Influence of Map Projection on Directions Measured over HiRISE and MOC Images

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HiRISE and MOC projected products

HiRISE images ranging from 65°N to 65°S are processed in Equirectangular projection, which is an equidistant cylindrical projection. In such projection only meridians are represented in true scale. It is neither conformal nor equivalent, which means that directions and areas measured over this projection do not correspond accurately to those measured on Mars surface. Given the radius *R* of the planet, the central meridian longitude λ_0 and the standard parallel φ_1, the formulas [1] for rectangular coordinates (*x*, *y*), the distortion along meridians *h*, the distortion along parallels *k* and the angular distortion ω are:

$$x = R(\lambda - \lambda_0)\cos\varphi_1 \qquad h = 1$$
$$y = R\varphi \qquad k = \cos\varphi_1 / \cos\varphi$$
$$\sin(\omega/2) = \frac{k-h}{k+h}$$

Fig. 1 shows the angular distortion expected for Equirectangular projection along 70°N to 70°S latitudes and 180°W to 180°E longitudes. The equator is represented in true scale but the angular distortion grows fast for latitudes far from that standard line and may reach 60° distortion at 70°N or S.

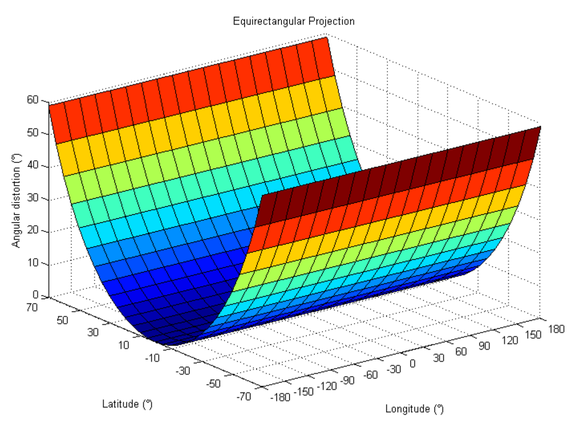

Fig. 1: Angular distortion surface for Equirectangular projection.

MOC NA images ranging from 65°N to 65°S are processed in Sinusoidal projection, which is an equal area projection. Thus, directions are also not presented in true scale. Distances are true scale only along the central meridian and vertically along the parallels. Fig. 2 shows the angular distortion expected for Sinusoidal projection along 70°N to 70°S and 180°W to 180°E. Given the radius *R* of the planet, and the central meridian longitude λ_0, the formulas [1] for rectangular coordinates (*x*, *y*), the distortion along meridians *h*, the distortion along parallels *k* and the angular distortion ω are:

$$x = R(\lambda - \lambda_0)\cos\varphi \qquad h = \left[1 + (\lambda - \lambda_0)^2 \sin^2\varphi\right]^{1/2}$$
$$y = R\varphi \qquad k = 1$$
$$\omega = 2\arctan\left|1/2(\lambda - \lambda_0)\sin\varphi\right|$$

As seen from Fig. 2 the angular distortion in Sinusoidal projection is a function of both latitude and longitude whereas the angular distortion in Equirectangular projection is a function solely of latitude. In both Figs. 1 and 2 the calculations were performed adopting a sphere of radius 3,396.19 km, which corresponds to the semi-major axis of the ellipsoid recommended by IAU [2].

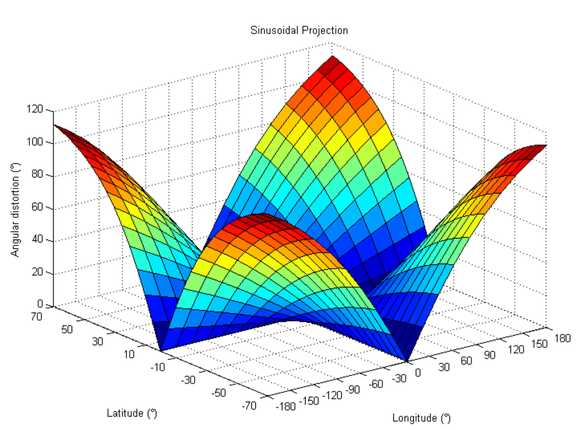

Fig. 2: Angular distortion surface for Sinusoidal projection.

