NICOLA SCAFETTA

THE FRONTIER OF CLIMATE SCIENCE

Solar variability, natural cycles and model uncertainty

INTERNATIONAL ASSOCIATION FOR GONDWANA RESEARCH
IAGR

Centro di Ricerca
Previsione Prevenzione e Controllo
dei Rischi Geologici - Ceri

Sapienza
Università di Roma

NICOLA SCAFETTA

THE FRONTIER OF CLIMATE SCIENCE

Solar variability, natural cycles and model uncertainty

Centro di Ricerca
Previsione Prevenzione e Controllo
dei Rischi Geologici - Ceri

Sapienza
Università di Roma

International Association for Gondwana Research
IAGR

ISBN: 9791298617605 (paperback grayscale ed.)
ISBN: 9791298617612 (hardcopy color ed.)
ISBN: 9791224067061 (ebook ed.)

Synopsis

How well do we truly understand Earth's climate?

What natural forces remain beyond our grasp?

Is Net Zero the only viable path forward?

The *Frontier of Climate Science* explores climate dynamics through physics, complex systems, and astronomy, synthesizing several decades of peer reviewed research.

The book critically reviews the scientific foundations of modern climate theory, the evolution of IPCC assessments, and the limits of global climate models (GCMs) when confronted with observations. It investigates natural variability across multiple timescales, including oceanic oscillations, solar variability, and astronomical cycles driving both solar and climate variability, integrating satellite data, paleoclimate reconstructions, and empirical modeling approaches.

From this evidence emerges a balanced view of climate risk, favoring pragmatic adaptation over narrowly defined policy pathways such as Net Zero. Rich in insights and analytical approaches, the book helps readers understand climate variability, assess risks, think critically, and explore key open questions in climate science.

Endorsed by the *International Association for Gondwana Research* (IAGR) and by the "*Centro di Ricerca Previsione, Prevenzione e Controllo dei Rischi Geologici*" (CERI), Sapienza University of Rome. Forewords by Prof. M. Santosh, Prof. Alberto Prestininzi, and Prof. Judith Curry.

About the Author

Nicola Scafetta is a physicist and climate scientist, and Professor of Oceanography, Meteorology, and Climatology at the University of Naples Federico II. He earned his Ph.D. in Physics from the University of North Texas and has conducted research at leading U.S. universities, primarily at Duke University. He served as a co-investigator on NASA-JPL's ACRIM project, dedicated to the satellite measurement of total solar irradiance. Since 2017, he has been ranked among the "World's Top 2% Scientists" in the Stanford University-Elsevier listing. His research focuses on climate and solar variability, solar influences on climate, and the analysis of long-term climate oscillations.

Selected Quotes from the Forewords

From the Foreword by Prof. M. Santosh:

"*This book ... offers an excellent window into the deep realms of climatology, complex systems physics, and astronomy in addressing three major aspects: (1) how well do we truly understand Earth's climate? (2) what natural forces remain beyond our grasp? (3) is Net-Zero the only viable path forward?*"

"*From an authoritative analysis, the author formulates insightful perspectives that demystify the exclusive attribution of global warming in the last century to human activities, and places more importance on the dynamic interplay of terrestrial and cosmic forces.*"

"*This work is an excellent window into climatology as a dynamic science, and calls for adaptive strategies grounded in economic sustainability and social equity to address climate change issues.*"

From the Foreword by Prof. Alberto Prestininzi:

"*In* The Frontier of Climate Science, *Scafetta constructs a theoretical and didactic journey that guides the reader through the multiple dimensions of the climate system. The book is conceived as a critical dialogue in which the processes that govern Earth's climate - many of which remain poorly understood or underestimated - are examined in depth.*"

"*The goal is to distinguish facts from rhetoric, restoring to science its role as a pluralistic, iterative, and non-dogmatic inquiry.*"

"*Scafetta's work fits fully within this long trajectory of scientific inquiry, but with a theoretical and systemic perspective...* The Frontier of Climate Science *is thus a work that invites reflection, verification, and debate.*"

From the Foreword by Prof. Judith Curry:

"*The seminal contribution of* The Frontier of Climate Science *is a new scientific paradigm that provides a broader interpretive framework capable of resolving the inconsistencies of the current anthropogenic climate change model.*"

"*Solar variability and its role in climate change remain among the most profound and unresolved issues in contemporary climate science. Scafetta makes a compelling argument that it is time to bring the Sun back to the center of climate discourse.*"

"*A healthy scientific culture embraces pluralism, methodological rigor, and open dialogue. Only through this lens can climate science remain credible, adaptive, and truly informative... Scafetta's framework offers a valuable opportunity for engagement.*"

Contents

Foreword by Prof. M. Santosh

A window into the climate change conundrum

Earth has the unique status in the Solar System as a planet having the combination of land (continents), oceans, and atmosphere. Continents (supplying nutrients and serving as the home for various ecosystems), oceans (functioning as the lungs of the planet, regulating climate, and acting as the largest carbon sink), and atmosphere (providing life breath, maintaining stable temperature, and shielding harmful solar radiation) define the trinity of our "*Habitable Planet*".

In the past 4.6 billion years of its history, Earth's climate was significantly influenced by geodynamic factors including solar luminosity, plate tectonic cycles, volcanic activities, and Milankovitch cycles. Thus, the formation, evolution, and disruption of continental assemblies (termed as supercontinent cycles), complemented by the opening and closing of major oceans (termed as the Wilson cycle), significantly influenced the climatic patterns. There were several alternating warm and cool (glacial and interglacial) periods including the well-known Neoproterozoic "*Snowball Earth*" with a thick blanket of ice covering the globe. It is estimated that there were at least eight cycles of ice ages and warmer episodes during the past 800,000 years.

However, the globe getting warmer in the last few decades, purportedly at a rate faster than through natural processes, is largely attributed to greenhouse gas emissions through the burning of fossil fuels, deforestation and other activities of modern human civilization.

Defined under the broader term of climate change, global warming has emerged as one of the focal themes in scientific and political spheres. Although geological events in the past have caused catastrophic punctuations in the planet's climate patterns, there is growing concern over the imminent challenge to the sustainability of the environment and our civilization, particularly in light of booming population growth as well as the rapidly depleting non-renewable natural resources. Thus emerged the concept of "*Net Zero 2050*", aimed at abolishing fossil fuels and transitioning to green energy on a global scale. The objectives of this target place heavy demand on the limited critical metal resources on Earth that are essential for various applications in green energy technology, compounded by the heterogeneous distribution of these resources, thus triggering some of the current political crises.

In this backdrop, this book — authored by Nicola Scafetta on "*The Frontier of Climate Science – Solar Variability, Natural Cycles and Model Uncertainty*" — offers an excellent window into the deep realms of climatology, complex systems physics, and astronomy in addressing three major aspects: (1) how well do we truly understand Earth's climate? (2) what natural forces remain beyond our grasp? (3) is Net-Zero the only viable path forward?

