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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.

The Arctic Climate System provides a comprehensive and accessible overview of the subject for researchers and advanced students in a wide range of disciplines.

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This series of upper-level texts and research monographs covers the physics and chemistry of different regions of the Earth's atmosphere, from the troposphere and stratosphere, up through the ionosphere and magnetosphere and out to the interplanetary medium.

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To Susan and Natalya

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Mark C. Serreze and Roger G. Barry
Frontmatter
More information

Contents

Preface page xi

Acknowledgements xii

List of Abbreviations xiii

1 The evolution of knowledge about the Arctic and its climate 1

1.1 Historical exploration 4
1.2 The beginning of systematic observations 10
1.3 The modern era 12

2 Physical characteristics and basic climatic features 17

2.1 The Arctic ocean 19
2.2 The Arctic lands 30
2.3 Basic climatic elements 37

3 The basic atmospheric heat budget 55

3.1 The Arctic and the global heat budget 56
3.2 The basic Arctic heat budget 60
3.3 Further analysis of F_{wall} 69

4 The atmospheric circulation 74

4.1 Historical perspective 75
4.2 The stratospheric circulation 79
4.3 The Arctic tropopause 90
4.4 The mid-tropospheric circulation 92

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CAMBRIDGE

Cambridge University Press
0521814189 - The Arctic Climate System
Mark C. Serreze and Roger G. Barry
Frontmatter
More information

4.5 Surface and near-surface circulation 94
4.6 Polar Lows 106

5 The surface energy budget 110

5.1 The energy balance equations 111
5.2 The downward solar radiation flux 115
5.3 Surface albedo 120
5.4 Longwave radiation fluxes 125
5.5 Distribution of net radiation 127
5.6 Cloud radiative forcing 128
5.7 Radiation fluxes from surface observations: examples from SHEBA 131
5.8 Partitioning of net radiation 131
5.9 Skin temperature, SAT and vertical structure 137
5.10 Radiation–climate feedbacks 143

6 Precipitation, net precipitation and river discharge 147

6.1 Precipitation 148
6.2 Evapo-transpiration and net precipitation 156
6.3 Mean annual cycles for the major terrestrial drainages 162
6.4 River discharge and runoff 166

7 Arctic ocean–sea ice–climate interactions 177

7.1 Sea ice formation, growth and melt 179
7.2 Mean circulation, ice zones and concentration 183
7.3 Sea ice motion 190
7.4 Examples of large-scale ocean–sea ice–climate interactions 197
7.5 The Fram Strait outflow and the thermohaline circulation 204

8 Climate regimes of the Arctic 208

8.1 The Greenland Ice Sheet 209
8.2 Polar desert 217
8.3 Maritime Arctic 220
8.4 Central Arctic Ocean 223
8.5 Mountains and uplands 226
8.6 Urban modifications of local climate 228

9 Modeling the Arctic climate system 229

9.1 General model types 230
9.2 Single-column models 232
9.3 Land surface models 237
9.4 Sea ice and ice–ocean models 240
9.5 Global climate models 245
9.6 Regional climate models 252
9.7 Numerical weather prediction models 255

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CAMBRIDGE

Cambridge University Press
0521814189 - The Arctic Climate System
Mark C. Serreze and Roger G. Barry
Frontmatter
More information

9.8 Ecosystem models 258
9.9 Summary of model errors 260

10 Arctic paleoclimates 262

10.1 The distant past 263
10.2 Paleoclimate records for the Quaternary 266
10.3 Features of the Quaternary 269
10.4 Rapid climate shifts 276
10.5 Regional aspects of the LGM 279
10.6 Deglaciation 283
10.7 The Holocene 287

11 Recent climate variability, trends and the future 291

11.1 Setting the stage 292
11.2 Summary of observed variability and change 295
11.3 The NAO and AO 306
11.4 The NAO/AO framework: merits and shortcomings 312
11.5 Related multiyear climate variability 324
11.6 The future 326
References 335

List of selected websites 377

Index 378

The plates will be found between pages 174 and 175

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Cambridge University Press
0521814189 - The Arctic Climate System
Mark C. Serreze and Roger G. Barry
Frontmatter
More information

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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Mark C. Serreze and Roger G. Barry
Frontmatter
More information

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Mark C. Serreze and Roger G. Barry
Frontmatter
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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

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Mark C. Serreze and Roger G. Barry
Frontmatter
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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

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Mark C. Serreze and Roger G. Barry
Frontmatter
More information

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

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Mark C. Serreze and Roger G. Barry
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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

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Mark C. Serreze and Roger G. Barry
Frontmatter
More information

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

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