GLOBAL CHANGE
IGBP
THE IGBP SERIES

PAVEL KABAT
MARTIN CLAUSSEN
PAUL A. DIRMEYER
JOHN H. C. GASH
LELYS BRAVO DE GUENNI
MICHEL MEYBECK
ROGER A. PIELKE SR
CHARLES J. VÖRÖSMARTY
RONALD W. A. HUTJES
SABINE LÜTKEMEIER
Editors

Vegetation, Water, Humans and the Climate

A New Perspective on an Interactive System

Springer

Kabat · Claussen · Dirmeyer · Gash · de Guenni · Meybeck
Pielke Sr. · Vörösmarty · Hutjes · Lütkemeier (Eds.)

Vegetation, Water, Humans and the Climate

A New Perspective on an Interactive System

With 246 Figures

Springer

Editors

Pavel Kabat

Wageningen University and Research Centre
ALTERRA Green World Research
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
E-mail: *pavel.kabat@wur.nl*

Martin Claussen

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *claussen@pik-potsdam.de*

Paul A. Dirmeyer

Center for Ocean-Land-Atmosphere Studies
4041 Powder Mill Road, Suite 302, Calverton MD 20705-3106, USA
E-mail: *dirmeyer@cola.iges.org*

John H. C. Gash

Centre for Ecology and Hydrology
Maclean Building, Crowmarsh Gifford, Wallingford,
Oxfordshire OX10 8BB, United Kingdom
E-mail: *jhg@ceh.ac.uk*

Lelys Bravo de Guenni

Universidad Simón Bolivar
Departamento de Cómputo Cientifico y Estadistica
P.O. Box 89.000, Caracas 1080-A, Venezuela
E-mail: *lbravo@cesma.usb.ve*

Michel Meybeck

Université de Paris 6/SYSYPHE, Laboratoire de Géologie Appliquée
4 place Jussieu, F-75252 Paris, France
E-mail: *meybeck@ccr.jussieu.fr*

Roger A. Pielke Sr.

Department of Atmospheric Sciences
Colorado State University, Fort Collins CO 80523, USA
E-mail: *pielke@snow.atmos.colostate.edu*

Charles J. Vörösmarty

University of New Hampshire, Institute for the Study of Earth
Oceans & Space (EOS)
Complex Systems Research Center, Water Systems Analysis Group
Morse Hall, 39 College Road, Durham NH 03824-3525, USA
E-mail: *charles.vorosmarty@unh.edu*

Ronald W. A. Hutjes

Wageningen University and Research Centre,
ALTERRA Green World Research
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
E-mail: *ronald.hutjes@wur.nl*

Sabine Lütkemeier

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Sabine.Luetkemeier@pik-potsdam.de*

Cover design:
Figures from left to right: *Well in the Sahel, West Africa:* courtesy of John H. C. Gash ©, Centre for Ecology and Hydrology, Wallingford, Oxfordshire, United Kingdom. *Model cloud:* adapted from Pielke RA, Lee TJ, Copeland JH, Eastman JL, Ziegler CL, Finley CA (1997) Use of USGS-provided data to improve weather and climate simulations. Ecol Applications 7:3–21. © printed by permission of Ecological Society of America and the authors. *Amazon near Manaus:* © Antonio D. Nobre, Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil. *Elbe flood:* Jeßnitz (near Bitterfeld) on the river Mulde on 15 August 2002 © M. Zebisch, Technische Universität Berlin/Potsdam-Institut für Klimafolgenforschung e. V., Germany.