The book is divided into seven major sections as: (1) Climate Science According to the "Scientific Consensus"; (2) Critical Perspectives on the Anthropogenic Global Warming Theory; (3) New Perspectives for Quantifying Climate Change; (4) The Role of the Sun: Alternative Perspectives on Climate Change Attribution; (5) Simulating Climate Change with Empirical and Semi-Empirical Models; (6) Spectral Coherence Between Planetary Harmonics and Solar–Climate Cycles; (7) Toward a New Paradigm.

Through 42 Chapters of excellent narration and elegant presentation, the author Nicola Scafetta, who is among the "*Top 2% Most Influential Scientists in the World*" (Stanford–Elsevier citation database), provides an insightful evaluation of the prevailing concept of anthropogenic causes of global warming, and reveals the uncertainties that plague the climate models and rhetorical strategies, particularly those pivoted by IPCC. From an authoritative analysis, the author formulates insightful perspectives that demystify the exclusive attribution of global warming in the last century to human activities, and places more importance on the dynamic interplay of terrestrial and cosmic forces. This work is an excellent window into climatology as a dynamic science, and calls for adaptive strategies grounded in economic sustainability and social equity to address climate change issues.

I wholeheartedly recommend this book to all libraries, academic institutions, and also to the general public who are interested in the topic of global climate change. Nicola Scafetta's book serves not only as an important reference for researchers and students, but is also a guide for policy makers and the public media.

M. Santosh
Professor of Earth Sciences
Founder and Secretary General of the
International Association for Gondwana Research (IAGR)
Founding Editor-in-Chief of *Gondwana Research*
Editorial Advisor of *Geoscience Frontiers*
China University of Geosciences (Beijing)
Beijing, China

Foreword by Prof. Alberto Prestininzi

Nicola Scafetta, author of *The Frontier of Climate Science*, has been active for over twenty years in the field of theoretical physics applied to complex systems, with particular focus on climatology, meteorology, and the interactions between terrestrial and solar dynamics. His approach is not that of an experimental scientist engaged in laboratory or fieldwork, but rather that of a theoretical physicist who, in the spirit of Galilean science, analyzes observational data to construct, step by step, a holistic and coherent interpretation of the climate system. It is within this framework that complex systems physics finds its place: a discipline that does not settle for reductionist simplifications, but instead seeks emergent regularities, spectral coherences, and interpretative models capable of integrating multiple temporal scales and forcing mechanisms.

The topic of anthropogenic global warming is addressed through a series of fundamental questions that every scientist should ask before formulating hypotheses and proposing solutions: How well do we truly understand Earth's climate? What natural mechanisms still elude us? Are the "Net Zero" policies promoted by many governments consistent with the dynamics that govern the climate system?

Answering these questions is essential to assess whether the elimination of entire industrial sectors — with severe repercussions on employment and the transfer of vast financial resources to powerful financial organizations, thereby undermining social achievements won through decades of struggle — is truly necessary.

In *The Frontier of Climate Science*, Scafetta constructs a theoretical and didactic journey that guides the reader through the multiple dimensions of the climate system. The book is conceived as a critical dialogue in which the processes that govern Earth's climate — many of which remain poorly understood or underestimated — are examined in depth. The goal is to distinguish facts from rhetoric, restoring to science its role as a pluralistic, iterative, and non-dogmatic inquiry.

Within this journey, astronomy and astrophysics emerge as key players, interacting with the endogenous dynamics of our planet. Like all celestial bodies in the solar system, Earth receives its primary energy from the Sun. Yet its uniqueness lies in the simultaneous presence of water, landmasses, and a complex atmosphere — formed through geodynamic and physico-chemical processes — that made life possible.

Throughout geological history, complex processes have alternated over millions of years, shaping the current features of Earth's surface. Studying these features allows us to reconstruct past climatic conditions and understand the variations that have occurred over time. It is in this context that the great milestones of geoscience are situated, such as Alfred Wegener's theory of Plate Tectonics and Milutin Milankovitch's orbital cycles, alongside a vast and growing body of scientific literature, as demonstrated by numerous recent studies.

Scafetta's work fits fully within this long trajectory of scientific inquiry, but with a theoretical and systemic perspective. He draws attention to the precarious position of those, such as the Intergovernmental Panel on Climate Change (IPCC), who attribute global warming solely to human activity, starting from the end of the nineteenth century. This attribution is critically examined and compared with geological, paleoclimatic, and modeling evidence, using empirical and semi-empirical tools and integrating data from meteorology, geophysics, and planetary sciences.

The Frontier of Climate Science is divided into seven parts, each addressing a crucial aspect of the climate debate: the vision of "scientific consensus" and the architecture of the IPCC; the epistemological and modeling limitations of the anthropogenic theory; the revision of observational data and systematic biases; the role of the Sun and alternative solar forcings; empirical and harmonic models as simulation tools; the spectral coherence between planetary, solar, and climatic cycles; and the proposal of a new scientific paradigm that is open and pluralistic.

In recent years, the scientific debate on climate has begun to show signs of a more nuanced and open evaluation of the uncertainties and structural limitations of traditional climate models. The recent report *A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate* (U.S. Department of Energy, 2025), authored by the DOE Climate Working Group — John R. Christy, Judith A. Curry, Steven E. Koonin, Ross McKitrick, and Roy W. Spencer — reflects this shift. Although developed independently, the report acknowledges many of the issues that Scafetta has long investigated and examines in this volume, and it frequently cites his scientific contributions, particularly regarding the representation of natural variability, the divergence between observations and simulations, the role of solar variability, and the need for a more pluralistic approach to climate modeling. This convergence of perspectives, emerging from distinct analytical paths, underscores the timeliness and relevance of the framework presented in *The Frontier of Climate Science*.

The Frontier of Climate Science is thus a work that invites reflection, verification, and debate. It does not offer absolute certainties, but rather tools to interrogate reality with critical thinking and intellectual openness. It is a valuable contribution for those who believe that science must be a process, not a dogma.

Alberto Prestininzi
Full Professor (retired) of Applied Geology
Founder and former Director of the
"*Centro di Ricerca Previsione, Prevenzione e Controllo dei Rischi Geologici*" (CERI)
Founding Editor and former Editor-in-Chief of the
Italian Journal of Engineering Geology and Environment
Sapienza University of Rome, Rome, Italy

Foreword by Prof. Judith Curry

Climate change is one of the most polarizing subjects in global public discourse. The challenge arises from the deep complexity of the issue, which has scientific, political, cultural, and ethical dimensions, with public perceptions shaped through the lens of a polarized media. In the zeal to eliminate fossil fuels, certain strands of climate science have drifted from critical inquiry, becoming instruments for legitimizing authority and advancing preferred policies. In short, politics has recast a complex scientific issue as an ideological tool.

The concept of the climate "consensus" has been weaponized as a form of social and political pressure, used to suppress debate and discourage intellectual pluralism. While the so-called "consensus" offers a clear and actionable narrative, there's growing realization that both the climate change problem and its solution have been vastly oversimplified. The entire debate has been stripped of depth, rigor, and nuance. Some of the challenges to the mainstream discourse on climate change have been rightfully characterized as "*climate denial*" — equally devoid of rigor and also driven by a political agenda.

