

# STATE OF THE CLIMATE IN 2010

J. Blunden, D. S. Arndt, and M. O. Baringer, Eds.

Associate Eds. H. J. Diamond, A. J. Dolman, R. L. Fogt, B. D. Hall, M. Jeffries, J. M. Levy,  
J. Richter-Menge, J. M. Renwick, P.W. Thorne, L.A. Vincent, and K. M. Willett,



**Special Supplement to the  
*Bulletin of the American Meteorological Society*  
Vol. 92, No. 6, June 2011**





# STATE OF THE CLIMATE IN 2010

## HOW TO CITE THIS DOCUMENT

---

Citing the complete report:

Blunden, J., D. S. Arndt, and M. O. Baringer, Eds., 2010: State of the Climate in 2010. *Bull. Amer. Meteor. Soc.*, **92** (6), S1–S266.

Citing a chapter (example):

Fogt, R. L., Ed., 2010: Antarctica [in “State of the Climate in 2010”]. *Bull. Amer. Meteor. Soc.*, **92** (6), S161–S171.

Citing a section (example):

Wovrosh, A. J., S. Barreira, and R. L. Fogt, 2010: [Antarctica] Circulation [in “State of the Climate in 2010”]. *Bull. Amer. Meteor. Soc.*, **92** (6), S161–S163.

## EDITOR & AUTHOR AFFILIATIONS (ALPHABETICAL BY NAME)

- Achberger, Christine**, Earth Sciences Centre, University of Gothenburg, Gothenburg, Sweden
- Ackerman, Steven A.**, CIMSS University of Wisconsin - Madison, Madison, Wisconsin
- Ahlström, A.**, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
- Alfaro, Eric J.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica
- Allan, Robert J.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom
- Alves, Lincoln**, CPTEC/Instituto Nacional de Pesquisas Espaciais (INPE), São Paulo, Brazil
- Amador, Jorge A.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica
- Amelie, Vincent**, Seychelles Meteorological Services, Seychelles
- Andrianjafinirina, Solonomenjanahary**, Direction Générale de la Météorologie Madagascar
- Antonov, John**, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland, and UCAR Joint Office for Science Support, Boulder, Colorado
- Arndt, Derek S.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Ashik, Igor**, Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Atheru, Zachary**, IGAD Climate Prediction and Applications Centre, Nairobi, Kenya
- Attaher, Samar M.**, Agricultural Research Center, MALR, Cairo, Egypt
- Baez, Julian**, DMH-DINAC/CTA-UCA, Asunción, Paraguay
- Banzon, Viva**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Baringer, Molly O.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Barreira, Sandra**, Argentine Naval Hydrographic Service, Buenos Aires, Argentina
- Barriopedro, David**, Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal
- Barthia, Pawan K.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Beal, Lisa M.**, Division of Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida
- Becker, Andreas**, Global Precipitation Climatology Centre, Deutscher Wetterdienst, Offenbach am Main, Germany
- Behrenfeld, Michael J.**, Oregon State University, Corvallis, Oregon
- Bell, Gerald D.**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Belward, Alan S.**, Global Environment Monitoring Unit, IES, EC Joint Research Centre, Ispra, Italy
- Benedetti, Angela**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Berrisford, Paul**, NCAS-Climate, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Berry, David I.**, National Oceanography Centre, Southampton, United Kingdom
- Beszczyńska-Moeller, Agnieszka**, Alfred Wegener Institute, Bremerhaven, Germany
- Bhatt, Uma S.**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Bidegain, Mario**, Unidad de Ciencias de la Atmósfera, Facultad de Ciencias, Universidad de la República, Uruguay
- Bindoff, Nathaniel L.**, Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research; and Institute for Marine and Antarctic Studies, University of Tasmania; and Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania, Australia
- Bissolli, Peter**, Deutscher Wetterdienst (German Meteorological Service, DWD), Offenbach, Germany, and WMO RA VI Regional Climate Centre on Climate Monitoring, Offenbach, Germany
- Blake, Eric S.**, NOAA/NWS National Hurricane Center, Miami, Florida
- Blunden, Jessica**, STG Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Booneeady, Prithviraj**, Mauritius Meteorological Services, Vacoas, Mauritius
- Bosilovich, Michael G.**, Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Boudet, Dagne R.**, Institute of Meteorology of Cuba, Habana, Cuba
- Box, Jason E.**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio
- Boyer, Timothy P.**, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland
- Bromwich, David H.**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio
- Brown, Ross**, Climate Research Division, Environment Canada, Montréal, Canada
- Bryden, Harry L.**, National Oceanography Centre, Southampton, United Kingdom
- Bulygina, Olga N.**, Russian Institute for Hydrometeorological Information, Obninsk, Russia
- Burrows, John**, University of Bremen, Bremen, Germany
- Butler, J.**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado

