWind and mark the station with a big X.



ClimateClaw in JupyterHub



- User-friendly chat experience
- Generate code , analyze cells, fix errors within a notebook

Outlook

- Self-hosted models instead of cloud services
- Autonomous agents that can break down complex scientific tasks, plan, follow up, and iterate
- Task-focused minimal agents, e.g. coding agent, planning agent
- Extend the knowledge base with RAG

Would you like to know more?

- Check out ClimateClaw
- Check out Github repo

Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG
VolkswagenStiftung
DKRZ
GFZ Helmholtz-Zentrum für Geoforschung
GERICS Climate Service Center Germany
MAX-PLANCK-INSTITUT FÜR METEOROLOGIE