ISSN 1619-2435
ISBN 3-540-42400-8 Springer-Verlag Berlin Heidelberg New York

Library of Congress Control Number: 2004102329

Bibliographic information published by Die Deutsche Bibliothek
Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data is available in the Internet at http://dnb.ddb.de

Springer-Verlag Berlin Heidelberg New York
a member of BertelsmannSpringer Science+Business Media GmbH
http://www.springer.de

Printed in Germany

Cover Design: Erich Kirchner, Heidelberg
Dataconversion: Büro Stasch (*stasch@stasch.com*), Klaus Häringer · Bayreuth

Printed on acid-free paper – 32/3141/lt – 5 4 3 2 1 0

Preface

This book is the result of an initiative by the *Biospheric Aspects of the Hydrological Cycle* (BAHC), a Core Project of the *International Geosphere-Biosphere Programme* (IGBP). It reports on the more than a decade-long research and findings of a large number of scientists studying the Earth system in terms of the connection between the terrestrial biosphere, the hydrologic cycle and the potential anthropogenic influences. The authors contributing to the five parts of the book have highlighted the research and findings of hundreds of scientists who have worked over the past 15 years on the interface between the hydrological cycle, the terrestrial biosphere and the atmosphere. As you read through the book, it becomes clear that the scientific progress goes well beyond any single international programme: it is interdisciplinary and reflects contributions made towards addressing many of the objectives set forth by a number of projects of IGBP, WCRP (*World Climate Research Programme*), and IHDP (*International Human Dimensions Programme on Global Environmental Change*).

At the programmatic level we often compartmentalise and label research as belonging to a specific named programme, but in reality and at the researchers' level, it is all a seamless process that tackles specific and challenging questions related to the highly interactive processes of vegetation, water and humans within the climate system. In their earliest years, BAHC and GEWEX (the *Global Energy and Water Cycle Experiment* of WCRP) recognised the need for thematic synergies and collaboration between the two research programmes. Both programmes have successfully collaborated in a large number of joint research, observational and modelling activities since their inception (BAHC in 1990 and GEWEX in 1988). The *International Satellite Land Surface Climatology Project* (ISLSCP), a GEWEX project, is perhaps one of the best examples of an excellent collaboration between the two programmes. BAHC and ISLSCP have operated "back to back" since the Tucson aggregation workshop in 1994 (Kabat and Sellers 1997)[1]. ISLSCP is a leading project in producing and consolidating global datasets for global change studies. BAHC and ISLSCP jointly initiated and coordinated an array of land-surface/atmosphere experiments, known as HAPEX and FIFE (for example *Hydrological and Atmospheric Pilot Experiment* in the Sahel and *First ISLSCP Field Experiment*, respectively). Both programmes jointly took the first steps to initiate the largest and most integrative Earth system experiment so far: the *Large Scale Biosphere Atmosphere Experiment in Amazonia* (LBA). It is gratifying to see some of the research and findings resulting from these joint activities presented in this book.

While we are both extremely pleased with the research progress reported in this volume, we are even more excited about the future results of the planned joint activities associated with the recently launched GEWEX Phase II and the new project in IGBP on the land-atmosphere interface, ILEAPS (*Integrated Land Ecosystem – Atmosphere Processes Study*)[2], to which the BAHC community will be a major contributor. For example, both the *Coordinated Enhanced Observing Period* (CEOP) of GEWEX,

[1] Kabat P, Sellers PJ (1997) Special issue: Aggregate description of land-atmosphere interactions, foreword. J Hydrol 190/3–4:173–175.

[2] *http://www.atm.helsinki.fi/ILEAPS/*

and the FLUXNET project of world-wide CO_2 flux measurement initiated by BAHC are positioned at the forefront of the Earth system measurement and monitoring approaches. By focusing on a series of reference field sites distributed over all continents (CEOP), on "transect studies" (FLUXNET), and on simultaneous use of satellite and ground observation, these experiments will provide a data set of unprecedented completeness and quality for our scientists to work with.

The *Global Land-Atmosphere System Study* (GLASS) and the *Global Soil Wetness Project* (GSWP) are other examples of successful collaborative activity between the two programmes in modelling land-surface/atmosphere processes and interactions within the climate system (e.g. Feddes et al. 2001)[3]. These projects are promising a new generation of land-surface schemes for Earth system models. The new schemes will evolve into interactive schemes that increasingly incorporate more hydrological, atmospheric, biogeochemical and ecological information.

Finally, while BAHC and GEWEX place much of their emphasis on the physical and biospheric aspects of water, they have also been very much interested in the potential impact of the alteration of the global hydrological cycle on regional water resources and ecosystems. However, despite the reported scenario and case studies (see Part D and E) and the proposed new approach for vulnerability assessments (Part E), at present, specific regional effects continue to be uncertain. This remaining uncertainty is one of the factors that has thus far hindered the effective application of GEWEX and BAHC research results to operational hydrology and water management strategies. Better links to applications in water resources is therefore one of the main priorities of Phase II of GEWEX and of the new joint project GWSP (*Global Water Systems Project*), co-sponsored by IGBP, WCRP, IHDP and DIVERSITAS (*International Programme of Biodiversity Science*). We remain optimistic that within this decade much progress in this area will be made and it will be the subject of a future publication.

Soroosh Sorooshian
Chair,
GEWEX-Scientific Steering Group

Pavel Kabat
Chair and Co-Chair,
BAHC and ILEAPS Science Steering Committees

[3] Feddes R A, Hoff H, Bruen M, Dawson TE, de Rosnay P, Dirmeyer P, Jackson RB, Kabat P, Kleidon A, Lilly A, Pitman AJ (2001) Modelling root water uptake in hydrological and climate models. Bull Amer Meteor Soc 82:2797–2809.

Acknowledgements

The editors emphasise that the results reported here are based on the research work of many individual scientists and research teams around the world who have been associated in some way with the objectives of the IGBP-BAHC and WCRP-GEWEX research programmes. Synthesising these results was only achieved through the commitment, and work, often voluntary, of these scientists, and their staff and students. We especially acknowledge the help of all those involved in developing databases, convening/hosting workshops and editing drafts, and all those who participated in the lively discussions which made the work so enjoyable and worthwhile.

We are grateful to the German Federal Ministry of Education and Research (BMBF) for funding the BAHC Project Office at the Potsdam Institute for Climate Impact Research (PIK) to whom thanks are also due. The Dutch National Research Programme on Global Air Pollution and Climate Change (grant 959291) provided support for part of the Science Synthesis process. Additional funding and support have been provided through the following institutions and agencies: the IGBP Central Office in Stockholm, The Netherlands Ministry of Agriculture, Nature Management and Fisheries, The Netherlands Organisation for Scientific Research (NWO), and the WCRP International GEWEX Project Office, Silver Spring, USA.

In particular we would like to thank Will Steffen for his continuous encouragement and support during the entire Synthesis process; Hans-Jürgen Bolle as the first BAHC Chair; Piers Sellers who as the former Chair of ISLSCP helped forge the connections between BAHC and GEWEX; the late Mike Fosberg, former head of the BAHC Core Project Office; and all the former members of the BAHC Scientific Steering Committee. Last but not least we also wish to thank two colleagues at the Potsdam Institute for Climate Impact Research: Dietmar Gibitz-Rheinbay, for helping with the technical side of putting together a book of this size, and Ursula Werner for redrawing many of the figures.

Contributors

Simon J. Allen

CECS, University of Edinburgh
John Muir Building, The King's Buildings
Mayfield Road, Edinburgh, EH9 3JK, United Kingdom
E-mail: *s.allen@ed.ac.uk*

Roni Avissar

Department of Civil and Environmental Engineering
Duke University
123 Hudson Hall, Durham NC 27708-0287, USA
E-mail: *avissar@duke.edu*

Dennis Baldocchi

Ecosystem Science Division and Berkeley Atmospheric Science Center, Department of Environmental Science, Policy and Management
University of California, Berkeley
151 Hilgard Hall, Berkeley CA 94720, USA
E-mail: *baldocchi@nature.berkeley.edu*

Brad Bass

Adaptations and Impacts Research Group
Environment Canada at the University of Toronto
33 Willcocks Street, Toronto, Ontario, Canada M5S 3E8
E-mail: brad.bass@ec.gc.ca

Alfred Becker

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Alfred.Becker@pik-potsdam.de*

Anton C. M. Beljaars

European Centre for Medium-Range Weather Forecasts (ECMWF)
Shinfield Park, Reading, Berkshire RG2 9AX, United Kingdom
E-mail: *beljaars@ecmwf.int*

Alan K. Betts

Atmospheric Research
58 Hendee Lane, Pittsford VT 05763-9405, USA
E-mail: *akbetts@aol.com*

