

ENCYCLOPEDIA *of*  
SNOW, ICE AND  
GLACIERS

# Encyclopedia of Earth Sciences Series

## ENCYCLOPEDIA OF SNOW, ICE AND GLACIERS

### Volume Editors

Vijay P. Singh holds the Caroline and W. N. Lehrer Distinguished Chair in Water Engineering, and is also Professor of Biological and Agricultural Engineering, and Civil and Environmental Engineering at Texas A & M University. He has authored 16 text and reference books, edited 49 books, authored 72 book chapters, and published more than 550 refereed journal articles, 320 conference proceedings papers and 70 technical reports. He is Editor-in-Chief of the Water Science and Technology Book Series of Springer, the ASCE Journal of Hydrologic Engineering, and Water Science and Engineering. He has received more than 60 national and international awards and numerous honors, including the ASCE's Arid Lands Hydraulic Engineering Award; Distinguished Research Master Award from Louisiana State University; ASCE's Ven Te Chow Award; AIH's Ray K. Linsley Award; Hon. Ph.D. from University of Basilicata, Italy; and Hon. Diplomate from American Academy of Water Resources Engineers. He is a fellow of ASCE, AWRA, IE, IAH, ISAE, and IWRS. He is a member/fellow of 10 international science and engineering academies. His research interests include surface and groundwater hydrology, hydraulic engineering, irrigation engineering, and mathematical and stochastic modeling.

Pratap Singh has over 30 years experience in snow and glacier hydrology with an emphasis on modeling of snow and glacier melt runoff. He developed a snow melt model (SNOWMOD), which has been applied for streamflow simulation for snow- and glacier-fed rivers. He has published over 100 technical papers in international/national journals and co-authored with Professor V.P. Singh a book on *Snow and Glacier Hydrology*, published by *Kluwer Academic Publishers*, The Netherlands. He is Associate Editor for the Hydrological Sciences Journal, Wallingford, UK.

Umesh K. Haritashya is a faculty member in the Department of Geology at the University of Dayton, where he teaches courses in glacial geology, geomorphology and remote sensing. He has extensive experience of working on many mountain regions around the world. His research interests include debris cover glacier characterization, glacier dynamics, contribution of glaciers to sea level rise, impact of climate change on mountain glaciers, and glacier hydrology. He is also associated with NASA's GLIMS project and is an editorial board member of the Journal of Hydrologic Engineering, the Open Hydrology Journal, and Himalayan Geology.

### Editorial Board

Richard Armstrong  
National Snow and Ice Data Center  
University of Colorado Boulder  
1540 30th Street  
Campus Box 449  
Boulder, CO, 80309-0449  
USA

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Department of Geography and Geology  
University of Nebraska at Omaha  
Omaha, NE 68182  
USA

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Building of Natural Sciences, Askja, room 329  
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IMAU  
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3508 TA Utrecht  
The Netherlands

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USA

Martyn Tranter  
School of Geographical Sciences  
University of Bristol  
University Road  
Bristol BS8 1SS  
UK

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Professor Charles W. Finkl has edited and/or contributed to more than eight volumes in the Encyclopedia of Earth Sciences Series. For the past 25 years he has been the Executive Director of the Coastal Education & Research Foundation and Editor-in-Chief of the international *Journal of Coastal Research*. In addition to these duties, he is Research Professor at Florida Atlantic University in Boca Raton, Florida, USA. He is a graduate of the University of Western Australia (Perth) and previously worked for a wholly owned Australian subsidiary of the International Nickel Company of Canada (INCO). During his career, he acquired field experience in Australia; the Caribbean; South America; SW Pacific islands; southern Africa; Western Europe; and the Pacific Northwest, Midwest, and Southeast USA.

### Founding Series Editor

Professor Rhodes W. Fairbridge (deceased) has edited more than 24 Encyclopedias in the Earth Sciences Series. During his career he has worked as a petroleum geologist in the Middle East, been a WW II intelligence officer in the SW Pacific and led expeditions to the Sahara, Arctic Canada, Arctic Scandinavia, Brazil and New Guinea. He was Emeritus Professor of Geology at Columbia University and was affiliated with the Goddard Institute for Space Studies.

ENCYCLOPEDIA OF EARTH SCIENCES SERIES

# ENCYCLOPEDIA *of* SNOW, ICE AND GLACIERS

*edited by*

**VIJAY P. SINGH**

*Texas A&M University  
College Station, Texas  
USA*

**PRATAP SINGH**

*New Delhi  
India*

**UMESH K. HARITASHYA**

*University of Dayton  
Dayton, Ohio  
USA*

 Springer

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Dedicated to Snow, Ice and Glacier Scientists around the World



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## Contributors

James S. Aber  
Emporia State University  
Emporia, KS 66801-5087  
USA  
jaber@emporia.edu

Vladimir Aizen  
College of Science, Mines Building  
University of Idaho  
Moscow, ID 83844-3025  
USA  
aizen@uidaho.edu

Ian Allison  
Australian Antarctic Division and Antarctic Climate and  
Ecosystems CRC  
Private Bag 80  
Hobart, Tasmania 7001  
Australia  
ian.allison@utas.edu.au

John T. Andrews  
Institute of Arctic and Alpine Research  
and Department of Geological Sciences  
University of Colorado  
Boulder, CO 80309  
USA  
andrewsj@colorado.edu

Manoj K. Arora  
Department of Civil Engineering  
Indian Institute of Technology Roorkee  
Roorkee 247667  
India  
manojfce@iitr.ernet.in

Monohar Arora  
National Institute of Hydrology (NIH)  
Roorkee 247667, UA  
India  
arora@nih.ernet.in

Cliff Atkins  
School of Geography, Environment and Earth Sciences  
Victoria University of Wellington  
P.O. Box 600  
Wellington 6140  
New Zealand  
Cliff.Atkins@vuw.ac.nz

David B. Bahr  
Department of Physics and Computational Science  
Regis University  
3333 Regis Blvd  
Denver, CO 80221-1099  
USA  
dbahr@regis.edu

Ian Baker  
Thayer School of Engineering  
Dartmouth College  
Hanover, NH 03755  
USA  
Ian.Baker@Dartmouth.edu

Jostein Bakke  
Department of Geography/Bjerknes Centre for Climate  
Research  
University of Bergen  
Fosswinckelsgate 6  
5020 Bergen  
Norway  
Jostein.Bakke@geog.uib.no

Lars Bengtsson  
Department of Water Resources Engineering  
Lund University  
P.O. Box 118  
22100 Lund  
Sweden  
Lars.Bengtsson@tvrl.lth.se

Martin Beniston  
Interdisciplinary Institute for Environmental Dynamics  
University of Geneva  
7 route de Drize  
1227 Carouge, Geneva  
Switzerland  
martin.beniston@unige.ch

Matthew R. Bennett  
The School of Applied Sciences  
Bournemouth University Talbot Campos  
Fern Barrow  
Dorset BH12 5BB  
UK  
MBennett@bournemouth.ac.uk

Andrzej Ber  
Polish Geological Institute – Polish Research Institute  
Warszawa  
Poland  
andrzej.ber@pgi.gov.pl

Etienne Berthier  
LEGOS/CNRS/UPS  
14 av. Ed. Belin  
31400 Toulouse  
France  
etienne.berthier@legos.obs-mip.fr

Nancy A. N. Bertler  
Joint Antarctic Research Institute  
Victoria University of Wellington and GNS Science  
P.O. Box 600  
Wellington 6140  
New Zealand  
Nancy.Bertler@vuw.ac.nz

Achim A. Beylich  
Quaternary Geology and Climate Group  
Geological Survey of Norway (NGU)  
Leiv Eirikssons vei 39  
7491 Trondheim  
Norway  
and  
Department of Geography  
Norwegian University of Science and Technology

(NTNU)  
Dragvoll  
7491 Trondheim  
Norway  
achim.beylich@NGU.NO

Mahendra R. Bhutiyani  
Hazard Assessment and Forecasting Division  
Snow and Avalanche Study Establishment  
Plot No. 1, Sector 37 A, Him Parisar  
Chandigarh 160036  
India  
mahendra\_bhutiyani@yahoo.co.in

