Written Comments of the Republic of Mauritius

Annex 1: Expert Report of Dr James E. Hansen (9 August 2024)

Expert Report of Dr. James E. Hansen
in Support of the Republic of Mauritius

August 9, 2024

I have been asked to provide this Expert Report in support of the written submissions made by the Republic of Mauritius in the ICJ Advisory Opinion on the Obligations of States in respect of Climate Change. As will be clear from my c.v. (attached below), I have been involved in these issues for more than four decades, including as an adviser to governments and the Intergovernmental Panel on Climate Change (IPCC).

The position adopted by Mauritius is that States have an overarching obligation under international law "to effect deep, rapid and sustained reductions of GHG emissions, including urgently reducing and phasing out the use of fossil fuels." From a scientific perspective, I fully support the arguments of Mauritius. To that end, I here summarize what we understand about the recent and continuing causes and consequences of dangerous climate change, and what we need to do to avert it. To keep this submission brief, I reference several key studies in endnotes.

I conclude with an observation about the vital need for the Court to give an Advisory Opinion that is based squarely on the science, and that can contribute to actions by States and others to avoid catastrophic climate change.

Greenhouse Gas (GHG) Concentrations and Earth's Energy Imbalance

More than three decades have passed since States committed "to achieve… stabilization of [GHG] concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[1] That stablization has not been achieved.

Most significantly, humanity continues to heat up the planet by releasing massive quantities of greenhouse gases (GHGs). Indeed, CO_2 and methane (CH_4) emissions arising predominantely from fossil fuel production, distribution, and utilization, continue at record high levels. In particular, fossil fuel CO_2 emissions increased by 0.9% during 2022, and again by 1.1% in 2023, to reach 36.8 Gt.[2] Trends in the atmospheric concentration of CO_2 and also CH_4, N_2O, and SF_6, are also in the upward direction, which is decidedly dangerous for present and future generations.[3]

Increasing GHG concentrations in turn strongly influence top-of-the-atmosphere radiative imbalance – known as Earth's Energy Imbalance (EEI). The IPCC acknowleges EEI to be "an important metric of the rate of global climate change,"[4] although surprisingly the term does not appear in the Paris Agreement (2015) or the recent Global Stocktake report.[5] In my view, and that of colleagues, EEI is "the most critical number defining the prospects for continued global warming and climate change."[6]

Earth's Energy Imbalance has increased markedly in recent decades. Indeed, we have found a total heat gain of 358±37 ZJ over the period 1971–2018. Moreover, "[o]ur results show that EEI is not only continuing, but also increasing. Over the period 1971–2018 average EEI amounts to 0.47±0.1 W m^{-2}, but it amounted to 0.87±0.12 W m^{-2} during 2010–2018."[7] If we are to stabilize climate at an ambient temperature conducive to human and natural systems then, at minimum, EEI must be reduced to approximately zero.[8] That requires a reduction in the atmospheric CO_2 concentration from the current 425ppm to 350ppm, the level passed during 1988.[9]

Global Warming and Urgency

The 1992 UNFCCC failed to define precisely what it meant by "dangerous anthropogenic interference with the climate system" and so, in a series of studies, international colleagues and I have set out to determine what is a reasonably "safe" level of CO_2 and the implications, with respect to Earth's critical systems, of a multi-decade overshoot of that atmospheric concentration. I incorporate the findings and conclusions of those studies here by reference.[10]

In brief, the safe level of atmospheric CO_2 has already been exceeded, as denoted above. We reside now in a period of consequences where the failure to decarbonize will with certainty inflict additional harm on communities and states.

In late 2021, the IPCC comprehensively reviewed some of those present and impending consequences, including that:

- Climate change has caused local species losses, increases in disease, mass mortality events of plants and animals, resulting in the first climate driven extinctions, ecosystem restructuring, increases in areas burned by wildfire, and declines in key ecosystem services.

