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Paris Climate Agreement: Beacon of Hope

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To the children of the sixties … the 2060s …
may you be born when half of all energy
is supplied by sources that release
no atmospheric greenhouse gases
and may you live during prosperous times
in a world that has not experienced global
warming catastrophe.

Preface

On 11 November 2014, a remarkable event occurred. President Barack Obama of the United States and President Xi Jinping of China announced a bilateral agreement to reduce the emission of greenhouse gases (GHGs) that cause global warming by their respective nations. On 12 December 2015, a year and a month later, representatives of 195 countries attending the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change meeting in Paris, France, announced the Paris Climate Agreement.

The goal of the Paris Climate Agreement is to limit the future emission of GHGs such that the rise in global mean surface temperature will be no more than 1.5 °C (target) or 2.0 °C (upper limit) above the pre-industrial level. The Paris Climate Agreement utilizes an approach for reducing the emissions of GHGs that is distinctly different than earlier efforts. The approach for Paris consists of a series of Intended Nationally Determined Contributions (INDCs), submitted by the world's nations, reflecting either a firm commitment (unconditional INDCs) or a plan contingent on financial and/or technological support (conditional INDCs).

The Obama–Xi announcement was instrumental in the framing of the Paris Climate Agreement. The INDCs submitted by the USA and China were built closely upon the November 2014 bilateral announcement. China and the USA rank number one and two, respectively, in terms of national emission of GHGs. Practically speaking, unified global action to combat global warming required these two nations to get on the same page.

Here we provide an analysis of the Paris Climate Agreement written for two audiences. The first audience is the bewildered public. Hardly a day goes by without some newsworthy item being reported on climate change. Often the stories are contradictory, tainted by parochialism, skepticism, and extremism by not only the conservative and liberal media but also the camps of so-called believers and deniers. Our book goes back to basics, outlining what is known and not known about climate change. If we have been successful, this book will enable readers to advance their own understanding of this topic, in a manner that will assist in the proverbial "separation of the wheat from the chaff" with regard to climate change.

Our second audience is the women and men who are charting the response of the world to the threat of global warming. As is clear from the title of this book, we believe the Paris Climate Agreement is truly a Beacon of Hope. The Agreement has been severely criticized by some scientists, even a few prominent in the field of climate change. In this book, we closely examine the behavior of the computer models commonly used to inform climate change policy. This examination will be eye opening to many. We urge policy makers to seek their own independent assessment of the veracity of the global warming projections that are being used to inform policy.

The heart of our evaluation of the Paris Climate Agreement is projections of global warming found using our own computer code, termed the Empirical Model of Global Climate (EM-GC). Calculations conducted in the EM-GC framework are the basis for our conclusion that the goal of the Paris Climate Agreement could actually be achieved, if the INDCs are fully implemented (conditional as well as unconditional) and if the reductions in the emission of GHGs needed to achieve the INDCs are propagated forward in time, with continuous decreases in the emission of GHGs until at least 2060.

This book emerged from a talk given by the lead author, at the January 2016 American Meteorology Society meeting. We thank the conveners of the meeting for giving our talk a prominent slot, which led to our work being noticed by Springer. We thank Zachary Romano of Springer Nature for his enthusiastic support throughout the duration of the project, as well as Susan Westendorf and Aroquiadasse JoyAgnes for their fantastic work during the production of this book. We appreciate the comments of many colleagues, way too plentiful to name, for constructive criticism of the emergent science from our EM-GC, as we gave talks at national meetings, small conferences, and department seminars.

This book emerged from a homework assignment, first given in September 2009, to a Numerical Methods in Atmospheric and Oceanic Science class at the University of Maryland. The assignment asked students to reproduce a figure involving multiple linear regression of global mean surface temperature from a paper written by Judith Lean and David Rind that had just appeared. Over the years, many students contributed to the development of our EM-GC code from its early root in this homework problem, which we sincerely appreciate. We especially thank Nora Mascioli, with whom we collaborated before she enrolled in graduate school at Columbia University. Three of us had the privilege of teaching a freshman Honors class on the Economics, Governance, and Science of climate change and two of us have taught a large freshman Introduction to Weather and Climate class. This book has benefited enormously from all we have learned from our students. We appreciate as well the collegial environment created by our colleagues, graduate students, and undergraduates at the University of Maryland.

For anyone who aspires to write a book, please know there will be a period of your life where “eat, sleep, and write” becomes the daily routine. The five authors sincerely appreciate our families and friends for their unwavering support during the long hours spent on campus. We greatly appreciate the time and effort of our

eagle-eyed proofreaders, Heidi and Michael Hope and Gordon Dryden, who greatly improved the final manuscript by their fastidious attention to detail.

We appreciate the support of the NASA Climate Indicators and Data Products for Future National Climate Assessment (INCA) program, the sponsor of the research that led to this book. Our proposal was selected in response to the 2014 NASA Research Opportunities in Space and Earth Sciences INCA call. The material in this book reflects the views of the authors, and not those of NASA, the US Government, or our employer, the State of Maryland.

Finally, the figures used throughout the book are available electronically at http://parisbeaconofhope.org. This book is published under a Creative Commons License that permits use of figures, provided proper attribution is given. Annual updates will be provided for many figures on our webpage.