Richard Bintanja  
Royal Netherlands Meteorological Institute (KNMI)  
Wilhelminalaan 10  
3732 De Bilt  
The Netherlands  
R.Bintanja@knmi.nl

Farjana S. Birajdar  
Centre of Studies in Resources Engineering  
Indian Institute of Technology Bombay  
Powai, Mumbai 400076, Maharashtra  
India

Michael P. Bishop  
Department of Geography and Geology  
University of Nebraska-Omaha  
6001 Dodge Street  
Omaha, NE 68182  
USA  
mpbishop@mail.unomaha.edu

Tobias Bolch  
Department of Geography  
University of Zürich-Irchel  
Winterthurerstr. 190  
8057 Zürich  
Switzerland  
tobias.bolch@geo.uzh.ch

Sarah Boon  
Department of Geography  
University of Lethbridge  
4401 University Dr  
Lethbridge, AB T1K 3M4  
Canada  
sarah.boon@uleth.ca

David A. Braaten  
Center for Remote Sensing of Ice Sheets  
Department of Geography  
University of Kansas  
Lawrence, KS 66045  
USA  
braaten@ku.edu

Roger J. Braithwaite  
Geography Programme, School of Environment and  
Development  
University of Manchester  
Oxford Road  
Manchester M13 9PL  
UK  
r.braithwaite@manchester.ac.uk

Claudio Bravo  
Centro de Estudios Científicos, CECS  
Arturo Prat 514  
Valdivia  
Chile  
cbravo@cecs.cl

Gary J. Brierley  
School of Environment  
The University of Auckland  
10 Symonds Street  
Private Bag 92019, Auckland 1142  
New Zealand  
g.brierley@auckland.ac.nz

Jason P. Briner  
Department of Geological Sciences  
University at Buffalo  
Buffalo, NY 14260  
USA  
jbriner@buffalo.edu

Margo M. Burgess  
Geological Survey of Canada  
Natural Resources Canada  
601 Booth Street  
Ottawa, ON K1A 0E8  
Canada  
Margo.Burgess@nrcan-mncan.gc.ca

Paolo Burlando  
Institute of Environmental Engineering  
ETH Zurich  
8093 Zurich  
Switzerland  
paolo.burlando@ifu.baug.ethz.ch

Katie Burles  
Department of Geography  
University of Lethbridge  
4401 University Dr  
Lethbridge, AB T1K 3M4  
Canada

Andrew B. G. Bush  
Department of Earth and Atmospheric Science  
University of Alberta  
1-26 Earth Sciences Building  
Edmonton, AB T6G 2E3  
Canada  
andrew.bush@ualberta.ca

David R. Butler  
Mountain GeoDynamics Research Group  
Department of Geography  
Texas State University-San Marcos  
San Marcos, TX 78666-4616  
USA  
db25@txstate.edu

Fay Campbell  
Department of Geographical and Earth Sciences  
University of Glasgow  
Glasgow G12 8QQ  
UK

Norm R. Catto  
Department of Geography  
Memorial University of Newfoundland  
St. John's, NL A1B 3X9  
Canada  
ncatto@mun.ca

Fiona Cawkwell  
Department of Geography  
University College Cork  
Cork  
Ireland  
f.cawkwell@ucc.ie

Anny Cazenave  
Laboratoire d'Etudes en Géophysique et Océanographie  
Spatiales (LEGOS)  
LEGOS-CNES, Observatoire Midi-Pyrénées  
18 Av. E. Belin  
31400 Toulouse  
France  
Anny.Cazenave@legos.obs-mip.fr  
anny.cazenave@gmail.com

Stanley A. Changnon  
University of Illinois  
Urbana, IL 61853  
USA  
schangno@illinois.edu

Arun Chaturvedi  
Antartic Division  
Geological Survey of India  
NH 5P  
Faridabad 121001  
India  
arun.daak@gmail.com

Anju Chaudhary  
Water Resources System Division  
National Institute of Hydrology  
Roorkee 247667  
India  
anju@nih.ernet.in

Jie Cheng  
College of Global Change and Earth System Science  
Beijing Normal University  
19 Xijiekouwai Street  
Beijing 100875  
China  
brucechan2003@126.com

Jessica Ellen Cherry  
International Arctic Research Center and Institute of  
Northern Engineering  
University of Alaska Fairbanks  
930 Koyukuk Dr.  
Fairbanks, AK 99775-7335  
USA  
jcherry@iarc.uaf.edu

Poul Christoffersen  
Scott Polar Research Institute  
University of Cambridge  
Lensfield Road  
Cambridge CB2 1ER  
UK  
pc350@cam.ac.uk

John J. Clague  
Department of Earth Sciences  
Centre for Natural Hazard Research  
Simon Fraser University  
8888 University Drive  
Burnaby, BC V5A 1S6  
Canada  
jclague@sfu.ca

J. Graham Cogley  
Department of Geography  
Trent University  
Peterborough ON, K9J 7B8  
Canada  
gcogley@trentu.ca

Jeffrey D. Colby  
Department of Geography and Planning  
Appalachian State University  
Boone, NC 28608  
USA  
colbyj@appstate.edu

Simon J. Cook  
Centre for Glaciology  
Institute of Geography and Earth Sciences  
Aberystwyth University  
H5, Llandinam  
Ceredigion, Wales SY23 3DB  
UK  
smc@aber.ac.uk  
basalice@gmail.com

Luke Copland  
Department of Geography  
University of Ottawa  
Ottawa, ON K1N 6N5  
Canada  
luke.copland@uottawa.ca

Michel Crucifix  
Georges Lemaitre Centre for Earth and Climate Research  
Université catholique de Louvain  
2 chemin du Cyclotron  
1348 Louvain-la-Neuve  
Belgium  
michel.crucifix@uclouvain.be

Ronald P. Daanen  
Geophysical Institute  
University of Alaska Fairbanks  
903 Koyukuk Dr.  
Fairbanks, AK 99775-7320  
USA  
rdaanen@alaska.edu

Prem Datt  
Research and Design Center (RDC)  
Snow and Avalanche Study Establishment  
Plot No-1, Sector 37-A  
Himparishar 160036, Chandigarh  
India  
datt\_prem@rediffmail.com

Carmen de Jong  
The Mountain Institute  
University of Savoy  
73376 Pôle Montagne, Le Bourget du Lac  
France  
carmen.dejong@institut-montagne.org



Reynald Delaloye  
Department of Geosciences  
Geography University of Fribourg  
Ch. du Musee 4  
1700 Fribourg  
Switzerland  
reynald.delaloye@unifr.ch

Philip Deline  
EDYTEM Lab  
Université de Savoie, CNRS  
73376 Le Bourget du Lac  
France  
pdeli@univ-savoie.fr

Michael N. Demuth  
Glaciology Section, Geological Survey of Canada  
Earth Sciences Sector Program on Climate Change  
Geoscience  
Natural Resources Canada  
601 Booth Street  
Ottawa, ON K1A 0E8  
Canada  
Mike.Demuth@NRCan-RNCan.GC.CA

Stephen J. Déry  
Environmental Science and Engineering Program  
University of Northern British Columbia  
3333 University Way  
Prince George, BC V2N 4Z9  
Canada  
sdery@unbc.ca

Guglielmina Diolaiuti  
Department of Earth Sciences "A. Desio"  
University of Milano  
Via Mangiagalli 34  
20133 Milano  
Italy  
guglielmina.diolaiuti@unimi.it

D. P. Dobhal  
Wadia Institute of Himalayan Geology  
33, General Mahadev Singh Road  
Dehradun 248001, Uttarakhand  
India  
dpdobhal@rediffmail.com

Florent Domine  
Laboratoire de Glaciologie et Géophysique de  
l'Environnement  
CNRS  
BP 96, 54 rue Molière  
38402 Saint Martin d'Hères  
France  
florent@lgge.obs.ujf-grenoble.fr

