Heading for Hyperion and EO-1 CalVal Missions

When:

- Hyperion data are being simulated by Hymap or
- an overpass is being pegged out for field sites or
- EO-1 data are being atmospherically corrected

we need to know the EO-1 satellite heading. Luckily, we know it has the same orbit as Landsat 7 so its orbital parameters can be used.

Given that most DCEs are short, the heading plus the centre position of the track (chosen by you) will provide the centre image line for the pass or the ideal flight line for Hymap. However, as we will see, the “effective heading” is the combination of a heading that defines the look angles in a line and a skew or “crab” angle due to earth rotation.

To compute these angles you need to know the orbital inclination of the satellite and the radius of the orbit plus a few things about the earth surface near your part of the world. But mainly it is a function of the latitude.

The published orbital inclination for Landsat 7 is 98.209 degrees. This is the “tip” of the normal to the orbit with zero as being a line around the equator and 90 degrees as parallel to the longitudes. The 8 degree tip defines the orbit precession and return times etc.

The heading for a descending path (daytime) is 8.209 degrees at the equator (well actually 189.209 but we will not worry about that here). As the latitudes increase it turns to be parallel to the latitude (and running due west) at an angle defined by the orbital inclination which is about 82 degrees South for Landsat (actually 81.791 degrees).

The exact calculation for the heading, or tangent to the trace of the orbital path across the ground for a circular orbit, (β) is:

$$Tan(\beta) = \frac{-1}{Tan(oi)\,Sin(\rho)}$$

where *oi* is the orbital inclination and ρ is the “time” since apogee in radians.

$$Cos(\rho) = \frac{Sin(\Phi_0')}{Sin(oi)}$$

where Φ_0' is the geocentric latitude:

$$\Phi_0' = \Phi_0 - Sin^{-1}\left(N\,e^2\,Sin(\Phi_0)Cos(\Phi_0)/R\right)$$

where Φ_0 is the Geodetic Latitude which is at the centre of the area of interest and *R* is the radius of the orbit.

$$N = \frac{a}{(1 - e^2 Sin^2(\Phi_0))}$$

T he spheroid used for the geodetic model defines the semi-major axis (*a*) and the squared eccentricity (e^2).

Because the equations are a bit messy I have also provided a spreadsheet for you to check my maths and see what happens for your site. (Astute readers will notice some formulae are presented slightly differently from above but the results will not be very different. The above is a simpler form).

But the above may not be all of the story.

The heading (β) is the direction for the normal to the line of a pushbroom scanner like Hyperion and is needed to compute the look angles across the line for BRDF and atmospheric corrections[1].

However, as the satellite track moves south on its descending orbit (the morning pass) the earth will rotate underneath it. This movement of the earth skews the satellite track and creates an "effective" heading which is the sum of the heading angle and the skew angle (or "crab" angle).

The formula I have used for the skew is:

$$Tan(Rotn) = \frac{\omega_0 Cos(\Phi_0')Cos(\beta)}{V_0 + \omega_0 Cos(\Phi_0')Sin(\beta)}$$

where ω_0 is the earth rotation at the equator and V_0 is the satellite angular velocity.

For example, at Lake Frome (30° 45' S) the heading is 9.55°, the skew is 3.3° and the effective heading is 12.85°. Actually the effective heading is strictly 192.85° on the descending pass.

Have a look at the plot below, the spreadsheet and then compute your site heading!

DLBJ
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[1] It seems that the satellite is "yawed" to bring it into a line that accounts for earth rotation in the instantaneous heading but it does not alter this analysis. It will alter the computation of the line heading for atmospheric correction. Dlbj.

Appendix

A plot of these as a function of Latitude is: