Contents

PART I: Defining Climate

CHAPTER 1: EARTH'S CLIMATE AS A DYNAMIC SYSTEM

Introduction
Climate and Society
The Importance of Climate Studies for Human Endeavors
Human Vulnerability to Climate
Importance of the Climate System
A Changing Climate
Climate Variability versus Climate Change
Assessing Credible Climate Information
Current Climate Paradigm
Modes by which Climate is defined
Climate System
Atmosphere
Hydrosphere
Cryosphere
Lithosphere
Biosphere
Carbon Cycle
Chapter 1 Big Ideas

CHAPTER 2: OBSERVING EARTH'S CLIMATE SYSTEM

Introduction

Essential Climate Variables

Acquisition of ECVs

Challenges in sampling ECVs

Other ECV-related Indicators of Climate

How and where we observe Earth's Climate System

Climate Observation Systems in the United States

Atmospheric Sampling on Earth's Surface Cataloging Observations in the Climate Record

Who observes Earth's Climate System?

Stewardship and Service Climatology

Climate Data Centers

How observations of Earth's Climate System are used and by whom

Climate Scientists around the World

Climate Modelers

Climate Forecasters

Private Sector Applications of Climate Observations

Chapter 2 Big Ideas

CHAPTER 3: TOOLS FOR INVESTIGATING EARTH'S CLIMATE SYSTEM

Introduction

Measures using Statistical Procedures

Displays of Statistical Data

Descriptive Statistics

Central Tendency Dispersion

Shape or Relative Position

Expected Frequency

Recurrence Interval

Climate Normals

GeoSpatial Analysis

Geographic Information System (GIS)

Climate Mapping

Applied Climate Information System (ACIS) PRISM Project

Climate Classification Techniques

Köppen Classification

Spatial Synoptic Classification (SSC)

Chapter 3 Big Ideas

PART II: Principles of Climatic Processes

CHAPTER 4: RADIATION AND HEAT IN THE CLIMATE SYSTEM

Introduction

Energy and Entropy

Types of Radiation

Radiation Principles

Greenhouse Effect

Global Warming

Global Radiation Budget

Solar Radiation Traversing the Atmosphere

Stratospheric Ozone Shield

Earth's Surface and Solar Radiation

Heat Imbalance: Earth's Atmosphere versus Earth's Surface

Thermal Energy across Space and Time

Temperature and Heat

Measuring Temperature and Heat Measuring Temperature

Energy Considerations for the Sun and Earth

Changes in Solar Altitude

Earth's Revolution and the Seasons

The Solar Constant

Transfer of Energy

Electromagnetic Radiation Conduction and Convection

Controls on Climate Characteristics

Latitudinal Influences

Clouds

Surface Characteristics

Air Mass Exchanges

Ocean Circulation

Chapter 4 Big Ideas

CHAPTER 5: WATER IN EARTH'S CLIMATE SYSTEM

Introduction Properties of Water in Earth's Climate System Latent Heating **Specific Heat Thermal Inertia** Maritime and Continental Climates **Global Water Cycle** Global Water Budget Humidity and Saturation

Vapor Pressure

Saturated Air

Relative Humidity

Dewpoint Temperature

Precipitable Water

Saturation and Clouds

Atmospheric Stability

Types of Stability

Clouds

Mechanisms of Cloud Formation

Fog

Precipitation Types

Monitoring Moisture in the Atmosphere

Instrumental Arrays to Monitor Moisture Variability

Snowfall Measures

Remote Sensing of Precipitation

Chapter 5 Big Ideas

CHAPTER 6: GLOBAL ATMOSPHERIC CIRCULATION

Introduction

Forces that Act on Atmospheric Circulation

Pressure Gradient Force

Coriolis Force

Friction

Gravity

Synergistic Forcing on Large Scale Wind Circulation

Geostrophic Wind

Gradient Winds

Surface Winds in Cyclones and Anticyclones

Monitoring Wind Circulations

Wind Direction Wind Speed Winds Aloft Boundary Conditions

Pressure Systems and Wind Belts

Circulation Aloft

Trade Wind Inversion

Zonal and Meridional Flow

Blocking Patterns and their Effects

Connection from Winds Aloft to the Surface

Supporting Processes

Climatic Characteristics of Cyclones

Climatically Favored Regions of Cyclogenesis

Climatology of Cyclone Paths

Chapter 6 Big Ideas

CHAPTER 7: ATMOSPHERE-OCEAN RELATIONSHIPS

Introduction Air-Sea Interactions Mean State of the Ocean Circulation Ekman Transport Upwelling and Downwelling Thermohaline Circulation El Niño, La Niña and the Southern Oscillation

Historical Perspective

Neutral Conditions in the Tropical Pacific

El Niño (Warm Phase)

La Niña (Cold Phase)