Divya Dudeja  
Department of Geology  
DBS (P.G.) College  
Dehradun 248001, Uttarakhand  
India  
divyadudeja@yahoo.co.in

Michael Durand  
Byrd Polar Research Center  
Ohio State University  
108 Scott Hall, 1090 Carmack Road  
Columbus, OH 43210  
USA  
durand.8@osu.edu

Jürgen Ehlers  
Geologisches Landesamt  
Billstrasse 84  
20539 Hamburg  
Germany  
juergen.ehlers@bsu.hamburg.de

Heidi Escher-Vetter  
Commission for Glaciology  
Bavarian Academy of Sciences and Humanities  
Alfons-Goppel-Strasse 11  
80539 Munich  
Germany  
Heidi.Escher@kfg.badw.de

Richard Essery  
School of GeoSciences  
University of Edinburgh  
Edinburgh EH9 3JW  
UK  
richard.essery@ed.ac.uk

Steven Fassnacht  
Snow Hydrology, Watershed Science Program  
Colorado State University  
Natural Resources Building Room 335  
Fort Collins, CO 80523  
USA  
srf@warnercnr.colostate.edu

Jiang Fengqing  
Xinjiang Institute of Ecology and Geography, CAS  
Chinese Academy of Sciences  
40-3 South Beijing Road  
Urumqi, Xinjiang 830011  
China  
jiangfengqing@gmail.com  
jiangfq@ms.xjb.ac.cn

Xavier Fettweis  
Institute for Marine and Atmospheric Research  
Utrecht University  
Princetonplein 5  
3584 CC Utrecht  
Netherlands  
and  
Department of Geography  
University of Liège  
Allée du 6 Août, 2  
4000 Liège  
Belgium  
xavier.fettweis@ulg.ac.be

Charles Fierz  
WSL Institute for Snow and Avalanche Research SLF  
7260 Davos Dorf  
Switzerland  
fierz@slf.ch

Sean J. Fitzsimons  
Department of Geography  
University of Otago  
P.O. Box 56  
Dunedin 9054  
New Zealand  
sjf@geography.otago.ac.nz

Andrew G. Fountain  
Department of Geology  
Portland State University  
P.O. Box 751  
Portland, OR 97207-0751  
USA  
andrew@pdx.edu

Hugh M. French  
University of Ottawa (retired)  
10945 Marti Lane  
North Saanich, British Columbia V8L 5S5  
Canada  
hmfrench@shaw.ca

Ping Fu  
Department of Earth and Atmospheric Sciences  
Purdue University  
550 Stadium Mall Dr  
West Lafayette, IN 47907  
USA  
pfu@purdue.edu

Yoshinori Furukawa  
Research Group for Phase Transition Dynamics of Ice  
Institute of Low Temperature Science  
Hokkaido University  
N19 W8  
Sapporo 060-0819  
Japan  
frkw@lowtem.hokudai.ac.jp

Olivier Gagliardini  
Laboratoire de Glaciologie et Géophysique de  
l'Environnement du CNRS/UJF  
54, rue Molière BP 96  
38402 Grenoble  
France  
gagliardini@lgge.obs.ujf-grenoble.fr

Isabelle Gärtner-Roer  
Glaciology, Geomorphodynamics and Geochronology  
Department of Geography  
University of Zürich  
Winterthurerstrasse 190  
8057 Zürich  
Switzerland  
isabelle.roer@geo.uzh.ch

John R. Giardino  
Department of Geology and Geophysics  
Texas A&M University  
College Station, TX 77843-3115  
USA  
rickg@tamu.edu

Philip Gibbard  
Quaternary Palaeoenvironments Group, Cambridge  
Quaternary  
Department of Geography  
University of Cambridge  
Downing Street  
Cambridge CB2 3EN  
UK  
plg1@cam.ac.uk

Alan R. Gillespie  
Department of Earth and Space Sciences  
Quaternary Research Center  
University of Washington  
Seattle, WA 98195-1310  
USA  
arg3@u.washington.edu

Neil F. Glasser  
Centre for Glaciology, Institute of Geography & Earth  
Sciences  
Aberystwyth University  
Aberystwyth, Ceredigion, Wales SY23 3DB  
UK  
nfg@aber.ac.uk

Manmohan Kumar Goel  
Water Resources System  
National Institute of Hydrology  
Roorkee 247667, Uttarakhand  
India  
goel\_m\_k@yahoo.com  
mkg@nih.ernet.in

Gavin Gong  
Department of Earth and Environmental Engineering  
Henry Krumb School of Mines  
Columbia University  
500 West. 120th Street, MC4711  
New York, NY 10027  
USA  
gg2138@columbia.edu

Alastair G. C. Graham  
Ice Sheets Programme, British Antarctic Survey  
High Cross, Madingley Road  
Cambridge CB3 0ET  
UK  
alah@bas.ac.uk

Amanda M. Grannas  
Department of Chemistry  
Villanova University  
800 Lancaster Ave  
Villanova, PA 19085  
USA  
amanda.grannas@villanova.edu

Thomas C. Grenfell  
Department of Atmospheric Sciences  
University of Washington  
Seattle, WA 98195-1640  
USA  
tcg@atmos.washington.edu

G. Hilmar Gudmundsson  
British Antarctic Survey  
High Cross Madingley Road  
Cambridge CB3 0ET  
UK  
ghg@bas.ac.uk

Ravi P. Gupta  
Department of Earth Sciences  
Indian Institute of Technology Roorkee  
Roorkee 247667, UA  
India  
rpgupta.iitr@gmail.com  
rpgesfes@iitr.ernet.in

Wilfried Haeberli  
Glaciology, Geomorphodynamics & Geochronology  
Geography Department  
University of Zurich  
Winterthurerstrasse 190  
8057 Zurich  
Switzerland  
wilfried.haeberli@geo.uzh.ch

Brenda L. Hall  
Department of Earth Sciences and  
Climate Change Institute  
Bryand Global Sciences Center  
University of Maine  
Orono, ME 04469  
USA  
BrendaH@maine.edu

Dorothy K. Hall  
Cryospheric Sciences Branch  
Code 614.1, NASA/Goddard Space Flight Center  
Greenbelt, MD 20771  
USA  
dorothy.k.hall@nasa.gov

Michael J. Hambrey  
Centre for Glaciology  
Institute of Geography & Earth Sciences  
Aberystwyth University  
Aberystwyth, Ceredigion, Wales SY23 3DB  
UK  
mjh@aber.ac.uk

Jonathan Harbor  
Department of Earth and Atmospheric Sciences  
Purdue University  
550 Stadium Mall Dr  
West Lafayette, IN 47907  
USA  
jharbor@purdue.edu

Douglas R. Hardy  
Climate System Research Center and  
Department of Geosciences  
University of Massachusetts  
Morrill Science Center  
611 North Pleasant Street  
Amherst, MA 01003-9297  
USA  
dhardy@geo.umass.edu  
doug.hardy@valley.net

Spencer P. Hardy  
Hanover High School  
41 Lebanon St  
Hanover, NH 03755  
USA

Chelamallu Hariprasad  
Centre for Studies in Resource Engineering  
Indian Institute of Technology, Bombay  
Powai, Mumbai 400076, Maharashtra  
India  
chariprasad@iitb.ac.in

Umesh K. Haritashya  
Department of Geology  
University of Dayton  
300 College Park  
Dayton, OH 45469-2364  
USA  
ukharit@yahoo.com  
Umesh.Haritashya@notes.udayton.edu

Stephan Harrison  
School of Geography, Archaeology and Earth Resources  
University of Exeter  
Cornwall Campus  
Penryn, Cornwall TR10 9EZ  
UK  
stephan.harrison@exeter.ac.uk

Kenneth Hewitt  
Cold Regions Research Centre  
Wilfrid Laurier University  
75 University Avenue West  
Waterloo, ON N2L 3C5  
Canada  
khewitt@wlu.ca

Christopher A. Hiemstra  
Cold Regions Research and Engineering Laboratory  
(CRREL)  
U.S. Army Corps of Engineers, ERDC  
P.O. Box 35170  
Fort Wainwright, AK 99703-0170  
USA  
Christopher.A.Hiemstra@usace.army.mil

