Using Atmospheric and BRDF Correction to Standardise time series of Landsat Data

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Current situation in Australia

- **Standardised high resolution satellite data (eg. Landsat) are needed to map land cover and biomass, detect effects of climate change and conduct time series analysis.**

- **A variety of empirical models are currently used to conduct Multi-View Angle (MVA) and atmospheric correction for Landsat in order to remove/reduce view, solar, BRDF and atmospheric effects.**

- **However, empirical models need extensive field data, are hard to apply to a new environments and cannot easily be validated using field reflectance measurements**

Motivation

- **Is it operationally important to use MVA and atmospheric correction for high resolution satellite data, e.g. Landsat?**
- **Can we operationally use a physically based model to conduct operational BRDF and atmospheric correction for Landsat?**
- **Can we operationally use MODIS BRDF products to normalise Landsat for BRDF at the same time as for atmosphere?**

Theory (1)

Semi-empirical BRDF can be expressed as:

$$\rho(\theta_s,\theta_v,\varphi, \lambda) = f_{iso}(\lambda)+f_{vol}(\lambda)K_{vol}(\theta_s,\theta_v,\varphi)+f_{geo}(\lambda)K_{geo}(\theta_s,\theta_v,\varphi)$$

Normalized BRDF can be expressed as:

$$N(\theta_s,\theta_v,\varphi, \lambda) = \rho(\theta_s,\theta_v,\varphi, \lambda) / f_{iso}(\lambda) =$$

$$1+f_{vol}(\lambda)/f_{iso}(\lambda)K_{vol}(\theta_s,\theta_v,\varphi)+f_{geo}(\lambda)/ f_{iso}(\lambda)K_{geo}(\theta_s,\theta_v,\varphi)$$

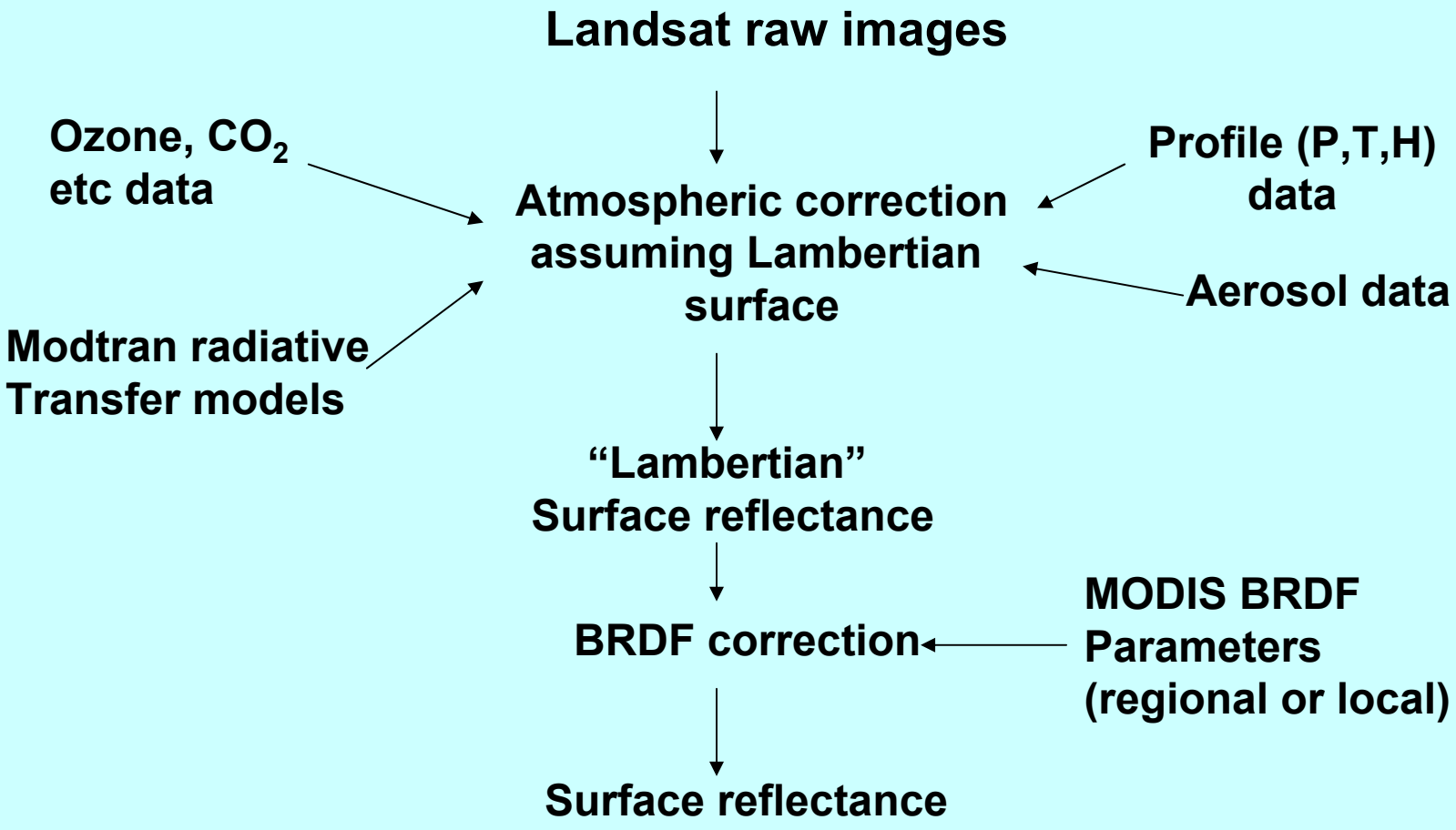
Theory (2)

$$\rho_{TOA} = \rho_A + t_V t_S \rho_S + t_V t_d(\theta_S)\overline{\rho} + t_S t_d(\theta_V)\overline{\rho'} + t_d(\theta_S) t_d(\theta_V)\overline{\overline{\rho}} + \frac{(t_S + t_d(\theta_S))(t_V + t_d(\theta_V)) S(\overline{\overline{\rho}})^2}{1 - S\overline{\overline{\rho}}}$$

ρ_A, t_V, t_S, $t_d(\theta_S)$, $t_d(\theta_V)$, S are available as MODTRAN outputs.

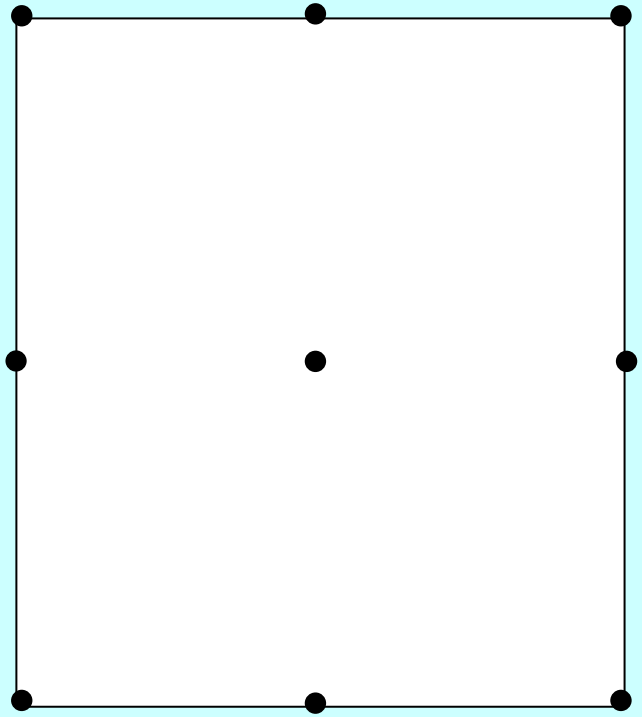
Using the MODIS BRDF shape function, we can allow for BRDF as well as atmosphere in Landsat using a physical model.