- Cais, Philippe**, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA-CNR-UVSQ, Gif-sur-Yvette, France
- Calderon, Blanca**, Center for Geophysical Research, University of Costa Rica, San Jose, Costa Rica
- Callaghan, T. V.**, Royal Swedish Academy of Sciences, Abisko Naturvetenskapliga Station, Abisko, Sweden
- Camargo, Suzana J.**, Lamont-Doherty Earth Observatory, The Earth Institute at Columbia University, Palisades, New York
- Cappelen, John**, Danish Meteorological Institute, Copenhagen, Denmark
- Carmack, Eddy**, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, Canada
- Chambers, Don P.**, University of South Florida, St. Petersburg, Florida
- Chelliah, Muthuvel**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Chidichimo, Maria P.**, Max-Planck-Institut für Meteorologie, Hamburg, Germany
- Christiansen, H.**, University Centre in Svalbard, Longyearbyen, Norway
- Christy, John**, University of Alabama, Huntsville, Alabama
- Coelho, Caio A. S.**, CPTEC/INPE, Center for Weather Forecasts and Climate Studies, Cachoeira Paulista, Brazil
- Colwell, Steve**, British Antarctic Survey, Cambridge, United Kingdom
- Comiso, Josefino C.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Compo, Gilbert P.**, CIRES Climate Diagnostics Center, University of Colorado, and NOAA/Earth System Research Laboratory, Boulder, Colorado
- Crouch, Jake**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Cunningham, Stuart A.**, National Oceanography Centre, Southampton, United Kingdom
- Cutié, Virgen C.**, Institute of Meteorology of Cuba, Habana, Cuba
- Dai, Aiguo**, Earth Observation Laboratory, NCAR, Boulder, Colorado
- Davydova-Belitskaya, Valentina**, Department of Environmental Sciences, CUCBA, University of Guadalajara, Mexico
- de Jeu, Richard**, Faculty of Earth and Life Sciences, Department of Hydrology and Geo-Environmental Sciences, VU University, Amsterdam, the Netherlands
- Decker, David**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio
- Dee, Dick**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Demircan, M.**, Turkish State Meteorological Service, Kalaba, Ankara, Turkey
- Derksen, Chris**, Climate Research Division, Environment Canada, Downsview, Canada
- Diamond, Howard J.**, NOAA/NESDIS National Climatic Data Center, Silver Spring, Maryland
- Dlugokencky, Ed J.**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Dohan, Kathleen**, Earth and Space Research, Seattle, Washington
- Dolman, A. Johannes**, Department of Earth Sciences, Faculty of Earth and Life Science, VU University Amsterdam, the Netherlands
- Dorigo, Wouter**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Vienna, Austria
- Drozdo, Dmitry S.**, Earth Cryosphere Institute, Tumen, Russia
- Durack, Paul J.**, Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research; and Institute for Marine and Antarctic Studies, University of Tasmania; and Wealth from Oceans National Research Flagship, CSIRO, Hobart, Tasmania, Australia
- Dutton, Geoffrey S.**, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado
- Easterling, David**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Ebita, Ayataka**, Japan Meteorological Agency (JMA), Tokyo, Japan
- Eischeid, Jon**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Elkins, James W.**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Epstein, Howard E.**, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia
- Euscátegui, Christian**, Instituto de Hidrología de Meteorología y Estudios Ambientales de Colombia (IDEAM), Colombia
- Faijka-Williams, Eleanor**, National Oceanography Centre, Southampton, United Kingdom
- Famiglietti, James S.**, UC Center for Hydrologic Modeling Earth System Science, Civil and Environmental Engineering, University of California, Irvine, California
- Faniriantsoa, Rija**, Direction Générale de la Météorologie Madagascar
- Feely, Richard A.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Fekete, Balázs M.**, CUNY Environmental CrossRoads Initiative, NOAA-CREST Center, The City College of New York City, University of New York, New York, New York

