Contents

List of figures .............................. x
List of tables .............................. xv
Acknowledgements ........................ xvii

1 Weather derivatives and the weather derivatives market ................................. 1
  1.1 Introduction ................................ 1
  1.2 Weather variables and indices ........................................ 10
  1.3 Derivative pay-offs ........................................ 19
  1.4 Principles of valuation ........................................ 28
  1.5 The correlation between weather and the stock market ................................ 34
  1.6 Overview of contents ........................................ 34
  1.7 Notes on citations ........................................ 35
  1.8 Further reading ........................................ 36

2 Data cleaning and trends ........................................ 37
  2.1 Data cleaning ........................................ 37
  2.2 The sources of trends in meteorological data ........................................ 42
  2.3 Removing trends in practice ........................................ 47
  2.4 What kind of trend and how many years of historical data to use? ......................... 53
  2.5 Conclusions ........................................ 57
  2.6 Further reading ........................................ 58

3 The valuation of single contracts using burn analysis ........................................ 59
  3.1 Burn analysis ........................................ 59
  3.2 Further reading ........................................ 72

4 The valuation of single contracts using index modelling ......................................... 73
  4.1 Statistical modelling methods ........................................ 73
  4.2 Modelling the index distribution ........................................ 74
  4.3 Parametric distributions ........................................ 77
  4.4 Non-parametric distributions ........................................ 85
## Contents

4.5 Estimating the pay-off distribution and the expected pay-offs  
4.6 Further reading  

5 Further topics in the valuation of single contracts  
5.1 Linear sensitivity analysis: the greeks  
5.2 The interpretation of delta and gamma  
5.3 A summary of the interpretation of the greeks  
5.4 Examples of the greeks  
5.5 The relative importance of choosing data, trends and distributions  
5.6 Comparing the accuracy of burn analysis and index modelling for option pricing  
5.7 The correlation between the results from burn and index modelling  
5.8 Pricing costless swaps  
5.9 Multi-year contracts  
5.10 Derived prices  
5.11 The pay-off integrand  
5.12 Pricing options using the swap price  
5.13 Hedging options with a single swap  
5.14 Sampling error and structuring  
5.15 Leap years  
5.16 Further reading  

6 The valuation of single contracts using daily modelling  
6.1 The advantages of daily modelling  
6.2 The disadvantages of daily modelling  
6.3 Modelling daily temperatures  
6.4 The statistical properties of the anomalies  
6.5 Modelling the anomalies  
6.6 Non-parametric daily modelling  
6.7 The use of daily models  
6.8 The potential accuracy of daily models versus index models  
6.9 Further reading  
6.10 Acknowledgements  

