

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Atmospheric Correction of New Zealand Landsat Imagery

A thesis presented in partial fulfilment of the requirements for the
degree of

Master of Philosophy
in
Earth Science

at Massey University, Palmerston North,
New Zealand

Sam Stafford Gillingham

2002



Abstract

In this study, MODIS data for New Zealand was downloaded and evaluated as input to the 6S atmospheric correction model. Data for one year were downloaded for aerosols, water vapour and ozone and trends of this data were studied. The sensitivity of retrieved reflectance of several targets to changes in the atmospheric components as seen in the MODIS data were also analysed. Several methods were developed for using this data for atmospheric correction and the output compared to a commercial atmospheric correction package (ATCOR 2).

In addition, ground measurements were used to confirm the accuracy of the MODIS data. This involved both data obtained from NIWA and readings taken with a hand held MICROTOPS instrument. These readings showed that the MODIS data has some inaccuracies. This can result in a significant error in the retrieved reflectance, especially for darker targets, such as forest. Therefore caution should be exercised when using aerosol values from MODIS in an atmospheric correction. However, the results for water vapour and ozone were reasonably close, giving confidence for using MODIS ozone and water vapour in atmospheric correction.

Ground measurements were also taken of targets with a GER 2600 Spectroradiometer and these readings compared to the atmospheric corrections of the same targets. This confirmed the accuracy of the atmospheric correction methods.

Acknowledgements

I would firstly like to thank my supervisors James Shepherd and Mike Tuohy for their time and thoughtful advice throughout the preparation of this thesis.

Financial assistance was gratefully received from the Massey Masterate Scholarship and from my parents, who in addition provided much support and advice.

Thanks must also go to Landcare Research for providing facilities and equipment, and to all the people there who assisted me directly, and indirectly.

To NIWA, Lauder who provided me with the ozone data very promptly and willingly.

Lastly, I thank John Dymond and Olivia Hamid for their invaluable assistance with preparing the final drafts of this thesis.

Contents

Abstract	iii
Acknowledgements	v
1 Introduction	1
1.1 Aim	1
1.2 The Terra Satellite	4
1.3 MODIS	5
1.4 Aerosols	6
1.5 Water Vapour	8
1.6 Ozone	9
1.7 Other Atmospheric Constituents	10
1.8 Landsat7	13
1.9 Landcare Research	15
2 Methods	17
2.1 Processing the MODIS data	17
2.1.1 Downloading the Data	17
2.1.2 Extracting the Data	17
2.1.3 Rectifying the data	18
2.1.4 Calculating the cloud mask	19
2.1.5 Managing the data	19
2.1.6 Obtaining statistics	20
2.1.7 Processing data for each product	21
2.2 Sensitivity Analysis with 6S	23
2.3 Ground Atmosphere Measurements	25
2.3.1 Measuring Aerosol Optical Depth	27
2.3.2 Setting up the Langley Plot	29

2.3.3	Problems with the 320nm data	31
2.3.4	Comparison with MODIS	31
2.3.5	MICROTOPS Ozone and Water Vapour data	32
2.3.6	NIWA Ozone and Water Vapour	32
2.4	Applying an Atmospheric Correction	34
2.4.1	Spatial Atmospheric Correction	34
2.4.2	Simple Atmospheric Correction	36
2.4.3	Atmospheric Correction using Monthly Composites	37
2.4.4	Lauder Data Based Atmospheric Correction	37
2.5	Atmospheric Correction using ATCOR	38
2.5.1	How it works	38
2.5.2	An atmospheric correction	39
2.6	Ground Cover Measurements	41
2.6.1	The Spectroradiometer Instrument	42
2.6.2	Ground cover selection	44
2.6.3	Applying the Landsat filter function	45
3	Results	47
3.1	MODIS Results	47
3.1.1	Aerosol Results	47
3.1.2	Water Vapour Results	51
3.1.3	Ozone Results	51
3.2	Sensitivity Analysis Results	55
3.2.1	Result over all possible values	56
3.2.2	Results for the New Zealand atmosphere	66
3.3	Ground Atmosphere Measurements	72
3.3.1	Estimating Rayleigh Scattering	72
3.3.2	Langley Plots	73
3.3.3	MICROTOPS Results	77
3.3.4	Results from MODIS Aerosol	78
3.3.5	Results from Paraparaumu NIWA Water Vapour data	78
3.3.6	Results from the Lauder NIWA Ozone data	80
3.4	Comparison of Atmospheric Correction Methods	81
3.4.1	CPU times of Atmospheric Correction	81
3.4.2	Target Comparisons	82
3.5	Ground Cover Measurements	87

