The Lake Frome Field Campaign in Support of Hyperion Instrument Calibration and Validation

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***Abstract* - Lake Frome, a dry salt lake in South Australia, was chosen as a calibration site for Hyperion primarily for its brightness, but also for its temporal invariance and spatial homogeneity. Surface spectral data were collected along a transect through the centre of the lake, during a four-day period prior to the Hyperion overpass. Meteorological data collected by a portable weather station and a multi-frequency shadow-band radiometer installed at the lake shore, along with data from a nearby radiosonde and CIMEL sun photometer sites were used to measure atmospheric conditions at the time of overpass. The spectra were processed to reduce noise and modeled to at-sensor radiance for the 242 Hyperion spectral bands. The Hyperion images were geo-located using distinct ground features. Spectra for the ground sites were compared with those taken in the field, overall the agreement was excellent. The combination of field and laboratory measurements have provided some hypotheses of the systematic and causal way the lake behaves and changes spectrally.**

INTRODUCTION

EO-1 is the first of NASA's New Millenium Program Earth Observing series of satellites. Hyperion is an experimental hyperspectral sensor carried on EO-1 and sites for testing and evaluation were selected worldwide by the instrument makers, TRW, prior to launch. One of the calibration sites, Lake Frome, a dry salt lake in South Australia, was chosen primarily for its brightness, but also for its expected temporal invariance and homogeneity at the resolution of Hyperion (30m pixels). At larger scales (1000m), there is variation in the thickness of the salt crust that alters the surface characteristics providing a range of spectral characteristics.

A field measurement campaign was undertaken at Lake Frome to coincide with a Hyperion overpass on December 20, 2000. Further atmospheric measurements were taken at the time of the next overpass on January 5, 2000.

This paper describes the field campaign at Lake Frome, the spectra obtained and the geo-location of the Hyperion images with the physical site which supported the calibration and validation studies for Hyperion.

LAKE FROME FIELD MEASUREMENTS

Lake Frome is a large, normally dry salt lake and provides a target of >30km along the Hyperion ground track. The salt is very bright at visible wavelengths (reflectance up to 70% was recorded) and dark in the short-wave infra-red (SWIR). Contrasting sites can also be found on small islands within the lake. The clay soils are darker in the visible region and bright in the SWIR.

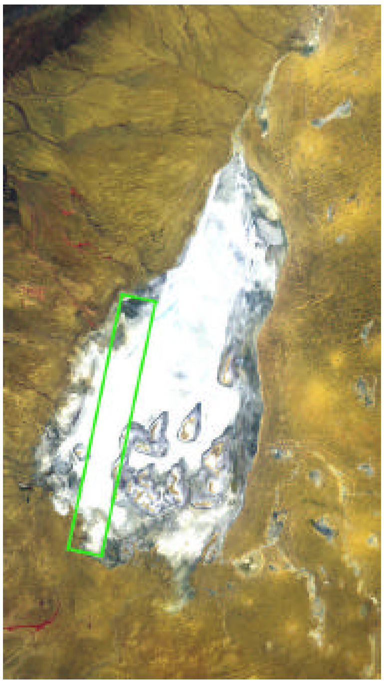

Fig.1 Landsat colour composite (bands 4, 3, 1) of Lake Frome, January 21, 2001. The Hyperion swath is shown outlined in green.

Fig. 1 is a colour composite of Landsat data for Lake Frome and shows the location of the section of the Hyperion swath used in this study. Potential field sites were chosen along the expected Hyperion ground track, ranging from the brightest salt to areas near the lake where the underlying dark mud is partly exposed. The Hyperion image with the location of field sites is shown in Fig. 2.

Fig.2 Hyperion image of Lake Frome showing the field sites along a transect chosen from the predicted ground track.

Using a field design and logistics described more fully in Graetz *et al*. [1] the field party visited selected sites during a four-day period prior to the December 20 overpass. Spectral measurements were taken with two ASD Fieldspec spectroradiometers and one GER 3700 spectroradiometer referenced to a Spectralon panel. All positions were accurately recorded with a GPS. The sites were sampled in a central cluster of points and along local transects of about 100m to characterise the spatial variance and produce a mean site signature at the scale of Hyperion. Salt and mud samples were also collected for laboratory characterisation.

Fig.3 shows mean reflectance spectra for the field sites. These spectra have been linearly interpolated over the main water absorption bands as the ASD spectra are very noisy in these regions. The form of the spectrum is very similar at all the salt sites. Variation is mostly related to the thickness of the salt crust (a thin crust allows the underlying mud to influence the spectrum) and the amount of liquid water present in the salt matrix. However, the full extent of the spatial variation and its components is being studied using a range of data available for Lake Frome including Hymap airborne hyperspectral data [1] and Landsat ETM data.

