

Table of Contents

Title Page

Foreword

Acknowledgements

Dedication

Preface December 2, 2022

Preface August 14, 2021

Preface January 18, 2021

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Overview of Guide

1.2 Special note on Nobel Prize winners

1.3 International organizations

1.3.1 World Meteorological Organization

1.3.2 United Nations Environment Programme, UNEP

1.3.3 World Climate Research Program

1.3.4 Future Earth

1.4 Information support

Chapter 2 History of the Scientific Study of Climate Change

2.1 Information support

Chapter 3 Weather vs. Climate

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xiv

3.1 Introduction

3.2 Weather observation and interpretation

3.3 Canada – meteorological data availability

3.4 Forecasting

3.4.1 Stochastic forecasting

3.4.2 Real-time forecasting

3.4.3 Distributed models

3.5 Information support

Chapter 4 Earth’s Energy Budget

4.1 Introduction

4.2 Concept of energy

4.3 Solar energy

4.4 Energy budget

4.5 Conservation of energy

4.6 Greenhouse effect

4.7 Impact of human activities on the energy budget

4.8 Information support

Chapter 5 Carbon Cycle

5.1 Introduction

5.2 Units

5.3 Carbon in the atmosphere

5.4 Plant biomass (terrestrial)

5.5 Oceans

5.6 Fossil pool

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

5.7 Fossil fuels, cement and land use change

5.8 Weathering

5.9 Carbon waste

5.10 Information support

Chapter 6 Hydrological Cycle

6.1 Introduction

6.2 Basic elements of the hydrological cycle

6.3 Evaporation and evapotranspiration

6.4 Convection and cloud formation

6.5 Precipitation

6.6 Snow and ice

6.7 Runoff

6.8 Distribution of water on Earth

**6.9 Ice caps, glaciers, ice streams, ice field, ice sheets, ice shelves,
and sea ice**

6.10 Isotopes of oxygen, hydrogen, deuterium and water

6.11 Hydrologic data availability

6.12 Forecasting

6.12.1 Stochastic forecasting

6.12.2 Real-time forecasting

6.12.3 Distributed forecasting

6.13 Flood Plain Delineation

6.14 Information support

Chapter 7 Global Circulation of the Atmosphere

7.1 Introduction

7.2 Characteristics of the atmosphere

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xvi

7.3 Early perception of global circulation of the atmosphere

7.4 Actual global circulation of the atmosphere

7.5 Atmospheric rivers

7.6 Ozone and the ozone hole

7.7 Heat dome

7.8 Information support

Chapter 8 Global Circulation of Water in the Ocean

8.1 Introduction

8.2 Ocean currents

8.3 Gulf Stream

8.4 Information support

Chapter 9 Climate and Seasons

9.1 Temperate zones – northern and southern hemispheres

9.2 Tropical zones

9.3 Monsoons

9.3.1 Southwest Indian monsoon

9.3.2 West African monsoon

9.3.3 West coast North America monsoon

9.4 Intertropical convergence zone (ICZ)

9.5 Predictability

9.6 Information support

Chapter 10 Hurricanes, Typhoons and Cyclones

10.1 Introduction

10.2 Hurricanes and tropical cyclones

10.3 Monitoring tropical cyclones

10.4 Effect of ENSO on tropical cyclones

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xvii

	10.5 Information support
Chapter 11	El Niño-Southern Oscillation
	11.1 Introduction
	11.2 ENSO normal conditions
	11.3 El Niño
	11.4 La Niña
	11.5 Global impact of ENSO
	11.6 Prediction of ENSO events
	11.7 Information support
Chapter 12	Climate Change – Natural Forces
	12.1 Introduction
	12.2 Tectonic activity
	12.3 Solar radiation, sun spots and cosmic radiation
	12.4 Milankovitch Cycles – changes in Earth’s orbit and orientation to the sun
	12.5 Volcanic activity
	12.6 Global dimming
	12.7 Information support
Chapter 13	Paleoclimatology
	13.1 Introduction
	13.2 Variation of Earth’s temperature over the last 500 million years
	13.3 Climatic data obtained from proxy sources
	13.3.1 Historical records
	13.3.2 Tree rings
	13.3.3 Lake sediments

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xviii

- 13.3.4 Corals**
- 13.3.5 Ice cores – Antarctica and Greenland**
- 13.3.6 Ice cores – ice caps**
- 13.3.7 Speleothems**
- 13.3.8 Loess**
- 13.3.9 Boreholes**
- 13.3.10 Marine sediments**
- 13.3.11 Geomorphic features**
- 13.3.12 Pollen**
- 13.3.13 Oxygen isotopes and hydrogen isotopes**
- 13.3.14 Stomatal density (Stomata Density Index, SDI)**
- 13.3.15 Radiocarbon or Carbon-14 dating**
- 13.3.16 Beryllium 10 and 7**
- 13.3.17 Radiometric dating or radioactive dating**
- 13.3.18 Leaf wax**
- 13.3.19 Anecdotal and ad hoc historical data**