- Widespread and severe loss and damage to human and natural systems are being driven by human-induced climate changes increasing the frequency and/or intensity and/or duration of extreme weather events, including droughts, wildfires, terrestrial and marine heatwaves, cyclones (high confidence), and flood (low confidence). Extremes are surpassing the resilience of some ecological and human systems.

- Extreme events and underlying vulnerabilities have intensified the societal impacts of droughts and floods and have negatively impacted agriculture, energy production and increased the incidence of water-borne diseases. Economic and societal impacts of water insecurity are more pronounced in low-income countries than in the middle- and high-income ones.

- Over 9 million climate-related deaths per year are projected by the end of the century, under a high emissions scenario and accounting for population growth, economic development, and adaptation.

- In many regions, the frequency and/or severity of floods, extreme storms, and droughts is projected to increase in coming decades, especially under high-emissions scenarios, raising future risk of displacement in the most exposed areas. Under all global warming levels, some regions that are presently densely populated will become unsafe or uninhabitable.

- Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change. A high proportion of species is vulnerable to climate change. Human and ecosystem vulnerability are interdependent.

The harm inflicted on humanity and nature is global. That point is critical here, wherein Mauritius and others have invited the Court to consider the comparative inability of least developed nations, including Small Island Developing States, to adapt to and survive unabated climate change. I wish to add that hundreds of millions of persons (at a minimum) in developed nations also retain little capacity to protect themselves from worsening climate impacts including, as I write, wildfire and associated smoke.[11] If it impels concerted

international action to phase out fossil fuel emissions, this Court's Advisory Opinion will protect communities everywhere.

The situation is urgent. More delay will elicit additional warming, amplified risk for natural and human systems,[12] and increased likelihood of crossing tipping points in the global system.[13] The IPCC observes, regarding abrupt changes, that "even a return to pre-threshold surface temperatures or to atmospheric carbon dioxide concentrations does not guarantee that the tipping elements return to their pre-threshold state."[14] I agree. In addition, following our study employing climate modeling, paleoclimate analyses, and modern observations, my international colleagues and I have determined that if fossil fuel emissions continue to climb, a shutdown of the North Atlantic Overturning Circulation is *likely* within the next several decades, which would make a multi-meter sea level rise over the next 50-150 year period practically unavoidable.[15] Attendant increases in climate extremes, associated economic disruption, and consequential social dislocation may render the planet ungovernable.[16]

And yet, as a recent report from the UN Environment Programme, et al., establishes, "governments are in aggregate planning to increase oil and gas production out to at least 2050" and coal production through 2030.[17] These planned fossil fuel production increases are incompatible with an international commitment to prevent dangerous climate change.

Responsibility

In its written submissions, Mauritius emphasizes that the responsibility of States to take the lead in combatting dangerous climate change is proportionate to their contribution to the problem over time. That proposition finds support in relevant science. In particular, CO_2, CH_4, N_2O, O_3 and assorted CFCs do not condense and precipitate out, but rather, once injected, remain in the atmosphere for decades or centuries.[18] Emissions from long ago have continuing effects. Accordingly, the radiative forcing contribution of any State is roughly proportional to the cumulative GHG emissions it has enabled (Figure 1b).[19] Thus, while China's current emissions may be highest, the heaviest burden at present falls on the United States, my own country – to decarbonize, to innovate and share technology, and to assist other States to adapt to the considerable additional warming that is already in the pipeline.[20]