Richard A. Betts

Met Office
Hadley Centre for Climate Prediction and Research
Fitzroy Road, Exeter, EX1 3PB, United Kingdom
E-mail: *richard.betts@metoffice.com*

Hans-Jürgen Bolle

Stücklenstraße 18c, 81247 München, Germany
E-mail: *hansj.bolle@lrz.badw-muenchen. de*

Mike Bonell

Section: Hydrological Processes and Climate
UNESCO Division of Water Sciences
1 rue Miollis, 75732 Paris Cedex 15, France
E-mail: *m.bonell@unesco.org*

Lelys Bravo de Guenni

Universidad Simón Bolivar
Departamento de Cómputo Cientifico y Estadistica
P.O. Box 89.000, Caracas 1080-A, Venezuela
E-mail: *lbravo@cesma.usb.ve*

Ross Brown

Climate Research Branch, Meteorological Service of Canada
2121 Trans Canada Highway, Dorval, QC, Canada H9P 1J3
E-mail: *Ross.Brown@ec.gc.ca*

Jake Brunner

Conservation International
1919 M Street, Washington DC 20036, USA
E-mail: *J.brunner@conservation.org*

Thomas Chase

Cooperative Institute for Research in Environmental Sciences (CIRES) and Department of Geography
Campus Box 216, University of Colorado, Boulder, CO 80309, USA
E-mail: *tchase@cires.colorado.edu*

Jing M. Chen

Department of Geography and Program in Planning
University of Toronto
100 St. George St., Toronto, Ontario, Canada M5S 3G3
E-mail: *chenj@geog.utoronto.ca*

Wenjun Chen

Environmental Monitoring Section
Canada Centre for Remote Sensing
588 Booth St., Ottawa, Ontario, Canada K1A 0Y7
E-mail: *wenjun.chen@ccrs.nrcan.gc.ca*

Martin Claussen

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *claussen@pik-potsdam.de*

Peter M. Cox

Met Office
Hadley Centre for Climate Prediction and Research
Fitzroy Road, Exeter, EX1 3PB, United Kingdom
E-mail: *peter.cox@metoffice.com*

Timothy L. Crawford †

Field Research Division NOAA/ARL
1750 Foote Drive, Idaho Falls, ID 83402, USA
E-mail: use: *dobosy@atdd.noaa.gov*

Alistair D. Culf

Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford
Oxfordshire OX10 8BB, United Kingdom
E-mail: use: *jhg@ceh.ac.uk*

Paul A. Dirmeyer

Center for Ocean-Land-Atmosphere Studies
4041 Powder Mill Road, Suite 302, Calverton MD 20705-3106, USA
E-mail: *dirmeyer@cola.iges.org*

Ronald J. Dobosy

Atmospheric Turbulence and Diffusion Division NOAA/ARL
Post Office Box 2456, Oak Ridge TN, 37831-2456, USA
E-mail: *dobosy@atdd.noaa.gov*

A. J. (Han) Dolman

Dept. Geo-Environmental Sciences
Free University
de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands
E-mail: *han.dolman@geo.falw.vu.nl*

Hervé Douville

Météo-France/CNRM, GMGEC/UDC
42 avenue Coriolis, 31057 Toulouse, France
E-mail: *herve.douville@meteo.fr*

Reinder A. Feddes

Wageningen University, Environmental Sciences,
Sub-Department Water Resources,
Chair Soil Physics, Agrohydrology and Groundwater Management
Nieuwe Kanaal 11, 6709 PA Wageningen, The Netherlands
E-mail: *reinder.feddes@wur.nl*

Balazs Fekete

University of New Hampshire
Institute for the Study of Earth, Oceans & Space (EOS)
Complex Systems Research Center, Water Systems Analysis Group
Morse Hall, 39 College Road, Durham NH 03824-3525, USA
E-mail: *balazs.fekete@unh.edu*

David R. Fitzjarrald

Atmospheric Sciences Research Center
University at Albany, SUNY
251 Fuller Road, Albany NY 12203, USA
E-mail: *fitz@asrc.cestm.albany.edu*

