HERA Project Master IPSA

Work session summary

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Overview

Obliquity

Solar flux received at 1 AU by a particular latitude is

$$S = S_{\odot} \cos Z \tag{1}$$

where Z is the solar zenith angle and

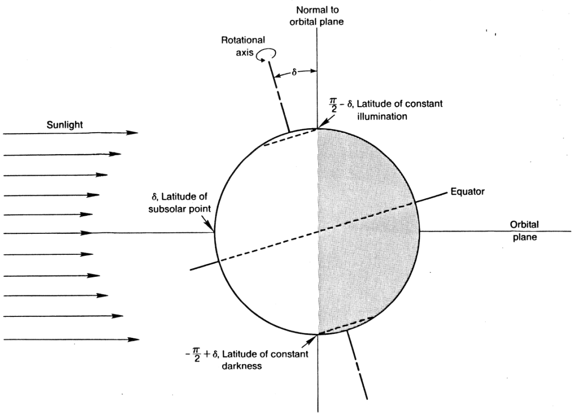
$$\cos Z = \sin\theta \sin\delta + \cos\theta \cos\delta \cos h \tag{2}$$

where θ is the latitude, δ the declination and h the hour angle. The declination is computed as

$$\sin\delta = -\sin\delta_0 \cos\left(L_s + \pi/2\right) \tag{3}$$

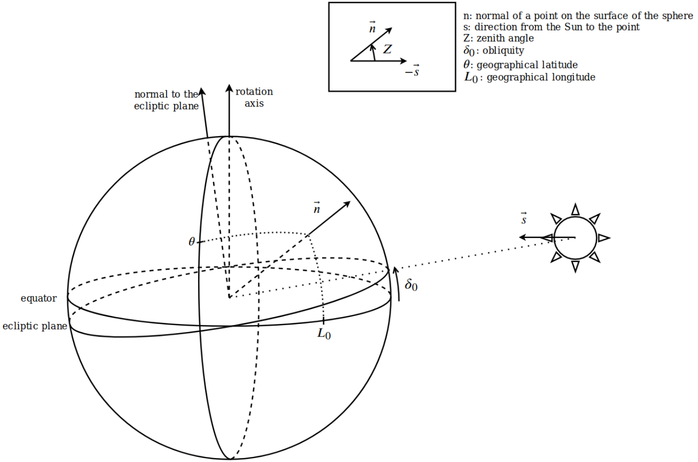
where δ_0 is the obliquity and L_s the orbital longitude.

Obliquity



Normal to orbital plane
Rotational axis
δ
$\frac{\pi}{2}$ - δ, Latitude of constant illumination
Sunlight
Equator
δ, Latitude of subsolar point
Orbital plane
$-\frac{\pi}{2}+\delta$, Latitude of constant darkness

Obliquity


$\vec{n}$
Z
$-\vec{s}$
n: normal of a point on the surface of the sphere
s: direction from the Sun to the point
Z: zenith angle
δ_0: obliquity
θ: geographical latitude
L_0: geographical longitude
normal to the ecliptic plane
rotation axis
$\vec{n}$
θ
equator
ecliptic plane
L_0
δ_0
$\vec{s}$

Obliquity

Solutions

1. Modelling the Sun's position from the Didymoon fixed inertial frame. This frame follows the rotations of Didymoon, thus it includes obliquity.
2. Computing the diurnally averaged solar flux

$$S = \frac{S_\odot}{\pi}\left(H \sin\theta \sin\delta + \cos\theta \cos\delta \sin H\right) \tag{4}$$

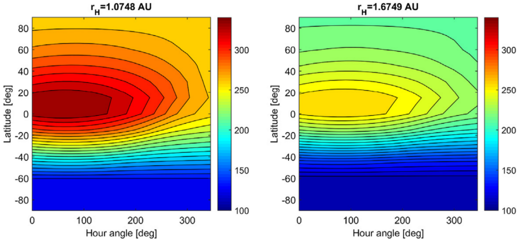
where H is the radian half-day length given by

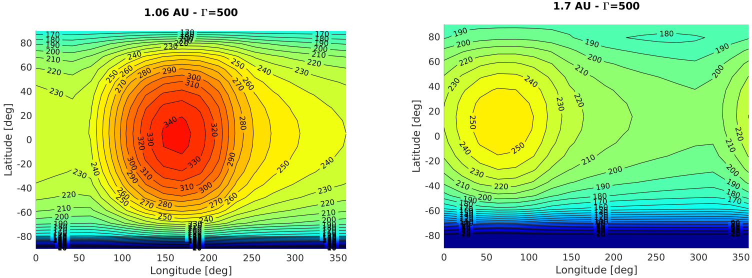
$$\cos H = -\tan\theta \tan\delta \tag{5}$$

where $0 < H < \pi$ & with h values from $-H$ to H.

