Calculating zenith and azimuth angles for GridSat-B1

The following is a summary of how solar and satellite angles can be calculated for GridSat-B1 files.

Solar Angles

Solar angles are solely dependent upon the location (latitude and longitude) and time. Thus, it is straightforward to calculate solar angles.

The hour angle (h) is defined as the longitude of the sun, which is calculated as:

$$h = -\frac{t - 12}{12}$$

where t is the frational GMT time (e.g., for hh:mm:ss then t = hh + mm/60. + ss/3600.)

Solar zenith angle (θ_o) is calculated as:

$$\cos\theta_o = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos h$$

Where δ is the solar declination angle and varies from -23.45 deg to +23.45 deg through the year and can be approximated as:

$$\delta = -23.45 \cos\left(\frac{2\pi J}{365} + \frac{20\pi}{365}\right)$$

Where J is the day of the year.

The solar azimuth angle (ϕ_o) is calculated as:

$$\sin\phi_o = \frac{\sin(h - \lambda)}{\sin\beta_o}$$

Where:

$$\cos\beta_o = \cos(\varphi)\cos(\lambda - \lambda_s)$$

Note: An assumption is made that the time is constant throughout the image. However, there will be some variation as to when each scan started and ended. A full disk scan takes about 30 minutes to complete and most files were started near the optimal time. A better approximation would be to use the start time of each satellite (which can be determined from the B1 filename) to better estimate the actual image time.

Satellite Angles

Satellite angles are more cumbersome to calculate. Converse to solar angles, they are largely independent of time. Instead, they depend on satellite orbital characteristics and location on Earth (latitude and longitude).

Satellite angles are based on the beta angle, which is the angle from the center of the Earth subtended by the satellite latitude and longitude (φ_s, λ_s) and point in question on the Earth (φ, λ). The values for (φ_s, λ_s) are stored in the netCDF variables satlat and satlon, respectively.

$$\cos\beta = \cos(\varphi - \varphi_s)\cos(\lambda - \lambda_s)$$

When the satellite has a small inclination angle, this can be approximated as:

$$\cos\beta = \cos(\varphi)\cos(\lambda - \lambda_s)$$

View zenith angle is calculated as:

$$\sin\theta = \frac{42164\sin\beta}{\sqrt{1.8084 \times 10^9 - 5.3725 \times 10^8\cos\beta}}$$

Azimuth angle (ϕ) is calculated as:

$$\sin\phi = \frac{\sin(\lambda_s - \lambda)}{\sin\beta}$$

Assumptions and Notes:

- Spherical Earth is assumed, so angles are less accurate at the limb
- Nominal (circular) geostationary orbital radius (42164. Km above the Equator) is assumed
- View zenith angle calculations should be checked for limits: square roots > 0 and arcsine input limit of [-1,+1], prior to calculation, otherwise an error will occur