Thomas Foken

Abteilung Mikrometeorologie
Universität Bayreuth
Universitätsstraße 30, D-95440 Bayreuth, Germany
E-mail: *thomas.foken@uni-bayreuth.de*

Burkhard Frenzel

Institut für Botanik
Universität Hohenheim
Garbenstr. 30, D-70599 Stuttgart, Germany
E-mail: *bfrenzel@uni-hohenheim.de*

Steve Frolking

Institute for the Study of Earth, Oceans, and Space
University of New Hampshire
39 College Rd., Durham NH 03824-2622, USA
E-mail: *steve.frolking@unh.edu*

Congbin Fu

START Regional Center for Temperate East Asia, c/o Institute of Atmospheric Physics, Chinese Academy of Sciences,
Qi Jia Huo Zi, De Sheng Men Wai Street, Beijing 100029, China
E-mail: *fcb@ast590.tea.ac.cn*

John H. C. Gash

Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford
Oxfordshire OX10 8BB, United Kingdom
E-mail: *jhg@ceh.ac.uk*

Pamela Green

University of New Hampshire
Institute for the Study of Earth, Oceans & Space (EOS)
Complex Systems Research Center, Water Systems Analysis Group
Morse Hall, 39 College Road, Durham NH 03824-3525
USA, E-mail: *pam.green@unh.edu*

Vijay Gupta

Dept. of Civil and Environmental Engineering and Coopreative Institute for Research in Environmental Sciences, Campus Box 216,
University of Colorado, Boulder CO 80309-0216, USA
E-mail: *guptav@cires.colorado.edu*

Florence Habets

Meteo-France - CNRM
42, avenue Gustave Coriolis, F-31057 Toulouse, France
E-mail: *florence.habets@meteo.fr*

Forrest G. Hall

Goddard Space Flight Center
National Aeronautic and Space Administration (NASA)
Code 923, Greenbelt MD 20771, USA
E-mail: *fghall@ltpmail.gsfc.nasa.gov*

Sven Halldin

Department of Earth Sciences, Uppsala University
Villavägen 16, SE-75236 Uppsala, Sweden
E-mail: *sven.halldin@hyd.uu.se*

Niall Hanan

Natural Resource Ecology Laboratory
Colorado State University
Fort Collins CO 80521, USA
E-mail: *niall@nrel.colostate.edu*

Richard J. Harding

Centre for Ecology and Hydrology, Maclean Building
Crowmarsh Gifford, Wallingford
Oxfordshire OX10 8BB, United Kingdom
E-mail: *rjh@ceh.ac.uk*

Holger Hoff

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *hhoff@pik-potsdam.de*

Paul Houser

Hydrological Sciences Branch
Goddard Space Flight Center (GSFC)
National Aeronautics and Space Administration (NASA)
Code 974, Bldg. 33, Greenbelt MD 20771, USA
E-mail: *houser@hsb.gsfc.nasa.gov*

Gordon H. Huang

Environmental Systems Engineering
University of Regina
Regina, Sask., Canada S4S 0A2
E-mail: *gordon.huang@uregina.ca*

Michael F. Hutchinson

Centre for Resource and Environmental Studies
Australian National University
GPO Box 4, Canberra ACT 0200, Australia
E-mail: *hutch@cres.anu.edu.au*

Ronald W. A. Hutjes

Wageningen University and Research Centre
ALTERRA Green World Research
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
E-mail: *ronald.hutjes@wur.nl*

Roy Jenne

National Center for Atmospheric Research
1850 Table Mesa Drive, Boulder, CO 80305-3000, USA
E-mail: *jenne@ucar.edu*

Pavel Kabat

Wageningen University and Research Centre
ALTERRA Green World Research
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
E-mail: *pavel.kabat@wur.nl*

Yann H. Kerr

Centre National d'Etudes Spatiales (CNES), CESBIO
18 Avenue Edouard Belin, 31401 Toulouse, France
E-mail: *yann.kerr@cesbio.cnes.fr*