Algorithm


Landsat raw images
Ozone, CO_2 etc data
Profile (P,T,H) data
Atmospheric correction assuming Lambertian surface
Aerosol data
Modtran radiative Transfer models
"Lambertian" Surface reflectance
BRDF correction
MODIS BRDF Parameters (regional or local)
Surface reflectance

Atmospheric Correction Method

Divide Landsat image into four rectangles (one scene) and run Modtran at 9 corner coordinates. Interpolate slowly varying Modtran atmospheric outputs from the 9 Points using a bilinear method to get correction parameters for each pixel.



BRDF Normalisation

- BRDF model used was the Ross-Li model as developed by the MODIS Team at Boston, obtained from the NASA DAAC as a 16-day composite.
- The average BRDF parameters over the Landsat scene were used for a regional BRDF shape function (a land cover based approach is also possible).
- The BRDF correction was applied to the intermediate “Lambertian” reflectance product. It can be applied rapidly and easily at each pixel.

Analysing BRDF and atmospheric correction for a single Landsat scene

Four cases were compared

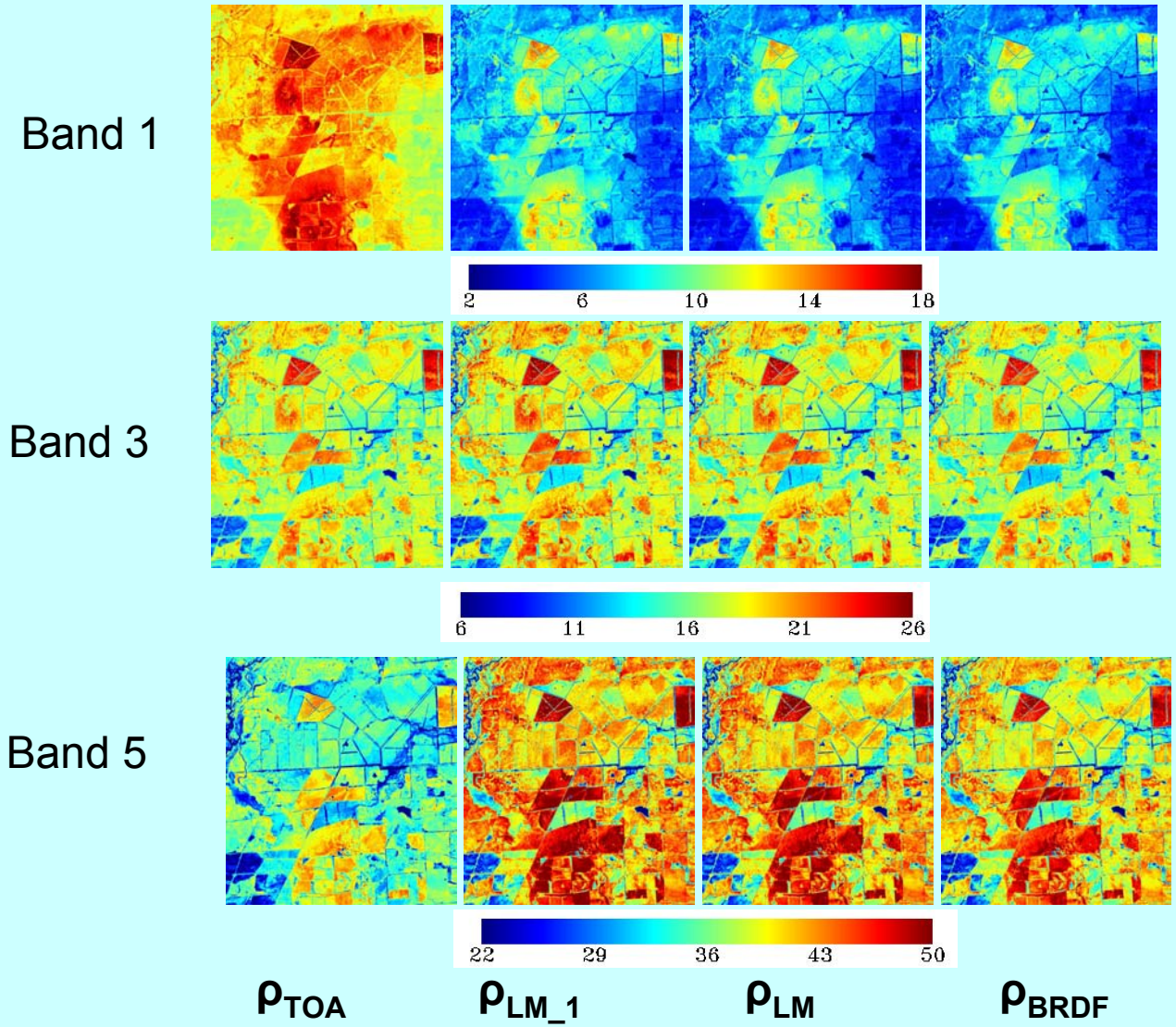
(1) Reflectance at top atmosphere, ρ_{TOA}