Obliquity

Results for the first solution - comparison with Pelivan





A complete thermophysical model

Mutual & Self heating method

I. Pelivan, L. Drube, E. Kührt, J. Helbert, J. Biele, M. Maibaum, B. Cozzoni, V. Lommatsch
Thermophysical modeling of Didymos' moon for the Asteroid Impact Mission, 2017

Complete Thermophysical model :

$$\boxed{U + W + u + w = \varepsilon\sigma T^4 + \kappa\frac{dT}{dx}} \quad (1)$$

With U, the direct solar flux :

$$U = \frac{F_s(1 - A)\cos\zeta(t)}{{r_H}^2(t)} \quad (2)$$

RED : must be implemented
GREEN : already implemented

κ : *Thermal conductivity*
T : *Temperature*
ε : *Thermal emissivity*
σ : *Stefan-Boltzman constant*
F_s : *Solar constant*
A : *Bond Albedo*
ζ : *Solar incidence angle*
r_H : *heliocentric distance*

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Mutual heating contribution from diffuse solar radiation :

$$W_{p,j} = \sum_{i \neq j}^{N} V_{ij} \frac{F_s A \cos\zeta_j(t)}{{r_H}^2(t)} v_{j,sun} \quad (3)$$

Direct thermal heating from the primary :

$$u_{p,j} = \sum_{i \neq j}^{N} V_{ij} \varepsilon \sigma {T_{s,i}}^4 \quad (4)$$

Due to the low albedo, the single-scattering mode is applied for which the diffuse thermal heating flux can be neglected :

$$w = 0 \quad (5)$$

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A complete thermophysical model

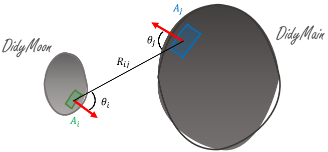
View factor for mutual heating

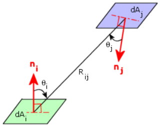
I. Pelivan, L. Drube, E. Kührt, J. Helbert, J. Biele, M. Maibaum, B. Cozzoni, V. Lommatsch
Thermophysical modeling of Didymos' moon for the Asteroid Impact Mission, 2017

V_{ij} Is the view factor describing the fraction of energy emitted from one facet towards another :

$$V_{ij} = \frac{A_i cos\theta_i cos\theta_j}{\pi {R_{ij}}^2} \qquad (6)$$

If $\theta_i \cup \theta_j \geq 0 \rightarrow V_{ij} = 0$





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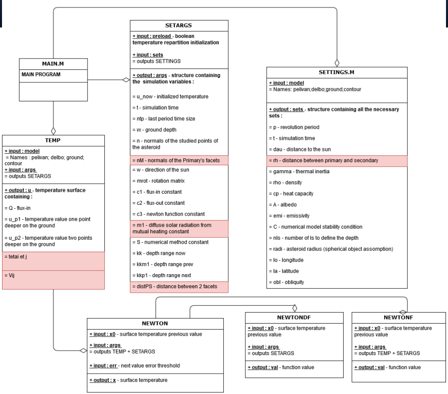
A complete thermophysical model

Software implementation



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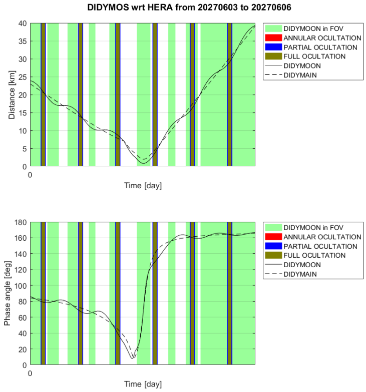
First, we want to test it with a simple **one-to-one facet system** to check if everything is fine before implement each variables inside the loops

Occultation

FOV, Phase angle and Ocultation Considerations
(Green means Didymoon is fully visible by HERA)