13.4 Ice ages

13.5 Little ice age

13.6 Information support

Chapter 14 Modern Instrumental Period

14.1 Introduction

14.2 Instrumental temperature record

14.3 Modern instrumentation

14.4 Satellites

14.5 Information support

Chapter 15 Greenhouse Gases and Aerosols

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

15.1 Introduction

15.1.1 Greenhouse gas emissions – an overview

15.1.2 Aerosols

15.2 Types of greenhouse gas emissions

15.3 Carbon dioxide emissions by fuel type

15.4 Carbon dioxide emissions from cement production

15.5 Methane (CH₄) emissions

15.6 Sources of greenhouse gases

15.6.1 World greenhouse gas emissions by sector in 2018

15.6.2 Global historical emissions

15.6.3 Comparison of global greenhouse gas emissions by country by Johannes Friedrich.

15.6.4 Global historical comparison of emissions by the top ten emitting countries.

15.7 Greenhouse gas emissions – reported

15.7.1 UNFCC country reports by country projected to 2030

15.7.2 Global Carbon Project

15.7.3 US National Academies of Science, Engineering and Medicine

15.8 Greenhouse gas emissions – observed

15.8.1 Land and ocean-based GHG monitoring and sampling

15.8.2 Aircraft GHG sampling

15.8.3 Satellite based monitoring

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

15.9 Natural and anthropogenic radiative forcing

15.10 Carbon footprint and auditing

15.11 Emission intensity or carbon intensity

15.12 Carbon neutral, decarbonizing, net zero, carbon efficiency

15.13 Carbon management

15.13.1 Cap-and-trade (carbon allowance, carbon cap, carbon credits, carbon offsets, negative emissions)

15.13.2 Carbon tax

15.13.3 Carbon dividend

15.13.4 Carbon leakage

15.13.5 Carbon tariff

15.13.6 Carbon pricing

15.13.7 Avoided emissions

15.13.8 Renewable energy certificate
15.12 Carbon neutral, decarbonizing, net zero, carbon efficiency

15.14 Net zero by 2050 objective and committed warming

15.15 Super pollutant concept

15.16 Immortal pollutants

15.17 Information support

Chapter 16 Observation and Impacts of Recent Climate Change – Attribution Science

