# **ANNALS** *of* the New York Academy of sciences

### SPECIAL ISSUE

## Advancing Tools and Methods for Flexible Adaptation Pathways and Science Policy Integration

New York City Panel on Climate Change 2019 Report



#### TABLE OF CONTENTS

- 5 NPCC 2019 Contributors and Reviewers
- 8 Acknowledgments
- 9 Disclaimers
- **10** Foreword Bill de Blasio

### **Original Articles**

- 11 New York City Panel on Climate Change 2019 Report Executive Summary
- **22** New York City Panel on Climate Change 2019 Report Chapter 1: Introduction *Cynthia Rosenzweig and William Solecki*
- **30** New York City Panel on Climate Change 2019 Report Chapter 2: New Methods for Assessing Extreme Temperatures, Heavy Downpours, and Drought *Jorge E. González, Luis Ortiz, Brianne K. Smith, Naresh Devineni, Brian Colle, James F. Booth, Arun Ravindranath, Luis Rivera, Radley Horton, Katie Towey, Yochanan Kushnir, Danielle Manley, Daniel Bader, and Cynthia Rosenzweig*
- **71** New York City Panel on Climate Change 2019 Report Chapter 3: Sea Level Rise *Vivien Gornitz, Michael Oppenheimer, Robert Kopp, Philip Orton, Maya Buchanan, Ning Lin, Radley Horton, and Daniel Bader*
- **95** New York City Panel on Climate Change 2019 Report Chapter 4: Coastal Flooding

Philip Orton, Ning Lin, Vivien Gornitz, Brian Colle, James Booth, Kairui Feng, Maya Buchanan, Michael Oppenheimer, and Lesley Patrick

1749652, 2019, 1, Downloaded from https://nyasputs.onlinelibrary.wiley.com/doi/10.1111/nyas.13889 by Test, Wiley Online Library on [31/10/2022]. See the Terms and Conditions (https://nlinelibrary.wiley.com/tem-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons LICENSE

EDITOR-IN-CHIEF Douglas Braaten

SENIOR SCIENTIFIC EDITORS Patrick C.H. Lo Anar Murphy

SENIOR EDITOR Steven E. Bohall

DESIGN Ash Ayman Shairzay

The New York Academy of Sciences 7 World Trade Center 250 Greenwich Street, 40th Floor New York, NY 10007-2157 annals@nyas.org www.nyas.org/annals

THE NEW YORK ACADEMY OF SCIENCES BOARD OF GOVERNORS SEPTEMBER 2018 - SEPTEMBER 2019

CHAIR Paul Horn

VICE-CHAIR Thomas Pompidou

PRESIDENT Ellis Rubinstein [ex officio]

SECRETARY Larry Smith [ex officio]

CHAIRS EMERITI John E. Sexton Torsten N. Wiesel Nancy L. Zimpher

HONORARY LIFE GOVERNORS Karen E. Burke John F. Niblack

GOVERNORS Sian Beilock Ellen de Brabander Jacqueline Corbelli Mikael Dolsten MaryEllen Elia Elaine Fuchs Beth Jacobs John E. Kelly III Seema Kumar Pablo Legorreta David K.A. Mordecai Gregory A. Petsko Lowell Robinson Kathe A. Sackler Mortimer D.A. Sackler Peter Thorén Grace Wang Michael Zigman

INTERNATIONAL GOVERNORS Seth F. Berkley Stefan Catsicas Gerald Chan Alice P. Gast S. "Kris" Gopalakrishnan Toni Hoover Johan Rockström Paul Stoffels Annals of the New York Academy of Sciences (ISSN: 0077-8923 [print]; ISSN: 1749-6632 [online]) is published semi-monthly on behalf of the New York Academy of Sciences by Wiley Subscription Services, Inc., a Wiley Company, 111 River Street, Hoboken, NJ 07030-5774.

Mailing: Annals of the New York Academy of Sciences is mailed standard rate.