<i>CONTENTS</i>	ix
3.5.1 Test reading	87
3.5.2 The Hockey Pitch	88
3.5.3 Lake Horowhenua	91
4 Discussion	93
4.1 MODIS data	93
4.2 Sensitivity Analysis with 6S	95
4.3 Ground Atmosphere Measurements	96
4.4 Methods of Atmospheric Correction	99
4.5 Comparison with Ground Readings	100
5 Conclusion and Future Work	103
5.1 Conclusion	103
5.2 Future Work	105
A Reference Spectra	107
Bibliography	113

List of Figures

1.1	Spectral Transmittance of H_2O [46].	9
1.2	Spectral Transmittance of Ozone [46].	11
1.3	Spectral Transmittance of carbon dioxide [46].	12
1.4	The response of the ETM+ sensor aboard Landsat7 excluding Band 6 and 8.	14
2.1	Data Processing steps for each Data Layer (Aerosols, Water Vapour and Ozone).	22
2.2	View of MICROTOPS instrument (top) and operation on the roof of Landcare building (bottom).	26
2.3	Sun position for Langley readings.	28
2.4	Sun Elevation for Massey University for the morning of 30 April 2002.	30
2.5	Comparison of different Atmospheric Correction Techniques.	35
2.6	Spatial Atmospheric Correction Process.	35
2.7	Screen shot of ATCOR 2 Spectra Module.	42
2.8	The GER 2600 instrument mounted on its tripod.	43
3.1	Monthly Aerosol Composites	48
3.2	Aerosol Optical Depth for New Zealand over one year.	49
3.3	Spatial and temporal variations in Aerosol Optical Depth over one year.	50
3.4	Apparent visibility over one year.	50
3.5	Monthly Water Vapour Composites	52
3.6	Precipitable Water Vapour for New Zealand over one year.	53
3.7	Spatial and Temporal variations of Water Vapour over one year.	53
3.8	Monthly Ozone Composites	54
3.9	Ozone for New Zealand for one year.	55
3.10	Spatial and Temporal variations in Ozone over one year.	56

3.11	Selected Targets in December 2000 Landsat Scene (Red=Band 4, Green=Band 5, Blue=Band 3).	57
3.12	Close up of Selected Targets in December 2000 Landsat Scene.	58
3.13	Specific Humidity vs Altitude for Paraparaumu.	59
3.14	Variation in Forest Target due to Aerosol.	60
3.15	Variation in Pasture Target due to Aerosol.	61
3.16	Variation in Soil Target due to Aerosol.	61
3.17	Variation in Forest Target due to Water Vapour.	63
3.18	Variation in Pasture Target due to Water Vapour.	63
3.19	Variation in Soil Target due to Water Vapour.	64
3.20	Variation in Forest Target due to Ozone.	64
3.21	Variation in Pasture Target due to Ozone.	65
3.22	Variation in Soil Target due to Ozone.	65
3.23	Variation in Forest Target due to Aerosol quantities in New Zealand.	67
3.24	Variation in Pasture Target due to Aerosol quantities in New Zealand.	67
3.25	Variation in Soil Target due to Aerosol quantities in New Zealand.	68
3.26	Variation in Forest Target due to Water Vapour quantities in New Zealand.	69
3.27	Variation in Pasture Target due to Water Vapour quantities in New Zealand.	69
3.28	Variation in Soil Target due to Water Vapour quantities in New Zealand.	70
3.29	Variation in Forest Target due to Ozone quantities in New Zealand.	70
3.30	Variation in Pasture Target due to Ozone quantities in New Zealand.	71
3.31	Variation in Soil Target due to Ozone quantities in New Zealand.	71
3.32	Langley plot for readings taken on 16 May at 1020nm.	74
3.33	Langley plot for readings taken on 16 May at 320nm.	74
3.34	Langley plot readings taken on 10 August at 1020nm.	75
3.35	Langley plot readings taken on 29 August at 1020nm.	76
3.36	Langley plot readings taken on 9 October at 1020nm.	76
3.37	NIWA and MODIS data for Paraparaumu.	79
3.38	Ozone recorded at Lauder compared to MODIS.	81
3.39	Original Landsat subset (left) and spatially atmospherically corrected scene (right). Bands 1, 2 and 3.	82
3.40	Landsat Extract including Palmerston North.	83
3.41	Selected Targets from the Landsat Extract.	84
3.42	Test run of the GER 2600.	88

3.43	Close up of Hockey ground with GPS positions overlaid.	89
A.1	Reference Spectra for Artificial Hockey Pitch (GER).	108
A.2	Reference Spectra for Manuka (GER).	108
A.3	Reference Spectra for Regrowing Bush (GER).	109
A.4	Reference Spectra for Pine (GER).	109
A.5	Reference Spectra for Soil (GER).	110
A.6	Reference Spectra for Asphalt (GER).	110
A.7	Reference Spectra for a Hokowhitu Lagoon (GER).	111
A.8	Reference Spectra for Sea (ATCOR).	111
A.9	Reference Spectra for Concrete (GER).	112
A.10	Reference Spectra for Grass (GER).	112

