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[Cover — Shuttle picture]

Using Digitised Handheld Space Shuttle Photography for Terrain Visualisation

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Introduction

Digital terrain models are becoming increasingly available and are readily generated at a whole range of scales. However, the lack of realistic colour and tone in images of terrains remains a problem. Realistic colour and tone are very desirable attributes because they contribute significantly to a powerful visualization of landscapes, both for scientists (Kam's ref) and for the general public. But these attributes are generally still unavailable because few sensors, air- or space-borne, provide true colour, and even fewer do so at a realistic cost.

The exception is the growing and accessible archive of US Space Shuttle photography which provides a wealth of potential data suited for more realistic visualization of landscapes.

Handheld Photography

Handheld photography, mainly from Space Shuttle flights, but from earlier programs and more recently from the Russian space station MIR, is acquired by astronauts and cosmonauts who have received some training in appropriate aspects of basic earth science. Crews are partly guided from the ground by daily messages on Space Shuttle flights and weekly messages on MIR flights. Crews attempt to obtain photographs of terrestrial, meteorologic and oceanic phenomena. Baseline photography remains a major goal of the collection, a purpose now vindicated as comparative views of changing landscapes become available from more recent flights. Approximately 360,000 photographs cover one of the longest records of any Earth-looking remote-sensing database (Lulla et al., 1994), a record which spans thirty-six years.

Particular emphasis is being put on remote sites and the capture of short-lived dynamic processes which otherwise remain unnoticed. Crews often report volcanic eruptions—even before the seismic scientific networks are aware of eruptions in remote parts of the world. Hurricanes, dust storms, smog events and plankton blooms are all observed for the duration of hours or days.

A variety of cameras, lenses and films are used, but the majority of photographs are captured using Hasselblad Cameras with f = 90mm, f = 100mm and f = 250mm lenses (see full description of manifested cameras and accessories in Lulla et al. 1994). Each Space Shuttle mission lasts from 4 to 16 days and returns ~3-6000 photographs—except in the case of the SIR-C missions where Earth photography was a prime objective of the flight and 12,000 frames were returned.

The metadata for each photograph (unique mission-roll-frame identifier, date if known, etc.—see Note 1) is individually catalogued at the NASA Johnson Space Center (JSC). This data searchable on the database erected by JSC's Office of Earth Science. Many frames can be seen on a JSC website in files of ~6MB in size (http://images.jsc.nasa.gov/iams/html/iams.txt).

Near-vertical photographs, taken with a medium- to long-focal length lens is of greatest use when generating digital images, are required to ensure relatively high geometric fidelity. Assuming an off-nadir viewing angle of <30° to be the suitable cut-off point, approximately 70,000 of photographs (see Note 2) are currently held in the JSC archive which is ~23% of the total collection. (Fig. 1—map of all NV centerpoints).

Photographs are taken from altitudes between 175 and 360 km. The average altitude for most Space Shuttle flights is 168 nautical miles or 296km, but this varies with eliptical orbits and high altitude missions like the Hubble repair missions. Some handheld photographs have been acquired from the Russian Space Station MIR and the MIR-supply missions flown by Space Shuttles from almost indentical altitudes (the International Space Station (ISS) will fly at this altitude also). Near-vertical views with f = 250mm lenses capture swath widths on the ground of 75 km at 168 nautical miles and 100 km at the high altitudes such as those of the Hubble telescope. Near-vertical views taken with the common shorter focal length lens (f = 100mm) gives swath widths between 175km and 210km at comparable altitudes.

Resolving power with the regularly flown long-focal-length lens (f = 250mm) can be as high as 16 m (1/500s) and 31 m (1/250s)(Lulla et al. 1994). Since mny views are oblique-looking, these are optimum numbers.

About 60% of the photographic coverage is limited to low- and mid-latitudes (29°N - 29°S) due to more frequent flights with orbital inclinations of 28° and 39° degrees. The majority of nadir views consequently lies in zones between 28°N -28°S and 39°N-39°SN respectively. An increasing proportion of views is now derived from high-latitude missions, in the latitudinal zone 51.6°N-51.6°S overflown by the Russian craft MIR (and the ISS when photographyt begins in 199), and also from the occasional high-latitude flights in the zone 57°N-57°S). Under clear skies, oblique views from high-latitude missions can take photographs as much as ten degrees beyond this envelope (i.e. commonly as far 61° N and S).