Richard Hodgkins  
Department of Geography  
Loughborough University  
Leicestershire LE11 3TU  
UK  
r.hodgkins@lboro.ac.uk

Bryn Hubbard  
Centre for Glaciology  
Institute of Geography and Earth Sciences  
Aberystwyth University  
Llandinam Building  
Aberystwyth, Ceredigion, Wales SY23 3DB  
UK  
byh@aber.ac.uk

Philip D. Hughes  
Geography, School of Environment and Development  
The University of Manchester  
Arthur Lewis Building  
Manchester M13 9PL  
UK  
philip.hughes@manchester.ac.uk

Terry Hughes  
Department of Earth Science  
University of Maine  
Orono, ME 04469-5790  
USA  
and  
Climate Change Institute  
University of Maine  
Orono, ME 04469-5790  
USA  
terry.hughes@maine.edu

Lasafam Iturrizaga  
Department of Geography/High Mountain  
Geomorphology  
Institute of Geography  
University of Göttingen  
Goldschmidtstr. 5  
37077 Göttingen  
Germany  
liturri@gwdg.de

C. K. Jain  
National Institute of Hydrology  
Centre for Flood Management Studies  
G. S. Road, Sapta Sahid Path, Mathura Nagar  
Dispur, Guwahati 781006, Assam  
India  
ckj\_1959@yahoo.co.in

Manoj K. Jain  
Department of Hydrology  
Indian Institute of Technology  
Roorkee 247667, Uttarakhand  
India  
jain.mkj@gmail.com

Sanjay K. Jain  
National Institute of Hydrology  
Roorkee, 247667 Uttarakhand  
India  
Sjain@nih.ernet.in

Adrian Jenkins  
British Antarctic Survey  
Natural Environment Research Council  
High Cross, Madingley Road  
Cambridge CB3 0ET  
UK  
ajen@bas.ac.uk  
a.jenkins@bas.ac.uk

Hester Jiskoot  
Department of Geography  
University of Lethbridge  
4401 University Drive W  
Lethbridge, AB T1K 3M4  
Canada  
hester.jiskoot@uleth.ca

Jerome B. Johnson  
Institute of Northern Engineering  
University of Alaska Fairbanks  
P.O. Box 755910  
Fairbanks, AK 99775-5910  
USA  
jerome.b.johnson@alaska.edu

Tobias Jonas  
Snow Hydrology Research Group  
WSL Institute for Snow and Avalanche Research SLF  
7260 Davos  
Switzerland  
jonas@slf.ch

M. Torre Jorgenson  
Alaska Ecoscience  
Fairbanks, AK 99709  
USA  
tjorgenson@abrinc.com

Andreas Käab  
Department of Geosciences  
University of Oslo  
Sem Sælands vei 1, 1047  
Blindern, 0316 Oslo  
Norway  
kaeab@geo.uio.no

M. Z. Kanevskiy  
Department of Civil and Environmental Engineering  
University of Alaska Fairbanks  
245 Duckering Building, P.O. Box 755900  
Fairbanks, AK 99775-59000  
USA  
mkanevskiy@alaska.edu

Shichang Kang  
Key Laboratory of Tibetan Environmental Changes and  
Land Surface Processes  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
No.18, Shuangqing Rd., P.O. Box 2871  
Haidian District, Beijing 100085  
China  
and  
State Key Laboratory of Cryospheric Sciences  
Chinese Academy of Sciences  
Lanzhou 730000  
China  
Shichang.Kang@itpcas.ac.cn

Martin Kappas  
Cartography, GIS and Remote Sensing Section  
Institute of Geography  
Georg-August University Göttingen  
Goldschmidtstr. 5  
37077 Göttingen  
Germany  
mkappas@gwdg.de

Rijan B. Kayastha  
Himalayan Cryosphere, Climate and Disaster Research  
Center (HiCCDRC)  
Kathmandu University  
Dhulikhel, Kavre  
P.O. Box 6250, Kathmandu  
Nepal  
rijan@ku.edu.np

Matt A. King  
School of Civil Engineering and Geosciences  
Newcastle University  
Cassie Building  
Newcastle upon Tyne NE1 7RU  
UK  
m.a.king@ncl.ac.uk

Martin P. Kirkbride  
Geography, School of the Environment  
University of Dundee  
Perth Road  
Dundee DD1 4HN, Scotland  
UK  
m.p.kirkbride@dundee.ac.uk

Peter G. Knight  
School of Physical and Geographical Sciences  
Keele University  
William Smith Building  
Staffordshire ST5 5BG  
UK  
p.g.knight@esci.keele.ac.uk

Johannes Koch  
Department of Earth Sciences  
Simon Fraser University  
Burnaby, BC V5A 1S6  
Canada  
jkoch@sfu.ca

Lynn Koehler  
University of Victoria Tree-Ring Laboratory  
Department of Geography  
University of Victoria  
Victoria, British Columbia V8W 3R4  
Canada  
lynn.koehler@gmail.com

Markus Konz  
Institute of Environmental Engineering  
Hydrology and Water Resources Management  
ETH Zürich  
Wolfgang-Pauli-Str. 15  
8093 Zurich  
Switzerland  
markus.konz@ifu.baug.ethz.ch

Nadine Konz  
Institute of Environmental Geosciences  
University of Basel  
4003 Basel  
Switzerland  
nadine.konz@unibas.ch

Akhouri Pramod Krishna  
Department of Remote Sensing  
Birla Institute of Technology (BIT)  
Deemed University  
P.O. Mesra  
Ranchi 835215, Jharkhand  
India  
apkrishna@ewca.eastwestcenter.org  
apkrishna@bitmesra.ac.in

Matthias Kuhle  
Department of Geography and High Mountain  
Geomorphology  
Geographical Institute  
University of Göttingen  
Goldschmidtstr. 5  
37077 Göttingen  
Germany  
mkuhle@gwdg.de

Amit Kumar  
Department of Geology  
Centre of Advanced Study in Geology  
Punjab University  
Sector-14  
Chandigarh 160014, Punjab  
India  
amithydrocoin@gmail.com  
amitwalia@wihg.res.in

Bhishm Kumar  
Hydrological Investigations Division  
National Institute of Hydrology  
Roorkee 247667, Uttarakhand  
India  
bk@nih.ernet.in  
bhishm\_nih@yahoo.co.in

Rajesh Kumar  
School of Engineering and Technology  
Sharda University  
32-34, Knowledge Park-III  
Greater Noida 201306, NCR  
India  
and  
Remote Sensing Division  
Birla Institute of Technology, Extension Centre Jaipur  
27, Malviya Industrial Area  
Jaipur 302017, Rajasthan  
India  
rajeshbhu@yahoo.com

Vijay Kumar  
National Institute of Hydrology  
Roorkee 247667, Uttarakhand  
India  
vijay@nih.ernet.in  
vk\_nih@yahoo.com

Christophe Lambiel  
Institute of Geography  
University of Lausanne  
Bâtiment Anthropole  
1015 Lausanne  
Switzerland  
christophe.lambiel@unil.ch

Wendy Lawson  
Department of Geography  
University of Canterbury  
Private Bag 4800  
Christchurch 8140  
New Zealand  
wendy.lawson@canterbury.ac.nz

Daniel J. Leathers  
Department of Geography  
University of Delaware  
Newark, DE 19716-2541  
USA  
leathers@udel.edu

Jean-Michel Lemieux  
Département de géologie et de génie géologique  
Université Laval  
1065 avenue de la Médecine  
Québec, QC G1V 0A6  
Canada  
jmlemieux@ggl.ulaval.ca

Eric M. Leonard  
Department of Geology  
Colorado College  
14E Cache la Poudre  
Colorado Springs, CO 80903  
USA  
eleonard@coloradocollege.edu

Matti Leppäranta  
Department of Physics  
University of Helsinki  
P.O. Box 64, (Gustaf Hällströmin katu 2a)  
00014 Helsinki  
Finland  
matti.lepparanta@helsinki.fi