Postmaster: Send all address changes to ANNALS OF THE NEW YORK ACADEMY OF SCIENCES, John Wiley & Sons Inc., C/O The Sheridan Press, PO Box 465, Hanover, PA 17331.

Disclaimer: The publisher, the New York Academy of Sciences, and the editors cannot be held responsible for errors or any consequences arising from the use of information contained in this publication; the views and opinions expressed do not necessarily reflect those of the publisher, the New York Academy of Sciences, and editors, neither does the publication of advertisements constitute any endorsement by the publisher, the New York Academy of Sciences and editors of the products advertised.

**Copyright and Copying:** Copyright© 2019. The New York Academy of Sciences. All rights reserved. No part of this publication may be reproduced, stored, or transmitted in any form or by any means without the prior permission in writing from the copyright holder. Authorization to copy items for internal and personal use is granted by the copyright holder for libraries and other users registered with their local Reproduction Rights Organization (RRO), e.g. Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923, USA (www.copyright.com), provided the appropriate fee is paid directly to the RRO. This consent does not extend to other kinds of copying such as copying for general distribution, for advertising or promotional purposes, for republication, for creating new collective works, or for resale. Permissions for such reuse can be obtained using the RightsLink "Request Permissions" link on Wiley Online Library. Special requests should be addressed to: permissions@wiley.com.

Publisher: Annals of the New York Academy of Sciences is published by Wiley Periodicals, Inc., 101 Station Landing, Suite 300, Medford, MA 02155; Telephone: 781 388 8200; Fax: 781 388 8210.

Journal Customer Services: For ordering information, claims, and any inquiry concerning your subscription, please go to https://hub.wiley.com/community/support/onlinelibrary or contact your nearest office. *Americas*: Email: cs-journals@wiley.com; Tel:+1781 388 8598 or 1 800 835 6770 (Toll free in the USA & Canada). *Europe, Middle East, Asia*: Email: cs-journals@wiley.com; Tel:+46 (0) 1865 778315. *Asia Pacific*: Email: cs-journals@wiley.com; Tel:+65 6511 8000. *Japan*: For Japanese speaking support, Email: cs-japan@wiley.com; Tel:+65 6511 8010 or Tel (toll-free): 005 316 50 480. Visit our Online Customer Help available in 7 languages at https://hub.wiley.com/community/ support/onlinelibrary.

Information for Subscribers: Annals of the New York Academy of Sciences is published in 24 volumes per year. Subscription prices for 2019 are: Print & Online: US\$9,380 (US), US\$10,214 (Rest of World), 66,619 (Europe), 25,216 (UK). Prices are exclusive of tax. Australian GST, Canadian GST, and European VAT will be applied at the appropriate rates. For more information on current tax rates, please go to https://onlinelibrary.wiley.com/library-info/products/ price-lists/payment. The price includes online access to the current and all online back files to January 1, 2015, where available. For other pricing options, including access information and terms and conditions, please visit https://onlinelibrary.wiley.com/library-info/products/price-lists.

Terms of use can be found here: https://onlinelibrary.wiley.com/terms-and-conditions.

Delivery Terms and Legal Title: Where the subscription price includes print volumes and delivery is to the recipient's address, delivery terms are Delivered at Place (DAP); the recipient is responsible for paying any import duty or taxes. Title to all volumes transfers Free of Board (FOB) our shipping point, freight prepaid. We will endeavour to fulfill claims for missing or damaged copies within six months of publication, within our reasonable discretion and subject to availability.

Back issues: Recent single volumes are available to institutions at the current single volume price from cs-journals@wiley.com. Earlier volumes may be obtained from Periodicals Service Company, 351 Fairview Avenue - Ste 300, Hudson, NY 12534, USA. Tel: +1 518 822 9300, Fax: +1 518 822 9305, Email: psc@periodicals.com.