- Fenimore, Chris**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Fettweis, Xavier**, Department of Geography, University of Liège, Liège, Belgium, and Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, the Netherlands
- Fields, Eric**, University of California at Santa Barbara, Santa Barbara, California
- Fioletov, Vitali E.**, Environment Canada, Toronto, Canada
- Fogarty, Chris T.**, Environment Canada, Dartmouth, Canada
- Fogt, Ryan L.**, Department of Geography, Ohio University, Athens, Ohio
- Forbes, B. C.**, Arctic Centre, University of Lapland, Rovaniemi, Finland
- Foster, Michael J.**, CIMSS University of Wisconsin Madison, Madison, Wisconsin
- Frajka-Williams, E.**, Ocean Observing and Climate Research Group, National Oceanography Centre, Southampton, United Kingdom
- Free, Melissa**, NOAA/OAR Air Resources Laboratory, Silver Spring, Maryland
- Frolov, Ivan**, Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Ganesan, A. L.**, Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, Massachusetts
- Ganter, Catherine**, Bureau of Meteorology, Melbourne, Australia
- Gibney, Ethan J.**, IMSG, Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Gill, Stephen**, NOAA/NOS Center for Operational Oceanographic Products and Services, Silver Spring, Maryland
- Gill, M.**, Environment Canada, Whitehorse, Canada
- Gitau, Wilson**, Department of Meteorology, University of Nairobi, Kenya
- Gleason, Karin L.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Gobron, Nadine**, Global Environment Monitoring Unit, IES, EC Joint Research Centre, Ispra, Italy
- Goldenberg, Stanley B.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Goni, Gustavo J.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- González, Idelmis G.**, Institute of Meteorology of Cuba, Habana, Cuba
- Good, Simon A.**, UK Met Office Hadley Centre, Exeter, United Kingdom
- Gottschalk, Jonathan**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Gould, William A.**, USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico
- Gouveia, Celia M.**, Centro de Geofísica da Universidade de Lisboa, Lisbon Portugal
- Griffiths, Georgina M.**, NIWA, Auckland, New Zealand
- Guard, Chip**, Weather Forecast Office, Guam
- Guevara, Vladimir V.**, Institute of Meteorology of Cuba, Habana, Cuba
- Haas, C.**, Earth Observation System Laboratory, University of Alberta, Edmonton, Canada
- Hall, Bradley D.**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Halpert, Michael S.**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Heidinger, Andrew K.**, NOAA/NESDIS University of Wisconsin Madison, Madison, Wisconsin
- Heil, A.**, ICG-2, Forschungszentrum Jülich, Jülich, Germany
- Heim, Richard R., Jr.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Hennon, Paula A.**, STG, Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Henry, Greg H. R.**, Geography Department, University of British Columbia, Vancouver, Canada
- Hidalgo, Hugo G.**, Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica
- Hilburn, Kyle**, Remote Sensing Systems, Santa Rosa, California
- Hirschi, Joël J-M.**, National Oceanography Centre, Southampton, United Kingdom
- Ho, Shu-peng (Ben)**, NCAR COSMIC, Boulder, Colorado
- Hobgood, Jay S.**, The Ohio State University, Columbus, Ohio
- Hoerling, Martin**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Holgate, Simon**, National Oceanography Centre, Liverpool, United Kingdom
- Hook, Simon J.**, Jet Propulsion Laboratory, Pasadena, California
- Hugony, Sebastien**, Météo-France, French Polynesia
- Hurst, D.**, Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder/NOAA, Boulder, Colorado
- Ishihara, Hiroshi**, Japan Meteorological Agency, Tokyo, Japan
- Itoh, M.**, Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan
- Jaimes, Ena**, Servicio Nacional de Meteorología e Hidrología de Perú (SENAMHI), Perú
- Jeffries, Martin**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Jia, Gensu J.**, RCE-TEA, Chinese Academy of Sciences, Institute for Atmospheric Physics, Beijing, China

- Jin, Xiangze**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Johns, William E.**, Division of Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida
- Johnson, Bryan**, NOAA/OAR Earth System Research Laboratory, and University of Colorado, Boulder, Colorado
- Johnson, Gregory C.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Jones, Philip D.**, Climatic Research Unit, University of East Anglia, Norwich, United Kingdom
- Jumaux, Guillaume**, Météo-France, Réunion
- Kabidi, Khadija**, Direction de la Météorologie Nationale, Rabat, Morocco
- Kaiser, Johannes W.**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Kanzow, Torsten O.**, IFM-GEOMAR, Kiel, Germany
- Kaplan, Alexey**, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York
- Kearns, Edward J.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Keller, Linda M.**, Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, Madison, Wisconsin
- Kennedy, John J.**, Met Office, Exeter, Devon, United Kingdom
- Khatiwala, Samar**, Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
- Kholodov, Alexander**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Khoshkam, Mahbobeh**, Islamic Republic of Iranian Meteorological Organization (IRIMO), Tehran, Iran
- Kikuchi, T.**, Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan
- Kimberlain, Todd B.**, NOAA/NWS National Hurricane Center, Miami, Florida
- Knaff, John A.**, NOAA/NESDIS Center for Satellite Applications and Research, Fort Collins, Colorado
- Kobayashi, Shinya**, Japan Meteorological Agency (JMA), Tokyo, Japan
- Kokelj, Steve V.**, Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, Canada
- Korshunova, Natalia N.**, All-Russian Research Institute of Hydrometeorological Information – World Data Center, Obninsk, Russia
- Kratz, David P.**, NASA Langley Research Center, Hampton, Virginia
- Krishfield, Richard**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Kruger, Andries**, South African Weather Service, Pretoria, South Africa
- Kruk, Michael C.**, STG, Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Kumar, Arun**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Lammers, Richard B.**, University of New Hampshire, Durham, New Hampshire
- Lander, Mark A.**, University of Guam, Mangilao, Guam
- Landsea, Chris W.**, NOAA/NWS National Hurricane Center, Miami, Florida
- Lantuit, Hugues**, International Permafrost Association Secretariat, Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany
- Lantz, Trevor C.**, University of Victoria, British Columbia, Canada
- Lapinel, Braulio P.**, Institute of Meteorology of Cuba, Habana, Cuba
- Lareef, Zubair**, International Research Institute for Climate and Society, Palisades, New York
- Lazzara, Matthew A.**, Space Science and Engineering Center, University of Wisconsin-Madison, Madison, Wisconsin
- León, Antonia L.**, Institute of Meteorology of Cuba, Habana, Cuba
- León, Gloria**, Instituto de Hidrología de Meteorología y Estudios Ambientales de Colombia (IDEAM), Colombia
- Leuliette, Eric**, NOAA/NESDIS Laboratory for Satellite Altimetry, Silver Spring, Maryland
- Levitus, Sydney**, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland
- Levy, Joel M.**, NOAA/OAR Climate Program Office, Silver Spring, Maryland
- L'Heureux, Michelle**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Lin, I-I**, Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan
- Liu, Hongxing**, Department of Geography, University of Cincinnati, Cincinnati, Ohio
- Liu, Yanju**, Beijing Climate Center, China Meteorological Administration, Beijing, China
- Liu, Yi**, School of Civil and Environmental Engineering, University of New South Wales, Sydney, Australia
- Loeb, Norman G.**, NASA Langley Research Center, Hampton, Virginia
- Long, Craig S.**, NOAA/NWS National Centers for Environmental Prediction, Camp Springs, Maryland
- Lorrey, Andrew M.**, National Institute of Water and Atmospheric Research, Ltd., Auckland, New Zealand
- Lumpkin, Rick**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Luo, Jing-jia**, Research Institute for Global Change, JAMSTEC, Yokohama, Japan



