Lunar Computed Surface Radiation (CSR)

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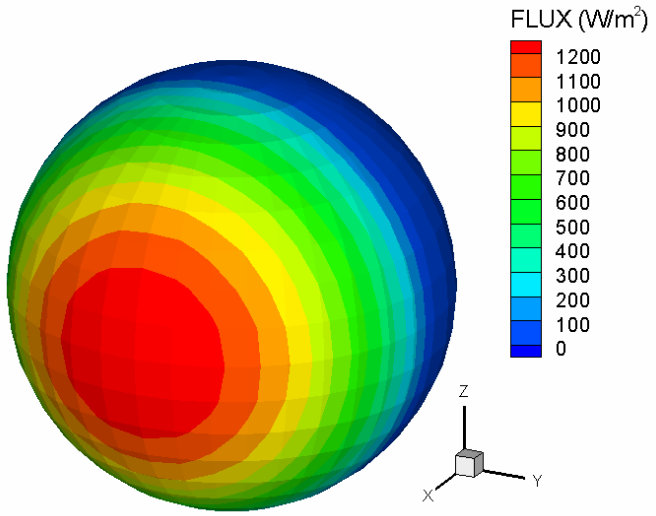
•What is Lunar Computed Surface Radiation (Lunar CSR)?

•The Lunar-shine (Lunar IR environment) is a directionally dependent surface flux because the temperature of the Lunar surface varies largely. This directional dependence is modeled by the Space 3D Thermal (commercial TSS) Lunar Computed Surface Radiation (Lunar CSR). In the ray-tracing Lunar CSR method, the ray energy for each individual ray depends on the where the ray was emitted from the lunar surface. This method accounts for the variable directionally dependent Lunar IR environment as shown.



Credit: NASA Goddard Space Flight Center, LRO project, 2005

•What is Lunar CSR (Cont.)?

•The Space 3D Thermal (commercial TSS) Lunar CSR model accurately represents this environment using the Monte Carlo ray-tracing technique. The technique computes a flux for every ray shot, based on where the ray leaves the lunar surface, using the following equation:

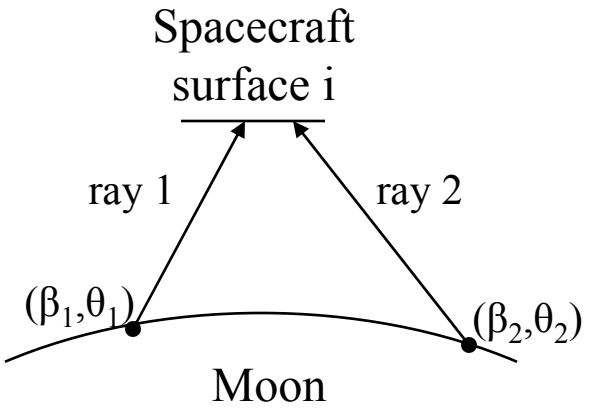
$$q''_{ir}(\beta,\theta) = (C_1 - C_2)[\cos\beta\cos\theta] + C_2$$

where $C_1 \approx 1268\ W/m^2$, $C_2 \approx 5.2\ W/m^2$

•The Lunar IR environment varies largely across the lunar surface. The highest flux is C_1 and the lowest is C_2, which the user can specify. Note: this q''_{ir} is calculated for each individual ray based on the β and θ from where it leaves the lunar surface.

•How is Lunar CSR directionally dependent?

•Simple 2 ray example:



ray 1

$q''_{ir,surface\ i}(\beta_1,\theta_1) = 400\ W/m^2$

ray 2

$q''_{ir,surface\ i}(\beta_2,\theta_2) = 700\ W/m^2$

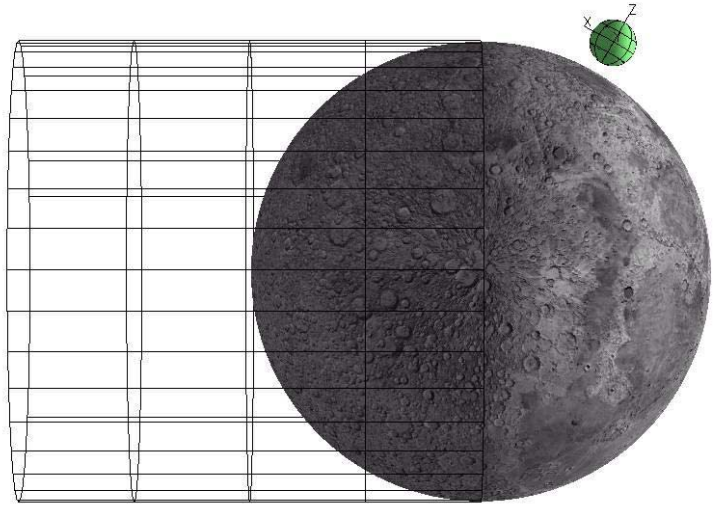
Average

$$Avg.\ q''_{ir,surface\ i} = \frac{\sum q''_{ir}(\beta_n,\theta_n)}{number\ of\ rays} = \frac{400+700}{2} = 550\ W/m^2$$

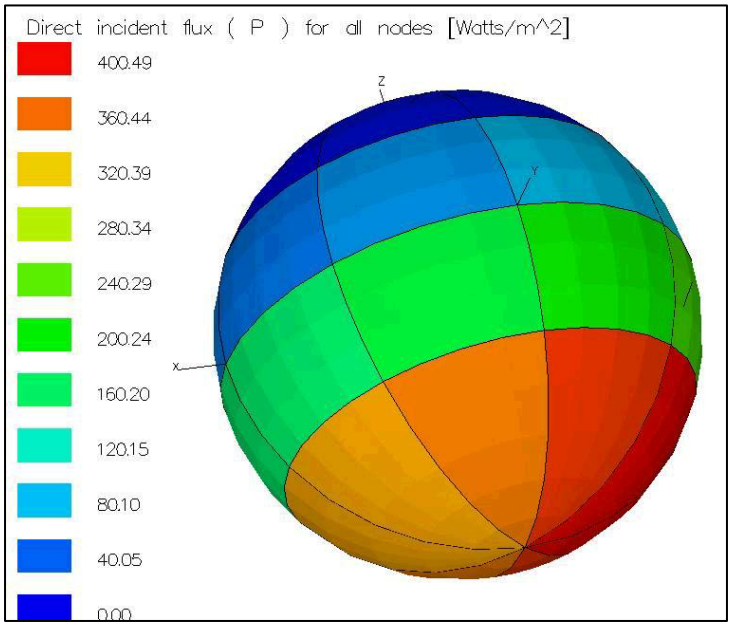
•So each surface in the model can have an independent flux value that depends on its direction. Although this is a simple 2 ray example, shooting more rays improves the accuracy of the calculated incident flux because more lunar surface locations are sampled.

•A sphere model can show Lunar CSR directional dependence.

•How is Lunar CSR directionally dependent (cont.)?



Solar vector



•Note: The interchange factors between sphere bottom surfaces and the planet are the same but the flux is directionally dependent, depending on which direction the surface is facing.

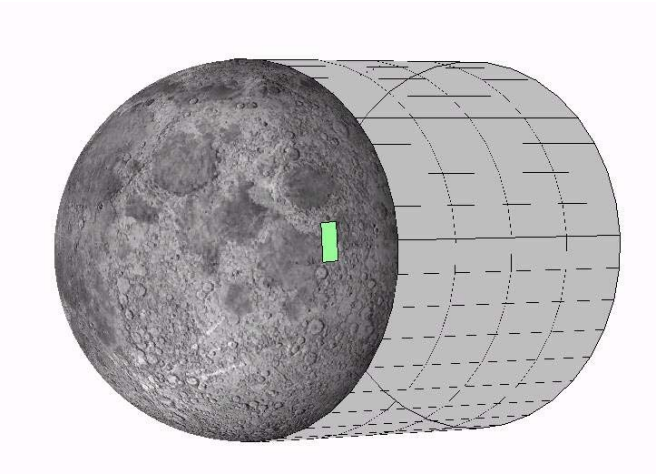
•How can the complexity of the Lunar IR environment be shown with Lunar CSR?

•The calculated flux can be quite complex, since it isn't just a function of the interchange factor to the planet. To show this complexity, we can eliminate the interchange factor as a variable.

•In the following example, the up and down side of a rectangle, one side facing the sub-solar point and the other facing away, are compared. Only the altitude is varied to show the difference in the incident flux (Δq"ir).

•For each altitude, the interchange factors are equal:

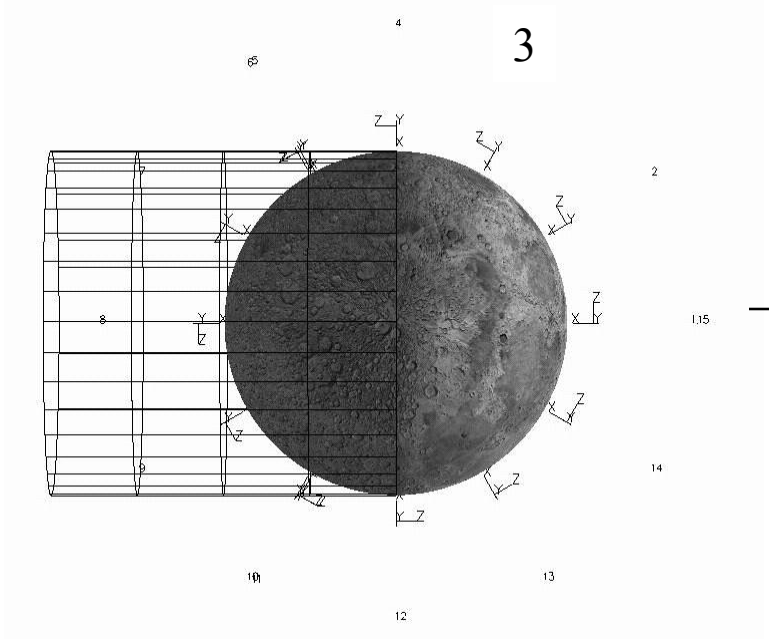
$$B_{rect.1:1:1:up\text{-}lunar\ surface} = B_{rect.1:1:1:down\text{-}lunar\ surface}$$