For submission instructions, subscription, and all other information visit: www.wileyonlinelibrary.com/journal/nyas.

Production Editor: Lia Zarganas (email: nyas@wiley.com).

Commercial Reprints: Dan Nicholas (email: dnicholas@wiley.com).

Membership information: Members may order copies of *Annals* volumes directly from the Academy by visiting www.nyas.org/annals, emailing customerservice@nyas.org, faxing +1 212 298 3650, or calling 1 800 843 6927 (toll free in the USA), or +1 212 298 8640. For more information on becoming a member of the New York Academy of Sciences, please visit www.nyas.org/membership. Claims and inquiries on member orders should be directed to the Academy at email: membership@nyas.org or Tel: 1 800 843 6927 (toll free in the USA) or +1 212 298 8640.

Printed in the USA by The Sheridan Group.

View Annals online at www.wileyonlinelibrary.com/journal/nyas.

Abstracting and Indexing Services: Annals of the New York Academy of Sciences is indexed by MEDLINE, Science Citation Index, and SCOPUS. For a complete list of A&I services, please visit the journal homepage at www.wileyonlinelibrary.com/journal/nyas.

Access to *Annals* is available free online within institutions in the developing world through the AGORA initiative with the FAO, the HINARI initiative with the WHO, the OARE initiative with UNEP, and the ARDI initiative with WIPO. For information, visit www.aginternetwork.org, www.who.int/hinari/en, www.oarescience.org, www.wipo.org/int/ardi/edn.

Annals of the New York Academy of Sciences accepts articles for Open Access publication. Please visit https://authorservices.wiley.com/author-resources/Journal-Authors/open-access/onlineopen.htm for further information about OnlineOpen.

Wiley's Corporate Citizenship initiative seeks to address the environmental, social, economic, and ethical challenges faced in our business and which are important to our diverse stakeholder groups. Since launching the initiative, we have focused on sharing our content with those in need, enhancing community philanthropy, reducing our carbon impact, creating global guidelines and best practices for paper use, establishing a vendor code of ethics, and engaging our colleagues and other stakeholders in our efforts. Follow our progress at www.wiley.com/go/citizenship.

New York City Panel on Climate Change 2019 Report Chapter 5: Mapping 115 Climate Risk Lesley Patrick, William Solecki, Vivien Gornitz, Philip Orton, and Alan Blumberg 126 New York City Panel on Climate Change 2019 Report Chapter 6: Community-Based Assessments of Adaptation and Equity Sheila Foster, Robin Leichenko, Khai Hoan Nguyen, Reginald Blake, Howard Kunreuther, Malgosia Madajewicz, Elisaveta P. Petkova, Rae Zimmerman, Cecil Corbin-Mark, Elizabeth Yeampierre, Angela Tovar, Cynthia Herrera, and Daron Ravenborg New York City Panel on Climate Change 2019 Report Chapter 7: Resilience 174 Strategies for Critical Infrastructures and Their Interdependencies Rae Zimmerman, Sheila Foster, Jorge E. González, Klaus Jacob, Howard Kunreuther, Elisaveta P. Petkova, and Ernest Tollerson 230 New York City Panel on Climate Change 2019 Report Chapter 8: Indicators and Monitoring Reginald Blake, Klaus Jacob, Gary Yohe, Rae Zimmerman, Danielle Manley, William Solecki, and Cynthia Rosenzweig New York City Panel on Climate Change 2019 Report Chapter 9: Perspectives on 280 a City in a Changing Climate 2008–2018 William Solecki and Cynthia Rosenzweig 306 New York City Panel on Climate Change 2019 Report: Conclusions and Recommendations

The New York Academy of Sciences believes it has a responsibility to provide an open forum for discussion of scientific questions. The positions taken by the authors and editors of *Annals of the New York Academy of Sciences* are their own and not necessarily those of the Academy unless specifically stated. The Academy has no intent to influence legislation by providing such forums.