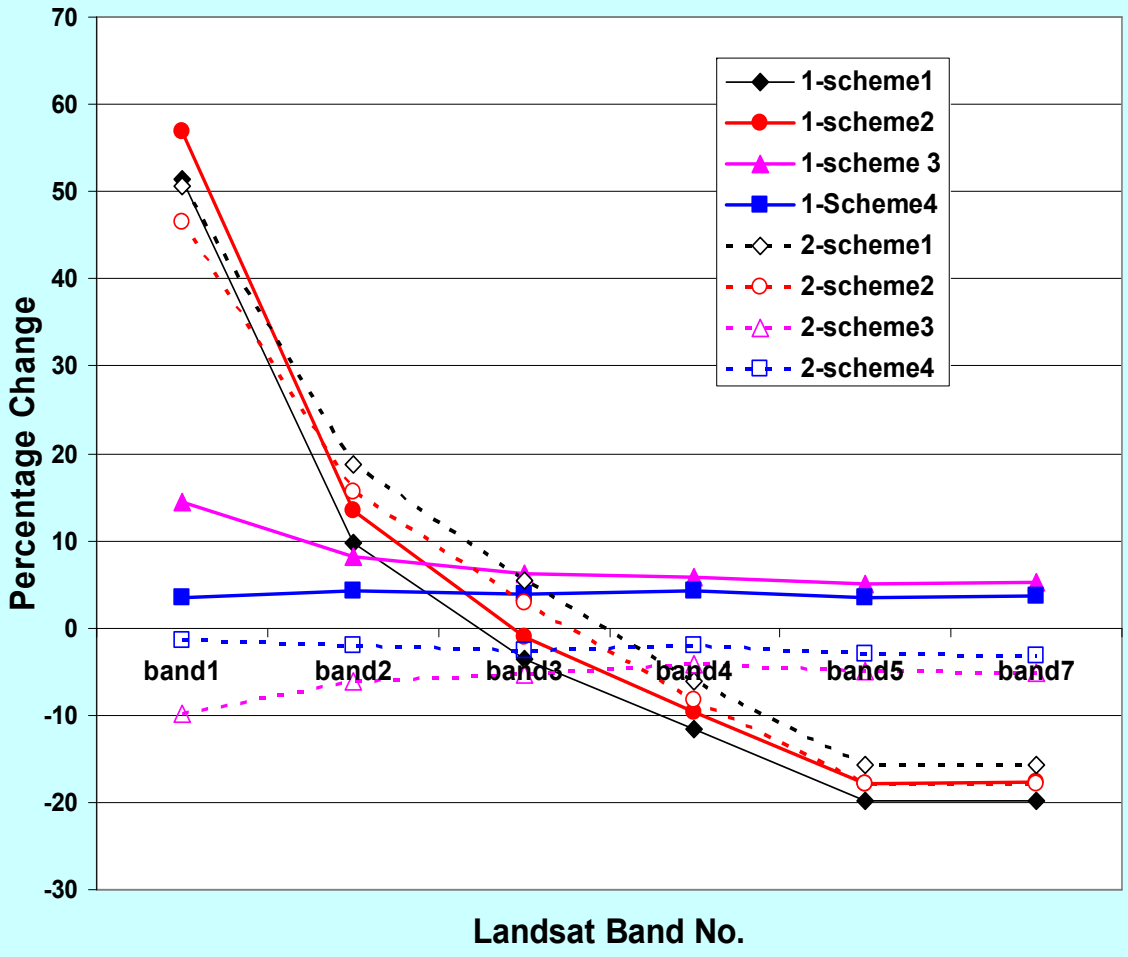
(2) Atmospherically corrected reflectance with single Modtran output (based on centre point MM), ρ_{LM_1}