Delphis F. Levia  
Department of Geography  
University of Delaware  
Newark, DE 19716-2541  
USA  
dlevia@udel.edu

Shunlin Liang  
Department of Geography  
University of Maryland  
2181 LeFrak Hall  
College Park, MD 20742  
USA  
sliang@umd.edu

Kenneth G. Libbrecht  
Department of Physics  
Caltech  
264-33 Caltech  
Pasadena, CA 91125  
USA  
kgl@caltech.edu

Ron Lindsay  
Polar Science Center  
Applied Physics Laboratory  
University of Washington  
1013 NE 40th Street  
Seattle, WA 98105-6698  
USA  
lindsay@apl.washington.edu

Glen E. Liston  
Cooperative Institute for Research in the Atmosphere  
Colorado State University  
1375 Campus Delivery  
Fort Collins, CO 80523-1375  
USA  
liston@cira.colostate.edu

Jingshi Liu  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
18 Shuangqing Rd.  
Haidian District, Beijing 100085  
China  
jsliu@itpcas.ac.cn

Yongqin Liu  
Laboratory of Tibetan Environment Changes and Land  
Surface Processes (TEL)  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
No. 18 Shuangqing Rd, P.O. Box 2871  
Haidian District, Beijing 100085  
China  
yqliu@itpcas.ac.cn

Christopher Lloyd  
Department of Geography  
University of Sheffield  
Sheffield S10 2TN  
UK  
ggp08ctl@sheffield.ac.uk

Rachel W. Lomonaco  
Thayer School of Engineering  
Dartmouth College  
Hanover, NH 03755  
USA

Reginald D. Lorrain  
Département des Sciences de la Terre et de  
l'Environnement  
Université Libre de Bruxelles  
Bruxelles  
Belgium  
rlorrain@ulb.ac.be

Mira Losic  
Department of Geography  
University of Calgary  
Earth Sciences 356, 2500 University Dr NW  
Calgary, AB T2N 1N4  
Canada  
mlosic@ucalgary.ca

Sven Lukas  
Department of Geography  
Queen Mary University of London  
Mile End Road  
London E1 4NS  
UK  
S.Lukas@qmul.ac.uk

Juha P. Lunkka  
Institute of Geosciences  
University of Oulu  
P.O. Box 3000  
90014 Oulu  
Finland  
juha.pekka.lunkka@oulu.fi

Kelly MacGregor  
Geology Department  
Macalester College  
1600 Grand Avenue  
Saint Paul, MN 55105  
USA  
macgregor@macalester.edu

William C. Mahaney  
Quaternary Surveys  
26 Thornhill Ave  
Thornhill, ON L4J 1J4  
Canada  
arkose@rogers.com  
bmahaney@yorku.ca

Shawn J. Marshall  
Department of Geography  
University of Calgary  
Earth Sciences 356, 2500 University Dr NW  
Calgary, AB T2N 1N4  
Canada  
shawn.marshall@ucalgary.ca

Richard A. Marston  
Department of Geography  
Kansas State University  
118 Seaton Hall  
Manhattan, KS 66506-2904  
USA  
Rmarston@ksu.edu  
Rmarston@k-state.edu

Christoph Marty  
WSL Institute for Snow and Avalanche Research SLF  
Flüelastr. 11  
7260 Davos  
Switzerland  
marty@slf.ch

Robert D. McCulloch  
School of Biological and Environmental Science  
University of Stirling  
Stirling FK9 4LA, Scotland  
UK  
robert.mcculloch@stir.ac.uk

Brian Menounos  
Geography Program and Natural Resources and  
Environmental Studies Institute  
University of Northern British Columbia  
3333 University Way  
Prince George, BC V2N 4Z9  
Canada

Justin R. Minder  
Department of Atmospheric Science  
University of Washington  
Box 351640  
Seattle, WA 98195-1640  
USA  
juminder@atmos.washington.edu

Debasmita Misra  
Department of Mining and Geological Engineering  
College of Engineering and Mines  
University of Alaska Fairbanks  
P.O. Box 755800  
Fairbanks, AK 99775-5800  
USA  
debu.misra@alaska.edu

Vanya I. Miteva  
Department of Biochemistry and Molecular Biology  
The Pennsylvania State University  
211 South Frear  
University Park, PA 16802  
USA  
vim1@psu.edu

Thomas Mölg  
Center for Climate & Cryosphere  
University of Innsbruck  
6020 Innsbruck  
Austria



Peter Molnar  
Institute of Environmental Engineering  
ETH Zurich  
8093 Zurich  
Switzerland  
molnar@ifu.baug.ethz.ch

Bruce F. Molnia  
U.S. Geological Survey  
562 National Center, 12201 Sunrise Valley Drive, 12201  
Reston, VA 20192  
USA  
bmolnia@usgs.gov

Brian Morse  
Department of Civil and Water Engineering  
Laval University  
1065, ave de la Médecine  
Quebec, QC G1V 0A6  
Canada

Nozomu Naito  
Department of Global Environment Studies  
Hiroshima Institute of Technology  
Miyake 2-1-1, Saeki-ku  
Hiroshima 731-5193  
Japan  
naito@cc.it-hiroshima.ac.jp

Jacob Napieralski  
Department of Natural Sciences  
University of Michigan-Dearborn  
Dearborn, MI 48128  
USA  
jnapiera@umd.umich.edu

Atle Nesje  
Department of Earth Science\Bjerknes Centre for  
Climate Research  
University of Bergen  
Allégaten 41  
5007 Bergen  
Norway  
atle.nesje@geo.uib.no

Thomas A. Neumann  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771  
USA  
thomas.neumann@nasa.gov

Peter W. Nienow  
School of Geosciences  
University of Edinburgh  
Drummond Street  
Edinburgh EH8 9XP  
UK  
pnienow@geo.ed.ac.uk

David C. Nobes  
Department of Geological Sciences  
University of Canterbury  
Private Bag 4800  
Christchurch 8140  
New Zealand  
david.nobes@canterbury.ac.nz

Rachel W. Obbard  
Thayer School of Engineering  
Dartmouth College  
Hanover, NH 03755  
USA  
Rachel.w.obbard@dartmouth.edu

Øyvind Paasche  
Bjerknes Centre for Climate Research  
University of Bergen  
Allégaten 55  
5007 Bergen  
Norway  
and  
Department of Research Management  
University of Bergen  
Professor Keyzers gt. 8  
5020 Bergen  
Norway  
oyvind.paasche@uni.no

Thomas H. Painter  
Jet Propulsion Laboratory/Caltech  
4800 Oak Grove Drive  
Pasadena, CA 91109  
USA  
Thomas.Painter@jpl.nasa.gov

Pratima Pandey  
Centre of Studies in Resources Engineering  
Indian Institute of Technology Bombay  
Powai, Mumbai 400076, Maharashtra  
India  
pratimapandey@iitb.ac.in

Himali Panthri  
Department of Geology  
D.B.S (P.G) College  
Dehradun 248001, Uttarakhand  
India  
himali.geo@gmail.co

Frank Paul  
Department of Geography  
University of Zurich  
Winterthurerstrasse 190  
8057 Zurich  
Switzerland  
frank.paul@geo.uzh.ch

Francesca Pellicciotti  
Institute of Environmental Engineering  
ETH Zurich  
8093 Zurich  
Switzerland  
francesca.pellicciotti@ifu.baug.ethz.ch

Mauri S. Pelto  
Department of Environmental Science  
Nichols College  
Dudley, MA 01571  
USA  
mauri.pelto@nichols.edu

Christine Pielmeier  
WSL Institute for Snow and Avalanche Research SLF  
Warning and Prevention  
Flüelastrasse 11  
7260 Davos Dorf  
Switzerland  
pielmeier@slf.ch

Jan A. Piotrowski  
Department of Earth Sciences  
University of Aarhus  
Høegh-Guldbergs Gade 2  
8000 Aarhus C  
Denmark  
and  
Department of Geography  
University of Sheffield  
Sheffield S10 2TN  
UK  
jan.piotrowski@geo.au.dk