College Park, MD
August 2016

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Contents

Abbreviations and Acronyms

ΔRF	Difference in the RF of climate relative to a baseline, usually year 1750
ΔT	Difference between GMST and a baseline, usually years 1850–1900
γ	Climate sensitivity parameter, dimensionless
κ	Ocean heat uptake efficiency coefficient, W m^{-2} °C^{-1}
λ	Climate feedback parameter, W m^{-2} °C^{-1}
λ_P	Planck response function, 3.2 W m^{-2} °C^{-1}
τ	Lifetime of a molecule in the atmosphere
AAWR	Attributable Anthropogenic Warming Rate
$AerRF_{2011}$	Radiative Forcing Due to Tropospheric Aerosols, year 2011
AH	Attain and Hold
AH^{UNC}	Attain and Hold scenario, for which only unconditional INDCs are considered
AI	Attain and Improve
AI^{UNC}	Attain and Improve scenario, for which only unconditional INDCs are considered
$AI^{UNC+COND}$	Attain and Improve scenario, for which unconditional and conditional INDCs are considered
AMO	Atlantic Multidecadal Oscillation
AMOC	Atlantic Meridional Overturning Circulation
AMV	Atlantic Multidecadal Variability
Annex I	UNFCCC list of developed nations, prominently featured in Kyoto Protocol
Annex I*	UNFCCC list of developed nations, minus the US. This is our nomenclature, not that of UNFCCC
BAU	Business As Usual
BTU	British Thermal Units
CCS	Carbon Capture and Sequestration
CDIAC	Carbon Dioxide Information Analysis Center of the US DOE
CFCs	Chlorofluorocarbons: these gases deplete stratospheric ozone and warm climate

CMIP5	Climate Model Intercomparison Project Phase 5
CO_2-eq	Emissions of $CO_2^{FF} + CO_2^{LUC} + CH_4 + N_2O$, expressed in terms of CO_2-equivalent, found using GWPs for CH_4 and N_2O
$CO_2^{EQ\text{-}IN}$	CO_2-equivalent emissions from individual nations
CO_2^{FF}	Atmospheric CO_2 released by the combustion of fossil fuels, flaring, and the cement manufacturing, globally
$CO_2^{FF\text{-}IN}$	Atmospheric CO_2 released by the combustion of fossil fuels, flaring, and the cement manufacturing, by individual nations
CO_2^{LUC}	Atmospheric CO_2 released by land use change, globally
COP	Conference of the Parties
CRU	Climatic Research Unit of the Univ. of East Anglia, UK
DNB	Day Night Band
DOE	Department of Energy
ECS	Equilibrium Climate Sensitivity
EDGAR	Emissions Database for Global Atmospheric Research of the JRC, European Commission
EIA	Energy Information Agency
EM-GC	Empirical Model of Global Climate
ENSO	El Niño Southern Oscillation
EPC	Electricity Power Consumption
ESRL	Earth System Research Laboratory of US NOAA
GCF	Green Climate Fund
GCMs	General Circulation Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GISS	Goddard Institute for Space Studies
GMST	Global Mean Surface Temperature
GWP	Global Warming Potential
Gt	Gigatonne, 10^9 metric ton
HCFCs	Hydrochlorofluorocarbons: these gases deplete stratospheric ozone, although not as strongly as CFCs; these gases also warm climate
HFCs	Hydrofluorocarbons: these gases do not deplete stratospheric ozone, but they warm climate
IEA	International Energy Administration
INDC	Intended Nationally Determined Contribution
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center of the European Commission
LUC	Land Use Change
MLO	Mauna Loa Observatory
MLR	Multiple Linear Regression
MODIS	Moderate Resolution Imaging Spectroradiometer of US NASA
MW	Megawatt, 10^6 W
MWP	Medieval Warm Period
NASA	National Aeronautics and Space Administration

NCEI	National Centers for Environmental Information
NOAA	National Oceanographic and Atmospheric Administration
Non-Annex I	UNFCCC list of developing nations, prominently featured in Kyoto Protocol
Non-Annex I*	UNFCCC list of developing nations, minus China and India. This is our nomenclature, not that of UNFCCC
NPP	National Polar-orbiting Partnership of the US NASA, NOAA, and Department of Defense
ODS	Ozone Depleting Substance
OHC	Ocean Heat Content
OHE	Ocean Heat Export
ORNL	Oak Ridge National Laboratory of the US DOE
PBL	Planbureau voor de Leefomgeving; the Environmental Assessment Agency of the Netherlands
$pC^{EQ\text{-}IN}$	Per-capita release of $CO_2^{FF}+CO_2^{LUC}+CH_4+N_2O$, expressed in terms of CO_2-equivalent, by individual nations
$pC^{EQ\text{-}GL}$	Per-capita release of $CO_2^{FF}+CO_2^{LUC}+CH_4+N_2O$, expressed in terms of CO_2-equivalent, globally
pC^{GL}	Per-capita release of CO_2 due to the combustion of fossil fuels, flaring, and the cement manufacturing, globally
pC^{IN}	Per-capita release of CO_2 due to the combustion of fossil fuels, flaring, and the cement manufacturing, by individual nations
PDO	Pacific Decadal Oscillation
PFCs	Perfluorocarbons: these gases do not deplete stratospheric ozone, but they warm climate
PICR	Potsdam Institute for Climate Research
ppy	Per person, per year
RCP	Representative Concentration Pathway
RF	Radiative Forcing
SEDAC	Socioeconomic Data and Applications Center
SOD	Stratospheric Optical Depth
SPO	South Pole Observatory
TCRE	Transient Climate Response to cumulative CO_2 Emissions
Tg	Teragram, 10^{12} g
TSI	Total Solar Irradiance
UNFCCC	United Nations Framework Convention on Climate Change
VEI	Volcanic Explosivity Index
VIIRS	Visible Infrared Imaging Radiometer Suite, US NASA and NOAA

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