Climate Visualizer Project Report

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Project Overview

Climate Visualizer is a full-stack web application for exploring, analyzing, and visualizing global air quality data.

It consists of:

- A backend (Python, Flask) that serves air quality data and advanced analysis via a REST API.
- A frontend (React) that provides interactive dashboards, charts, and maps for users to explore air quality trends, pollutant composition, temporal patterns, correlations, comparative analysis, and forecasting.

Backend (Flask API)

Location: backend/

Key Features:

- Data Source: Uses a CSV file (global_air_quality_dataset.csv) containing air quality and weather data for various cities and countries.
- Data Cleaning: Loads and cleans the data (removes missing values, sorts by country/city/date).
- API Endpoints:
  - /api/countries - List all countries in the dataset.
  - /api/cities - List cities, optionally filtered by country.
  - /api/pollutants - List all pollutants tracked (e.g., PM2.5, PM10, NO2, SO2, CO, O3).
  - /api/data - Get air quality data, filterable by country, city, pollutant, and date range.
  - /api/city-aqi-trends - Get monthly/yearly AQI trends, pollution spikes, and trend direction for each city.
  - /api/pollutant-composition - For each city, get average, max, and percentage contribution of each pollutant to AQI.
  - /api/pollutant-composition-timelapse - Monthly pollutant composition for each city, including health risks and sources.
  - /api/temporal-patterns - Analyze AQI by month, weekday/weekend, daily/weekly trends, pollutant levels, holiday/event effects, extreme events, and year-over-year/month-over-month changes.
  - /api/correlation-analysis - Statistical correlations between AQI, pollutants, and weather variables (temperature, humidity, wind speed), including time-lag and partial correlations.
  - /api/comparative-analysis - Compare AQI, trends, and pollutant composition across multiple cities or countries, with clustering and benchmarking.

- /api/forecast - Forecast AQI or pollutant levels for a city, with scenario analysis (simulate emission reductions), anomaly detection, and confidence intervals.
- Analysis Functions:
  - Summary statistics for each country/city.
  - AQI trends and pollution spikes detection.
  - Correlation analysis (Pearson/Spearman) between pollutants and weather.
  - Comparative analysis with clustering and benchmarking.
  - Forecasting with scenario simulation and anomaly detection.
  - Pollutant composition timelapse with health risk and source info.

Frontend (React App)

Location: frontend/

Key Features:

- Modern UI: Built with React, styled with Tailwind CSS, and uses charting libraries (Chart.js, react-chartjs-2) and mapping (react-leaflet).
- Navigation: Sidebar with links to Dashboard, City Trends, Pollutant Composition, Temporal Patterns, Correlation Analysis, Comparative Analysis, and Forecasting.
- Global Search: Modal for searching cities, countries, pollutants, and navigating to different analysis screens.

Main Screens/Components:

- Dashboard: Summary cards (average AQI, number of cities, latest date, dominant pollutant), filters, trend charts, and map.
- City Trends: Select a city to view monthly/yearly AQI trends, pollution spikes, and trend direction.
- Pollutant Composition: Select a city to view average, max, and percentage contribution of each pollutant.
- Pollutant Composition Timelapse: Visualize monthly changes in pollutant composition, health risks, and sources.
- Temporal Patterns: Analyze AQI by month, weekday/weekend, daily/weekly trends, holiday/event effects, extreme events, and year-over-year/month-over-month changes.
- Correlation Analysis: View statistical correlations between AQI, pollutants, and weather variables, including time-lag and partial correlations.
- Comparative Analysis: Compare multiple cities/countries, view clusters, benchmarks, and detailed tables/charts.

- Forecasting & Scenario Analysis: Forecast AQI/pollutant levels, detect anomalies, and simulate emission reduction scenarios. Includes summary cards, interactive charts, and a collapsible forecast table.
- Map Section: Interactive map with city markers colored by AQI and cluster.

Data Flow:

- The frontend fetches data from the backend API based on user selections (filters, city, pollutant, etc.).
- Data is visualized using charts and maps, with real-time updates as filters change.
- Scenario analysis, clustering, benchmarking, and anomaly detection are supported in relevant screens.

Technologies Used

- Backend: Python, Flask, Pandas, NumPy, SciPy, Flask-CORS
- Frontend: React, Tailwind CSS, Chart.js, react-chartjs-2, react-leaflet, react-router-dom, lucide-react (icons)
- Data: CSV file with air quality and weather data

How It Works (User Flow)

1. User opens the app (frontend).
2. Dashboard loads with summary statistics and a map.
3. User applies filters (country, city, pollutant, date range) to explore specific data.
4. User navigates to different analysis screens:
   - City Trends: See AQI trends and spikes for a city.
   - Pollutant Composition: See which pollutants dominate in a city.
   - Pollutant Composition Timelapse: See monthly changes in pollutant composition, health risks, and sources.
   - Temporal Patterns: See how AQI changes over time, by day type, and during holidays/events or extreme events.
   - Correlation Analysis: See how pollutants and weather variables are related, including time-lag and partial correlations.
   - Comparative Analysis: Compare multiple cities/countries, view clusters, benchmarks, and detailed tables/charts.
   - Forecasting & Scenario Analysis: Forecast AQI/pollutant levels, detect anomalies, and simulate emission reduction scenarios.
5. All data and charts are fetched from the backend API, which processes and analyzes the CSV data on demand.

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Summary Table

Layer | Technology | Main Purpose/Features

Backend | Flask, Pandas | Serve air quality data, perform advanced analysis, expose REST API (comparative, forecasting, timelapse, clustering, scenario analysis)

Frontend | React, Tailwind | Interactive dashboards, charts, maps, filters, navigation, scenario analysis, clustering, benchmarking, anomaly detection

Data | CSV | Global air quality and weather data (city, country, date, AQI, pollutants, weather)

Conclusion

Climate Visualizer is a data-driven web app for exploring and analyzing global air quality.

It provides interactive visualizations and advanced statistical insights, including comparative analysis, forecasting, scenario simulation, and pollutant health/source info, making it useful for researchers, policymakers, and the public interested in air pollution trends and their relationships with weather.