- Lyman, John M.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington; and Joint Institute for Marine and Atmospheric Research, University of Hawaii, Honolulu, Hawaii
- Macdonald, Alison M.**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Maddux, Brent C.**, AOS/CIMSS University of Wisconsin Madison, Madison, Wisconsin
- Maier, Frank**, Laboratory for Climatology and Remote Sensing (LCRS), Department of Geography, University of Marburg, Germany
- Malkova, Galina**, Earth Cryosphere Institute, Tumen, Russia
- Marchenko, Sergey**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Marengo, Jose A.**, CCST/INPE, São Paulo, Brazil
- Maritorena, Stephane**, University of California at Santa Barbara, Santa Barbara, California
- Marotzke, Jochem**, Max-Planck-Institut für Meteorologie, Hamburg, Germany
- Martínez Güingla, Rodney**, Centro Internacional para la Investigación del Fenómeno El Niño (CIIFEN), Guayaquil, Ecuador
- Maslanik, Jochem**, Aerospace Engineering Sciences, University of Colorado, Boulder, Colorado
- Masson, Robert A.**, Australian Antarctic Division and Antarctic Climate and Ecosystems Cooperative Research Center (ACE CRC), University of Tasmania, Sandy Bay, Australia
- McBride, Charlotte**, South African Weather Service, Pretoria, South Africa
- McGree, Simon**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia
- McLaughlin, Fiona**, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, Canada
- McPeters, Rich**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- McVicar, Tim R.**, CSIRO Land and Water, Canberra, Australia
- Mears, Carl A.**, Remote Sensing Systems, Santa Rosa, California
- Medany, Mahmoud A.**, Agricultural Research Center, MALR, Cairo, Egypt
- Meier, Walt**, National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Meinen, Christopher S.**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Merrifield, Mark A.**, University of Hawaii at Manoa, Honolulu, Hawaii
- Miller, Laury**, NOAA/NESDIS Laboratory for Satellite Altimetry, Silver Spring, Maryland
- Mitchum, Gary T.**, College of Marine Science, University of South Florida, St. Petersburg, Florida
- Montzka, Steve**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Morcrette, Jean-Jacques**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Mote, Thomas**, Department of Geography, University of Georgia, Athens, Georgia
- Mühle, Jens**, Scripps Institution of Oceanography, University of California San Diego, La Jolla, California
- Mullan, A. Brett**, National Institute of Water and Atmospheric Research, Ltd., Wellington, New Zealand
- Murray, Don**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Nash, Eric R.**, Science Systems and Applications, Inc., NASA Goddard Space Flight Center, Greenbelt, Maryland
- Nerem, Steven R.**, University of Colorado, Boulder, Colorado
- Newman, Paul A.**, Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Nishino, S.**, Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan
- Njau, Leonard**, African Centre of Meteorological Applications for Development (ACMAD), Niamey, Niger
- Noetzli, J.**, University of Zürich, Zürich, Switzerland
- Oberbauer, S. F.**, Department of Biological Sciences, Florida International University, Miami, Florida
- Oberman, Naum**, MIREKO, Syktivkar, Russia
- Obregón, Andre**, Deutscher Wetterdienst (German Meteorological Service, DWD), Offenbach, Germany, and WMO RA VI Regional Climate Centre on Climate Monitoring, Offenbach, Germany
- Ogallo, Laban**, IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi, Kenya
- Oludhe, Christopher**, Department of Meteorology, University of Nairobi, Kenya
- O'Malley, Robert T.**, Oregon State University, Corvallis, Oregon
- Overland, James**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Park, Geun-Ha**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Parker, David E.**, Met Office, Exeter, Devon, United Kingdom
- Pasch, Richard J.**, NOAA/NWS National Hurricane Center, Miami, Florida
- Pegion, Phil**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Peltier, Alexandre**, Météo-France, Noumea, New Caledonia
- Pelto, Mauri S.**, Nichols College, Dudley, Massachusetts
- Penalba, Olga C.**, Departamento de Ciencias de la Atmósfera y los Océanos, Universidad de Buenos Aires, Argentina