Because the Space Shuttle, MIR and ISS do not orbit Earth in sun-synchronous fashion, the Earth's surface can be viewed under a wide range of illumination conditions. This often provides unique perspectives of many parts of the globe.

Example and Method

In this particular example, photographs of the Central Namib Desert were obtained, depicting a variety of features of regional geomorphic significance. The two colour slides (STS037-99-078 and STS054-151-099) were scanned at JSC on a flatbed, desktop Arcus II scanner (Agfa) with a maximum resolution of 600 x 1200 dpi. These files were then imported into ERDAS where they were geometrically corrected using 1: 250,000 maps. This produced pixels at a size of ~x m with an RMS error of around 10. The DEM used was the readily available x by the USGS, and with a resolution of x m is ideally suited, as are handheld photographs, for mapping at a regional scale. Once the DEM is draped over a handheld photograph, any viewing geometry is feasible; as are the well-known simulated fly-bys.

The close correlation between colors in the photographs and natural colors of the landscape aid in interpreting handheld photographs. Examples illustrated here are two major structures in the central Namib Desert of Namibia in southwestern Africa. The Brandberg massif, which includes the highest point in Namibia, appears in two east-looking, oblique views from different elevations (Figs. 2a and 2b). The Brandberg also appears in the middleground of Fig. 3, with the Messum Crater in the foreground (Namibia's Skeleton Coast lies just outside the picture in the foreground), a volcanic feature. The dark hues of ancient rocks contrast with the light hues of the Quaternary sediments of the lower Omaruru River floodplain (right).

An application of combined DEM/handheld-photograph overlays in the Namib Desert is that they reveal the topographic controls of the strongest winds in the region. The Namib Desert is a coastal desert with some of the strongest wind regimes on the planet (strong southerlies and strong winter easterlies—Lancaster 1989). The behavior of winds on the eolian distribution of mineral sand and dust (see Eckardt 1997 for discussion of the contribution to the evolution of surface gypsum accumulation), and on the ecology of the region through transport of vegetal debris, has become a major topic of interest (Eckardt and Wilkinson, in prep). In some areas the location of wind and sand streaks is related precisely to subtle topographic gaps in chains of hills, a correlation immediately apparent from oblique DEMs but difficult to appreciate or even suspect using the detailed near-vertical photographs and maps alone.

(Frank: see addendum below with questions for you)

Conclusion

While true-colour film may limit the overall spectral information sought by scientific communities, we believe handheld photography from low earth orbit is an undervalued and untapped source of historically significant data which can be fused digitally with other forms of data, provided that the photographs are carefully selected. Similar true colour applications should be possible with handheld photographs obtained from Mir and the ISS, and the less accessible data from the Russian space program.

Another valuable aspect of the film is apparently its power to aid the visualization of natural phenomena, an recognized component of all scientific endeavor.

Further, the dramatic nature of handheld photographs appears be popular with the general public, as demonstrated by the success of a recent popular publication based on this source (Apt et al. 1996).

Notes

1. Example of database screen for a frame exposed on Space Shuttle fight 37 (STS037) in April 1991:

MISSION_CODE :	STS037
ROLL :	78
CAMERA_TYPE :	HB (Hasselblad)
FILM_TYPE :	5017

FLIGHT	ROLL	FRAME	FEATURE	CENTER PT.	NADIR PT.	CLD
STS037	78	8	SW ARIZONA DESERT	33.0N 112.5W	28.2N 111.5W	0

TL	ECDI	DR	FCL	S	DATE/GMT	ALT	AZIM	ELE	ORB
LO	N-	N	250	N	9-Apr-1991 15:02:12	244	94	24	63

CLD = Percentage cloud cover
TL = Camera tilt: NV = near vertical, LO = low oblique, HO = high oblique
ECDI in 4 fields:
E = Film exposure: N = normal, O = over, U = under, F = out of focus
C = Caption flag: C = caption exists, - = no caption, blank = not scanned
D = Laser disk flag
I = Image file flag: I = there is an image, - = there isn't an image
DR = Direction the camera was pointing
FCL = Focal length of camera lens
S = Stereo: Y = overlapping view, N = no overlapping view
ALT = Altitude of orbiter in nautical miles
AZIM = Azimuth; horizontal angle from north clockwise to the sun measured from nadir
ELE = Elevation of the sun from the nadir plane in degrees
ORB = orbit

2. All frame counts include problematic frames with high cloud cover, poor focus, poor exposure levels and a few non-earth-observation views.

References

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