(3) Atmospherically corrected reflectance with 9 point Modtran output and a bilinear scale method ρ_{LM}

(4) Case (3) followed by BRDF correction ρ_{BRDF}

Reflectance product (scale*100)





Pixel 1 is located at upper left of the image.

Pixel 2 is located at low right of the image.

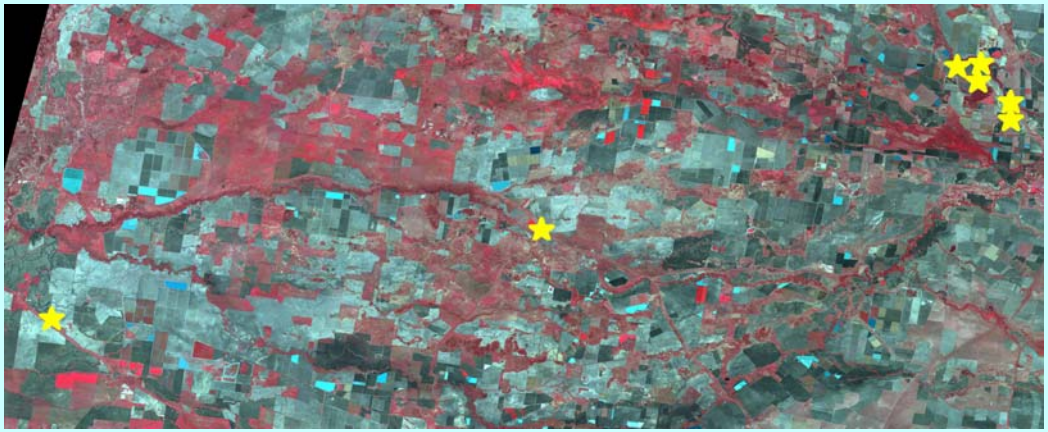
1-scheme1 is $(\rho_{TOA} - \rho_{LM_1}) / \rho_{TOA} * 100$ for pixel 1,
1-scheme2 is $(\rho_{TOA} - \rho_{LM}) / \rho_{TOA} * 100$ for pixel 1,
1-scheme3 is $(\rho_{LM-1} - \rho_{BRDF}) / \rho_{LM-1} * 100$ for pixel1,
1-scheme4 is $(\rho_{LM} - \rho_{BRDF}) / \rho_{LM} * 100$ for pixel 1,

Results

- **The BRDF effect accounts for 2-3% of the variation in Gwydir area. Atmosphere dominates the correction. If the scene were in the northern part of Australia and acquired in the summer, the BRDF effect would be stronger.**