- Pérez, Ramón S.**, Institute of Meteorology of Cuba, Habana, Cuba
- Perlwitz, Judith**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Perovich, Donald**, ERDC-Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire
- Peterson, Thomas C.**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Pezza, Alexandre B.**, University of Melbourne, Melbourne, Australia
- Phillips, David**, Environment Canada, Toronto, Canada
- Pinzon, Jorge E.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Pitts, Michael C.**, NASA Langley Research Center, Hampton, Virginia
- Proshutinsky, A.**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Quegan, S.**, Centre for Terrestrial Carbon Dynamics, University of Sheffield, Sheffield, United Kingdom
- Quintana, Juan**, Dirección Meteorológica de Chile, Santiago, Chile
- Quintero, Alexander**, Servicio de Meteorología de la Aviación (SEMETAVIA), Venezuela
- Rabe, B.**, Alfred Wegener Institute, Bremerhaven, Germany
- Rahimzadeh, Fatemeh**, Atmospheric Science and Meteorological Research Center (ASMERC), Tehran, Iran
- Rajeevan, Madhavan**, National Atmospheric Research Laboratory, Gadanki, India
- Rayner, Darren**, National Oceanography Centre, Southampton, United Kingdom
- Rayner, Nick A.**, Met Office Hadley Centre, Exeter, United Kingdom
- Raynolds, Martha K.**, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska
- Razuvaev, Vyacheslav N.**, All-Russian Research Institute of Hydrometeorological Information, Obninsk, Russia
- Reagan, James R.**, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland
- Reid, Phillip**, Australian Bureau of Meteorology and CAWRC, Hobart, Australia
- Renwick, James A.**, National Institute of Water and Atmospheric Research, Ltd., Wellington, New Zealand
- Revadekar, Jayashree**, Indian Institute of Tropical Meteorology, Pune, India
- Reynolds, Richard W.**, Cooperative Institute for Climate and Satellites – NC, North Carolina State University, and NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Richter-Menge, Jacqueline**, ERDC-Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire
- Rignot, Eric**, University of California-Irvine, NASA Jet Propulsion Laboratory, Irvine, California
- Robinson, David A.**, Rutgers University, Piscataway, New Jersey
- Rodell, Matthew**, Hydrospheric and Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Rogers, Mark**, Met Office, Exeter, Devon, United Kingdom
- Romanovsky, Vladimir**, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
- Romero-Cruz, Fernando**, National Meteorological Service of Mexico, CONAGUA, Mexico City, Mexico
- Ronchail, Josyane**, Université de Paris-Diderot, France
- Rosenlof, Karen**, NOAA/OAR Earth System Research Laboratory, Boulder, Colorado
- Rossi, Shawn**, National Weather Service, San Juan, Puerto Rico
- Rutledge, Glenn**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Saatchi, Sassan**, Jet Propulsion Laboratory, Pasadena, California
- Sabine, Christopher L.**, NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington
- Saha, Suranjana**, NOAA/NWS Environmental Modeling Center, Camp Springs, Maryland
- Sánchez-Lugo, Ahira**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Santee, Michelle L.**, NASA Jet Propulsion Laboratory, Pasadena, California
- Sato, Hitoshi**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom, and Japan Meteorological Agency (JMA), Tokyo, Japan
- Sawaengphokhai, P.**, Science Systems Applications, Inc., Hampton, Virginia
- Sayouri, Amal**, Direction de la Météorologie Nationale, Rabat, Morocco
- Scambos, Ted A.**, National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Schauer, U.**, Alfred Wegener Institute, Bremerhaven, Germany
- Schemm, Jae**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Schmid, Claudia**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Schneider, Philipp**, Jet Propulsion Laboratory, Pasadena, California
- Schueller, Dominique**, Météo-France, Réunion
- Sensoy, Serhat**, Turkish State Meteorological Service, Kalaba, Ankara, Turkey
- Sharp, Martin**, Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada
- Shaver, Gus R.**, Ecosystem Center, Marine Biological Laboratory, Woods Hole, Massachusetts