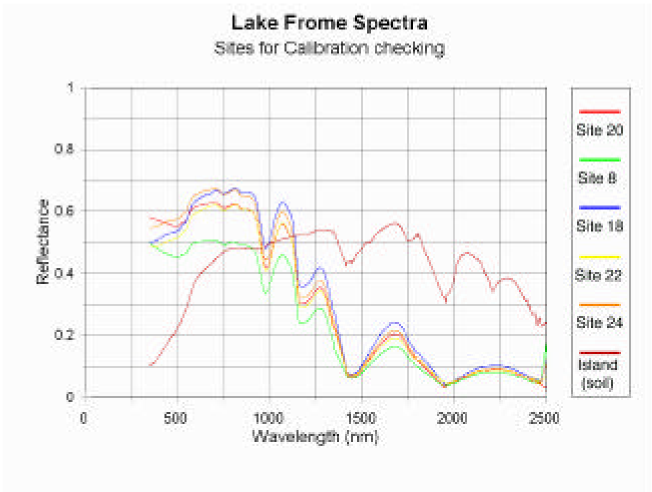

Fig 3. ASD Spectra recorded at field sites shown in Fig.2. Spectra have been linearly interpolated over regions of strong atmospheric water vapour absorption.

Meteorological data were collected during the mission using a portable weather station and a Yankee Environmental Systems multi-frequency shadow-band radiometer (MFR) operating at the lake shore. Data were also acquired from Bureau of Meteorology radiosondes launched from Woomera (250 km west of Lake Frome) and a CIMEL sun photometer located at another CSIRO field site 150 km to the north of the lake.

The meteorological data were taken as inputs to an atmospheric model and the ground spectra converted to at-sensor radiances. The comparison of these radiances with Hyperion data and their role in checking calibration is discussed in the paper by Clancy *et al*. [3]. In that study, Hyperion data were also used to estimate atmospheric water vapour and Hyperion radiances inverted to check the atmospheric correction consistency at the field sites.

Preliminary laboratory spectral measurements of the salt samples collected at the sites shows a systematic spectral change with addition of water. Water is occasionally present on the surface of Lake Frome and if this site is to be used as an inert calibration target, it is necessary to account for variations in water content of the salt crust. Further investigations of the relationship between the spectra and liquid water content of the salt crust may enable the use of Hyperion data to monitor the amount of water present at Lake Frome. This work is continuing.

GEO-LOCATION OF HYPERION IMAGES

The utility of the field measurements is crucially dependent on their accurate location (and re-location) on the Lake and in the image data. The GPS readings provided a very accurate base of geo-located data and so it was necessary to establish accurate image geolocation. A set of ground control points (GCPs) was identified in the image of Hyperion band 22 (568 nm) and an accurately geo-rectified Landsat ETM image (acquired on January 21, 2001). Analysis of the data fits based on predictive error showed that a bi-linear transformation was best. This allows for x, y shifts, separate changes of scale in x and y, skew and rotation plus an xy interaction term. The statistical significance of the xy interaction term shows there is a projective geometry in the Hyperion image on the surface. This is likely to be even more significant in other cases since Lake Frome is imaged at near nadir view. The main characteristics of the geometry can be summarised in Table I.

TABLE I
HYPERION GEOMETRIC CHARACTERISTICS

Pixel-X	30.646 m
Pixel-Y	30.528 m
Rotation	-12.38°
Skew	0.006°

EO-1 has a specific yaw to compensate for the Earth rotation skew. It seems to be very effective. The pixel shape is also very close to square. The predictive error for the VNIR sensor was 15 metres in x and 20 metres in y. This close registration and the uniformity of much of the Lake Frome site means we can identify the pixels relating to the ground sites with considerable confidence.

The GCPs were also identified in band 94 of the Hyperion image (1084 nm) to test the alignment of the two spectrometers. The data were again well-fitted by a bi-linear transformation. An offset of approximately one pixel in x and a fraction of a pixel in y was noted between the VNIR and SWIR sensors. The magnitude of the offset varied between about 1.0 and 1.2 pixels across the 256 element array. This seems to be due to slight misalignment in the two arrays and may be significant in highly variable terrain.

DISCUSSION

The Lake Frome field campaign was the first time the lake had been visited for a ground based spectral measurement effort. Given the nature of the environment it was highly successful. It is planned to re-visit the site and undertake more intensive measurements and also extend the range of target sites for future EO-1 data collection. The site provides an excellent base with which to cross-compare Landsat ETM, ALI and Hyperion and compare their performance with that of other polar orbiting satellites of varying resolution and scale, such as AVHRR, ATSR2 and SPOT VGT.

While some site spectra provided a very accurate match with the Hyperion data, at others there were variations between the Hyperion data and site measurements that may have a range of causes. Among these is the surface BRDF which it was intended that we measure but is still not completely determined. The Hymap data will provide insight into this factor. Visual assessment indicates the BRDF of the lake is likely to be stable and able to be characterised. This, and other issues raised above, are subjects of on-going work.

The combination of field and laboratory measurements have provided some hypotheses of the systematic and causal way the Lake behaves and changes spectrally. It is intended to test these ideas to establish a predictable and well characterised target for vicarious calibration in the optical wavebands for all satellites. Initial evaluation of Hyperion confirms Lake Frome as a valuable site and Hyperion as a valuable entry to space data of the earth.

REFERENCES

[1] Graetz, R.D., Campbell, S., Lovell, J., King, E. & Byrne, G. (in preparation). Lake Frome, Australia: A site for vicarious calibration of broadband and narrow band sensors.

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[3] Clancy, P., Jarecke, P., Pearlman, J, Jupp, D, Lovell, J, Campbell, S. (2001). Use of Lake Frome Ground Truth Campaign as a Cross-Calibration of the Hyperion Instrument. IGARSS’01 Special Session 40, paper 1780.