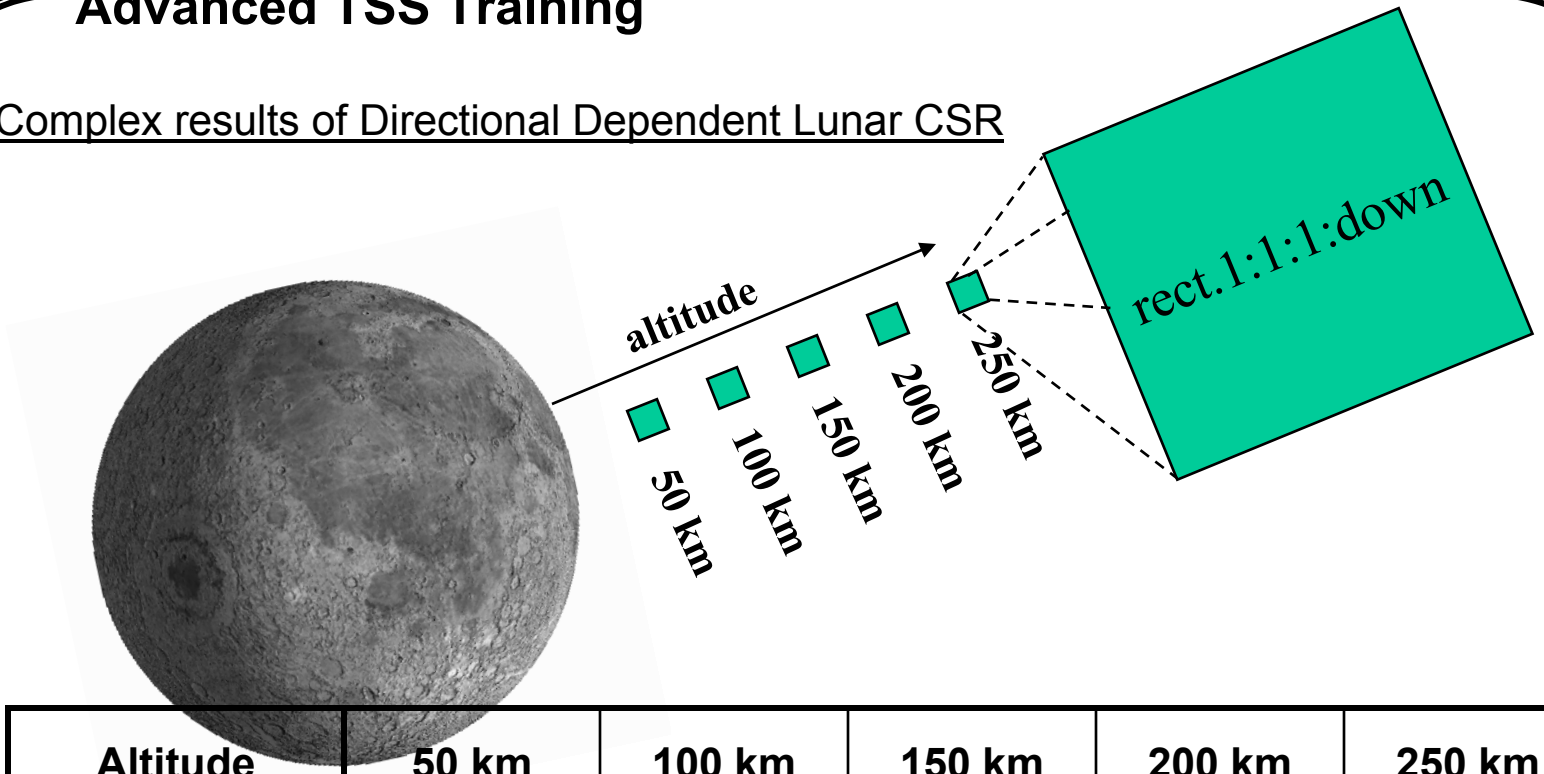
•How can the complexity of the Lunar IR environment be shown with Lunar CSR (cont.)?

•A comparison of flux values for a 1 m^2 rectangle is presented for altitudes of 50, 100, 150, 200, and 250 km.

•Position 3 provides a good demonstration of the differences in flux values seen by opposite sides of a rectangle.



•Complex results of Directional Dependent Lunar CSR



Altitude	50 km	100 km	150 km	200 km	250 km
q''_{ir} rect.1:1:1:down	243.91	213.31	189.09	174.76	160.68
q''_{ir} rect.1:1:1:up	206.48	160.05	132.91	111.70	94.58
$\Delta q''_{ir}$	**37.43**	**53.26**	**56.18**	**63.06**	**66.10**

All values are in W/m^2.

•How can the complexity of the Lunar IR environment be shown with Lunar CSR (cont.)?

•So the $\Delta q''_{ir}$ increases with altitude even though the interchange factors are equal at each altitude. This shows the flux is dependent on what area of the lunar surface a surface sees, not just how much area it sees.

•Although the magnitude of the incident flux goes down as the altitude increases (interchange factor decreases) the difference in the fluxes gets larger (down side sees higher avg. flux and up side sees lower avg. flux). This shows the complexity of the directionally dependent Lunar CSR model when predicting the Lunar IR environment.

•Conclusions and benefits of using TSS Lunar CSR

•Lunar CSR accurately represents the complex (varying) directionally dependent Lunar IR environment, by calculating a flux for each ray shot using a continuous function.

•Space 3D Thermal has demonstrated the ability to handle the Lunar IR environment with its complexity of directional and altitude dependence.

•The Spacedesign Corporation commercially available Space 3D Thermal (formerly TSS) product has the most accurate Monte Carlo Lunar IR calculations.

•Lunar CSR modeling is one of over one-hundred commercially developed enhancements to TSS that meets our customers needs!

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