Beyond the polarizing rhetoric of "*climate catastrophism*" and "*climate denial*" stands the more rigorous, methodologically grounded perspective of skeptical scholars. Skeptical scholars regard science as a process, not dogma — they don't advocate overthrowing anthropogenic global warming theory for ideological reasons, but rather work to properly test it. Skeptical scholars focus on concerns about the quality of the data and its analysis, the utility of global climate models, and the ideological framing of climate science and policy. Driven by curiosity rather than conformity, they recognize that science is built not on authority but on evidence. They understand that science works by examining assumptions, questioning hypotheses, and evaluating uncertainties.

Following in the tradition that includes recent books such as Steve Koonin's *Unsettled* and my book *Climate Uncertainty and Risk*, the early chapters of Nicola Scafetta's book *The Frontier of Climate Science* challenge key elements of anthropogenic global warming theory. Scafetta clearly justifies his arguments that the exclusive attribution of recent warming to anthropogenic emissions is scientifically premature and that climate models omit or oversimplify critical climate dynamical processes.

Even in the face of serious criticism, flawed theories can persist when there is no conceptually robust alternative. What has been lacking is an alternative theory of climate change that is supported by observations and goes beyond vague attributions to natural climate variability. The seminal contribution of *The Frontier of Climate Science* is a new scientific paradigm that provides a broader interpretive framework capable of resolving the inconsistencies of the current anthropogenic climate change model.

Arguably, the most egregious oversimplification in climate science has been the marginalization of solar variability. Solar variability and its role in climate change remain among the most profound and unresolved issues in contemporary climate science. Scafetta makes a compelling argument that it is time to bring the Sun back to the center of climate discourse. If, as multiple lines of evidence suggest, solar activity has played a significant role in recent global warming, then the global climate forcing datasets and climate models may be structurally misleading, and the attribution of all recent warming to anthropogenic emissions is incorrect.

Beyond solar variability, Scafetta proposes a dynamic interplay of a broad range of forcings — both natural and anthropogenic — operating across a range of spatial and temporal scales in a dynamic, interconnected web of terrestrial and cosmic forces. This is a framework in which solar variability, planetary harmonics, and natural internal climate variability are integral components of the Earth's climate architecture.

Under Scafetta's vision, climate science reclaims its astronomical dimension, governed by gravitational rhythms, orbital geometries, and resonant harmonics that are only partly understood. Scafetta's harmonic planetary approach is not so much a rival to conventional climate models, but rather a complementary and empirically grounded extension. He presents an empirical climate model and attribution framework, whereby more than half of the modern warming is caused by natural and local processes that are underrepresented or omitted in current global climate models.

A healthy scientific culture embraces pluralism, methodological rigor, and open dialogue. Only through this lens can climate science remain credible, adaptive, and truly informative. For a scientific community genuinely committed to open inquiry, Scafetta's framework offers a valuable opportunity for engagement — whether through the refinement of its premises or their rigorous contestation.

The Frontier of Climate Science is a very important contribution toward grasping the true complexity of the Earth's climate. Anchored in the history and philosophy of science, with at times a poetic feel to its narrative, this book provides a crucial step toward shaping a more realistic and mature approach to climate science.

Scafetta says it best in the closing statement of the book:

> "*We may discover that Earth's climate is not merely a product of internal feedbacks and anthropogenic forcings, but a resonant expression of the solar system's deeper architecture.*"

Judith Curry
Co-founder and President of *Climate Forecast Applications Network*
Professor Emerita of Atmospheric Sciences and Climatology and
former Chair of the School of Earth and Atmospheric Sciences
Georgia Institute of Technology
Atlanta, Georgia, United States

Introduction

Over the past several decades, climate change has become one of the most prominent and debated subjects in global public discourse. Institutions such as the *Intergovernmental Panel on Climate Change* (IPCC), along with governments, academic bodies, media outlets, and environmental organizations, have increasingly emphasized the role of human activity in driving global warming since the late 19th century. This framing has contributed to the perception of climate change as a critical challenge for future generations, prompting calls for urgent and far-reaching mitigation policies. This narrative has influenced collective perceptions of climate risk and supported major policy decisions, including large-scale investments in energy transition strategies and the promotion of environmentally responsible behaviors.

In parallel, a minority of scholars and professionals have offered alternative perspectives, questioning the magnitude of future warming projected by certain global climate models (GCMs) and advocating for a more nuanced interpretation of climate data. These voices highlight the importance of maintaining scientific pluralism and critically examining the assumptions underlying climate projections and policy responses. A similar re-evaluation is reflected in the recent 2025 report by the U.S. Department of Energy, which acknowledges key uncertainties in current climate modeling and attribution frameworks.[1]

Among them are Judith Curry, former director of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology, who in her 2023 essay *Climate Uncertainty and Risk: Rethinking Our Response* proposed a reassessment of climate strategies. Steven Koonin, theoretical physicist and former U.S. Undersecretary for Energy, emphasized in *Unsettled* (2024) the distinction between the cautious language of scientific reports and the more emphatic tone often found in public discourse. Richard Lindzen, emeritus professor at MIT, has long discussed the uncertainties surrounding climate sensitivity to CO_2 and the limitations of numerical modeling. William Happer, physicist at Princeton University, has similarly argued for a balanced evaluation of CO_2's role in climate dynamics.

In Italy, the scientific community has contributed to this debate through initiatives such as the climate-related hearing given by Nobel laureate Carlo Rubbia to the Italian Senate in 2014,[2] and the 2019 *Petition on Anthropogenic Global Warming* signed by over 180 scholars, including renowned scientists such

[1]Christy, J.R., Curry, J.A., Koonin, S.E., McKitrick, R., Spencer, R.W., 2025. A critical review of impacts of greenhouse gas emissions on the U.S. climate. U.S. Department of Energy, Washington, DC. Available at: *https://www.energy.gov/topics/climate*

[2]Available at: https://www.youtube.com/ watch?v=ooBPJeDp6k8

as Antonino Zichichi, Renato Angelo Ricci, Giuliano Panza, Franco Prodi, and Uberto Crescenti.[3] These efforts advocate for a cautious and evidence-based approach to environmental policy. The 2022 publication *Dialogues on Climate: Between Emergency and Knowledge*, edited by Alberto Prestininzi, further explores these themes through contributions from sixteen Italian academics.

Beyond the scientific domain, other commentators have examined the socioeconomic implications of climate policy. Bjorn Lomborg, in *False Alarm* (2023), discusses the potential impact of climate strategies on vulnerable populations and suggests pragmatic alternatives. Michael Shellenberger, in *Apocalypse Never* (2020), explores the role of nuclear energy in sustainable development. The documentary *Planet of the Humans* (2019),[4] directed by Jeff Gibbs and produced by Michael Moore, raises questions about the environmental and economic viability of certain green technologies. *Climate: the Movie* (*the cold truth*) (2024) is another intriguing documentary.[5] Patrick Moore, co-founder of Greenpeace, has also expressed concerns about the politicization of environmental discourse.