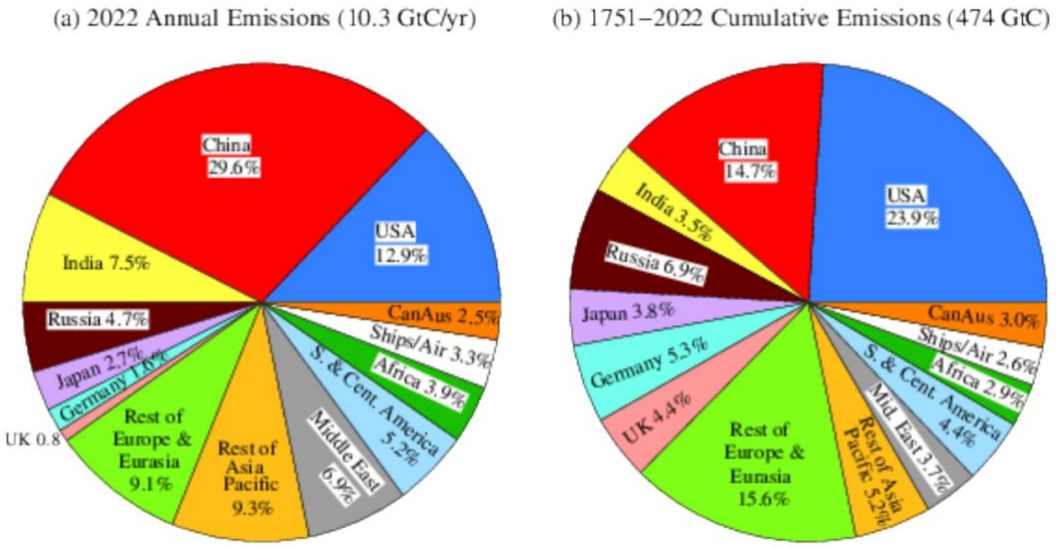

Fig. 1: Source Climate Science, Awareness and Solutions.[21]

Conclusion

The major carbon polluting nations – along with the multi-national corporations over which they can and should exercise control – retain the capacity to dial-back the CO_2 control knob,[22] yet in defiance of the common interest they continue along a fatal path.[23] An Advisory Opinion from the Court that is based on the relevant science and that spells out its necessary implications should inform the content and application of the law.

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[1] United Nations Framework Convention on Climate Change (1992, UNFCCC).

[2] Carbon Budget Project data available here.

[3] *See* NOAA Global Monitoring Laboratory, Trends in CO_2, CH_4, N_2O, SF_6 at https://gml.noaa.gov/ccgg/trends/.

[4] Forster, P. et al., 2021: *The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity*, Section 7.2, In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* at www.ipcc.ch/report/ar6/wg1/chapter/chapter-7/

[5] Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its fifth session, held in the United Arab Emirates from 30 November to 13 December 2023 Decision 1/CMA.5: Outcome of the first global stocktake. Dec. 13, 2023. https://unfccc.int/topics/global-stocktake

[6] von Schuckmann, K., Hansen, J. et al., *Heat stored in the Earth system: where does the energy go?*, Earth Syst. Sci. Data, 12, 2013–2041, https://doi.org/10.5194/essd-12-2013-2020, 2020.

[7] *Ibid*.

[8] *Ibid.*

[9] *Op cit* nte 3, data at https://gml.noaa.gov/ccgg/trends/data.html. *See also*, Hansen, J et al, Target atmospheric CO_2: Where should humanity aim? (2008) *Open Atmos. Sci. J.*, **2**, 217-231, doi:10.2174/1874282300802010217.

[10] They are Hansen, J. et al., *Target atmospheric CO_2: Where should humanity aim?* Open Atmos. Sci. *J.*, **2**, 217-231 (2008); Hansen, J., et al., *Earth's energy imbalance and implications*, Atmos. Chem. Phys., **11**, 13421-13449 (2011); Hansen, J. et al., *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature*. PLOS ONE, **8**, e81468 (2013); Hansen, J., P. Kharecha, and M. Sato, *Climate forcing growth rates: Doubling down on our Faustian bargain*, Environ. Res. Lett., **8** (2013); Hansen, J., et al., *Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations that 2 C Global Warming is Highly Dangerous*. (*Ice Melt*.) Atmos. Chem. & Phys. Discussions (2016); Hansen, J., et al., *Young people's burden: requirement of negative CO_2 emissions,* Earth Syst. Dynam., **8**, 577-616 (2017); von Schuckmann, J. Hansen et al., 2020: *Heat stored in the Earth system: where does the energy go?*, Earth System Science Data **12**, 2013-2041 (2020); Hansen, J.E., et al., *Global warming in the pipeline* (Pipeline), Oxford Open Climate Change, 3, 1 (2023).