- Shiklomanov, Alexander I.**, University of New Hampshire, Durham, New Hampshire
- Shiklomanov, N.**, George Washington University, Washington D.C.
- Shimada, Koji**, Tokyo University of Marine Science and Technology, Tokyo, Japan
- Siegel, David A.**, University of California at Santa Barbara, Santa Barbara, California
- Simmons, Adrian**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Skansi, Maria**, Servicio Meteorológico Nacional, Buenos Aires, Argentina
- Smith, Adam**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Smith, Cathy**, CIRES Climate Diagnostics Center, University of Colorado, and NOAA/Earth System Research Laboratory, Boulder, Colorado
- Smith, S.**, Geological Survey of Canada, Ottawa, Canada
- Smith, Thomas M.**, NOAA/NESDIS Center for Satellite Applications and Research, Silver Spring, Maryland; and Cooperative Institute for Climate and Satellites, University of Maryland, College Park, Maryland
- Sokolov, Vladimir**, Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Spence, Jacqueline M.**, Meteorological Service of Jamaica, Kingston, Jamaica
- Srivastava, Arvind Kumar**, India Meteorological Department, Pune, India
- Stackhouse, Paul W., Jr.**, NASA Langley Research Center, Hampton, Virginia
- Stammerjohn, Sharon**, University of California Santa Cruz, Santa Cruz, California
- Steele, Mike**, University of Washington, Seattle, Washington
- Steinbrecht, Wolfgang**, DWD (German Weather Service), Hohenpeissenberg, Germany
- Stephenson, Tannecia S.**, University of the West Indies, Mona, Jamaica
- Stolarski, Richard S.**, Johns Hopkins University, Baltimore, Maryland
- Tahani, Lloyd**, Ministry of Environment, Climate Change, Disaster Management and Meteorology, Honiara, Solomon Islands
- Takahashi, Taro**, Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
- Taylor, Michael A.**, University of the West Indies, Mona, Jamaica
- Thépaut, Jean-Noël**, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
- Thiaw, Wassila M.**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Thorne, Peter W.**, Cooperative Institute for Climate and Satellites, NCSU/NOAA NCDC, Asheville, North Carolina
- Timmermans, M.-L.**, Yale University, New Haven, Connecticut
- Tobin, Skie**, Bureau of Meteorology, Melbourne, Australia
- Toole, John**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Trewin, Blair C.**, National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia
- Trigo, Ricardo M.**, Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal
- Tucker, Compton J.**, NASA Goddard Space Flight Center, Greenbelt, Maryland
- Tweedie, Craig E.**, Department of Biology, University of Texas at El Paso, El Paso, Texas
- van As, D.**, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
- van de Wal, R. S. W.**, Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, the Netherlands
- van der A, Ronald J.**, KNMI (Royal Netherlands Meteorological Institute), De Bilt, the Netherlands
- van der Werf, G. R.**, Department of Earth Sciences, Faculty of Earth and Life Sciences, VU University Amsterdam, the Netherlands
- Vautard, Robert**, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA-CNR-UVSQ, Gif-sur-Yvette, France
- Vieira, G.**, University of Lisbon, Lisbon, Portugal
- Vincent, Lucie A.**, Environment Canada, Toronto, Canada
- Vinther, B.**, Niels Bohr Institute, Copenhagen, Denmark
- Vose, Russell**, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Wagner, Wolfgang**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Vienna, Austria
- Wahr, John**, Department of Physics, University of Colorado, Boulder, Colorado
- Walker, David A.**, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska
- Walsh, John**, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, Alaska
- Wang, Chunzai**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Wang, Junhong**, Earth Observation Laboratory, NCAR, Boulder, Colorado
- Wang, Lei**, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana

- Wang, Muyin**, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, Washington
- Wang, Sheng-Hung**, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio
- Wanninkhof, Rik**, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
- Weaver, Scott**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Webber, Patrick J.**, Department of Plant Biology, Michigan State University, East Lansing, Michigan
- Weber, Mark**, University of Bremen, Bremen, Germany
- Weller, Robert A.**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Weyman, James**, NOAA/NWS Central Pacific Hurricane Center, Honolulu, Hawaii (retired)
- Whitewood, Robert**, Environment Canada, Toronto, Canada
- Wijffels, Susan E.**, Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research, and Wealth from Oceans National Research Flagship, CSIRO, Hobart, Tasmania, Australia
- Wilber, Anne C.**, Science Systems Applications, Inc., Hampton, Virginia
- Willett, Katharine M.**, Met Office Hadley Centre, Exeter, Devon, United Kingdom,
- Williams, W.**, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia, Canada
- Willis, Joshua K.**, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Wolken, Gabriel**, Alaska Division of Geological & Geophysical Surveys, Fairbanks, Alaska
- Wong, Takmeng**, NASA Langley Research Center, Hampton, Virginia
- Woodgate, Rebecca**, University of Washington, Seattle, Washington
- Woodworth, Philip**, National Oceanography Centre, Liverpool, United Kingdom
- Wovrosh, Alex J.**, Department of Geography, Ohio University, Athens, Ohio
- Xue, Yan**, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
- Yamamoto-Kawai, M.**, Tokyo University of Marine Science and Technology, Tokyo, Japan
- Yin, Xungang**, STG, Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
- Yu, Lisan**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
- Zhang, Liangying**, Earth Observation Laboratory, NCAR, Boulder, Colorado
- Zhang, Peiqun**, National Climate Centre, CMA, Beijing, China
- Zhao, L.**, Cold and Arid Regions Environmental and Engineering Research Institute, Lanzhou, China
- Zhou, Xinjia**, NCAR COSMIC, Boulder, Colorado
- Zimmermann, S.**, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, Canada