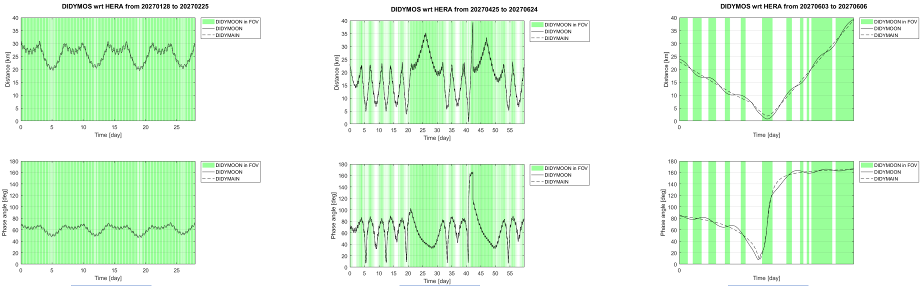


Detailed occultation type visible on figure

- Not in FOV
- In FOV, no occultation
- In FOV, but oculted
    - Partial occultation
    - Annular occulation
    - Full ocultation

Occultation

FOV, Phase angle and Ocultation Considerations
(Green means Didymoon is fully visible by HERA)

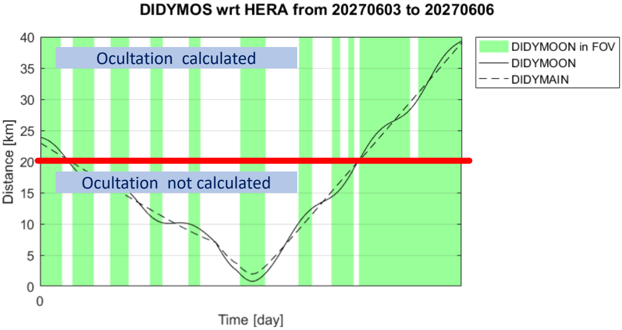


ECF | DCP3 | VCF

Simplified figure (occultation type not shown)
- Fully visible
- Not fully Visible

Occultation

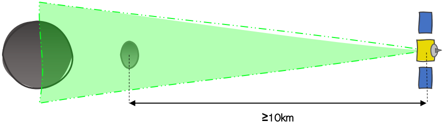
VCF with and without considering occultation



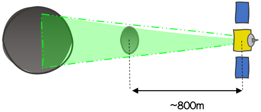
AREACOV

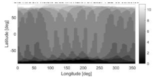
FOV Problem with SPICE

Wrong Didymoon visible area plot for Very Close Fly-By Phase (DCP3VCF)

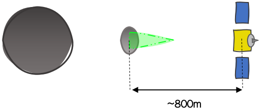


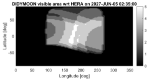
FOV configuration for DCP1 in Cosmographia





Expected FOV configuration for DCP3VCF





Actual FOV configuration for DCP3VCF in our program

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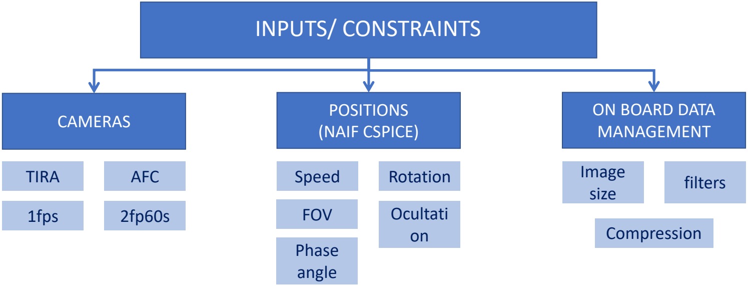
Technical characteristics



Technical characteristics

OUTPUTS

NUMBER OF IMAGES

How many images can we take for each phase?

Time of phase , constraints of the camera, FOV , Phase angle, occultation

MEMORY

How many images can be stored in memory

n×p×8 bits

With n and p the number of pixels

Noise reduction of the image on board?

EMISSION

Energy to be attributed to the emission of datas.

Which band to use

Band K_a with 550 kbit/s ?

Bibliography

Darren M. Williams & James F. Kasting. "Habitable Planets with Hight Obliquities". In: (1997).

Ivanka Pelivan et al. "Thermophysical modeling of Didymos' moon for the Asteroid Impact Mission". In: (2017).