

---

This is the final Report of Working Group 1 of the Intergovernmental Panel on Climate Change, which is sponsored jointly by the World Meteorological Organization and the United Nations Environment Programme. The report considers the scientific assessment of climate change. Several hundred working scientists from 25 countries have participated in the preparation and review of the scientific data. The result is the most authoritative and strongly supported statement on climate change that has ever been made by the international scientific community. The issues confronted with full rigour include: global warming, greenhouse gases, the greenhouse effect, sea level changes, forcing of climate, and the history of Earth's changing climate. The information presented here is of the highest quality. It will inform the necessary scientific, political and economic debates and negotiations that can be expected in the immediate future. Appropriate strategies in response to the issue of climate change can now be firmly based on the scientific foundation that the Report provides. The Report is, therefore, an essential reference for all who are concerned with climate change and its consequences.

# Climate Change

---

THE IPCC SCIENTIFIC ASSESSMENT

---

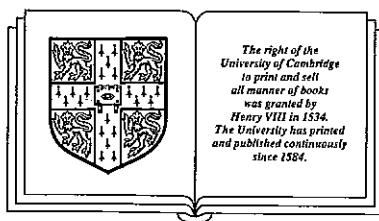
# Climate Change

The IPCC Scientific Assessment

---

Edited by

J. T. HOUGHTON, G. J. JENKINS and J. J. EPHRAUMS



*Published for the  
Intergovernmental Panel on Climate Change*

**CAMBRIDGE UNIVERSITY PRESS**

*Cambridge*

*New York Port Chester Melbourne Sydney*

Published by the Press Syndicate of the University of Cambridge  
The Pitt Building, Trumpington Street, Cambridge CB2 1RP  
40 West 20th Street, New York, NY 10011, USA  
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© Intergovernmental Panel on Climate Change 1990

First published 1990  
Reprinted 1991

Printed in Great Britain at the University Press, Cambridge

*British Library cataloguing in publication data*

Intergovernmental Panel on Climate Change  
Climate Change.

1. Climate Changes

I. Title II. Houghton, John T. (John Theodore) 1931–

III. Jenkins, G. J. IV. Ephraums, J. J.

551.6

*Library of Congress cataloguing in publication data available*

ISBN 0 521 40360 X hardback

ISBN 0 521 40720 6 paperback

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

---

# CLIMATE CHANGE

## The IPCC Scientific Assessment

---

Report Prepared for IPCC by Working Group 1

Edited by J.T.Houghton, G.J.Jenkins and J.J.Ephraums  
*(Meteorological Office, Bracknell, United Kingdom)*



WMO



UNEP

# Contents

---

<i>Preface</i>	<i>iii</i>
<i>Foreword</i>	<i>v</i>
<i>Policymakers Summary</i>	<i>vii</i>
<i>Introduction</i>	<i>xxxv</i>
1 Greenhouse Gases and Aerosols R.T. WATSON, H. RODHE, H. OESCHGER AND U. SIEGENTHALER	1
2 Radiative Forcing of Climate K.P. SHINE, R.G. DERWENT, D.J. WUEBBLES AND J-J. MORCRETTE	41
3 Processes and Modelling U. CUBASCH AND R.D. CESS	69
4 Validation of Climate Models W.L. GATES, P.R. ROWNTREE AND Q-C. ZENG	93
5 Equilibrium Climate Change J.F.B. MITCHELL, S. MANABE, T. TOKIOKA AND V. MELESHKO	131
6 Time-Dependent Greenhouse-Gas-Induced Climate Change F.P. BRETHERTON, K. BRYAN AND J.D. WOODS	173
7 Observed Climate Variations and Change C.K. FOLLAND, T. KARL AND K.YA. VINNIKOV	195
8 Detection of the Greenhouse Effect in the Observations T.M.L. WIGLEY AND T.P. BARNETT	239

9	Sea Level Rise R.A. WARRICK AND H. OERLEMANS	257
10	Effects on Ecosystems J.M. MELILLO, T.V. CALLAGHAN, F.I. WOODWARD, E. SALATI AND S.K. SINHA	283
11	Narrowing the Uncertainties G. McBEAN AND J. McCARTHY	311
	<i>Annex</i>	329
	<i>Appendix 1 Emission Scenarios</i>	341
	<i>Appendix 2 Organisation of IPCC and WGI</i>	343
	<i>Appendix 3 Contributors to the WGI Report</i>	345
	<i>Appendix 4 Reviewers of the WGI Report</i>	353
	<i>Appendix 5 Acronyms - Institutions</i>	359
	<i>Appendix 6 Acronyms - Programmes and Miscellaneous</i>	361
	<i>Appendix 7 Units</i>	363
	<i>Appendix 8 Chemical Symbols</i>	365

# Preface

---

The Intergovernmental Panel on Climate Change (IPCC) was jointly established by our two organisations in 1988. Under the chairmanship of Professor Bert Bolin, the Panel was charged with:

- (i) assessing the scientific information that is related to the various components of the climate change issue, such as emissions of major greenhouse gases and modification of the Earth's radiation balance resulting therefrom, and that needed to enable the environmental and socio-economic consequences of climate change to be evaluated.
- (ii) formulating realistic response strategies for the management of the climate change issue.