# TABLE OF CONTENTS

List of authors and affiliations.....	3
Abstract.....	16
<b>1. INTRODUCTION</b> .....	<b>17</b>
<b>2. GLOBAL CLIMATE</b> .....	<b>27</b>
a. Overview .....	27
b. Temperature .....	36
1. Surface temperature .....	36
2. Lower tropospheric temperatures.....	37
3. Lower stratospheric temperatures .....	38
4. Lake temperature.....	39
c. Hydrologic cycle .....	40
1. Surface humidity .....	40
2. Total column water vapor .....	41
3. Precipitation .....	42
4. Northern Hemisphere continental snow cover extent.....	44
5. Global cloudiness .....	45
6. River discharge.....	46
7. Permafrost thermal state .....	48
8. Groundwater and terrestrial water storage.....	49
9. Soil moisture.....	52
10. Lake levels.....	53
d. Atmospheric circulation .....	55
1. Mean sea level pressure.....	55
2. Ocean surface wind speed.....	56
e. Earth radiation budget at top-of-atmosphere .....	58
f. Atmosphere composition.....	59
1. Atmosphere chemical composition.....	59
2. Aerosols.....	65
3. Stratospheric ozone .....	67
g. Land surface properties.....	68
1. Alpine glaciers and ice sheets .....	68
2. Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) .....	72
3. Biomass burning.....	72
4. Forest biomass and biomass change .....	74
<b>3. GLOBAL OCEANS</b> .....	<b>77</b>
a. Overview .....	77
b. Sea surface temperatures.....	78
c. Ocean heat content .....	81
d. Global ocean heat fluxes .....	84
e. Sea surface salinity .....	86
f. Subsurface salinity .....	88
g. Surface currents.....	92
1. Pacific Ocean .....	93
2. Indian Ocean.....	94
3. Atlantic Ocean .....	95
h. Meridional overturning circulation observations in the subtropical North Atlantic .....	95

i. Sea level variations.....	98
j. The global ocean carbon cycle.....	100
1. Air-sea carbon dioxide fluxes .....	100
2. Subsurface carbon inventory .....	102
3. Global ocean phytoplankton.....	105
<b>4. TROPICS.....</b>	<b>109</b>
a. Overview .....	109
b. ENSO and the tropical Pacific.....	109
1. Oceanic conditions.....	109
2. Atmospheric circulation: Tropics.....	110
3. Atmospheric circulation: Extratropics .....	112
4. ENSO temperature and precipitation impacts.....	113
c. Tropical intraseasonal activity.....	113
d. Tropical cyclones .....	114
1. Overview.....	114
2. Atlantic basin.....	115
3. Eastern North Pacific basin.....	121
4. Western North Pacific basin.....	123
5. Indian Ocean basins.....	127
6. Southwest Pacific basin.....	129
7. Australian region basin .....	130
e. Tropical cyclone heat potential.....	132
f. Intertropical Convergence Zones.....	134
1. Pacific.....	134
2. Atlantic.....	136
g. Atlantic multidecadal oscillation.....	137
h. Indian Ocean Dipole.....	138
<b>5. THE ARCTIC.....</b>	<b>143</b>
a. Overview .....	143
b. Atmosphere.....	143
c. Ocean .....	145
1. Wind-driven circulation .....	145
2. Ocean temperature and salinity.....	145
3. Biology and geochemistry.....	146
4. Sea level .....	148
d. Sea ice cover .....	148
1. Sea ice extent.....	148
2. Sea ice age .....	149
3. Sea ice thickness.....	150
e. Land.....	150
1. Vegetation .....	150
2. Permafrost.....	152
3. River discharge.....	153
4. Terrestrial snow .....	154
5. Glaciers outside Greenland.....	155
f. Greenland.....	156

1. Coastal surface air temperature .....	156
2. Upper air temperatures .....	158
3. Atmospheric circulation .....	158
4. Surface melt extent and duration and albedo .....	159
5. Surface mass balance along the K-Transect.....	159
6. Total Greenland mass loss from GRACE .....	160
7. Marine-terminating glacier area changes .....	160
<b>6. ANTARCTICA.....</b>	<b>161</b>
a. Overview .....	161
b. Circulation.....	161
c. Surface manned and automatic weather station observations .....	163
d. Net precipitation .....	164
e. 2009/10 Seasonal melt extent and duration.....	167
f. Sea ice extent and concentration.....	167
g. Ozone depletion.....	170
<b>7. REGIONAL CLIMATES.....</b>	<b>173</b>
a. Overview .....	173
b. North America.....	173
1. Canada .....	173
2. United States.....	175
3. México.....	179
c. Central America and the Caribbean .....	182
1. Central America.....	182
2. The Caribbean .....	183
d. South America .....	186
1. Northern South America and the Tropical Andes.....	186
2. Tropical South America east of the Andes .....	187
3. Southern South America.....	190
e. Africa.....	192
1. Northern Africa .....	192
2. Western Africa .....	193
3. Eastern Africa.....	194
4. Southern Africa.....	196
5. Western Indian Ocean countries.....	198
f. Europe .....	199
1. Overview.....	199
2. Central and Western Europe .....	202
3. The Nordic and Baltic countries.....	203
4. Iberia.....	205
5. Mediterranean, Italian, and Balkan Peninsulas.....	206
6. Eastern Europe .....	207
7. Middle East.....	208
g. Asia.....	210
1. Russia.....	210
2. East Asia .....	215
3. South Asia .....	217
4. Southwest Asia .....	218