16.1 Attribution

16.2 Temperature and greenhouse gas

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxi

16.3 Ocean acidification

16.4 Arctic

16.4.1 Sea ice

16.4.2 Permafrost

16.4.3 Loss and change of habitat

16.4.4 Transportation

16.4.5 Territorial claims

16.4.6 Methane and GHG's

16.4.7 Glaciers

16.5 Greenland

16.6 Antarctica

16.6.1 Loss of ice mass.

16.6.2 Break up of Larson C ice shelf

16.6.3 Break up of ice shelf at the terminus of Thwaites Glacier in West Antarctica

16.6.4 Effect of climate change on the ecology of Antarctica

16.7 Oceans

16.7.1 Warming

16.7.2 Sea level

16.7.3 AMOC – Atlantic Meridional Overturning 2022

16.8 Coral reefs

16.9 Thermal habitat of oceans and lakes

16.10 Droughts

16.11 Desertification

16.12 Wildfires

16.13 Tropical cyclones

16.14 Intergovernmental Panel on Biodiversity and Ecosystem

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxii

Services, IPBES

16.15 Biological Diversity (Biodiversity)

16.15.1 Convention on Biological Diversity, CBD

16.15.2 International Union for Conservation of Nature

16.15.3 World Wildlife Fund (WWF) – Living Planet Report 2020

16.15.4 World Wildlife Fund – Living Planet Report 2022

16.16 Habitat change – natural environment – general

Comments

16.17 Glaciers

16.18 Regional impacts of climate change

IPCC Climate Change 2014, Synthesis Report, AR5

16.19 Extreme weather

16.19.1 Heat dome - heatwave Pacific Northwest 2021

16.19.2 Atmospheric river - extreme rainfall caused by multiple atmospheric rivers British Columbia, Canada 2021

16.19.3 Increasing major snowstorms

16.19.4 USEPA climate change indicators

16.19.5 Double jet streams – heatwaves over Europe 2022

16.19.6 Extreme weather 2022

16.20 US EPA Report May 2021

16.21 Health

16.21.1 Heat and hot weather

16.21.2 Present and potential health impacts of climate change

16.21.3 Stress and anxiety among our children and youth and everyone else.

16.22 Forecasting

16.22.1 Overview

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxiii

16.22.2 Climate change models

16.22.3 Stochastic

16.23 Social impacts

16.23.1 Economic impacts

16.23.2 Poverty

16.23.3 Migration

16.23.4 War

16.24 Tipping points, domino effects, knock-on effects, runaway global warming and hothouse Earth

16.25 Future updates

16.26 Information support

Chapter 17 Climate Models

17.1 Introduction

17.2 Climate models

17.3 Data available for climate models

17.4 Climate models

17.4.1 Atmosphere-ocean general circulation models (AOGCM)

17.4.2 Earth system models (ESM)

17.4.3 Regional climate models

17.4.4 Emulator models

17.4.5 Ensemble models

17.5 CMIP5 Coupled model intercomparison project AR5

17.6 CMIP5 model predictions of surface temperature change compared to observed

17.7 CMIP6 Coupled model intercomparison project AR6

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxiv

17.8 CMIP6 model predictions of surface temperature change compared to observed

17.9 CORDEX regional climate model

17.10 CMIP6 models and CORDEX model results

17.11 Confidence, agreement and likelihood terminology - assessment of model predictions

17.12 Integrated assessment models, IAMs

17.13 Information support

Chapter 18 IPCC 2014 AR5 - Impacts of Climate Change on Physical Systems

18.1 Introduction

18.2 Scenarios

18.3 Projected impacts physical impacts

18.3.1 Temperature

18.3.2 Water – soil moisture, runoff, precipitation, evaporation

18.3.3 Cryosphere

18.3.4 Sea level

18.3.5 Ocean chemistry

18.3.6 Jet stream

18.3.7 Atlas of global and regional climate projections

18.4 Climate phenomena and regional climate change

18.5 Tipping points, domino effects, knock-on effects, runaway global warming and hothouse Earth

18.6 Snow melt from mountainous regions

18.7 Atmospheric rivers

18.8 Net-zero by 2050 objective and committed warming

18.9 Information support

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxv

Chapter 19 IPCC 2014 AR5 - Adaptation

19.1 Introduction

19.2 Nature

19.3 Humans and human managed systems

19.4 Financial implications of global warming and climate change

19.5 Climate justice

19.6 Information support

Chapter 20 IPCC 2014 AR5 - Mitigation

20.1 Introduction

20.2 The science

**20.3 Consequences of unconstrained continued emission of
greenhouse gases.**

**20.4 Strategies for limiting temperature increases to between
1-2 °C**

20.5 Mitigation strategies

20.6 Paris Agreement

20.7 Net-zero by 2050 objective and committed warming

20.8 Information support

Chapter 21 Sixth Assessment Report – AR6 WGI Climate Change 2021: The Physical Science Basis

21.1 Introduction

21.2 Outcomes of note

21.3 Shared socio-economic pathways, SSPs

21.4 AR6

21.4.1 Validity of AR6 simulations

21.4.2 Details of emission scenarios used in AR6 simulations

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxvi

21.4.3 Global impact of human activities (also taken from AR6 WG1 SPM)

2.4.4 Climatic impact-drivers

21.4.5 Limiting future climate change to 1.5°C

21.4.5 IPCC WG1 Interactive Atlas <https://interactive-atlas.ipcc.ch/>

21.4.6 NASA/ IPCC Sea level projection tool

21.4.7 Climate Information web site

<https://climateinformation.org/>

21.4.8 Climate data for a resilient Canada <https://climatedata.ca/>

21.4.9 Carbon Brief's In-depth Q&A: The IPCC's sixth assessment report on climate science

21.5 Net zero by 2050 objective and committed warming

21.6 Information support

Chapter 22 Sixth Assessment Report – AR6 WGII Climate Change 2021: Impacts, Adaptation and Vulnerability

Chapter 23 Sixth Assessment Report – AR6 WGIII Climate Change 2021: Mitigation

Chapter 24 Comments

Chapter 25 Glossary

Chapter 26 Selected Web Sites

24.1 Educational

24.2 Newsletters

26.3 International organizations

26.3.1 World Meteorological Organization

26.3.2 United Nations Environment Programme, UNEP

26.3.3 World Climate Research Program

26.3.4 Future Earth

26.3.5 United Kingdom Met Office

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxvii

26.3.6 United Nations Office for Disaster Risk Reduction

26.3.7 Urban Climate Change Research Network

December 12, 2020 – Fifth Anniversary of the Paris Agreement

August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change, The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

Guide to the Science of Climate Change in the 21st Century, August 14, 2021

xxviii