Evaluation

We quantified the influence of map projection on direction measurements in images HiRISE PSP_006163_1345 and MOC M12-02214 HiRISE. The center coordinates of the HiRISE image are φ = -45.303° and λ = 316.288°. The center of projection is φ = -45° and λ = 180°. As the image is approximately 8 km wide and 24 km long and assuming a local radius of 3,386.15 km, the extent of the scene in degrees is 0.1354° by 0.4061°. The angular distortion expected to occur in the HiRISE image is shown in Fig. 3. As it is a function solely of latitude, the distortion is not affected by the fact that the longitudinal center of projection is 180°, far away 136.288° from the scene center longitude. On the other hand, the latitudinal center of projection does not lie on scene and contributes to increase distortion over the region. Even though, the maximum distortion expected to be found in direction measures is about 0.6°.

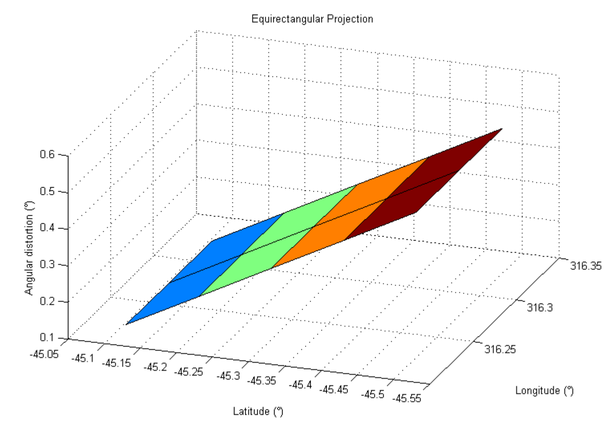

Fig. 3: Angular distortion for PSP_006163_1345 HiRISE image.

The MOC image has center coordinates φ = -51.21° and λ = 44.90°. The projection center coordinates are φ = 0° and λ = 44.90°. The image is approximately 0.048° wide and 0.2964° long. Fig. 4 shows the angular distortion expected to occur in the MOC image, which is a function of both latitude and longitude. The center meridian of projection is set close to the center of the image, which is relatively narrow, so the distortion is well behaved, reaching a maximum of about 0.02°.

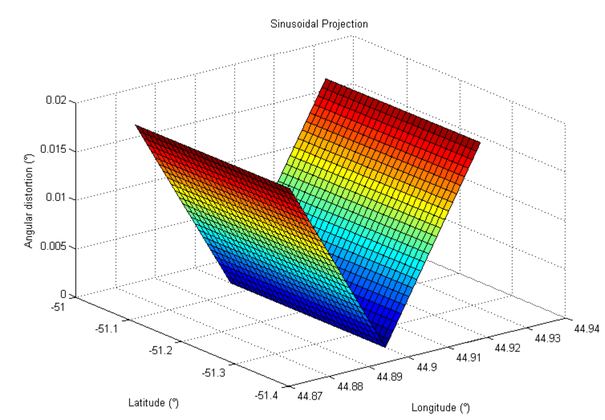

Fig. 4: Angular distortion for M12-02214 MOC image.

In latitudes higher than 65°N and S both HiRISE and MOC images are projected into Stereographic projection which is conformal.

Conclusions

In the examples shown here the maximum distortions were about 0.6° for the HiRISE and about 0.02° for the MOC**.** Therefore, if the accuracy of the method used to measure directions is coarser than the maximum distortion there is no need to re-project the images into a conformal system. When map projection errors are considerable, which is common for more regional or global studies, an alternative would have been to perform geodesic calculations through a software such as "Tools for Graphics and Shapes", available freely online [3].

References

[1] Snyder, J.P.(1926) *Map projections - a working manual*. [2] Duxbury et al. (2002) *ISPRS XXXIV*, 512. [3] Jenness, J. (2011) Tools for Graphics and Shapes Manual.