Periodicity

Monitoring ENSO

Other Oscillations between the Atmosphere-Ocean

North Atlantic Oscillation

Arctic Oscillation

Pacific Decadal Oscillation

Madden-Julian Oscillation

Monsoons

Asian Monsoon

Monsoon of the American Southwest

Changing Ocean in a Changing Climate

Ocean Warming

Ocean as a Carbon Sink

Ocean Acidification

Sea-level Rise

Chapter 7 Big Ideas

PART III: Variability of Climate

CHAPTER 8: NATURAL AND ANTHROPOGENIC DRIVERS OF CLIMATE CHANGE

Introduction

Current State of the Climate System from the Instrumental Record

Integrity of Instrument Data

Lessons from Climate Data

Natural Drivers of Climate Change

Solar Changes

Faint Young Sun Paradox Sunspots Maunder Minimum and the Little Ice Age

Changes in Earth's Orbit

Milankovitch Cycles Evidence from Deep-Sea Sediment Cores

Geologic Contributions

Plate Tectonics Volcanoes

Feedbacks

Types of Feedbacks

Snow and Ice Cover

Shrinkage of Arctic Sea-Ice Cover

Biogeochemical Cycles

Greenhouse Gas Contributions

Trends in Greenhouse Gases

Aerosols

Changes in Land Use and Land Cover

Anthropogenic versus Natural Forcing of Climate

Chapter 8 Big Ideas

CHAPTER 9: PALECLIMATIC INVESTIATIONS: RELEVANCY TO THE PRESENT STATE OF CLIMATE

Introduction

Reconstructing Climates of the Past

Proxy Climate Data Sources

Historical Media Dendrochronology Pollen Analysis Ocean Sediments Speleothems Coral Glacial Ice Cores Geologic Record Climates of Geologic Times

Climates of the Pleistocene

Glaciers

The Role of Climate in Glacial Dynamics Historical Perspective on Pleistocene Glaciation Glaciers and Landscapes Chronology and Temperature Trends Heinrich Events Climates of the Holocene Climates of the Holocene Climates of the Last Millennium Medieval Climate Anomaly Little Ice Age Chapter 9 Big Ideas

Chapter 10: FUTURE PROJECTIONS AND EXTREMES OF CLIMATE

Introduction

What are Models?

Global Climate Models

Weather versus Climate Models

Model Limits

Physical Basis for modeling Earth's Climate

Search for Cycles and Analogs

Enhanced Greenhouse Effect and Global Warming

Climate Sensitivity

Assessment of Climate Model Output

Search for Changes in Extreme Events

Convective Weather

Tornado Characteristics Tornado Hazards Tornado Climatology

Heavy Precipitation

Tropical Cyclones

Climatological Causes of Tropical Cyclones Hurricane Life Cycle Hurricane Hazards Trends and Future Projections Winter Storms

Drought

Climate Singularities Climate Tipping Points

Chapter 10 Big Ideas

PART IV: Our Relationship to Climate Variability

Chapter 11: HUMAN AND ECOSYSTEM VULNERABILITIES

Introduction

Ocean and Cryosphere Vulnerabilities

Rising Sea Levels

Shrinking Glaciers

Arctic Environment

Marine Life

Human Vulnerabilities

Agriculture

Global Food Supply

Green Revolution Food Security in the U.S. Security Considerations

Vulnerabilities in the Biosphere

Human Health

Infectious Diseases Vector-borne Diseases Ecosystem Limitations

Forests and Wildfires

Deforestation

Species Migrations

Biodiversity

Chapter 11 Big Ideas

Chapter 12: ENERGY USE MITIGATION BY AND FOR HUMANS

Introduction

Managing Anthropogenic Climate Change

The Energy-CO2 Connection

Fossil Fuels Coal Petroleum Natural Gas Nuclear Power Renewable Energy Sources Solar Wind Geothermal Tidal Power Hydropower Biofuels Carbon Trading and Taxation Carbon Capture and Storage Geoengineering the Climate System **Ecosystem Sequestration** Sulfurous Haze **Brighter Ocean Clouds Ocean Iron Fertilization** Efficacy of Geoengineering Role of Energy Efficiency Improving Transportation Sector Efficiency Adaptation and Resiliency

Chapter 12 Big Ideas

Chapter 13: HUMAN NEEDS, ACTIONS AND PUBLIC POLICY

Introduction

Policy Lessons from Stratospheric Ozone Depletion

Climate Policy Making at the National Level

Political Response

Incremental Decision-making

Mitigation

International Mitigation Efforts

UN Framework Convention On Climate Change

Kyoto Protocol

Doha Amendment

U.S. Mitigation Efforts

Regional Mitigation Efforts

Adaptation

U.S. Adaptation Efforts

Geoengineering Management and Policy

Knowledge Base Expansion

Climate Change Policy

Climate, Sustainability and Stewardship

Climate Change: The Economic Perspective

Free Markets

Government Regulation

Analytic Tools

Overall Role of Policy in a Changing Climate

Chapter 13 Big Ideas

Chapter 14: CLIMATE STUDY AS AN ONGOING SCIENTIFIC ENDEAVOR

Introduction

Resistance to Climate Change Evidence

Skepticism versus "Denialism"

Uncertainty

Scientific Consensus

Historical Analogs to Resistance

Copernicus, Wegener and Callendar Tobacco Industry

Dangers of Denialism

Denialism in the Political Realm

Reframing the Discourse in Media

Campaigns Orchestrated by Denialists

Communicating Science

Public Perception

Role of the Broadcast Meteorologist

Disparaging Science and the Climate Scientist

Climategate

Climate Science Legal Defense Fund

Chapter 14 Big Ideas