ENGLISH

Topic/Title

Use of Machine Learning Methodologies for the Estimation and Attribution of Climate Change

Proposer (Tutor)

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Research proposal

In recent decades, the rise in global temperatures and the intensification of extreme climate events have raised crucial questions about the causes of these phenomena. While the scientific community agrees on a role of anthropogenic activities in global warming, the quantitative separation of human impact from natural climate variations remains an open challenge. This project aims to harness the potential of Artificial Intelligence (AI) to improve global climate records and better distinguish anthropogenic causes from natural ones, thereby enhancing our understanding of climate change and optimizing the estimation of future risks resulting from climate change, which in turn influence political and economic decisions.

In particular, the Coupled Model Intercomparison Project (CMIP) global climate models play a fundamental role in climate change research and policy formulation. According to their simulations, nearly 100% of the observed warming between 1850–1900 and 2011–2020 is attributed to anthropogenic factors, primarily greenhouse gas emissions. However, several significant scientific uncertainties remain regarding climate change detection, the representation of natural climate variability, climate sensitivity, and solar influence.

This research proposes the use of Artificial Intelligence (AI) and advanced

classification techniques based on Machine Learning to improve the distinction between anthropogenic and natural climate impacts.

The project aims to explore both—or at least one—of the following key aspects:

1. Optimizing climate change estimations, for example, quantifying potential spurious warming trends, such as those caused by urban heat effects.
2. Climate attribution through machine learning, developing models capable of separating human contributions from various potential natural factors.

The project seeks to: 1) Develop an AI model based on classification techniques to analyze climate data and identify distinctive patterns between anthropogenic causes and natural variations; 2) Integrate multidisciplinary climate datasets, including satellite measurements, meteorological station data, and climate simulations; 3) Apply AI interpretability techniques to ensure the model not only provides accurate results but also makes classification factors transparent; 4) Validate results with existing climate attribution studies, comparing model predictions with conclusions from the scientific community.

The integration of AI techniques into climate research will enable: 1) Refining climate attribution, enhancing the reliability of predictions and existing models; 2) Supporting climate policies, providing more robust data for developing mitigation and adaptation strategies; 3) Optimizing climate simulations, reducing uncertainties and improving the representation of natural variability.

This project represents a significant step forward in AI applications for climate analysis, combining advanced classification techniques and causal analysis to refine the distinction between anthropogenic and natural impacts. The transparency and interpretability of the models will ensure that the results are understandable and useful for political and scientific decision-making.

Research Plan

I° year

During the first year, the focus will be on establishing the theoretical and methodological foundations, as well as collecting and preparing the data:

1. Literature Review – In-depth analysis of existing studies on climate attribution and applicable AI techniques. Identification of key climate datasets and suitable machine learning methods.
2. Data Collection and Pre-processing – Acquisition of climate data from authoritative sources (NASA, NOAA, ECMWF). Cleaning, normalization, and handling of missing data to ensure dataset quality.
3. Definition of Key Variables – Selection of the most relevant climate variables for classification. Determination of the most appropriate ML and AI techniques to extract meaningful insights from the collected data.

II° year

Nel secondo anno, l'attenzione sarà sulla costruzione e ottimizzazione dei modelli basati sull'AI per l'attribuzione del cambiamento climatico.

1. Sviluppo del modello di classificazione – Implementazione di diversi algoritmi di machine learning (reti neurali, SVM, alberi decisionali). Creazione di un modello robusto in grado di distinguere le cause antropogeniche dalle variazioni naturali.
2. Interpretabilità – Applicazione di tecniche di interpretabilità per garantire che il modello fornisca non solo risultati accurati, ma anche trasparenti e comprensibili.
3. Validazione e Test su Dati Storici – Confronto delle previsioni del modello con dati climatici storici e studi di attribuzione esistenti per valutare l'affidabilità del sistema.

III° year

Nel terzo anno, il progetto si concentrerà sull'affinamento dell'analisi causale e sull'applicazione pratica del modello e sulla scrittura della dissertazione.

1. Implementazione di modelli Bayesiani per inferenza causale – Utilizzo di reti bayesiane e tecniche statistiche per stabilire connessioni robuste tra attività antropiche e cambiamenti climatici osservati.

2. Sperimentazione e Applicazione a Scenari Futuri – Test del modello su proiezioni climatiche future per valutare la capacità di attribuzione in contesti predittivi.

3. Pubblicazione e Disseminazione – Redazione di articoli scientifici e presentazione dei risultati a conferenze internazionali per contribuire alla comunità scientifica sul cambiamento climatico e AI, e scrittura e discussione della dissertazione.

Additional notes:

To ensure the success of the research, the candidate should have a solid foundation in physics, mathematics, statistics, meteorology, and climatology, as well as programming skills, preferably using tools such as MatLab. These competencies will enable the candidate to conduct climate data analysis, develop computational models, and apply advanced machine learning techniques effectively and rigorously.