Stefan W. Kienzle

Department of Geography, The University of Lethbridge
4401 University Drive, Lethbridge, Alberta, Canada T1K 3M4
E-mail: *stefan.kienzle@uleth.ca*

Timothy Kittel

National Center for Atmospheric Research
1850 Table Mesa Drive, Boulder, CO 80305-3000, USA
E-mail: *kittel@ucar.edu*

Randal Koster

Global Modeling and Assimilation Office
Goddard Space Flight Center (GSFC)
National Aeronautics and Space Administration (NASA)
Code 900.3, NASA/GSFC, Greenbelt, MD 20771, USA
E-mail: *randal.d.koster@nasa.gov*

Bart Kruijt

Wageningen University and Research Centre
ALTERRA Green World Research
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
E-mail: *bart.kruijt@wur.nl*

Valentina Krysanova

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Valentina.Krysanova@pik-potsdam.de*

Yumiko Kura

World Resources Institute (WRI)
10 G Street, NE, Washington DC 20002, USA
E-mail: *yumiko@wri.org*

Pierre Lacarrère

Meteo-France - CNRM
42 avenue Gustave Coriolis, F-31057 Toulouse, France
E-mail: *pierre.lacarrere@meteo.fr*

Eric F. Lambin

Department of Geography
Université Catholique du Louvain
3 place Louis Pasteur, B-1348 Louvain La Neuve, Belgium
E-mail: *lambin@geog.ucl.ac.be*

Thierry Lebel

Laboratoire d'étude des Transferts en Hydrologie et
Environnement (LTHE), UMR 5564
BP 53, F-38041 Grenoble cedex 9, France
E-mail: *Thierry.Lebel@inpg.fr*

John Leese

GEWEX Continental Scale International Project (GCIP) Office
Office of Global Programs
National Oceanic and Atmospheric Administration (NOAA)
1100 Wayne Avenue, Silver Spring MD 20901, USA
E-mail: *leese@ogp.noaa.gov*

Rik Leemans

Environmental Systems Analysis Group
Department of Environmental Sciences, Wageningen University
De Drijenborch, Ritzema Bosweg 32a
6703 AZ Wageningen, The Netherlands
E-mail: *rik.leemans@wur.nl*

Dennis P. Lettenmaier

Department of Civil and Environmental Engineering
University of Washington
Seattle, WA, USA
E-mail: *lettenma@ce.washington.edu*

Changming Liu

Institute of Geographic Science and Natural Resources Research
Chinese Academy of Sciences, Anwai
Datun Road, Building 917, Beijing 100101, P. R. China
E-mail: *liucm@igsnrr.ac.cn*

Lei Liu

Department of Civil Engineering, Dalhousie University
1360 Barrington St., Halifax, NS, Canada B3J 1Z1
E-mail: *lei.liu@dal.ca*

Simon Lorentz

School of Bioresources Engineering and Environmental Hydrology
University of KwaZulu-Natal, Pietermaritzburg
Carbis Road, Scottsville, 3201 Pietermaritzburg, RSA
E-mail: *lorentz@ukzn.ac.za*

Sabine Lütkemeier

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Sabine.Luetkemeier@pik-potsdam.de*

José A. Marengo

Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)
Instituto Nacional de Pesquisas Espaciais (INPE)
Rodonia Presidente Dutra, km 40,
Cachoeira Paulista, SP 12630-000, Brazil
E-mail: *marengo@cptec.inpe.br*

Luis Antonio Martinelli

Centro de Energia Nuclear na Agricultura
Universidade de Sao Paulo/Piracicaba
Avenida Centenario 303, Piracicaba SP, Brazil
E-mail: *lamartin@pintado.ciagri.usp.br*

Emilio Mayorga

School of Oceanography, University of Washington
P. O. Box 357940, Seattle WA 98195-7940, USA
E-mail: *emiliom@u.washington.edu*

Jeffrey J. McDonnell

Department of Forest Engineering, Oregon State University
Corvallis OR 97331-5706, USA
E-mail: *jeff.mcdonnell@orst.edu*

Robert H. Meade

U.S. Geological Survey, Denver Federal Center
Lakewood CO 80225-0046, USA
E-mail: *rhmeade@usgs.gov*