Philip R. Porter  
Division of Geography and Environmental Sciences  
School of Life Sciences  
University of Hertfordshire  
Hatfield, Hertfordshire AL10 9AB  
UK  
p.r.porter@herts.ac.uk

George Postma  
Faculty of Geosciences  
EUROTANK Laboratories  
P.O. Box 80.021  
3508 TA Utrecht  
The Netherlands  
gpostma@geo.uu.nl

P. Pradeep Kumar  
Department of Atmospheric and Space Sciences  
Pune University  
Pune 411007, Maharashtra  
India  
ppk@physics.unipune.ac.in

Daniel J. Pringle  
Arctic Region Supercomputing Center and Geophysical  
Institute  
University of Alaska  
Fairbanks, AK 99775  
USA  
danielpringle75@gmail.com

John C. Prisco  
Department of Land Resources and Environmental  
Sciences  
Montana State University  
Bozeman, MT 59717  
USA  
jprisco@montana.edu

Duncan J. Quincey  
Institute of Geography and Earth Sciences  
Penglais Campus  
Aberystwyth University  
Aberystwyth, Wales SY23 3DB  
UK

Camilo Rada  
Centro de Estudios Científicos, CECS  
Arturo Prat 514  
Valdivia  
Chile

Y. S. Rao  
Centre of Studies in Resources Engineering  
Indian Institute of Technology  
Powai, Mumbai 400076  
India  
ysrao@iitb.ac.in

Donald Rapp  
Independent Contractor  
1445 Indiana Avenue  
South Pasadena, CA 91030  
USA  
drdrapp@earthlink.net

Rasik Ravindra  
National Centre for Antarctic and Ocean Research  
Headland Sada, Vasco-Da-Gama  
Goa 403804  
India  
rasik@ncaor.org

Netra R. Regmi  
Department of Geology and Geophysics  
Texas A&M University  
College Station, TX 77843-3115  
USA  
netraregmi@neo.tamu.edu

Helen E. Reid  
School of Environment  
The University of Auckland  
10 Symonds Street  
Private Bag 92019, Auckland 1142  
New Zealand  
h.reid@auckland.ac.nz

Alan W. Rempel  
Department of Geological Sciences  
University of Oregon  
Eugene, OR 97403-1272  
USA  
rempel@uoregon.edu

Jeffrey Ridley  
Met Office, Hadley Centre  
FitzRoy Road  
Exeter EX1 3PB  
UK

George A. Riggs  
SSAI  
10210 Greenbelt Road, Suite 600  
Lanham, MD 20706  
USA  
george.a.riggs@nasa.gov

Eric Rignot  
Department of Earth System Science  
University of California Irvine  
Irvine, CA 92697  
USA  
and  
Jet Propulsion Laboratory  
4800 Oak Grove Drive  
Pasadena, CA 91214  
USA  
erignot@uci.edu

Vincent Rinterknecht  
School of Geography and Geosciences  
University of St Andrews  
North Street  
St Andrews KY16 9AL, Scotland  
UK  
vr10@st-andrews.ac.uk

Daniel Riseborough  
Geological Survey of Canada  
601 Booth Street  
Ottawa, ON K1A 0E4  
Canada  
drisebor@nrcan.gc.ca

Andrés Rivera  
Centro de Estudios Científicos, CECS  
Arturo Prat 514  
Valdivia  
Chile  
and  
Universidad de Chile  
Marcoleta 250  
Santiago  
Chile  
and  
Centro de Ingeniería de la Innovación, CIN  
Arturo Prat 514  
Valdivia  
Chile  
arivera@cecs.cl

Gerard H. Roe  
Department of Atmospheric Science  
University of Washington  
Box 351640  
Seattle, WA 98195-1640  
USA  
and  
Department of Earth and Space Sciences  
University of Washington  
2206 N41 St  
Seattle, WA 98103  
USA  
gerard@ess.washington.edu

Neil Ross  
School of Geosciences  
University of Edinburgh  
Geography Building  
Drummond Street  
Edinburgh EH8 9XP  
UK  
neil.ross@ed.ac.uk

Anders Schomacker  
Institute of Earth Sciences  
University of Iceland  
Askja, Sturlugata 7  
101 Reykjavík  
Iceland  
and  
Department of Geology  
Norwegian University of Science and Technology  
7491 Trondheim  
Norway  
anders@hi.is

Bob E. Schutz  
Center for Space Research  
University of Texas at Austin  
Austin, TX 78759  
USA  
schutz@csr.utexas.edu

Annette Semádeni-Davies  
Department of Water Resources Engineering  
Lund University  
22100 Lund  
Sweden  
annette.davies@tvrl.lth.se

Hung Tao Shen  
Department of Civil and Environmental Engineering  
Clarkson University  
P.O. Box 5710  
Potsdam, NY 13699-5710  
USA  
htshen@clarkson.edu

Arun B. Shrestha  
International Centre for Integrated Mountain  
Development (ICIMOD)  
Khumaltar, Lalitpur, G.P.O. Box 3226  
Kathmandu  
Nepal  
abshrestha@icimod.org

John F. Shroder  
Department of Geography and Geology  
University of Nebraska at Omaha  
6001 Dodge Street  
Omaha, NE 68182  
USA  
jshroder@mail.unomaha.edu

Aparna Shukla  
Uttarakhand Space Application Centre  
Dehradun  
India  
aparna.shukla22@gmail.com

Yuri Shur  
Department of Civil and Environmental Engineering  
University of Alaska Fairbanks  
245 Duckering Building, P.O. Box 755900  
Fairbanks, AK 99775-59000  
USA  
yshur@alaska.edu

Martin J. Siegert  
School of GeoSciences  
University of Edinburgh  
Grant Institute  
West Mains Road  
Edinburgh EH9 3JW  
UK  
m.j.siegert@ed.ac.uk

Oddur Sigurðsson  
Veðurstofu Íslands  
Icelandic Meteorological Office  
Bústaðavegi 9  
150 Reykjavík  
Iceland  
oddur@vedur.is

A. K. Singh  
DIAT (Deemed University)  
Girinagar  
Pune 411025, Maharashtra  
India  
draksingh@hotmail.com  
aksingh@diat.ac.in

Gulab Singh  
Centre of Studies in Resources Engineering  
Indian Institute of Technology Bombay  
Powai  
Mumbai 400076, Maharashtra  
India  
gskaliar@iitb.ac.in

Pratap Singh  
Integrated Natural Resources Management (INRM)  
Consultants Pvt. Ltd  
An Incubatee Company of IIT Delhi  
New Delhi  
India  
and  
Hydro Tasmanier Consulting  
Nehru Place  
New Delhi 110019  
India  
pratap\_singh\_1@yahoo.com  
pratapsingh.iitd@gmail.com

Vijay P. Singh  
Department of Biological and Agricultural Engineering  
Texas A&M University  
Scoates Hall  
2117 TAMU  
College Station, TX 77843-2117  
USA  
vsingh@tamu.edu

Subhajit Sinha  
DBS College  
Dehradun, Uttarakhand  
India  
sinha\_subho@rediffmail.com

Claudio Smiraglia  
Department of Earth Sciences "A. Desio"  
University of Milano  
Via Mangiagalli 34  
20133 Milano  
Italy  
claudio.smiraglia@unimi.it

Andy M. Smith  
British Antarctic Survey, High Cross  
Madingley Road  
Cambridge CB3 0ET  
UK  
amsm@bas.ac.uk

Dan J. Smith  
University of Victoria Tree-Ring Laboratory  
Department of Geography  
University of Victoria  
Victoria, British Columbia V8W 3R4  
Canada

Sharon L. Smith  
Geological Survey of Canada  
Natural Resources Canada  
601 Booth Street  
Ottawa, ON K1A 0E8  
Canada  
Sharon.Smith@nrcan-rncan.gc.ca

Rudolph R. Stea  
Stea Surficial Geology Services  
851 Herring Cove Road  
Halifax, Nova Scotia B3R 1Z1  
Canada  
ralphstea@eastlink.ca