At the European level, the Clintel Foundation (Climate Intelligence),[6] founded in 2019 by geophysicist Guus Berkhout and journalist Marcel Crok, promotes open scientific dialogue on climate issues. While acknowledging the reality of global warming and possible anthropogenic influences, Clintel calls for a measured approach to climate policy. Its *World Climate Declaration*, signed by approximately 2,000 scholars — including Nobel laureates Ivar Giaever and John F. Clauser — emphasizes the importance of maintaining scientific rigor and pluralism. Clintel's 2023 publication *The Frozen Climate Views of the IPCC*[7] offers a scientific critique of prevailing climate narratives.

This work builds on the ideas I first presented at the U.S. Environmental Protection Agency's National Center for Environmental Economics (NCEE) on 26 February 2009, during my invited lecture '*Climate Change and Its Causes: A Discussion about Some Key Issues*',[8] delivered while I was a researcher in the Physics Department at Duke University (NC, USA) and collaborating with Richard Willson of the ACRIM team on the study of total solar irradiance within the NASA Earth Sciences ACRIMSAT/ACRIM3 project, and further develops them in light of the scientific research I have conducted in the years since.

---

[3]Antonino Zichichi, Professor Emeritus of Physics at the University of Bologna, Founder and President of the Ettore Majorana Center for Scientific Culture in Erice; Renato Angelo Ricci, Professor Emeritus of Physics at the University of Padova, former President of the Italian Physical Society and of the European Physical Society; Giuliano Panza, Distinguished Professor of Geophysics at the University of Trieste, Academician of the Lincei and of the Italian National Academy of Sciences, known as the XL; Franco Prodi, Distinguished Professor of Atmospheric Physics at the University of Ferrara, Academician of the Italian National Academy of Sciences, known as the XL; Uberto Crescenti, former President of G. D'Annunzio University, Chieti–Pescara, and former President of the Italian Geological Society. The petition is available at: https://www.scienzanazionale.it/e-nata-astri-per-la-ricerca-italiana/petizione-sul-riscaldamento-globale-antropico/

[4]Gibbs, J. (Dir.), Moore, M. (Exec. Prod.), 2019. Planet of the Humans [Film]. Rumble Media.

[5]Martin Durkin (director), Tom Nelson (producer). Available at: https://climatethemovie.net/

[6]Climate Intelligence (Clintel) Foundation: https://clintel.org/.

[7]Crok, M., May, A. (Eds.), 2023. The Frozen Climate Views of the IPCC. Clintel Foundation. Available at: https://clintel.org

[8]The presentation (pdf and video) is available at: https://web.archive.org/web/20091220063025/http://yosemite.epa.gov/ee/epa/eed.nsf/vwpsw/360796B06E48EA0485257601005982A1

Scientific foundations and methodological challenges

Climate science is structured around two core tasks: identifying climatic shifts (“*detection*”) and determining their origins (“*attribution*”).

Detection refers to the process of measuring climate data and statistically identifying significant changes within the system, independent of their underlying causes. It represents the initial step in recognizing that a shift has occurred beyond the bounds of short time-scale natural variability. For example, a rise in global average temperature may be considered “detected” when the probability of it occurring by random chance is sufficiently low, typically below 10%.

Attribution seeks to identify the physical causes behind observed changes by evaluating the relative contributions of anthropogenic factors (such as greenhouse gas emissions) and natural influences (such as solar variability, volcanic activity, and others). Since direct experimentation on the climate system is not feasible, attribution relies on climate models and statistical inference, comparing observed outcomes with hypothetical scenarios that exclude human influence. This process involves degrees of uncertainty and often depends on expert judgment, particularly in the case of extreme events. The complex interactions within the climate system, combined with limited observational data, make attribution a persistent and evolving scientific challenge.

Several attribution methods are employed to distinguish between natural and anthropogenic drivers of climate change. Among the most widely used is optimal fingerprinting, which applies linear regression and other statistical techniques to compare observed data with model simulations, aiming to isolate human influence. Time series analysis examines temporal patterns to identify causal relationships between natural variability and anthropogenic forcings. Process-based attribution focuses on the physical mechanisms underlying specific changes, particularly useful for regional phenomena such as monsoons. Extreme event attribution evaluates how human activity may have influenced the likelihood or intensity of specific events, using probabilistic and narrative approaches to construct counterfactual scenarios.

Both detection and attribution are subject to inherent uncertainties. Detection requires reliable and representative data capable of revealing significant changes. Attribution, in turn, demands rigorous interpretation of those data to determine causality. As a result, many aspects of climate science remain under active investigation due to both the complexity of the phenomena involved and the methodological limitations in collecting and analyzing evidence.

While acknowledging the reality of global warming and the role of human influence, some scholars — including those cited earlier — adopt a critical stance focused on epistemological and methodological aspects. They distinguish their position from more polarized views often found in public discourse, which may simplify or exaggerate scientific findings. These scholars emphasize the importance of maintaining scientific rigor and transparency, particularly in the communication of uncertainties and probabilistic outcomes.

Genuine scientific critiques center on the reliability of model projections, the selective use of data, and the framing of climate science in media and policy contexts. In this view, there is a growing disconnect between the nuanced language of scientific literature, which is expressed in terms of probabilities, confidence

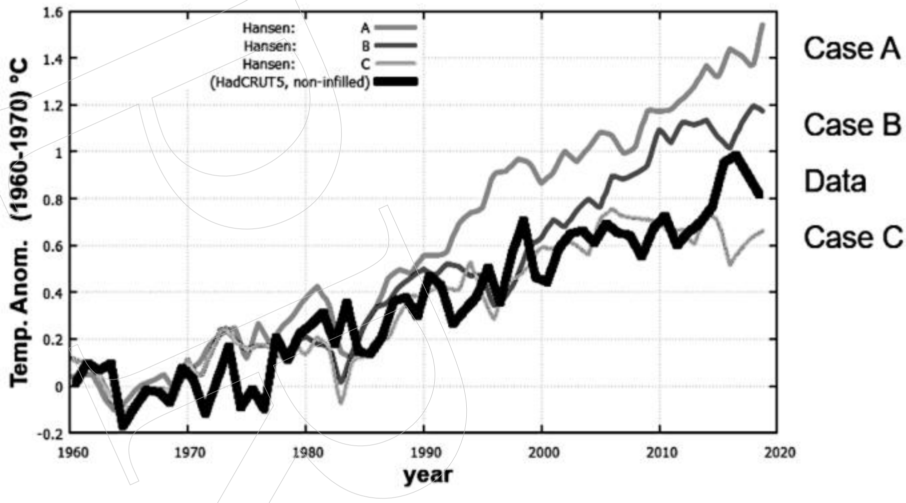


FIGURE I.1. Comparison between the three climate projections presented by James Hansen to the U.S. Congress in 1988 (Scenarios A, B, and C) and a recent reconstruction of global surface temperatures based on the HadCRUT5 dataset Morice et al. (2021). The figure highlights the divergence between Hansen's predictions and observed data: the black curve, representing actual temperatures, aligns most closely with Scenario C, which assumed a drastic reduction in anthropogenic emissions starting in 1990, while real-world emissions have followed a trajectory between Scenario A and Scenario B.

intervals, and scenarios, and the public narrative, which may translate these into definitive conclusions and urgent alarms.