[11] Claire Moses, *Fires Have Burned 4.5 Million Acres This Year, Blanketing Much of North America in Smoke*, New York Times (Aug. 3, 2024).

[12] Climate-related risks for natural and human systems "are higher for global warming of 1.5°C than at present" and far higher still than at 2°C." V. Masson-Delmotte, et al., IPCC, 2018: Summary for Policymakers (SPM) in *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Section A.3.

[13] The IPCC foresees potential for abrupt climate shifts in the following critical global systems: monsoons, tropical forests, boreal forest, permafrost, Arctic sea ice, global sea-level rise, AMOC, Southern MOC, ocean acidification, and ocean deoxygenation. IPCC 6th Assessment Report, The Physical Science Basis, Table 4.10.

[14] AR WG 1 Technical Report at 106.

[15] *Op. cit.* nte 10, *Ice Melt* at 3799.

[16] *Ibid*.

[17] UNEP et al., Production Gap Report 2023.

[18] Lacis, A.A., J.E. Hansen et al., *The role of long-lived greenhouse gases as principal LW control knob that governs the global surface temperature for past and future climate change*, Tellus B, 65 (2013).

[19] *See also*, Jones, M.W., Peters, G.P., Gasser, T. *et al. National contributions to climate change due to historical emissions of carbon dioxide, methane, and nitrous oxide since 1850*, Nature Sci Data **10**, 155 (2023).

[20] *Op. cit.* nte. 10, Pipeline.

[21] *See* https://www1.columbia.edu/~mhs119/CO2Emissions/Emis_moreFigs/

[22] *Op. cit.* nte. 17.

[23] My own nation, for instance, has yet even to impose a rising price on carbon, though in recent years US production of both oil and natural gas for export to the global market has climbed markedly.

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1-paragraph bio/introduction:

Dr. James Hansen, formerly Director of the NASA Goddard Institute for Space Studies, is an Adjunct Professor at Columbia University's Earth Institute, where he directs a program in Climate Science, Awareness and Solutions. Dr. Hansen is best known for his testimony on climate change in the 1980s that helped raise awareness of global warming. He is a member of the U.S. National Academy of Sciences and has received numerous awards including the Sophie and Blue Planet Prizes. Dr. Hansen is recognized for speaking truth to power and for outlining actions needed to protect the future of young people and all species on the planet.

1-long-paragraph bio:

Dr. James Hansen, formerly Director of the NASA Goddard Institute for Space Studies, is an Adjunct Professor at Columbia University's Earth Institute, where he directs a program in Climate Science, Awareness and Solutions. He was trained in physics and astronomy in the space science program of Dr. James Van Allen at the University of Iowa. His early research on the clouds of Venus helped identify their composition as sulfuric acid. Since the late 1970s, he has focused his research on Earth's climate, especially human-made climate change. Dr. Hansen is best known for his testimony on climate change to congressional committees in the 1980s that helped raise broad awareness of the global warming issue. He was elected to the National Academy of Sciences in 1995 and was designated by Time Magazine in 2006 as one of the 100 most influential people on Earth. He has received numerous awards including the Carl-Gustaf Rossby and Roger Revelle Research Medals, the Sophie Prize and the Blue Planet Prize. Dr. Hansen is recognized for speaking truth to power, for identifying ineffectual policies as greenwash, and for outlining actions that the public must take to protect the future of young people and other life on our planet.