7 Modelling portfolios  
7.1 Portfolios, diversification and hedging  
7.2 Index dependences  
7.3 Burn analysis for portfolios  
7.4 Modelling the multivariate index distribution
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5 The daily modelling of portfolios</td>
<td>163</td>
</tr>
<tr>
<td>7.6 Parametric models for multivariate temperature variability</td>
<td>163</td>
</tr>
<tr>
<td>7.7 Dimension reduction</td>
<td>164</td>
</tr>
<tr>
<td>7.8 A general portfolio aggregation method</td>
<td>167</td>
</tr>
<tr>
<td>7.9 Further reading</td>
<td>168</td>
</tr>
<tr>
<td>8 Managing portfolios</td>
<td>169</td>
</tr>
<tr>
<td>8.1 Risk and return</td>
<td>169</td>
</tr>
<tr>
<td>8.2 Expanding a portfolio</td>
<td>181</td>
</tr>
<tr>
<td>8.3 Pricing against a portfolio</td>
<td>182</td>
</tr>
<tr>
<td>8.4 Market making</td>
<td>184</td>
</tr>
<tr>
<td>8.5 Efficient implementation methods for adding single contracts to a portfolio</td>
<td>184</td>
</tr>
<tr>
<td>8.6 Understanding portfolios</td>
<td>186</td>
</tr>
<tr>
<td>8.7 Reducing portfolio risk</td>
<td>189</td>
</tr>
<tr>
<td>8.8 Further reading</td>
<td>191</td>
</tr>
<tr>
<td>9 An introduction to meteorological forecasts</td>
<td>192</td>
</tr>
<tr>
<td>9.1 Weather forecasts</td>
<td>192</td>
</tr>
<tr>
<td>9.2 Forecasts of the expected temperature</td>
<td>196</td>
</tr>
<tr>
<td>9.3 Forecast skill</td>
<td>198</td>
</tr>
<tr>
<td>9.4 Improving forecasts of the expected temperature</td>
<td>203</td>
</tr>
<tr>
<td>9.5 Probabilistic forecasts</td>
<td>207</td>
</tr>
<tr>
<td>9.6 The use of ensemble forecasts for making probabilistic forecasts</td>
<td>209</td>
</tr>
<tr>
<td>9.7 Seasonal forecasts</td>
<td>212</td>
</tr>
<tr>
<td>9.8 Predicting El Niño and its effects</td>
<td>216</td>
</tr>
<tr>
<td>9.9 Other sources of seasonal predictability</td>
<td>218</td>
</tr>
<tr>
<td>9.10 Further reading</td>
<td>219</td>
</tr>
<tr>
<td>10 The use of meteorological forecasts in pricing</td>
<td>220</td>
</tr>
<tr>
<td>10.1 The use of weather forecasts</td>
<td>221</td>
</tr>
<tr>
<td>10.2 Linear swaps on separable linear indices</td>
<td>222</td>
</tr>
<tr>
<td>10.3 Linear swaps on separable indices</td>
<td>223</td>
</tr>
<tr>
<td>10.4 The general case: any contract, any index</td>
<td>224</td>
</tr>
<tr>
<td>10.5 Seasonal forecasts</td>
<td>240</td>
</tr>
<tr>
<td>10.6 Further reading</td>
<td>240</td>
</tr>
<tr>
<td>10.7 Acknowledgements</td>
<td>240</td>
</tr>
<tr>
<td>11 Arbitrage pricing models</td>
<td>241</td>
</tr>
<tr>
<td>11.1 Standard arbitrage theory</td>
<td>242</td>
</tr>
<tr>
<td>11.2 Comments on the standard theory</td>
<td>247</td>
</tr>
<tr>
<td>11.3 Extensions to the standard theory</td>
<td>252</td>
</tr>
</tbody>
</table>
## Contents

11.4 Weather swap price processes 254  
11.5 Pricing dual-trigger contracts 266  
11.6 Further reading 266

12 Risk management 268  
12.1 Risk management in liquid markets 268  
12.2 Marking positions 269  
12.3 Expiry risk 273  
12.4 Actuarial value at risk 275  
12.5 Liquidation value at risk 279  
12.6 Credit risk 280  
12.7 Liquidity risk 280  
12.8 Summary 281  
12.9 Further reading 281

13 Modelling non-temperature data 282  
13.1 Precipitation 282  
13.2 Wind 287  
13.3 Further reading 291

A Trend models 292  
A.1 A general theory for trend modelling and the uncertainty of trend estimates 292

B Parameter estimation 295  
B.1 Statistical models 295  
B.2 Parameter estimation 295

C Goodness of fit tests 298  
C.1 Goodness of fit tests 298

D Expected pay-offs for normally distributed indices 302  
D.1 Pay-off definitions 302  
D.2 Pay-off distributions 303  
D.3 Useful relations for deriving expressions for the expected pay-off 306  
D.4 Closed-form expressions for the expected pay-off 307  
D.5 Numerical examples 313

E Pay-off variances for normally distributed indices 315  
E.1 Useful relations for deriving expressions for the pay-off variance 315  
E.2 Closed-form expressions for the pay-off variance 316  
E.3 Numerical examples 322

F Greeks for normally distributed indices 324  
F.1 Useful relations for deriving expressions for the greeks 324  
F.2 Closed-form expressions for the greeks 325  
F.3 Numerical examples 332
Contents ix

G Exact solutions for the kernel density 334
   G.1 Closed-form solutions for the expected pay-off on a kernel density 334
   G.2 Closed-form solutions for the delta on a kernel density 335
   G.3 Closed-form solutions for the gamma on a kernel density 337
   G.4 Closed-form solutions for the pay-off variance on a kernel density 337
   G.5 An example 338

H The beta for a normally distributed index 340
   H.1 Useful relations 340
   H.2 Definitions 344
   H.3 Closed-form expressions for the beta 344
   H.4 Discussion 349
   H.5 Numerical examples 350

I Simulation methods 353
   I.1 Introduction 353

J Efficient methods for pricing against a portfolio 358
   J.1 Efficient methods for modelling one extra contract 358

References 360

Index 369