As with any developing scientific discipline, the science of climate relies on mathematical models, numerical simulations, indirect estimates, and imperfect measurements, all of which involve margins of uncertainty. Moreover, future climate projections depend on multiple interconnected and difficult-to-predict variables, including technological innovation, policy evolution, demographic trends, feedback mechanisms, and natural variability.

Natural variability itself is influenced by solar and astronomical factors that remain only partially understood and are not comprehensively represented in current climate models. According to some authors, the limited integration of solar and astrophysical knowledge, which is often due to disciplinary specialization, may constrain the scope of climate analyses.

Despite advances in modeling and the publication of numerous reports, the IPCC has acknowledged that from 1988 to 2021, it has not been possible to narrow the uncertainty range of *Equilibrium Climate Sensitivity* (ECS), which refers to the long-term increase in global surface temperature expected from a doubling of atmospheric CO_2 concentration.

Climate sensitivity to radiative forcing remains one of the most debated variables in climate science, due to its central role in determining future warming.

Surveys and scientific publications have raised questions about the reliability of high-sensitivity models, often referred to as "*hot models*", suggesting that they may overestimate the rate and magnitude of warming, and associated hazards.

One frequently discussed issue is the use of extreme scenarios such as SSP5–8.5, sometimes described as "*business-as-usual*." This scenario projects exponential growth in fossil fuel emissions, tripling current levels by the end of the 21st century. A growing number of experts consider SSP5–8.5 unlikely under current technological and policy trajectories, and suggest it may be more suitable for stress-testing than for baseline forecasting.

According to official climate reconstructions, global surface temperature has increased by approximately +1.1 °C from the 1850–1900 pre-industrial period to the decade 2011–2020. While this represents a significant warming, it is lower than some early projections made in the 1990s.

For instance, the projections presented by James Hansen to the U.S. Congress in 1988[9] anticipated a rise in global temperatures by 2020 that exceeded observed values by approximately one-third. Hansen's testimony, delivered on June 23, 1988, preceded the formal establishment of the IPCC later that year.

Models, observations, and uncertainties

Figure I.1 presents a comparison between the three climate projections formulated by James Hansen in 1988 (Scenarios A, B, and C) and a reconstruction of global surface temperatures based on the HadCRUT5 dataset (Morice et al., 2021).[10] The black curve represents observed data and aligns most closely with Scenario C, which assumed a substantial reduction in anthropogenic emissions beginning in 1990, targeting net-zero emissions by 2000.

However, from 1988 to 2020, global CO_2 emissions have steadily increased following a trajectory between Scenarios A and B, with a trend closer to A in terms of cumulative growth. The fact that observed temperatures align more closely with Scenario C (despite higher-than-assumed emissions) invites reflection on the climate sensitivity embedded in Hansen's original models and the complexity of the relationship between anthropogenic emissions and global warming. Natural mechanisms not fully represented in early models, such as oceanic oscillations (e.g., ENSO – *El Niño Southern Oscillation*; AMO – *Atlantic Multidecadal Oscillation*; PDO – *Pacific Decadal Oscillation*) and solar variability, may have contributed to modulating the observed warming.

Cryosphere, sea level, and extreme events

Discrepancies between model projections and observational data continue to motivate scientific inquiry into the robustness of long-term climate forecasts. NSIDC 12-month averaged records (1979–2025) show a persistent decline in Arctic sea-ice extent, but with a marked slowdown after the mid-2000s, deviating from the more linear decreases anticipated by several climate models (England

[9] James Hansen's testimony before the U.S. Senate Committee on Energy and Natural Resources on June 23, 1988: https://www.sealevel.info/1988_Hansen_Senate_Testimony.html

[10] Morice, C.P., Kennedy, J.J., Rayner, N.A., Winn, J.P., Hogan, E., et al., 2021. An updated assessment of near-surface temperature change from 1850: the HadCRUT5 data set. Journal of Geophysical Research: Atmospheres, 126, e2019JD032361.

et al., 2025).[11] The Southern Hemisphere displays even greater complexity: Antarctic sea ice alternates between phases of expansion and contraction, with a modest increase until the mid-2010s followed by a sharp decline. This irregular evolution — already noted in earlier analyses (Scafetta & Mazzarella, 2015a)[12] — suggests that Antarctic sea-ice dynamics are strongly shaped by internal variability, ocean–atmosphere coupling, and regional geophysical processes. These mechanisms remain only partially represented in current climate models, contributing to persistent uncertainties in long-term projections.

Global mean sea level is rising, with satellite altimetry data since 1993 estimating an increase of approximately 3.0–3.5 mm/year, primarily due to ice melt and thermal expansion (Cazenave & Moreira, 2022).[13] However, regional variability challenges the notion of a uniform trend. Geological uplift and subsidence affect local measurements. In geologically stable regions such as the Skagerrak between Denmark and southern Norway, tide gauge data indicate a rise of about 1.0–1.5 mm/year, with no significant acceleration (Voortman & De Vos, 2025).[14] When corrected for vertical land motion, similar patterns are observed in other coastal cities. In New York, for instance, sea level has risen at about 3 mm/year since 1900, but with an estimated portion between 1.5 and 2.0 mm/year attributed to urban subsidence (Boretti, 2025; Parsons et al., 2023).[15]

The complexity of sea level change mainly arises from its dual nature: a steric component, driven by temperature and salinity variations, and a mass component, resulting from the addition of water to the oceans. When temperature increases but salinity decreases (such as when freshwater from rivers or melting glaciers enters the ocean) the steric effect may be reduced or even neutralized. In general, satellite altimetry estimations suggest that globally, thermal expansion contributes approximately +1.4 mm/year to sea level rise, while mass addition from ice melt and terrestrial water storage accounts for about +1.9 mm/year (Cazenave & Moreira, 2022). In regions where water warming is offset by freshening, the steric contribution may approach zero, causing the local sea level trend to fall below the estimated global average of +3.3 mm/year.

However, satellite altimetry estimates are subject to several methodological limitations that affect their reliability, particularly in coastal and tectonically active regions (Birol et al., 2025; Döhne et al., 2024).[16] Instrumental biases between missions, dependence on geoid models, and the need for atmospheric

[11] England, M.R., Polvani, L.M., Screen, J., Chan, A.C., 2025. Minimal Arctic seaice loss in the last 20 years, consistent with internal climate variability. Geophysical Research Letters, 52, e2025GL116175.

[12] Scafetta, N., Mazzarella, A., 2015. The Arctic and Antarctic sea-ice area index records versus measured and modeled temperature data. Advances in Meteorology, 481834, 1–8.

[13] Cazenave, A., Moreira, L., 2022. Contemporary sea-level changes from global to local scales: a review. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 478(2261), 20220049.

[14] Voortman, H. G., De Vos, R., 2025. A global perspective on local sea level changes. Journal of Marine Science and Engineering, 13(9), 1641.

[15] Boretti, A., 2025. Subsidence: critical factor inlocal sea level rise assessments. Ocean & Coastal Management, 245, 107646.

Parsons, T.E., Wu, P.-C., Wei, M., D'Hondt, S., 2023. The weight of New York City: possible contributions to subsidence from anthropogenic sources. Earth's Future, 11(5), e2022EF003465.