3-paragraph bio:

Dr. James Hansen, formerly Director of the NASA Goddard Institute for Space Studies, is an Adjunct Professor at Columbia University's Earth Institute, where he directs a program in Climate Science, Awareness and Solutions. He was trained in physics and astronomy in the space science program of Dr. James Van Allen at the University of Iowa, receiving a bachelor's degree with highest distinction in physics and mathematics, master's degree in astronomy, and Ph. D. in physics in 1967. Dr. Hansen was a visiting student, at the Institute of Astrophysics, University of Kyoto and Dept. of Astronomy, Tokyo University, Japan from 1965-1966. He received his Ph.D. in physics from the University of Iowa in 1967. Except for 1969, when he was an NSF post-doctoral scientist at Leiden Observatory under Prof. H.C. van de Hulst, he has spent his post-doctoral career at NASA GISS.

In his early research Dr. Hansen used telescopic observations of Venus to extract detailed information on the physical properties of the cloud and haze particles that veil Venus. Since the mid-1970s, Dr. Hansen has focused on studies and computer simulations of the Earth's climate, for the purpose of understanding the human impact on global climate. He is best known for his testimony on climate change to Congress in the 1980s that helped raise broad awareness of the global warming issue. In recent years Dr. Hansen has drawn attention to the danger of passing climate tipping points, producing irreversible climate impacts that would yield a different planet from the one on which civilization developed. Dr. Hansen disputes the contention, of fossil fuel interests and governments that support them, that it is an almost god-given fact that all fossil fuels must be burned with their combustion products discharged into the atmosphere. Instead Dr. Hansen has outlined steps that are needed to stabilize climate, with a cleaner atmosphere and ocean, and he emphasizes the need for the public to influence government and industry policies.

Dr. Hansen was elected to the National Academy of Sciences in 1995 and, in 2001, received the Heinz Award for environment and the American Geophysical Union's Roger Revelle Medal. Dr. Hansen received the World Wildlife Federation's Conservation Medal from the Duke of Edinburgh in 2006 and was designated by Time Magazine as one of the world's 100 most influential people in 2006. In 2007 Dr. Hansen won the Dan David Prize in the field of Quest for Energy, the Leo Szilard Award of the American Physical Society for Use of Physics for the Benefit of Society, and the American Association for the Advancement of Science Award for Scientific Freedom and Responsibility. In 2008, he won the Common Wealth Award for Distinguished Service in Science and was also awarded both the Ohio State University's Bownocker Medal and the Desert Research Institute's Nevada Medal. In 2009, Dr. Hansen received the American Meteorological Society's Carl-Gustaf Rossby

Research Medal. In 2010 he received the Sophie Prize and the Blue Planet Prize.

Additional Information:

Http://www.columbia.edu/~jeh1/
http://www.columbia.edu/~mhs119/
Photos: http://www.mediafire.com/folder/8ecel33ccmg8l/Hansen_Photos

Education:

BA with highest distinction (Physics and Mathematics), University of Iowa, 1963
MS (Astronomy), University of Iowa, 1965
Visiting student, Inst. of Astrophysics, University of Kyoto & Dept. of Astronomy, Tokyo University, Japan, 1965-1966
Ph.D. (Physics), University of Iowa, 1967

Research Interests:

Analysis of the causes and consequences of global climate change using the Earth's paleoclimate history, ongoing global observations, and interpretive tools including climate models. Connecting the dots all the way from climate observations to the policies that are needed to stabilize climate and preserve our planet for young people and other species.

Professional Employment:

1967-1969	NAS-NRC Resident Research Associate: Goddard Institute for Space Studies (GISS), NY
1969	NSF Postdoctoral Fellow: Leiden Observatory, Netherlands
1969-1972	Research Associate: Columbia University, NY
1972-1981	Staff Member/Space Scientist: Goddard Institute for Space Studies (GISS), Manager of GISS Planetary and Climate Programs
1978-1985	Adjunct Associate Professor: Department of Geological Sciences, Columbia University
1981-2013	Director: NASA Goddard Institute for Space Studies
1985-2013	Adjunct Professor: Earth and Environmental Sciences, Columbia University
2013-present	Director: Program on Climate Science, Awareness and Solutions, Columbia University