Blanche W. Meeson

Goddard Space Flight Center
National Aeronautics and Space Administration (NASA)
Greenbelt MD 20771, USA
E-mail: *meeson@see.gsfc.nasa.gov*

Michel Meybeck

Université de Paris 6/SYSYPHE
Laboratoire de Géologie Appliquée
4 place Jussieu, F-75252 Paris, France
E-mail: *meybeck@ccr.jussieu.fr*

John Moncrieff

Institute of Ecology and Resource Management
University of Edinburgh, Mayfield Rd., Darwin Building
Edinburgh EH9 3JU, United Kingdom
E-mail: *j.moncrieff@ed.ac.uk*

Bart Nijssen

Departments of Hydrology and Water Resources / Civil Engineering and Engineering Mechanics, The University of Arizona
Tucson, AZ 85721, USA
E-mail: *nijssen@u.arizona.edu*

Carlos A. Nobre

Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)
Instituto Nacional de Pesquisas Espaciais (INPE)
Rodovia Presidente Dutra, km 40
Cachoeira Paulista, SP 12630-000, Brazil
E-mail: *nobre@cptec.inpe.br*

Joel Noilhan

Meteo-France - CNRM
42, avenue Gustave Coriolis, F-31057 Toulouse, France
E-mail: *joel.noilhan@meteo.fr*

Dennis Shoji Ojima

Natural Resource Ecology Laboratory, Colorado State University
Fort Collins CO 80523, USA
E-mail: *dennis@nrel.colostate.edu*

Taikan Oki

Institute of Industrial Science, University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
E-mail: *taikan@iis.u-tokyo.ac.jp*

Richard J. Olson

Oak Ridge National Laboratory
2105 Driftwood Drive, Stevens Point, Wi 54481, USA
E-mail: *olson627@juno.com*

Lucille Perks

School of Bioresources Engineering and Environmental Hydrology
University of KwaZulu-Natal, Pietermaritzburg
Carbis Road, Scottsville, 3201 Pietermaritzburg, RSA
E-mail: *perksl@ukzn.ac.za*

Gerhard Petschel-Held

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Gerhard.Petschel@pik-potsdam.de*

Thomas J. Phillips

Program for Climate Model Diagnosis and Intercomparison (PCMDI), Lawrence Livermore National Laboratory
P.O. Box 808, L-103, Livermore, CA 94551-0808, USA
E-mail: *phillips14@llnl.gov*

Roger A. Pielke Sr.

Department of Atmospheric Sciences, Colorado State University
Fort Collins CO 80523, USA
E-mail: *pielke@snow.atmos.colostate.edu*

Roger A. Pielke Jr.

Center for Science and Technology Policy Research
University of Colorado/CIRES, UCB 488
1333 Grandview Ave., Boulder CO 80309-0488, USA
E-mail: *pielke@cires.colorado.edu*

Andrew J. Pitman

Macquarie University, Division of Environmental and Life Sciences
North Ryde, NSW 2109, Australia
E-mail: *apitman@penman.es.mq.edu.au*

Jan Polcher

Laboratoire de Météorologie Dynamique du CNRS
Université Pierre et Marie Curie, 4 pl Jussieu, F-75252 Paris, France
E-mail: *jan.polcher@lmd.jussieu.fr*

Steven D. Prince

Department of Geography, University of Maryland
1113 Lefrak Hall, College Park MD 20742-8225, USA
E-mail: *sp43@umail.umd.edu*

Robert Rabin

National Severe Storms Laboratory
National Oceanic and Atmospheric Administration
Norman, OK 73072, USA
E-mail: rabin@ssec.wisc.edu

Carmen Revenga

Senior Associate, Information Program
World Resources Institute (WRI)
10 G Street, NE, Washington DC 20002, USA
E-mail: *carmenr@wri.org*

Jeffrey E. Richey

School of Oceanography, University of Washington
Seattle, WA 98195-7940, USA
E-mail: *jrichey@u.washington.edu*

Steven W. Running

Montana Forest and Conservation Experiment Station
School of Forestry, University of Montana
Missoula MT 59812-1063, USA
E-mail: *swr@ntsg.umt.edu*