The Panel began its task by establishing Working Groups I, II and III respectively to:

- (a) assess available scientific information on climate change.
- (b) assess environmental and socio-economic impacts of climate change.

- (c) formulate response strategies.

It also established a Special Committee on the Participation of Developing Countries to promote, as quickly as possible, the full participation of developing countries in its activities.

This volume is based upon the findings of Working Group I, and should be read in conjunction with the rest of the IPCC first assessment report; the latter consists of the reports and policymakers summaries of the 3 Working Groups and the Special Committee, and the IPCC overview and conclusions.

The Chairman of Working Group I, Dr John Houghton, and his Secretariat, have succeeded beyond measure in mobilizing the co-operation and enthusiasm of hundreds of scientists from all over the world. They have produced a volume of remarkable depth and breadth, and a Policymakers Summary which translates these complex scientific issues into language which is understandable to the non-specialist.

We take this opportunity to congratulate and thank the Chairman for a job well done.

**G.O.P. Obasi**  
*Secretary-General*  
*World Meteorological Organization*

**M.K. Tolba**  
*Executive Director*  
*United Nations Environment Programme*



# Foreword

---

Many previous reports have addressed the question of climate change which might arise as a result of man's activities. In preparing this Scientific Assessment, Working Group I<sup>1</sup> has built on these, in particular the SCOPE 29 report of 1986<sup>2</sup>, taking into account significant work undertaken and published since then. Particular attention is paid to what is known regarding the detail of climate change on a regional level.

In the preparation of the main Assessment most of the active scientists working in the field have been involved. One hundred and seventy scientists from 25 countries have contributed to it, either through participation in the twelve international workshops organised specially for the purpose or through written contributions. A further 200 scientists have been involved in the peer review of the draft report. Although, as in any developing scientific topic, there is a minority of opinions which we have not been able to accommodate, the peer review has helped to ensure a high degree of consensus amongst authors and reviewers regarding the results presented. Thus the Assessment is an authoritative statement of the views of the international scientific community at this time.

The accompanying Policymakers' Summary, based closely on the conclusions of the Assessment, has been prepared particularly to meet the needs of those without a strong background in science who need a clear statement of the present status of scientific knowledge and the associated uncertainties.

The First Draft of the Policymakers Summary was presented to the meeting of the Lead Authors of the Assessment (Edinburgh, February 1990), and the Second Draft which emanated from that meeting was sent for the same wide peer review as the main report, including nationally designated experts and the committees of relevant international scientific programmes. A Third Draft incorporating a large number of changes suggested by peer-reviewers was tabled at the final plenary meeting of Working Group I (Windsor, May 1990) at which the Lead Authors of the main report were present, and the final version was agreed at that meeting.

It gives me pleasure to acknowledge the contributions of so many, in particular the Lead Authors, who have given freely of their expertise and time to the preparation of this report. All the modelling centres must be thanked for providing data so readily for the model intercomparison. I also acknowledge the contribution of the core team at the Meteorological Office in Bracknell who were responsible for organising most of the workshops and preparing the report. Members of the team were Professor Cao Hong Xing from China, Dr Reindert Haarsma from The Netherlands, Dr Robert Watson from the USA, and Dr John Mitchell, Dr Peter Rowntree, Dr Terry Callaghan, Chris Folland, Jim Ephraums, Shelagh Varney, Andrew Gilchrist and Aileen Foreman from the UK. Particular acknowledgment is due to Dr Geoff Jenkins, the Coordinator of Working Group I who led the team. Thanks

<sup>1</sup> Organisational details of IPCC and Working Group I are shown in Appendix 2.

<sup>2</sup> The Greenhouse Effect, Climate Change and Ecosystems, SCOPE 29, Bolin, B., B. Doos, J. Jager and R. A. Warrick (Eds.), John Wiley and Sons, Chichester, 1986.

are also due to Dr Sundararaman and the IPCC Secretariat in Geneva. Financial support for the Bracknell core team was provided by the Departments of the Environment and Energy in the UK.

I am confident that the Assessment and its Summary will provide the necessary firm scientific foundation for the

forthcoming discussions and negotiations on the appropriate strategy for response and action regarding the issue of climate change. It is thus, I believe, a significant step forward in meeting what is potentially the greatest global environmental challenge facing mankind.



**Dr John Houghton**  
**Chairman, IPCC Working Group I**

Meteorological Office  
Bracknell  
July 1990