[16] Birol, F., Bignalet-Cazalet, F., Cancet, M., Daguze, J.-A., Fkaier, W., et al., 2025. Understanding uncertainties in the satellite altimeter measurement of coastal sea level: insights from a round-robin

and wet tropospheric corrections introduce systematic uncertainties. Moreover, satellite altimetry provides spatially average measurements over ocean surfaces and lacks direct geodetic anchoring to the solid Earth, making it difficult to disentangle true sea level changes from vertical land motions. Crucially, there is no direct observational benchmark against which satellite-derived sea level trends can be independently validated, especially on a global scale. When compared to tide gauge records that are locally anchored but sensitive to land uplift or subsidence, discrepancies often emerge, particularly in coastal zones. These challenges underscore the importance of integrated approaches that combine satellite altimetry, tide gauges, GPS geodesy, and gravimetric data to achieve robust and physically consistent estimates of sea level trends.

Historically, sea level rose by approximately 120–130 meters during the transition from the Last Glacial Maximum (about 21,000 years ago) to the present interglacial, with rates peaking at 10–15 mm/year during meltwater pulses. In particular, the Meltwater Pulse 1A (MWP-1A) was a rapid sea level rise event occurring around 14,600 years ago, during which global sea level surged by approximately 12–22 meters over a few centuries, with peak rates exceeding 40 mm/year, which makes it one of the fastest natural rises in the late Quaternary and a benchmark for evaluating modern trends. These values represent the upper bounds of natural sea level rise and provide a critical paleoclimatic reference for evaluating modern trends, which remain significantly lower in magnitude, and climate model estimates.

Public discourse often associates climate change with an increase in extreme weather events. However, scientific literature adopts a more cautious approach. According to the IPCC Sixth Assessment Report (2021, AR6 WG1 Chapter 12 Table 12.12),[17] for many types of extreme events (including hurricanes, floods, droughts, and wildfires) the evidence of significant long-term changes or future increases remains classified as "limited" or "low," due to the dominant role of natural variability.

Studies by Roger Pielke Jr. suggest that, when adjusted for population growth and economic development, financial losses from meteorological disasters do not show a consistent upward trend.[18] The perception of increasing severity is often linked to human expansion into vulnerable areas, inflation, and intensified media coverage, rather than to demonstrable climate changes.

The observed increase in recorded global natural disasters over recent decades does not necessarily indicate a rise in the frequency or intensity of natural hazard events. Alimonti et al. (2022)[19] critically examined major international databases and found no robust evidence of a systematic increase in extreme events attributable to anthropogenic climate change. Their analysis

analysis. Ocean Science, 21, 133–150.
Döhne, T., Horwath, M., Thomas, M., 2024. Ocean mass change from GRACE/GRACE-FO and satellite altimetry: updated estimates and uncertainty assessment. EGU General Assembly 2024, Abstract EGU24-288.

[17]IPCC, 2021. Climate Change 2021: The Physical Science Basis. Cambridge University Press.

[18]Pielke Jr., R., 2019. Tracking progress on the economic costs of disasters under the indicators of the sustainable development goals. Environmental Hazards, 18(1), 1–6.

[19]Alimonti, G., Mariani, L., Prodi, F., Ricci, R.A., 2022. A critical assessment of extreme events trends in times of global warming. European Physical Journal Plus, 137, Article 112.

underscores the importance of distinguishing between a hazard, which is a physical phenomenon, and a disaster, which is its societal impact. This conceptual distinction is essential for interpreting long-term trends and for designing effective risk reduction strategies. Indeed, the apparent upward trend in disaster records is largely driven by socio-technical factors, including population growth, urban expansion, enhanced detection capabilities, and more comprehensive reporting practices (Alimonti & Mariani, 2023).[20]

Regarding wildfires, global data indicate a decline in the annual extent of burned forested areas over the past two decades (Chen et al., 2023b),[21] attributed to improved land management, agricultural practices, and early warning systems. While dramatic images from regions such as California, Australia, or Greece receive widespread attention, many experts emphasize the importance of local governance, urban planning, and resource allocation in reducing wildfires.

Emissions, media, and public discourse

Many industrialized nations have begun reducing greenhouse gas emissions through the adoption of renewable energy sources, improvements in energy efficiency, and the deployment of low-impact technologies. In this context, the European Union stands out, having recorded a steady decline in emissions over the past thirty years (EDGAR).[22] Part of this reduction is also attributable to the relocation of emission-intensive industrial activities to regions such as Asia, where production has increasingly shifted. As a result, the overall progress in many industrialized nations has been offset by the economic and demographic expansion of developing countries, particularly emerging economies such as China and India. This asymmetry raises important questions regarding climate equity, global geopolitical dynamics, and the feasibility of coordinated decarbonization strategies.[23]

The goal of achieving net-zero emissions within a few decades remains ambitious and uncertain, unless supported by transformative technological breakthroughs or structural changes in global economic systems. While such transitions are theoretically possible, many observers consider them politically and economically challenging in the short term.

Recent IPCC reports reflect a more cautious and nuanced tone, acknowledging persistent scientific uncertainties. The language has evolved to include clearer distinctions between levels of confidence and probability. Several chapters explicitly recognize knowledge gaps, limitations in available data, and interpretive divergences among research groups. This shift suggests growing awareness of the importance of methodological transparency and the risks associated with consensus-driven approaches.

[20] Alimonti, G., Mariani, L., 2023. Is the number of global natural disasters increasing? Environmental Hazards, 22(4), 345–368.

[21] Chen, Y., van der Werf, G.R., Randerson, J.T., Rogers, B.M., Mu, M., Li, F., Giglio, L., 2023b. Multidecadal trends and variability in burned area from the fifth version of the Global Fire Emissions Database (GFED5). Earth System Science Data, 15(12), 5227–5247.

[22] EDGARD: Emission Database for Global Atmospheric Research. https://edgar.jrc.ec.europa.eu/

[23] International Energy Agency (IEA): CO_2 Emissions: Global Energy Review 2025. https://www.iea.org/reports/global-energy-review-2025

Despite this evolution, public discourse, particularly in Western media, often employs emotionally charged language, including terms such as "*collapse*," "*imminent crisis*," or "*we only have ten years to save the planet*." While such rhetoric may increase public engagement, it does not always reflect the complexity of the underlying science. Since the 1980s, warnings about limited time to act have been recurrent. For example, a 1989 UN report raised concerns; in 2006, *An Inconvenient Truth* by Al Gore renewed public attention; in 2009, Gore predicted a 75% chance that the Arctic polar cap could be ice-free during summer months within 5–7 years. Yet in 2021, summer Arctic ice still covered approximately $4.72 \cdot 10^6$ km², which is higher than the 2007 minimum of $4.16 \cdot 10^6$ km².

In 2018, the IPCC emphasized the urgency of limiting warming to 1.5 °C within twelve years. In 2020, initiatives such as TED Countdown reiterated the importance of the 2020–2030 decade.[24] Public figures and activists have used vivid metaphors — such as "*Our house is on fire*" by the Swedish activist Greta Thunberg et al. (2020) — to communicate urgency.[25] However, numerous websites now catalog climate predictions that have not materialized, highlighting the challenges of long-term forecasting and the importance of distinguishing between advocacy and scientific projection.[26]

This recurring narrative, while effective in mobilizing attention, may oversimplify a complex issue. The proliferation of alarmist and contradictory messages sometimes described as a "*climate infodemic*" can distort public perception and contribute to psychological distress, including eco-anxiety. Such dynamics may hinder society's ability to address climate challenges in a rational and proportionate manner.