Chris R. Stokes  
Department of Geography  
Durham University  
Science Site, South Road  
Durham DH1 3LE  
UK  
c.r.stokes@durham.ac.uk

Tim Stott  
Physical Geography and Outdoor Education  
Liverpool John Moores University  
I. M. Marsh Campus, Barkhill Road  
Liverpool L17 6BD  
UK  
t.a.stott@ljmu.ac.uk

Edward A. Sudicky  
Department of Earth and Environmental Sciences  
University of Waterloo  
Waterloo, ON N2L 3G1  
Canada  
sudicky@sciborg.uwaterloo.ca

Kazuyoshi Suzuki  
Research Institute for Global Change  
Japan Agency for Marine-Earth Science and Technology  
3173-25 Showa-machi  
Yokohama 236-0001  
Japan  
skazu@jamstec.go.jp

Ryohei Suzuki  
Graduate School of Environmental Studies  
Nagoya University  
c/o Hydrospheric Atmospheric Research Center  
Furo-cho Chikusa-ku  
Nagoya 464-8601  
Japan  
cryosuzuki@nagoya-u.jp

Darrel A. Swift  
Department of Geography  
University of Sheffield  
Sheffield S10 2TN  
UK  
D.A.Swift@sheffield.ac.uk

Nozomu Takeuchi  
Department of Earth Sciences  
Graduate School of Science  
Chiba University  
1-33 Yayoicho, Inage-ku, Chiba-city  
Chiba 263-8522  
Japan  
ntakeuch@faculty.chiba-u.jp

Renoj J. Thayyen  
Western Himalayan Regional Centre  
National Institute of Hydrology  
Jammu (J&K) 180003  
India  
renojthayyen@gmail.com

Malte Thoma  
Bavarian Academy and Sciences, Commission for  
Glaciology  
Alfons-Goppel-Str. 11  
80539 Munich  
Germany  
and

Alfred Wegener Institute for Polar and Marine Research  
Bussestrasse 24  
27570 Bremerhaven  
Germany  
Malte.Thoma@awi.de

David N. Thomas  
School of Ocean Sciences, College of Natural Sciences  
Bangor University  
Menai Bridge, Anglesey LL59 5AB  
UK  
d.thomas@bangor.ac.uk

Anita M. Thompson  
Department of Biological Systems Engineering  
University of Wisconsin-Madison  
230 Ag. Eng. Building, 460 Henry Mall  
Madison, WI 53706  
USA  
amthompson2@wisc.edu

Thierry Toutin  
Canada Centre for Remote Sensing  
Natural Resources Canada  
Ottawa, ON K1A 0Y7  
Canada  
thierry.toutin@ccrs.nrcan.gc.ca

Martyn Tranter  
Bristol Glaciology Centre  
School of Geographical Sciences  
University of Bristol  
University Road  
Bristol BS8 1SS  
UK  
m.tranter@bristol.ac.uk

Donna F. Tucker  
Department of Geography  
University of Kansas  
1475 Jayhawk Blvd., Room 213  
Lawrence, KS 66045-7613  
USA  
dtucker@ku.edu

Hugh Tuffen  
Lancaster Environment Centre  
Lancaster University  
Lancaster LA1 4YQ  
UK  
h.tuffen@lancaster.ac.uk

Fiona Tweed  
Department of Geography  
Staffordshire University  
College Road  
Stoke-on-Trent, Staffordshire ST4 2DE  
UK  
f.s.tweed@staffs.ac.uk

Michiel Van den Broeke  
Institute for Marine and Atmospheric Research  
Utrecht University  
Princetonplein 5  
3584 CC Utrecht  
Netherlands  
m.r.vandenbroeke@uu.nl

C. J. van der Veen  
Department of Geography and  
Center for Remote Sensing of Ice Sheets  
University of Kansas  
203 Lindley Hall  
1475 Jayhawk Blvd  
Lawrence, KS 66045-7613  
USA  
cjdvdv@ku.edu

Veerle Vanacker  
TECLIM, Earth and Life Institute  
University of Louvain  
Place L. Pasteur, 3  
1348 Louvain-la-Neuve, BW  
Belgium  
veerle.vanacker@uclouvain.be

Dominic Vella  
Department of Applied Mathematics and Theoretical  
Physics  
Institute of Theoretical Geophysics  
University of Cambridge  
Wilberforce Road  
Cambridge CB3 0WA  
UK  
d.vella@damtp.cam.ac.uk

G. Venkataraman  
Centre of Studies of Resources Engineering  
Indian Institute of Technology Bombay  
Mumbai 400076  
India  
gv@iitb.ac.in

Ashok Kumar Verma  
Department of Geography and Environmental Studies  
Cold Regions Research Center  
Wilfrid Laurier University  
75 University Ave. West  
Waterloo, ON N2L 3C5  
Canada  
ashokpph@gmail.com  
verm3620@wlu.ca

Andreas Vieli  
Department of Geography  
Durham University  
Durham DH1 3LE  
UK  
Andreas.Vieli@durham.ac.uk

Timo Vihma  
Finnish Meteorological Institute  
Erik Palménin aukio 1, P.O. Box 503  
00101 Helsinki  
Finland  
timo.vihma@fmi.fi

John D. Vitek  
Department of Geology and Geophysics  
Texas A&M University  
College Station, TX 77843-3115  
USA  
jvitek@neo.tamu.edu

Mathias Vuille  
Department of Atmospheric and Environmental Sciences  
University at Albany  
State University of New York  
1400 Washington Avenue  
Albany, NY 12222  
USA  
mathias@atmos.albany.edu

John Wahr  
Department of Physics and CIRES  
University of Colorado  
Boulder, CO 80309-0390  
USA  
wahr@lemond.colorado.edu

Stephen J. Walsh  
Department of Geography  
University of North Carolina  
Chapel Hill, NC 27599-3220  
USA  
swalsh@email.unc.edu

Charles R. Warren  
School of Geography and Geosciences  
University of St. Andrews  
Irvine Building  
St. Andrews, Fife KY16 9AL, Scotland  
UK  
charles.warren@st-andrews.ac.uk

Daniel J. Weiss  
Department of Geography  
University of North Carolina  
Chapel Hill, NC 27599-3220  
USA

John Wettlaufer  
Yale University  
New Haven, CT 06520-8109  
USA  
john.wettlaufer@yale.edu

Roger Wheate  
Geography Program and Natural Resources and  
Environmental Studies Institute  
University of Northern British Columbia  
3333 University Way  
Prince George, BC V2N 4Z9  
Canada  
wheate@unbc.ca

Ian C. Willis  
Department of Geography  
Scott Polar Research Institute  
University of Cambridge  
Lensfield Road  
Cambridge CB2 1ER  
UK  
iw102@cam.ac.uk

John Woodward  
Division of Geography  
School of Applied Sciences  
Northumbria University  
Ellison Place  
Newcastle upon Tyne NE1 8ST  
UK  
john.woodward@unn.ac.uk

Cunde Xiao  
State Key Laboratory of Cryospheric Sciences  
Cold and Arid Regions Environmental and Engineering  
Research Institute, Chinese Academy of Sciences  
Lanzhou, Gansu 730000  
China  
cdxiao@ns.lzb.ac.cn  
cdxiao@cams.cma.gov.cn

Zhang Yanwei  
Xinjiang Institute of Ecology and Geography  
Chinese Academy of Sciences  
40-3 South Beijing Road  
Urumqi, Xinjiang 830011  
China

Tandong Yao  
Laboratory of Tibetan Environment Changes and Land  
Surface Processes (TEL)  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
No. 18 Shuangqing Rd, P.O. Box 2871  
Haidian District, Beijing 100085  
China  
tdyao@itpcas.ac.cn

Jacob C. Yde  
Center for Geomicrobiology  
University of Aarhus  
Ny Munkegade building 1540  
8000 Århus C  
Denmark  
and  
Bjerknes Centre for Climate Research  
University of Bergen  
Allégaten 55  
5007 Bergen  
Norway  
yde@phys.au.dk