Project Experience:

1971-1974	Co-Principal Investigator AEROPOL Project (airborne terrestrial infrared polarimeter)
1972-1985	Co-Investigator, Voyager Photopolarimeter Experiment
1974-1994	Principal Investigator (1974-8) and subsequently Co-Investigator, Pioneer Venus Orbiter Cloud-Photopolarimeter Experiment
1977-2000	Principal Investigator, Galileo (Jupiter Orbiter) Photopolarimeter Radiometer Experiment

Teaching Experience:

Atmospheric Radiation (graduate level): New York Univ., Dept. of Meteorology & Oceanography
Intro. to Planetary Atmospheres & Climate Change: Columbia Univ., Dept. of Geological Sciences

Awards:

1977	Goddard Special Achievement Award (Pioneer Venus)
1978	NASA Group Achievement Award (Voyager, Photopolarimeter)
1984	NASA Exceptional Service Medal (Radiative Transfer)
1989	National Wildlife Federation Conservation Achievement Award
1990	NASA Presidential Rank Award of Meritorious Executive
1991	University of Iowa Alumni Achievement Award
1992	American Geophysical Union Fellow
1993	NASA Group Achievement Award (Galileo, Polarimeter/Radiometer)
1996	Elected to National Academy of Sciences
1996	GSFC William Nordberg Achievement Medal
1996	Editors' Citation for Excellence in Refereeing for Geophysical Research Letters
1997	NASA Presidential Rank Award of Meritorious Executive
2000	University of Iowa Alumni Fellow
2000	GISS Best Scientific Publication (peer vote): "Global warming – alternative scenario"
2001	John Heinz Environment Award
2001	Roger Revelle Medal, American Geophysical Union

2004	GISS Best Scientific Publication (peer vote): 'Soot Climate Forcing'
2005	GISS Best Scientific Publication (peer vote): 'Earth's Energy Imbalance'
2006	Duke of Edinburgh Conservation Medal, World Wildlife Fund (WWF)
2006	GISS Best Scientific Publication (peer vote): 'Global Temperature Change'
2006	*Time Magazine* designation as one of World's 100 Most Influential People.
2007	Laureate, Dan David Prize for Outstanding Achievements & Impacts in Quest for Energy
2007	Leo Szilard Award, American Physical Society for Outstanding Promotion & Use of Physics for the Benefit of Society
2007	Haagen-Smit Clean Air Award
2008	American Association for the Advancement of Science Award for Scientific Freedom and Responsibility
2008	Nevada Medal, Desert Research Institute
2008	Common Wealth Award for Distinguished Service in Science
2008	Bownocker Medal, Ohio State University
2008	Rachel Carson Award for Integrity in Science, Center for Science in the Public Interest
2009	Carl-Gustaf Rossby Research Medal, American Meteorological Society
2009	Peter Berle Environmental Integrity Award
2010	Sophie Prize for Environmental and Sustainable Development
2010	Blue Planet Prize, Asahi Glass Foundation – shared with Robert Watson
2011	American Association of Physics Teachers Klopsteg Memorial Award for communicating physics to the general public
2011	Edinburgh Medal from City of Edinburgh, Edinburgh Science Festival
2012	Steve Schneider Climate Science Communications Award
2012	*Foreign Policy* designation as one of its Top 100 Global Thinkers
2013	Ridenhour Courage Prize
2013	NASA Distinguished Service Medal
2014	Center for International Environmental Law's Frederick R. Anderson Award for Outstanding Contributions to Addressing Climate Change
2014	Walker Prize, Museum of Science, Boston
2017	2017 AAG Honorary Geographer, American Association of Geographers
2017	BBVA Foundation Frontiers of Knowledge Award in Climate Change, Spain – shared with Suki Manabe
2018	Tang Prize in Sustainable Development – shared with Veerabhadran Ramanathan

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