Polarization in public debate is increasingly evident. On one side are those advocating for immediate and radical measures, viewing climate change as an existential threat. On the other are those who minimize or question the severity of the problem. This polarization complicates the development of balanced and effective solutions, making it difficult to assess cost–benefit ratios and the practical feasibility of proposed policies.

Recognizing climate change as a serious issue is essential. At the same time, addressing it responsibly requires moving beyond the idea of a confrontation between "catastrophists" and "denialists", because the climate discussion is not a match between opposing fan bases but a scientific and societal challenge that requires scientific rigor, professional competence, and unwavering intellectual honesty. Interpretations that lack realism or balanced socioeconomic analysis may lead to unintended consequences, as drastic or erroneous policies risk disproportionately affecting vulnerable populations and exacerbating existing

[24] TED Countdown: https://countdown.ted.com/

[25] Thunberg, G., Ernman, M., Ernman, B., Thunberg, S., 2020. Our house is on fire: Scenes of a family and a planet in crisis. Penguin Books.

[26] For example: https://extinctionclock.org/ ;
https://www.survivalworld.com/outdoors/33-climate-predictions-that-never-happened-a-history-of-inaccuracy/ ;
https://www.aei.org/carpe-diem/50-years-of-failed-doomsday-eco-pocalyptic-predictions-the-so-called-experts-are-0-50/ ;
https://globalsouth.live/2025/03/06/top-ten-failed-climate-predictions-a-historical-overview/ .

inequalities. It is needed an analytical approach that promotes critical thinking, open dialogue, and evidence-based evaluation of available strategies.

Toward a balanced scientific approach

In response to this evolving context, alternative visions are gaining attention. These include policies focused on adaptation, risk management, resilience, and sustainable development driven by technological innovation. Some scholars suggest that a moderately warmer climate, if properly managed, could also present new opportunities.

For instance, warmer winters may reduce cold-related mortality and lower heating energy consumption, particularly in temperate countries such as the U.S. and Italy, and in colder regions like Northern Europe, Canada, and Russia. In net terms, the reduction in winter mortality may outweigh the increase in summer mortality due to heat stress, especially in regions with historically harsh winters, although this balance depends on local adaptation and healthcare infrastructure. From an energy perspective, milder winters could reduce demand for heating fuels, potentially lowering seasonal consumption peaks and associated emissions. These benefits may be partially offset by increased electricity use for cooling during hotter summers, particularly in regions not traditionally equipped for high temperatures. Additionally, the retreat of Arctic Sea ice may facilitate the opening of new maritime trade routes such as the Northern Sea Route and the Northwest Passage with potential economic and strategic implications.

This book aims to restore complexity, proportionality, and methodological rigor to the scientific debate on climate change. It does not deny the reality of global warming nor the anthropogenic contribution to it. Rather, it seeks to examine the fundamental open questions in climate science through the lens of peer-reviewed literature (about 650 works), which remains largely unknown to the public. Particular attention is given to uncertainties in detection and attribution, the limitations of predictive models, and the potential side effects of climate policies based primarily on simulations.

The reader is offered an updated overview of emerging research that may contribute to the development of a new paradigm in climate science. The author has contributed to this research over twenty-five years of work conducted between the United States of America and Italy.[27]

---

[27] Selection of Scafetta's most recent publications on climate change and solar activity:
Scafetta, N., Bianchini, A., 2022. The planetary theory of solar activity variability: a review. *Frontiers in Astronomy and Space Sciences*, 9, 937930.
Scafetta, N., 2023. CMIP6 GCM ensemble members versus global surface temperatures. *Climate Dynamics*, 60, 3091–3120.
Scafetta, N., 2023. Empirical assessment of the role of the Sun in climate change using balanced multi-proxy solar records. *Geoscience Frontiers*, 14(6), 101650.
Scafetta, N., 2024. Impacts and risks of "realistic" global warming projections for the 21st century. *Geoscience Frontiers*, 15(2), 101774.
Scafetta, N., 2026. Detection, attribution, and modeling of climate change: Key open issues. *Gondwana Research*, 152, 92–128.
Scafetta, N., Bianchini, A., 2026. Planetary modulation of solar and climate oscillations. *Habitable Planet*, 2(1), 46–62.

Acknowledgments

I sincerely thank Prof. M. Santosh,[5] Prof. Alberto Prestininzi,[6] and Prof. Judith Curry[7] for their kind contributions to this volume. Their forewords offer unique and thoughtful views from different areas of Earth Science, adding real depth to the work. I'm truly grateful for their support and encouraged by their strong dedication to open and honest discussion in climate science.

---

[5]Prof. M. Santosh is a globally renowned geoscientist specializing in petrology, geochemistry, geochronology, metallogeny, and supercontinent tectonics. He currently serves as Professor at the China University of Geosciences in Beijing and as Emeritus Professor at Kochi University in Japan. He previously worked as Senior Scientist at the Centre for Earth Science Studies (India) for 18 years and was Full Professor at Kochi University from 2000 to 2012. He is the Founding Editor of the journals "*Gondwana Research*" and "*Habitable Planet*," and the Founding Secretary General of the "*International Association for Gondwana Research*" (IAGR). He also serves as Editorial Advisor for "*Geoscience Frontiers*," Advisor for "*Geosystems and Geoenvironment*," and Associate Editor for "*Ore Geology Reviews*" and "*Geological Journal*." Prof. Santosh has authored over 1600 peer-reviewed research papers (Scopus), edited numerous volumes and special issues, and co-authored the influential book "*Continents and Supercontinents*" (Oxford University Press, 2004). He has received several prestigious awards, including the National Mineral Award, Outstanding Geologist Award, Thomson Reuters Research Front Award, and Global Talent Award. He has also been recognized as a Highly Cited Researcher by Clarivate for eight consecutive years. According to the 2025 Stanford–Elsevier ranking of the "*World's Top 2% Scientists*," Prof. Santosh is ranked #1 in the subfield of Geology.

[6]Prof. Alberto Prestininzi is a renowned Italian geologist and (retired) Full Professor of Applied Geology at Sapienza University of Rome and teaches *Risk Analysis* at the University eCampus, Civil Engineering. He is internationally recognized for his expertise in hydrogeological risk, slope instability, and geotechnical hazards. He founded and directed the Research center on Prediction, Prevention and Control of Geological Risks ("*Centro di Ricerca Previsione, Prevenzione e Controllo dei Rischi Geologici*" — CERI) of Sapienza University of Rome. He has been Chair of the National Commission for Major Risks of the Italian Civil Protection Department and Secretary of the Italian Section of the "*International Association for Engineering Geology*" (IAEG), and also founded and served as editor-in-chief of the "*Italian Journal of Engineering Geology and Environment*." In 2023, he was appointed coordinator of the scientific committee overseeing the technical update of the "*Strait of Messina Bridge*" project, contributing his expertise in geological stability and seismic risk. His work combines scientific rigor with public outreach, and he has played a key role in shaping Italy's approach to geological risk management.