Wusheng Yu  
Laboratory of Tibetan Environment Changes and Land  
Surface Processes (TEL)  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
No. 18 Shuangqing Rd, P.O. Box 2871  
Haidian District, Beijing 100085  
China

Tingjun Zhang  
National Snow and Ice Data Center  
Cooperative Institute for Research in Environmental  
Sciences  
University of Colorado at Boulder  
Boulder, CO 80309-0449  
USA  
tzhang@nsidc.org

Huabiao Zhao  
Laboratory of Tibetan Environment Changes and Land  
Surface Processes (TEL)  
Institute of Tibetan Plateau Research  
Chinese Academy of Sciences  
No. 18 Shuangqing Rd, P.O. Box 2871  
Haidian District, Beijing 100085  
China

H. J. Zwally  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771  
USA  
zwally@icesat2.gsfc.nasa.gov



## Preface

Snow, ice and glaciers (SIG) are the components constituting what is called cryosphere. They exist at all latitudes and contain the majority of the earth's fresh water. Due to their dominant prevalence, they influence weather, climate, ecosystems, vegetation, and life and human activities in a variety of ways. Indeed they shape human civilization. Owing to looming climate change and global warming, temperature changes now seem inevitable and are changing the landscape of snow, ice and glaciers, or even the existence thereof. In fact, the changes occurring in SIG can be construed as major indicators of climate change. The nature of cryosphere is highly interdisciplinary and calls for an updated interdisciplinary account of its dynamics. Recent decades have witnessed increasing attention to SIG and scientific communities have started working collectively to develop the basic foundation upon which the broad understanding of cryosphere rests. However, there is still a long way to go.

Discussions on climate change and global warming now seem to be occupying the center stage in public debates, professional forums, news media, and political dialog. As a result, the general public has become much more aware of what is happening to our climate. Since both climate change and climate variability have been found to be closely linked with the cryosphere, it is important for scientists and professionals in the field of earth, environmental, oceanic and atmospheric sciences to develop a better understanding of this sphere from conceptual, theoretical, technical and applied viewpoints. This is especially important for snow, ice and glacier covered areas, since they are rarely stable and are continuously changing in their thickness, areal extent, and flow speeds. Recent advances in field-based studies and quantitative and numerical modeling have provided answers to several key questions but have also highlighted the urgent need for cryospheric studies in many areas, for example, contribution of snow, ice and glacier melt to the sea level rise; importance of snow and glacier to water resources; and so on.

The objective of this Encyclopedia is to present the current state of scientific understanding of various aspects of earth's cryosphere – snow, glaciers, ice caps, ice sheets, ice shelves, sea ice, river and lake ice, and permafrost – and their related interdisciplinary connections under one umbrella. Therefore, every effort has been made to provide a comprehensive coverage of cryosphere by including a broad array of topics, such as the atmospheric processes responsible for snow formation; snowfall observations; snow cover and snow surveys; transformation of snow to ice and changes in their properties; classification of ice and glaciers and their worldwide distribution; glaciation and ice ages; glacier dynamics; glacier surface and subsurface characteristics; geomorphic processes and landscape formation; hydrology and sedimentary systems; hydrochemical and isotopic properties; permafrost modeling; hazards caused by cryospheric changes; trends of glacier retreat on a global scale along with the impact of climate change; and many more quantitative estimates of various glacier parameters, such as degree-day, mass balance, extent and volume, and downwasting. Also included are articles on GPS application, and satellite image application in glaciology; GPR analysis; and sea level rise.

For purposes of the Encyclopedia 463 articles were selected. Literature on snow, ice and glaciers has grown too large to be fully treated in a single volume; therefore, the selection of articles included some subjectivity but was reviewed by many experts who have long been at the forefront of research in the field of cryosphere. We truly understand that given the scope of this subject it is almost impossible to include each and every topic in this type of reference book, but we have tried our best to avoid any glaring omissions or miss something which could significantly hamper the quality of the Encyclopedia. Therefore, we have made the contents of the Encyclopedia exhaustive, but we understand that we might have missed certain topics. We are also aware of some partial omissions. As it frequently happens, willing contributors

cannot unfortunately be always found for all the suggested topics. It may be noted that if the reader does not see an entry for the particular topic that interests him or her, then he or she should look in the index because that topic may have been covered under a different heading and perhaps in more than one article. In making the list exhaustive, it is possible that there might be a little bit of repetition here and there, but we do not want readers to read two articles to understand one.

The material presented in the articles consists of established information on a particular topic and represents easily accessible digested knowledge. The level of material is such that a graduate student can benefit from the presentation which is not necessarily from his or her area of expertise. An effort has been made such that each article stands on its own, without an assumption that a reader will be seeing any other portion of the Encyclopedia. Although entries are presented in alphabetical order, they have been organized under major compilation headings which should become particularly obvious when the reader uses the cross-references with each entry. This is not an exhaustive list but hopefully it gives a structure to the Encyclopedia's contents. Of equal value are the many references given with the entries.

This *Encyclopedia of Snow, Ice and Glaciers* is supposed to provide clear explanations of current topics, and is not structured as a student textbook, but it is rather for quick access to particular terms and concepts in self-contained entries. We hope that this volume will also tempt the casual reader to browse through and become curious about the different facets and foci of cryosphere.

The contributors represent varying backgrounds and many of them represent WHO'S WHO in the cryosphere. It is hoped that the Encyclopedia will serve as a reference to scholars and students. The Encyclopedia will also be a valuable resource for geologists, geographers, climatologists, hydrologists, and water resources engineers; as well as to those who are engaged in the practice of agricultural and civil engineering, earth sciences, environmental sciences and engineering, ecosystems management, and other relevant fields.

The encyclopedia is comprised of articles under three categories: A, B, and C. Tables 1, 2 and 3 provide a list of major headings of articles included in the encyclopedia for a quick reference (see List of Articles, pages 1233–1237). 64 articles in category A represent major divisions and review topics. These also serve to coordinate the widely scattered entries of categories B and C. 182 Category B articles constitute building block items, inspired by textbook subheads, but also the cookbook items. 217 articles in category C are mini-entries dealing with materials, fancy terms, or outdated concepts. All these categorical entries on different topics are compiled in an alphabetical order, with their length being related to their relative importance.

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Vijay P. Singh  
Pratap Singh  
Umesh K. Haritashya  
(Editors-in-Chief)

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Richard Armstrong, NSIDC, Boulder, Colorado, USA;  
Michael P. Bishop, University of Nebraska-Omaha, USA;  
Helgi Björnsson, Institute of Earth Sciences, Iceland;  
Wilfried Haerberli, WGMS, University of Zurich, Iceland;  
Johannes Oerlemans, University of Utrecht, Netherlands;  
John F. Shroder, University of Nebraska-Omaha, USA;  
Martyn Tranter, University of Bristol, UK;

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## Guide to the Reader

For the beginners, it is good to start with a general article, then track the list of cross-references provided at the end of the article to locate similar or relevant articles. For example, if one wants to learn about hydrological aspects of snow and glaciers, then one should go to Glacier Hydrology and Snow Hydrology, then Melt Runoff Modeling, then Impacts of Snow and Glaciers on Runoff, then Hydrochemical Characteristics of Snow, Ice and Glaciers, then Hydropower: Hydroelectric Power Generation from Alpine Glacier Melt, or several other specific Snow or Glacier Hydrology related articles. The list of cross-references provided at the end of the article is not exhaustive, otherwise it would lead to a long listing, rather it is a guide for the reader to find other relevant articles, which are further cross-referenced.

Experts or other readers with background in cryosphere may directly search for specific topics. For example, Ice Age Cycles: Data, Models, and Uncertainties, or Basal Sediment Evacuation by Subglacial Drainage Systems. If one does not find the topic one is looking for, it is possible that it may have been covered under a different heading. Therefore, one should go to the index that would lead to the articles that may cover the topic of interest. If a reader is looking for more explanation than what is already described under any particular topic, then most articles provide important and landmark bibliographic references that relate to both general and research articles. Some articles provide older references which allow readers to find the historical aspect of the topic.

