Contents

Abstract	ii
Acknowledgements	iii
Contents	V
List of Figures	ix
List of Tables	xviii

1. Introduction	1
1.1 The detection and attribution framework	1
1.2 Observational datasets	4
1.2.1 The HadCRUTv gridded surface temperature record	8
1.2.2 The HadRT radiosonde temperature record	10
1.2.3 Reconciling recent trend differences between near-surface and	12
radiosonde temperature records	
1.3 The Hadley Centre General Circulation Models	15
1.4 Previous detection studies	21
1.5 Conclusions	31
2. The HadRT temperature record: Treatment and quality control	33
2.1 Averaging to seasonal and annual values	34
2.2 Quality control procedures	35
2.3 Results from the Quality Control exercise	39
2.4 Sensitivity of results to methodological assumptions	43
2.5 Analysis of the treated HadRT2.1s temperature dataset	46
2.6 Conclusions	48
3. An intercomparison of modelled and observed fields	65
3.1 Method	65
3.1.1 Model data treatment	65
3.1.2 Diagnostics used in the intercomparison	67

3.2 A comparison of modelled and observed upper air temperature	71
diagnostics	
3.2.1 Global-mean temperature trends	71
3.2.2 Zonal-mean temperature changes	72
3.2.3 Changes in temperatures on pressure levels	73
3.2.4 Changes in tropospheric lapse rates	77
3.2.5 Overall model skill	79
3.3 Suitability for use of the full field HadRT temperature record in	81
formal detection and attribution studies	
3.4 Conclusions	82
4. Optimal detection methodologies	96
4.1 The basics of climate change detection	96
4.2 Detection seen as optimal regression	101
4.2.1 Ordinary Least Squares Regression	101
4.2.1.1 The basic regression model	101
4.2.1.2 Accounting for uncertainty in the model control variability	107
estimate	
4.2.1.3 A consistency check on the residuals	110
4.2.1.4 Recombining input fields to yield individual signal	112
amplitude estimates	
4.2.1.5 Addressing possible input signal degeneracy	113
4.2.1.6 Signal-to-noise ratio analysis	114
4.2.1.7 Applications of the results from OLS regressions and	115
remaining uncertainties	
4.2.2 Total Least Squares regression	119
4.2.2.1 Accounting for the presence of noise in the signal estimates	119
4.2.2.2 Accounting for uncertainty in the control estimate of natural	124
variability	
4.2.2.3 Remaining problems	126
4.3 Other multi-variate detection approaches	127
4.4 Conclusions	131

5.	Zonal-mean detection studies: Sensitivity to observational, model and	133
	pre-formatting uncertainties	
	5.1 Identifying and testing for sources of uncertainty in fixed-signal	134
	zonally-averaged optimal regression detection studies	
	5.2 Assessing the sensitivity of fixed-signal zonal-mean optimal detection	140
	results	
	5.3 Conclusions	149
6.	The most likely causes of late 20 th Century observed temperature	167
	changes at the near-surface and within the free troposphere	
	6.1 Observed and modelled field pre-processing	167
	6.2 Upper tropospheric temperatures	172
	6.3 Lower tropospheric temperatures	182
	6.4 Near-surface temperatures	186
	6.5 Free troposphere lapse rates	190
	6.6 Entire troposphere lapse rates	196
	6.7 Lower troposphere lapse rates	200
	6.8 Discussion	204
	6.8.1 The most likely causes of differences in detection results	205
	between HadRT versions	
	6.8.2 A summary of principal tropospheric temperature detection	206
	study results for two state-of-the-art climate models	
	6.8.2.1 HadCM2	207
	6.8.2.2 HadCM3	213
	6.9 Conclusions	215
7.	A framework for quantitatively advancing detection studies to begin	255
	to rigorously consider the internal consistency of state-of-the-art	
	climate models	
	7.1 The OLS regression algorithm revisited	257
	7.2 Relaxing the conditions from an ideal situation to the real world situation	258
	7.3 Checking for model consistency: A conceptual framework	261

8. Conclusions	264
8.1 Summary of principal findings	264
8.1.1 Principal conclusions	273
8.2 Remaining uncertainties and avenues for future research	274
References	277
Glossary	287