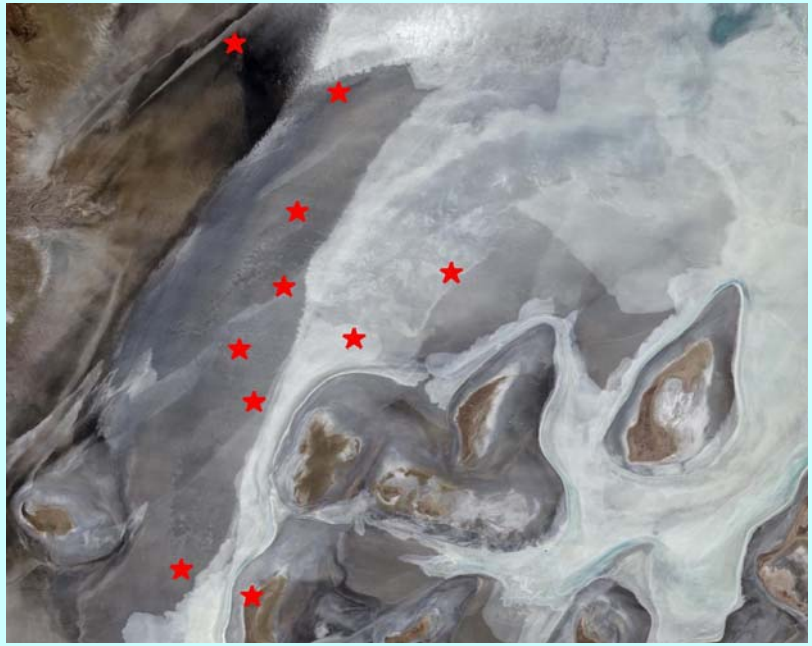
- **For time series analysis, BRDF correction is particularly important because the sun angle varies a great deal between summer and winter, between south and north.**

Gwydir Field measurements (23/06/2008 to 25/06/2008)



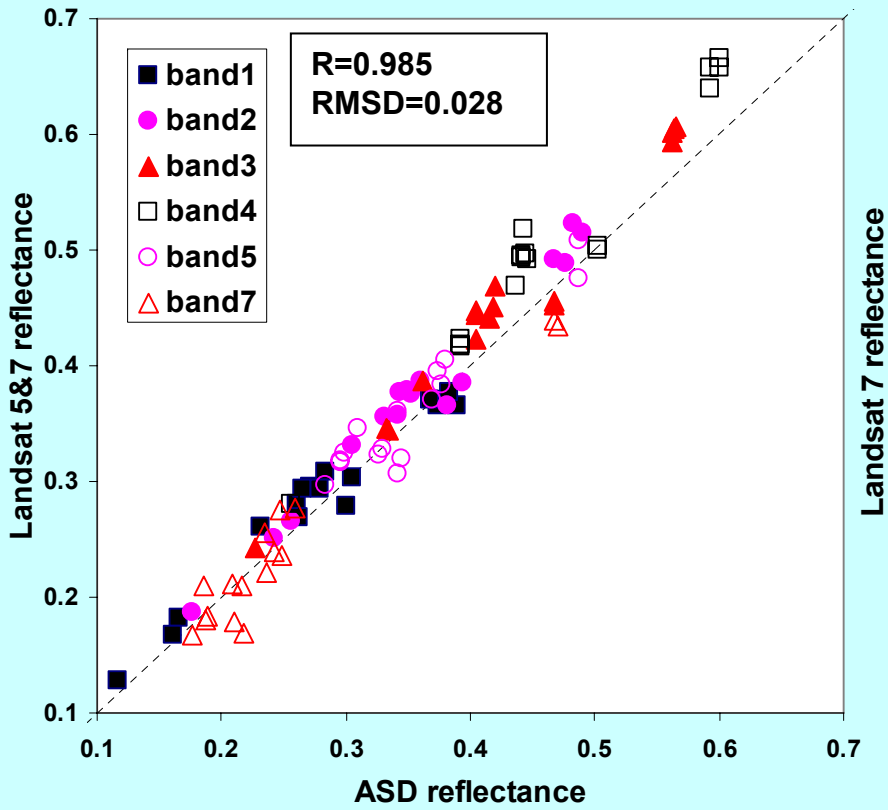
Gwydir field experiment
23/06/2008 to 25/06/2008
Northern New South Wales
bare soil and vegetation