[7]Prof. Judith Curry is an American climatologist and former Chair of the School of Earth and Atmospheric Sciences at Georgia Tech. She is known for her research on atmospheric dynamics, climate modeling, and hurricane variability. Curry has contributed extensively to the scientific debate on climate uncertainty and risk assessment, and she is Co-founder and President of the climate consulting firm "*Climate Forecast Applications Network*" (CFAN, https://www.cfanclimate.net/). Her work emphasizes the complexity of climate systems and the importance of open scientific dialogue. Curry is one of the five contributing authors of the US Department of Energy (DOE) report "*A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate*" (https://www.energy.gov/topics/climate; July 29, 2025). The report has renewed debate over rescinding the Endangerment Finding and its vehicle emission standards, potentially marking a pivotal shift in U.S. climate regulation.

I wish to express my sincere gratitude to the *International Association for Gondwana Research* (IAGR, https://iagrglobal.org/), to its Secretary General, Prof. M. Santosh, and to the designated members of the IAGR Scientific Committee for endorsing *The Frontier of Climate Science* and for authorizing the use of the official IAGR logo in this publication.

I also wish to express my sincere gratitude to the "*Centro di Ricerca Previsione, Prevenzione e Controllo dei Rischi Geologici*" ("*Centre for Research on Prediction, Prevention, and Mitigation of Geological Risks*") — CERI, Sapienza University of Rome (https://ceri.web.uniroma1.it/) — and to its Director, Prof. Gabriele Scarascia Mugnozza, for endorsing *The Frontier of Climate Science* and for authorizing the use of the official CERI logo in this publication.

The recognition of the book by IAGR and CERI as a meaningful contribution to geoethical and interdisciplinary research is deeply appreciated.

Finally, I am also grateful to Prof. Antonio Bianchini[8] and Prof. Sergio Ortolani[9] for their careful reading of the manuscript and for their valuable scientific insights, which greatly contributed to enhancing its clarity and style.

[8]Prof. Antonio Bianchini is a (retired) Associate Professor of Astronomy at the University of Padua and is currently affiliated with the National Institute for Astrophysics (INAF) – Astronomical Observatory of Padua. His research has primarily focused on interacting binary stars and cataclysmic variables. In particular, he investigated how magnetic activity cycles in the solar-type components of cataclysmic variables shed light on both their variability and long-term evolution. In recent years, he has also extended his scientific interests to climatology. He has authored over 190 publications in stellar astrophysics, observational astronomy, and climate-related studies (NASA/ADS).

[9]Prof. Sergio Ortolani is a (retired) Full Professor of Astronomy at the University of Padua. His research has focused on stellar populations, galactic structure, and photometric surveys. With over 500 publications indexed in NASA/ADS, he has made significant contributions to the study of the Milky Way and the dynamics of globular clusters, often in collaboration with major international observatories and space missions. He is also recognized as an expert in astronomical site selection and atmospheric science.

The author

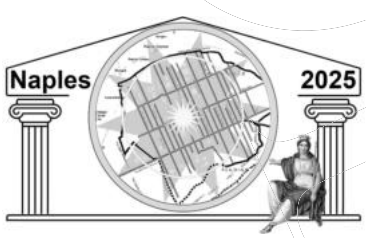
Nicola Scafetta earned his Physics degree from the University of Pisa and, in 2001, a Ph.D. in Physics at the University of North Texas (USA), specializing in Statistical Physics and Complex Systems. From 1998 to 2014, he conducted research and taught in several U.S. institutions — including the University of North Texas, Duke University, UNC Chapel Hill, UNC Greensboro, and Elon University — offering courses in Physics and Astronomy.

He was co-investigator of NASA-JPL's ACRIM team, analyzing satellite measurements of Total Solar Irradiance (TSI) and the Sun's role in Earth's climate.

Since 2014, he has been Associate Professor of Oceanography, Meteorology, and Climatology at the University of Naples Federico II, and in 2018 he was appointed Laboratory Teaching and Research Supervisor (RaDOR) of the Federico II Meteorological Observatory.

His research spans climatology, solar physics, meteorology, oceanography, astronomy, archaeology, and environmental medicine, with a focus on statistical methodologies for complex signals and astronomical models of climate variability. He has also worked on predictive modeling and environmental risk assessment of phenomena such as earthquakes, floods, and air pollution.

Over the course of his career, he has authored more than 130 peer-reviewed scientific papers and several books, and he has delivered over 200 scientific presentations at academic conferences as well as to the general public. Since 2017, he has been ranked among the prestigious "*World's Top 2% Scientists*," based on data from Stanford University and Elsevier.



2500 years from the founding of Neapolis

How well do we truly understand Earth's climate?

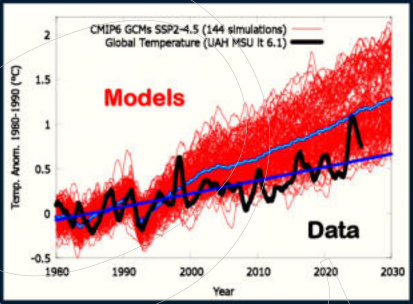
What natural forces remain beyond our grasp?

Is Net-Zero the only viable path forward?

The *Frontier of Climate Science* explores climate dynamics through physics, complex systems, and astronomy, synthesizing several decades of peer-reviewed research. The book critically reviews the scientific foundations of modern climate theory, the evolution of IPCC assessments, and the limits of global climate models (GCMs) when confronted with observations. It investigates natural variability across multiple timescales, including oceanic oscillations, solar variability, and astronomical cycles driving both solar and climate variability, integrating satellite data, paleoclimate reconstructions, and empirical modeling approaches. From this evidence emerges a balanced view of climate risk, favoring pragmatic adaptation over narrowly defined policy pathways such as *Net Zero*. Rich in insights and analytical approaches, the book helps readers understand climate variability, assess risks, think critically, and explore key open questions in climate science.

Endorsed by the "*International Association for Gondwana Research*" (IAGR) and by the "*Centro di Ricerca Previsione, Prevenzione e Controllo dei Rischi Geologici*" (CERI) Sapienza University of Rome.

Author:
Nicola Scafetta is a physicist and climate scientist, and Professor of Oceanography, Meteorology, and Climatology at the University of Naples Federico II. He earned his Ph.D. in Physics from the University of North Texas and has conducted research at leading U.S. universities, primarily at Duke University. He served as a co-investigator on NASA–JPL's ACRIM project, dedicated to the satellite measurement of total solar irradiance. Since 2017, he has been ranked among the "*World's Top 2% Scientists*" in the Stanford University–Elsevier listing. He is the author of over 130 peer-reviewed scientific papers and several books on climate science, solar physics, and complex systems.



Forewords:
Prof. M. Santosh
Prof. Alberto Prestininzi
Prof. Judith Curry

ISBN 979-12-986176-0-5

9 791298 617605

COMPLEXITY INSIGHT PRESS