

Contents

Contributors ix

1. Introduction of artificial intelligence in Earth sciences 1

Ziheng Sun and Nicoleta Cristea

- 1 Background and motivation 1
- 2 AI evolution in Earth sciences 4
- 3 Latest developments and challenges 6
- 4 Short-term and long-term expectations for AI 8
- 5 Future developments and how to adapt 9
- 6 Practical AI: From prototype to operation 9
- 7 Why do we write this book? 11
- 8 Learning goals and tasks 12
- 9 Assignments & open questions 14
- References 14

2. Machine learning for snow cover mapping 17

Kehan Yang, Aji John, Ziheng Sun, and Nicoleta Cristea

- 1 Introduction 17
- 2 Machine learning tools and model 18
- 3 Data preparation 19
- 4 Model parameter tuning 21
- 5 Model training 28
- 6 Model performance evaluation 32
- 7 Conclusion 38
- 8 Assignment 39
- 9 Open questions 39
- References 39

3. AI for sea ice forecasting 41

Sahara Ali, Yiyi Huang, and Jianwu Wang

- 1 Introduction 41
- 2 Sea ice seasonal forecast 42

- 3 Sea ice data exploration 44
- 4 ML approaches for sea ice forecasting 45
- 5 Results and analysis 55
- 6 Discussion 56
- 7 Open questions 57
- 8 Assignments 57
- References 57

4. Deep learning for ocean mesoscale eddy detection 59

Edwin Goh, Annie Didier, and Jinbo Wang

- 1 Introduction 59
- 2 Chapter layout 60
- 3 Data preparation 61
- 4 Training and evaluating an eddy detection model 75
- 5 Discussion 94
- 6 Summary 97
- 7 Assignments 97
- 8 Open questions 98
- Acknowledgments 99
- References 99

5. Artificial intelligence for plant disease recognition 101

Jayme Garcia Arnal Barbedo

- 1 Introduction 101
- 2 Data retrieval and preparation 103
- 3 Step-by-step implementation 105
- 4 Experimental results and how to select a model 111
- 5 Discussion 113
- 6 Conclusion 115
- 7 Assignment 115
- 8 Open questions 115
- References 116

6. Spatiotemporal attention ConvLSTM networks for predicting and physically interpreting *wildfire spread* 119

Arif Masrur and Manzhu Yu

- 1 Introduction 119
- 2 Methodology 121
- 3 Earth AI workflow 123
- 4 Results 148
- 5 Conclusions 154
- 6 Assignment 155
- 7 Open questions 155
- References 155

7. AI for physics-inspired hydrology modeling 157

Andrew Bennett

- 1 Introduction and background 157
- 2 PyTorch and autodifferentiation 160
- 3 Extremely brief background on numerical optimization 169
- 4 Bringing things together: Solving ODEs inside of neural networks 177
- 5 Scaling up to a conceptual hydrologic model 186
- 6 Conclusions 201
- References 202
- Further reading 203

8. Theory of spatiotemporal deep analogs and their application to solar forecasting 205

Weiming Hu, Guido Cervone, and George Young

- 1 Introduction 206
- 2 Research data 208
- 3 Methodology 211
- 4 Results and discussion 218
- 5 Final remarks 234
- 6 Assignment 235
- 7 Open questions 236
- Appendix A Deep learning layers and operators 236
- Appendix B Verification of extended analog search with GFS 238
- Appendix C Weather analog identification under a high irradiance regime 240

Appendix D Model attribution 242

References 244

9. AI for improving ozone forecasting 247

Ahmed Alnuaim (Alnaim), Ziheng Sun, and Didarul Islam

- 1 Introduction 247
- 2 Background 249
- 3 Data collection 251
- 4 Dataset preparation 254
- 5 Machine learning 255
- 6 ML workflow management 264
- 7 Discussion 265
- 8 Conclusion 266
- 9 Assignment 267
- 10 Open questions 267
- 11 Lessons learned 267
- References 268

10. AI for monitoring power plant emissions from space 271

Ahmed Alnuaim (Alnaim) and Ziheng Sun

- 1 Introduction 271
- 2 Background 274
- 3 Data collection 275
- 4 Preprocessing 281
- 5 Machine learning 285
- 6 Managing emission AI workflow in Geoweaver 290
- 7 Discussion 291
- 8 Summary 292
- 9 Assignment 292
- 10 Open questions 293
- 11 Lessons learned 293
- References 294

11. AI for shrubland identification and mapping 295

Michael J. Mahoney, Lucas K. Johnson, and Colin M. Beier

- 1 Introduction 295
- 2 What you'll learn 296
- 3 Background 296
- 4 Prerequisites 297
- 5 Model building 299
- 6 Discussion 312

7 Summary	315
8 Assignment	315
9 Open questions	315
References	316

12. Explainable AI for understanding ML-derived vegetation products 317

Geetha Satya Mounika Ganji and Wai Hang Chow Lin

1 Introduction	317
2 Background	318
3 Prerequisites	320
4 Method & technique	320
5 Experiment & results	322
6 Summary	333
7 Assignment	334
8 Open questions	334
9 Lessons learned	334
Acknowledgments	335
References	335
Further reading	335

13. Satellite image classification using quantum machine learning 337

Olawale Ayoade, Pablo Rivas, Javier Orduz, and Nurul Rafi

1 Introduction	337
2 Data	340
3 Applying QML on MODIS hyperspectral images	342
4 Conclusions	353
5 Assignments	354
6 Open questions	354
Acknowledgment	354
References	354

14. Provenance in earth AI 357

Amruta Kale and Xiaogang Ma

1 Introduction	357
2 Overview of relevant concepts in provenance, XAI, and TAI	359
3 Need for provenance in earth AI	363
4 Technical approaches	365
5 Discussion	372
6 Conclusions	374
7 Assignment	374
8 Open questions	374
Acknowledgments	375
References	375

15. AI ethics for earth sciences 379

Pablo Rivas, Christopher Thompson, Brenda Tafur, Bikram Khanal,
Olawale Ayoade, Tonni Das Jui, Korn Sooksatra, Javier Orduz, and
Gissella Bejarano

1 Introduction	379
2 Prior work	380
3 Addressing ethical concerns during system design	380
4 Considering algorithmic bias	382
5 Designing ethically driven automated systems	384
6 Assessing the impact of autonomous and intelligent systems on human well-being	386
7 Developing AI literacy, skills, and readiness	387
8 On documenting datasets for AI	388
9 On documenting AI models	390
10 Carbon emissions of earth AI models	391
11 Conclusions	393
12 Assignments	393
13 Open questions	394
References	394

Index 397