LabEx UnivEarthS Scientific Committee
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Pleiades 1-B

SOILSPECT
Decoupling surface moisture and roughness in soil radiometric response

PRISMA

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Soil water content / surface roughness

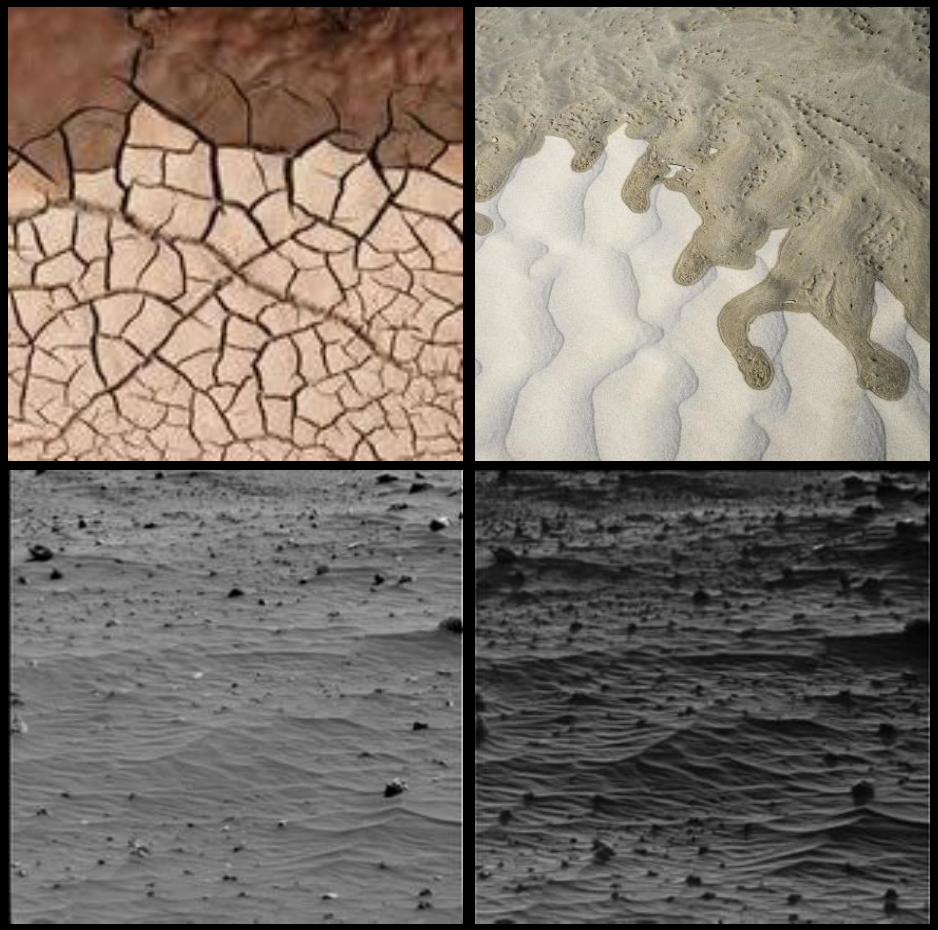
Knowledge of soil surface water content and roughness is essential to many research fields such as climate, micrometeorology, agriculture, forestry, ecology, continental hydrology, civil engineering, defense or homeland security, and planetary studies.

- Climate: desertification, water and wind erosion
- Micrometeorology: temperature, evaporation, wind speed, distribution of incident radiation
- Agriculture: soil sensitivity to wind erosion, gas exchange, aeration of the soil
- Continental hydrology: runoff process of infiltration and water storage
- Defense or homeland security: trafficability
- Planetary science: space weathering, surface processes, rover mobility

Measurement of soil surface water content and roughness is difficult, local, and expensive

$\rightarrow$ Remote sensing in the solar domain, thermal infrared, and microwaves

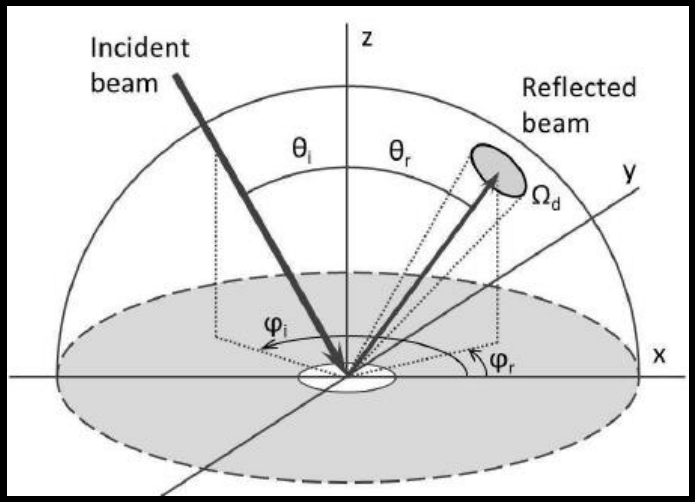
The dark side of soils…



→ Development/validation of radiative transfer models

Light scattering properties of bare soils

Irradiance [W m^{-2}] Radiance [W m^{-2} sr^{-1}]