Lake Frome field measurements (10/02/2009 to 13/02/2009)

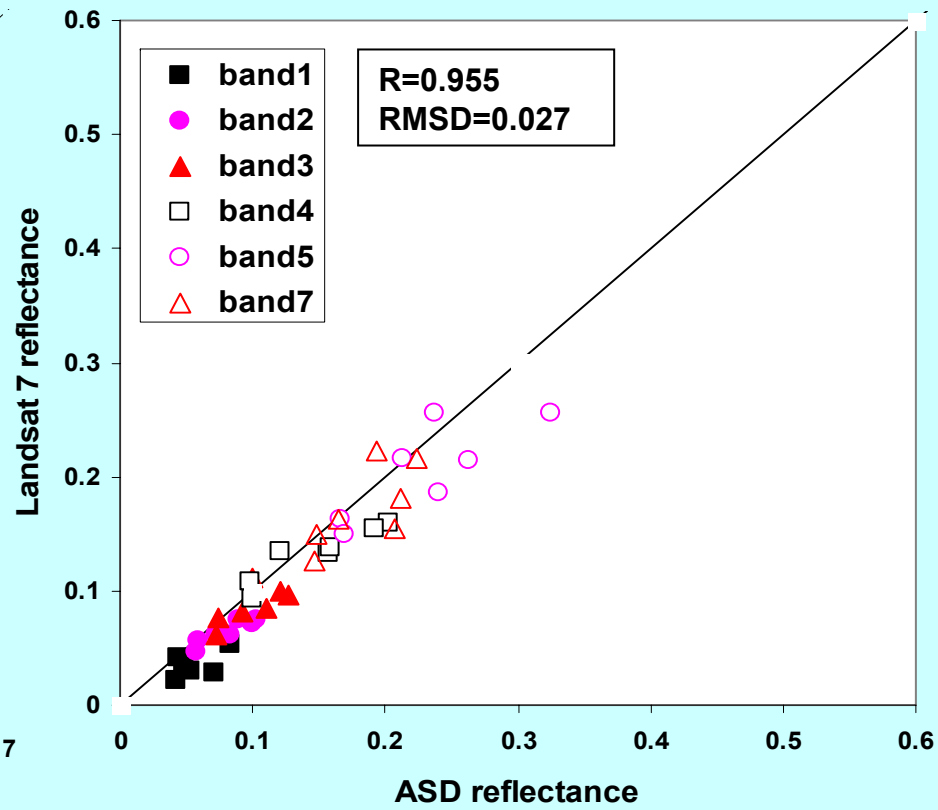


Lake Frome field experiment
09/02/2009 to 13/02/2009
South Australia, Dry salty lake

