The Arctic Climate System

The Arctic can be viewed as an integrated system, characterized by intimate couplings between its atmosphere, ocean and land, linked in turn to the larger global system. This comprehensive, up-to-date assessment begins with an outline of early Arctic exploration and the growth of modern research, followed by an overview of the Arctic's basic physical characteristics and climatic features. Using an integrated systems approach, subsequent chapters examine the atmospheric heat budget and circulation, the surface energy budget, the hydrologic cycle and interactions between the ocean, atmosphere and sea ice cover. Reviews of recent directions in numerical modeling and the characteristics of past Arctic climates set the stage for detailed discussion of recent climate variability and trends, and projected future states. Throughout, satellite remote sensing data and results from recent major field programs are used to illustrate key processes.

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To Susan and Natalya

Contents

Preface

This book provides the reader with an overview of the nature of the Arctic climate system and its links with the global system. The book begins with a historical perspective, addressing the early exploration of the Arctic, the growth of systematic observations and the advent of the modern research era. This is followed by discussion of the basic physical and climatic characteristics of the Arctic, laying groundwork for subsequent chapters. These address the atmospheric heat budget, the atmospheric circulation, the surface energy budget, the hydrologic budget, atmosphere–ocean–sea ice interactions and regional climate regimes. Modeling is an important tool in Arctic climate research, and is accorded its own chapter. Following a review of past climates (paleoclimates), the book closes with an assessment of recent climate variability, trends and the projected future state of the Arctic. While the subject matter is targeted at the level of the advanced undergraduate and graduate student, it should be accessible to anyone with an interest in the Arctic and a basic understanding of climate science. The text contains numerous illustrations to help the reader, and references to many review papers on specialized topics.

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Abbreviations

AAAS	American Association for the Advancement of Science
ACIA	Arctic Climate Impact Assessment
ACSYS	Arctic Climate System Study
ADEOS	Advanced Earth Observing Satellite
AGCM	Atmospheric Global Climate Model (or General Circulation Model)
AGU	American Geophysical Union
AH	Azores High
AMIP	Atmospheric Model Intercomparison Project
AMS	American Meteorological Society
AO	Arctic Oscillation
AOGCM	Atmosphere–Ocean Global Climate Model (or General Circulation Model)
AOMIP	Arctic Ocean Model Intercomparison Project
APP	Arctic Polar Pathfinder
ARCMIP	Arctic Regional Climate Model Intercomparison Project
ARCSS	Arctic System Science Program
ARCSyM	Arctic Regional Climate System Model
ASOF	Arctic–Subarctic Ocean Fluxes Program
ASR	Arctic System Reanalysis
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automatic Weather Station
BOREAS	Boreal Ecosystem–Atmosphere Study
CCN	Cloud Condensation Nuclei
CFC	Chlorofluorocarbon

CHAMP	Community-wide Hydrologic Analysis and Modeling Program
CHASM	Chameleon Surface Model
CISK	Conditional Instability of the Second Kind
CLASS	Canadian Land Surface Scheme
CliC	Climate and Cryosphere program
COADS	Comprehensive Ocean Atmosphere Data Set
CRYSYS	Cryosphere System in Canada program
DAO	Data Assimilation Office
DEWLINE	Distant Early Warning Line
DMSP	Defense Meteorological Satellite Program
D-O	Dansgaard–Oeschger cycle
DOE	Department of Energy
DU	Dobson Unit
ECMWF	European Centre for Medium-range Weather Forecasts
ELA	Equilibrium Line Altitude
ENSO	El-Niño Southern Oscillation
EOF	Empirical Orthogonal Function
EP	Eliassen–Palm flux
ERA-15	ECMWF 15-year reanalysis project
ERA-40	ECMWF 40-year reanalysis project
ERBE	Earth Radiation Budget Experiment
ESMR	Electrically Scanning Microwave Radiometer
ET	Evapo-transpiration
FYI	Firstyear Ice
GCM	Global Climate Model (or General Circulation Model)
GC-Net	Greenland Climate Network
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GIN	Greenland–Iceland–Norwegian sea
GISP2	Greenland Ice Sheet Project 2
GPP	Gross Primary Production
GRIP	Greenland Ice Core Project
GSA	Great Salinity Anomaly
HARC	Human Dimensions of the Arctic System
HIRLAM	High Resolution Limited Area Model
HR	Heterotrophic Respiration
HTM	Holocene Thermal Maximum
IABP	International Arctic Buoy Program
ICE Sat	Ice, Cloud, and Land Elevation Satellite
IGY	International Geophysical Year

IL	Icelandic Low
IPA	International Permafrost Association
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IRD	Ice Rafted Detritus
ISCCP	International Satellite Cloud Climatology Project
JMA	Japan Meteorological Agency
LAII	Land–Atmosphere–Ice Interactions Program
LGM	Last Glacial Maximum
LIA	Little Ice Age
LSM	Land Surface Model
MIP	Model Intercomparison Project
MIS	Marine Isotope Stage
MIZ	Marginal Ice Zone
MMC	Mean Meridional Circulation
MM5:	Pennsylvania State University/NCAR Fifth Generation Mesoscale Model
MODIS	Moderate Resolution Imaging Spectro-radiometer
MYI	Multiyear Ice
NADW	North Atlantic Deepwater
NAM	Northern Annular Mode
NAO	North Atlantic Oscillation
NARR	North American Regional Reanalysis
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
NEP	Net Ecosystem Production
NIC	National Ice Center
NMF	Net Mass Flux
NOAA	National Oceanic and Atmospheric Administration
NP	North Pole (drifting station program)
NPO	North Pacific Oscillation
NPP	Net Primary Production
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
OAII	Ocean–Atmosphere–Ice Interactions Program

PACTS	Pan-Arctic Cycles, Transitions and Sustainability Program
PARCA	Program for Arctic Regional Climate Assessment
PARCS	Paleo-environmental Arctic Studies Program
PC	Principal Component
PDO	Pacific Decadal Oscillation
$P-$ET	Precipitation minus Evapo-transpiration
PILPS	Project for Intercomparison of Land Surface Parameterization Schemes
PIZ	Perennial Ice Zone
PNA	Pacific North America teleconnection pattern
PSC	Polar Stratospheric Cloud
PV	Potential Vorticity
PW	Petawatt
QBO	Quasi-Biennial Oscillation
RBL	Radiative Boundary Layer
SAR	Synthetic Aperture Radar
SAT	Surface Air Temperature
SCM	Single Column Model
SE	Stationary Eddy
SEARCH	Study of Environmental Arctic Change
SHEBA	Surface Heat Budget of the Arctic Ocean
SIC	Sea Ice Concentration
SIZ	Seasonal Ice Zone
SLP	Sea Level Pressure
SMMR	Scanning Multichannel Microwave Radiometer
SMOW	Standard Mean Ocean Water
SO	Southern Oscillation
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
SZA	Solar Zenith Angle
TE	Transient Eddy
TEM	Transformed Eulerian Mean
TEM	Terrestrial Ecosystem Model
TFP	Thermal Front Parameter
THC	Thermohaline Circulation
TIROS	Television Infrared Observation Satellite
TOA	Top of Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Spectrometer
TPDS	Transpolar Drift Stream

UHI	Urban Heat Island
ULS	Upward Looking Sonar
VHRR	Very High Resolution Radiometer
VIC	Variable Infiltration Capacity model
WCRP	World Climate Research Programme
WISHE	Wind Induced Surface Heat Exchange
YD	Younger Dryas