

# Parameterization Schemes

Keys to Understanding Numerical  
Weather Prediction Models

David J. Stensrud

CAMBRIDGE

# PARAMETERIZATION SCHEMES

## Keys to Understanding Numerical Weather Prediction Models

DAVID J. STENSRUD

*National Severe Storms Laboratory  
National Oceanic and Atmospheric Administration  
Norman, Oklahoma*

Weather prediction models have developed rapidly over the last two decades, and they now have the ability to predict the weather days in advance. This book provides a comprehensive introduction to the theory and practice of numerical weather prediction, with emphasis on the physical processes that control the weather and climate.

The book begins with an introduction to the basic principles of numerical weather prediction, followed by a detailed discussion of the physical processes that control the weather and climate. It then covers the development of numerical weather prediction models, including the use of observational data to validate the models and the use of the models to predict the weather and climate.

The book is intended for students and researchers in atmospheric science, meteorology, and related fields. It is also suitable for anyone interested in learning about the science of weather prediction. The book is divided into three main parts: Part I covers the basic principles of numerical weather prediction; Part II covers the physical processes that control the weather and climate; and Part III covers the development of numerical weather prediction models.



CAMBRIDGE  
UNIVERSITY PRESS

# Contents

<i>Preface</i>	page xi
<i>List of principal symbols and abbreviations</i>	xv
<b>1 Why study parameterization schemes?</b>	1
1.1 Introduction	1
1.2 Model improvements	3
1.3 Motivation	7
1.4 Question	11
<b>2 Land surface–atmosphere parameterizations</b>	12
2.1 Introduction	12
2.2 Overview of the surface energy budget	14
2.3 Net radiation	23
2.4 Sensible heat flux	28
2.5 Latent heat flux	42
2.6 Ground heat flux	48
2.7 Surface energy budget equation	55
2.8 Representation of terrain	56
2.9 Discussion	58
2.10 Questions	60
<b>3 Soil–vegetation–atmosphere parameterizations</b>	63
3.1 Introduction	63
3.2 Describing vegetation in models	66
3.3 Describing soils in models	75
3.4 Biophysical control of evapotranspiration	80
3.5 Momentum transfer	92
3.6 Soil moisture availability	93
3.7 Radiation	107

3.8	Specifying soil temperature and soil moisture	109
3.9	Discussion	109
3.10	Questions	117
4	Water-atmosphere parameterizations	120
4.1	Introduction	120
4.2	Observing sea surface temperature	124
4.3	Sensible heat flux	127
4.4	Latent heat flux	133
4.5	Coupled ocean-atmosphere models	135
4.6	Discussion	135
4.7	Questions	137
5	Planetary boundary layer and turbulence parameterizations	138
5.1	Introduction	138
5.2	Reynolds averaging	146
5.3	Turbulence closure	147
5.4	Non-local closure schemes	151
5.5	Local closure schemes	164
5.6	Turbulence and horizontal diffusion	175
5.7	Discussion	176
5.8	Questions	181
6	Convective parameterizations	185
6.1	Introduction	185
6.2	Influences of deep convection on the environment	193
6.3	Deep-layer control convective schemes	201
6.4	Low-level control convective schemes	227
6.5	Shallow convection	249
6.6	Trigger functions	249
6.7	Discussion	250
6.8	Questions	258
7	Microphysics parameterizations	260
7.1	Introduction	260
7.2	Particle types	265
7.3	Particle size distributions	274
7.4	Bulk microphysical parameterizations	275
7.5	Discussion	297
7.6	Questions	304
8	Radiation parameterizations	306
8.1	Introduction	306
8.2	Basic concepts	309

8.3	Longwave radiative flux	315
8.4	Shortwave radiative flux	326
8.5	Radiative transfer data sets	335
8.6	Discussion	337
8.7	Questions	343
9	Cloud cover and cloudy-sky radiation parameterizations	346
9.1	Introduction	346
9.2	Cloud cover parameterizations	349
9.3	Cloud–radiation interactions	360
9.4	Discussion	367
9.5	Questions	371
10	Orographic drag parameterizations	373
10.1	Introduction	373
10.2	Simple theory	375
10.3	Gravity wave drag parameterizations	384
10.4	Low-level blocking drag parameterizations	387
10.5	Discussion	388
10.6	Questions	392
11	Thoughts on the future	393
11.1	Introduction	393
11.2	Ensemble predictions	395
11.3	Ensembles and high-resolution single forecasts	401
11.4	Statistical postprocessing	403
11.5	The road forward	405
	<i>References</i>	408
	<i>Index</i>	449

basic research areas, such as the development of new physical theories and the identification of new observational datasets.

changed? What are the major challenges? What are the opportunities?

also presented some of the major challenges and opportunities for the field about how to move forward. These challenges include what approaches to take to improve the quality of forecasts and parameters used in the models, and how to incorporate new observations and datasets for parameterization development.

There are also some general themes that have been identified as being sufficiently important to warrant continued and accelerated research.

major research themes are discussed in the following sections. In addition, a list of the major research themes is included in Table 11.1.

the schemes described in the following sections are not necessarily the only numerical methods used in the field, nor are they the best methods for all applications.

understanding of the strengths and weaknesses of different numerical methods is critical for their effective use.

numerical methods are often used in combination with other methods, such as statistical postprocessing or ensemble forecasting, to improve the quality of forecasts.

These combined approaches can help to address some of the challenges in the field, such as the need for more accurate parameterizations and improved observational datasets.

There are also some general themes that have been identified as being sufficiently important to warrant continued and accelerated research.

major research themes are discussed in the following sections. In addition, a list of the major research themes is included in Table 11.1.

the schemes described in the following sections are not necessarily the only numerical methods used in the field, nor are they the best methods for all applications.

understanding of the strengths and weaknesses of different numerical methods is critical for their effective use.

numerical methods are often used in combination with other methods, such as statistical postprocessing or ensemble forecasting, to improve the quality of forecasts.

These combined approaches can help to address some of the challenges in the field, such as the need for more accurate parameterizations and improved observational datasets.