Validation using field data

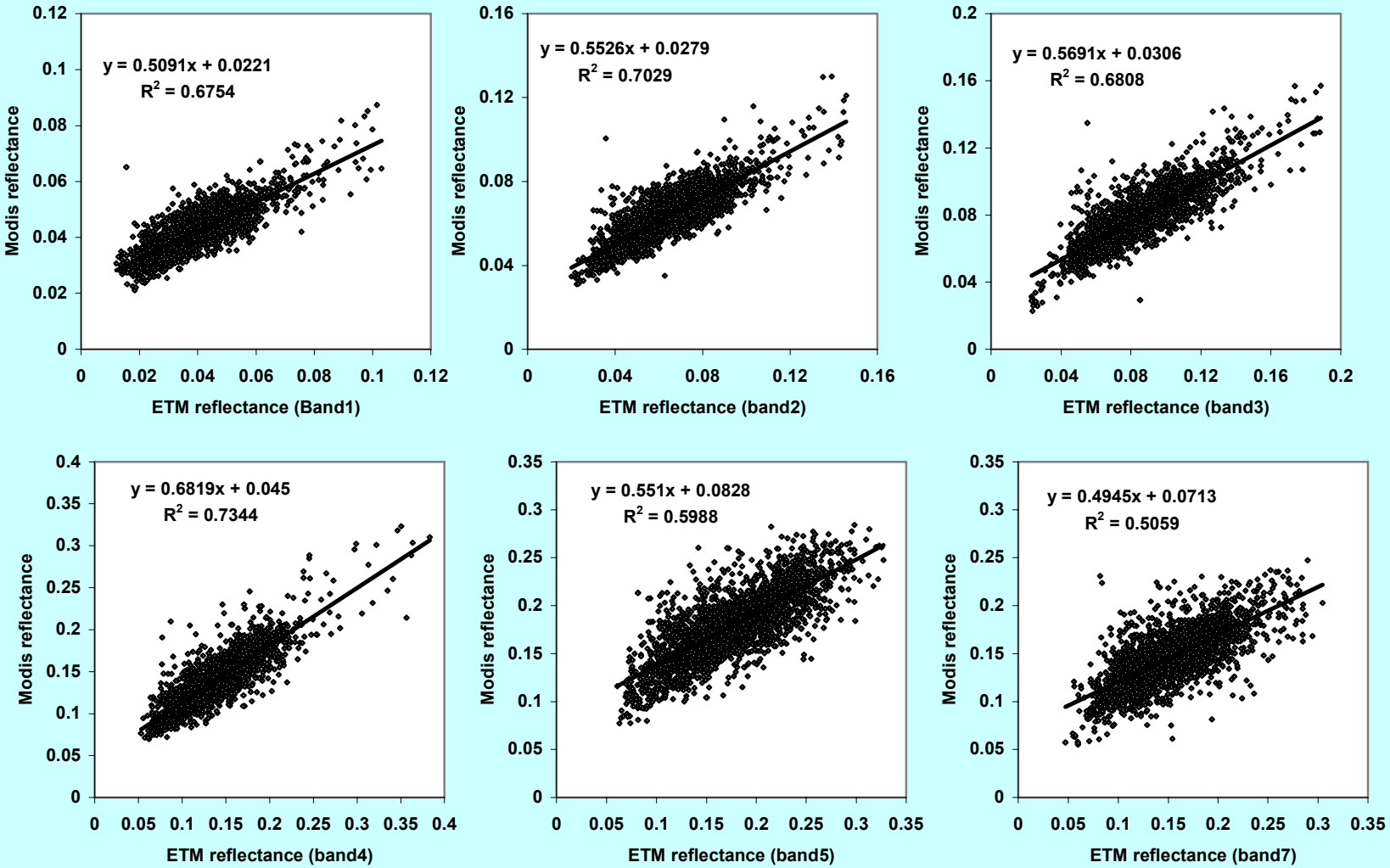


Lake Frome Field Measurement
09/02/2009-13/02/2009



Gwydir Field measurement
23/06/2008-24/06/2008

Comparison between MODIS and Landsat 22/06/2008 at Gwydir area, NSW



Conclusions

- **Using MODTRAN with a MODIS BRDF shape function can provide consistent products and the retrieved reflectance has a good agreement with ground based ASD measurements.**

- **There is a strong relationship between MODIS NBAR and the Landsat NBAR products. This relationship could be used to cross-calibrate and validate with MODIS NBAR products.**

- **If a standardised set of choices for atmospheric and BRDF functions can be established, a time series of data close to physical surface reflectance at standard sun and view angles could be derived.**

Future work

- **Define objective and consistent choices for atmospheric (aerosol, water vapour etc) and BRDF parameters.**
- **Establish surrogate estimators for MODIS BRDF data to process Landsat data from before MODIS was available to the public.**
- **Establish standard calibration and validation sites for operational quality assurance.**
- **Test the validity and stability of the product for land cover change mapping.**

Acknowledgements

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