Joel Schafer

Biospheric Sciences Branch, Science Systems & Applications
NASA/Goddard Space Flight Center
Greenbelt, MD 20771, USA
E-mail: *Joel.S.Schafer.1@gsfc.nasa.gov*

Roland E. Schulze

School of Bioresources Engineering and Environmental Hydrology
University of KwaZulu-Natal
Pietermaritzburg
Carbis Road, Scottsville, 3201 Pietermaritzburg, RSA
E-mail: *schulzeR@ukzn.ac.za*

Maria Assuncão Silva Dias

IAG, Universidade de São Paulo
Rua do Matao 1226, São Paulo 05508-900 SP, Brazil
E-mail: *mafdsdia@model.iag.usp.br*

Thomas J. Stohlgren

U.S. Geological Survey
Fort Collins Science Center
Natural Resource Ecology Laboratory
Colorado State University, Fort Collins CO 80523, USA
E-mail: *Tom_Stohlgren@USGS.gov*

Kiyotoshi Takahashi

Meteorological Research Institute (MRI)
Japan Meteorological Agency (JMA)
Nagamine 1-1, Tsukuba, Ibaraki, 305-0035, Japan
E-mail: *ktakahas@mri-jma.go.jp*

Kirsten Thompson

World Resources Institute (WRI)
10 G Street, NE, Washington DC 20002, USA
E-mail: *kirsten@wri.org*

Christian Valentin

IRD, Institut de Recherche pour le Développement
32 rue Henri Varagnat, 93143 Bondy, France
E-mail: *Christian.Valentin@bondy.ird.fr*

Riccardo Valentini

Department of Forest Science and Environment
Università degli Studi della Tuscia
Via S. Camillo de Lellis, I-01100 Viterbo, Italy
E-mail: *rik@unitus.it*

Kristine Verdin

EROS Data Center
47914 252nd Street, Sioux Falls, SD 57198-0001, USA
E-mail: *kverdin@edcsgw6.cr.usgs.gov*

Reynaldo Luiz Victoria

Centro de Energia Nuclear na Agricultura
Universidade de Sao Paulo/Piracicaba
Avenida Centenario, 303, Piracicaba, SP 13416-000, Brazil
E-mail: *reyna@mail.cena.usp.br*

Pedro Viterbo

European Centre for Medium-Range Weather Forecasts (ECMWF)
Shinfield Park, Reading, Berkshire RG2 9AX, United Kingdom
E-mail: *p.viterbo@ecmwf.int*

Charles J. Vörösmarty

University of New Hampshire
Institute for the Study of Earth, Oceans & Space (EOS)
Complex Systems Research Center, Water Systems Analysis Group
Morse Hall, 39 College Road, Durham NH 03824-3525, USA
E-mail: *charles.vorosmarty@unh.edu*

Christopher P. Weaver

Center for Environmental Prediction and Department of
Environmental Sciences, Rutgers University
New Brunswick, NJ 08901, USA
E-mail: *weaver@cep.rutgers.edu*

Frank Wechsung

Potsdam-Institut für Klimafolgenforschung
Telegrafenberg, 14473 Potsdam, Germany
E-mail: *Frank.Wechsung@pik-potsdam.de*

David Werth

Department of Environmental Sciences, Cook College
Rutgers University
New Brunswick, NJ 08903, USA
E-mail: *werth@cep.rutgers.edu*

Yongkang Xue

Department of Geography
University of California, Los Angeles
1255 Bunche Hall, Los Angeles CA 90095-1524, USA
E-mail: *yxue@geog.ucla.edu*

Tetsuzo Yasunari

Frontier Research System for Global Change (FRSGC), and
Hydrospheric Atmospheric Research Center (HyARC)
Nagoya University, Nagoya, Aichi 464-8601, Japan
E-mail: *yasunari@ihas.nagoya-u.ac.jp*

Xubin Zeng

Department of Atmospheric Sciences
University of Arizona
PAS Building 81, Tucson AZ 85721, USA
E-mail: *zeng@atmo.arizona.edu*

Contents