h. Oceania .....	222
1. Southwest Pacific.....	222
2. Northwest Pacific, Micronesia.....	224
3. Australia.....	227
4. New Zealand.....	229
<b>8. SEASONAL SUMMARIES .....</b>	<b>233</b>
Acknowledgments.....	237
Appendix: Acronyms and Abbreviations.....	238
References.....	240





Several large-scale climate patterns influenced climate conditions and weather patterns across the globe during 2010. The transition from a warm El Niño phase at the beginning of the year to a cool La Niña phase by July contributed to many notable events, ranging from record wetness across much of Australia to historically low Eastern Pacific basin and near-record high North Atlantic basin hurricane activity. The remaining five main hurricane basins experienced below- to well-below-normal tropical cyclone activity. The negative phase of the Arctic Oscillation was a major driver of Northern Hemisphere temperature patterns during 2009/10 winter and again in late 2010. It contributed to record snowfall and unusually low temperatures over much of northern Eurasia and parts of the United States, while bringing above-normal temperatures to the high northern latitudes. The February Arctic Oscillation Index value was the most negative since records began in 1950.

The 2010 average global land and ocean surface temperature was among the two warmest years on record. The Arctic continued to warm at about twice the rate of lower latitudes. The eastern and tropical Pacific Ocean cooled about 1°C from 2009 to 2010, reflecting the transition from the 2009/10 El Niño to the 2010/11 La Niña. Ocean heat fluxes contributed to warm sea surface temperature anomalies in the North Atlantic and the tropical Indian and western Pacific Oceans. Global integrals of upper ocean heat content for the past several years have reached values consistently higher than for all prior times in the record, demonstrating the dominant role of the ocean in the Earth's energy budget. Deep and abyssal waters of Antarctic origin have also trended warmer on average since the early 1990s. Lower tropospheric temperatures typically lag ENSO surface fluctuations by two to four months, thus the 2010 temperature was dominated by the warm phase El Niño conditions that occurred during the latter half of 2009 and early 2010 and was second warmest on record. The stratosphere continued to be anomalously cool.

Annual global precipitation over land areas was about five percent above normal. Precipitation over the ocean was drier than normal after a wet year in 2009. Overall, saltier (higher evaporation) regions of the ocean surface continue to be anomalously salty, and fresher (higher precipitation) regions continue to be anomalously fresh. This salinity pattern, which has held since at least 2004, suggests an increase in the hydrological cycle.

Sea ice conditions in the Arctic were significantly different than those in the Antarctic during the year. The annual minimum ice extent in the Arctic—reached in September—was the third lowest on record since 1979. In the Antarctic, zonally averaged sea ice extent reached an all-time record maximum from mid-June through late August and again from mid-November through early December. Corresponding record positive Southern Hemisphere Annular Mode Indices influenced the Antarctic sea ice extents.

Greenland glaciers lost more mass than any other year in the decade-long record. The Greenland Ice Sheet lost a record amount of mass, as the melt rate was the highest since at least 1958, and the area and duration of the melting was greater than any year since at least 1978. High summer air temperatures and a longer melt season also caused a continued increase in the rate of ice mass loss from small glaciers and ice caps in the Canadian Arctic. Coastal sites in Alaska show continuous permafrost warming and sites in Alaska, Canada, and Russia indicate more significant warming in relatively cold permafrost than in warm permafrost in the same geographical area. With regional differences, permafrost temperatures are now up to 2°C warmer than they were 20 to 30 years ago. Preliminary data indicate there is a high probability that 2010 will be the 20th consecutive year that alpine glaciers have lost mass.

Atmospheric greenhouse gas concentrations continued to rise and ozone depleting substances continued to decrease. Carbon dioxide increased by 2.60 ppm in 2010, a rate above both the 2009 and the 1980–2010 average rates. The global ocean carbon dioxide uptake for the 2009 transition period from La Niña to El Niño conditions, the most recent period for which analyzed data are available, is estimated to be similar to the long-term average. The 2010 Antarctic ozone hole was among the lowest 20% compared with other years since 1990, a result of warmer-than-average temperatures in the Antarctic stratosphere during austral winter between mid-July and early September.



Libraries: Please file with the *Bulletin of the American Meteorological Society*, Vol. 92, Issue 6