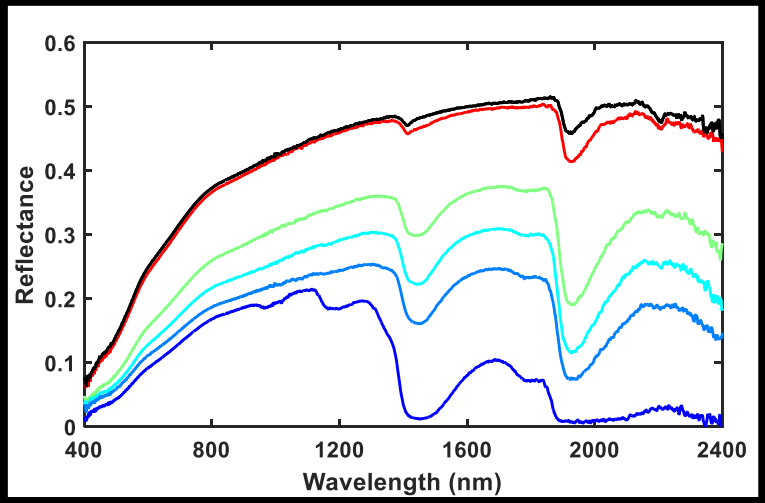


Bidirectional Reflectance Distribution Function [sr^{-1}]

$$BRDF\left(\theta_s,\varphi_s,\theta_v,\varphi_v,\lambda\right)=\frac{L_R\left(\theta_s,\varphi_s,\theta_v,\varphi_v,\lambda\right)}{E_I\left(\theta_s,\varphi_s,\lambda\right)}$$

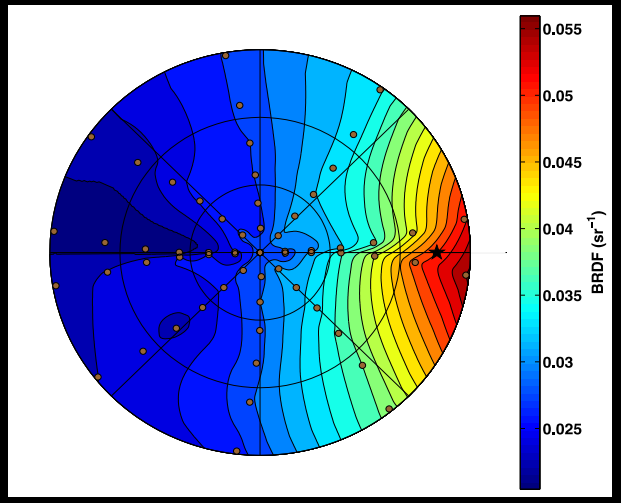
→ Reflectance Factor

Spectral optical properties



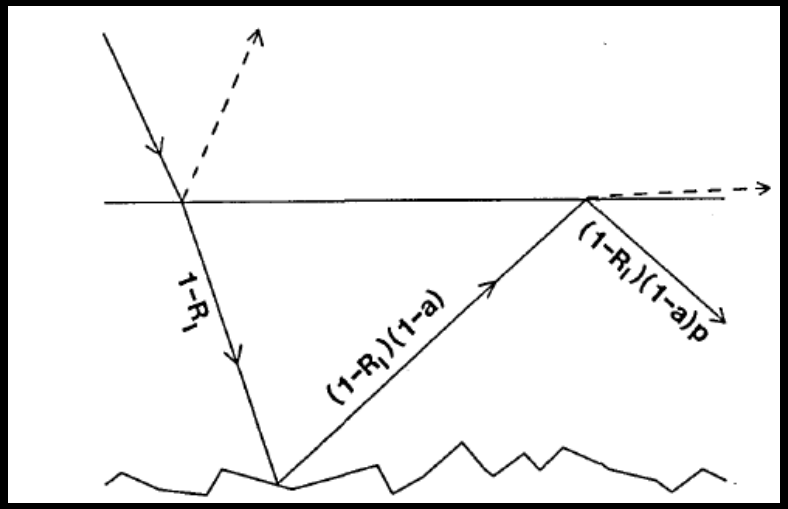
Bablet et al. (2018), *Remote Sensing of Environment*, 217:1-17.

Directional optical properties

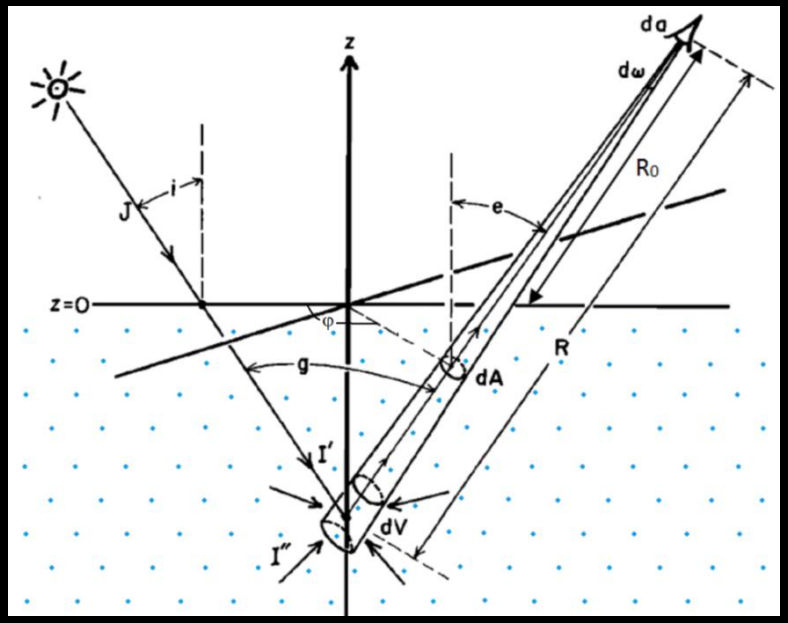


Labarre et al. (2019), *Remote Sensing of Environment*, 225:1-15.

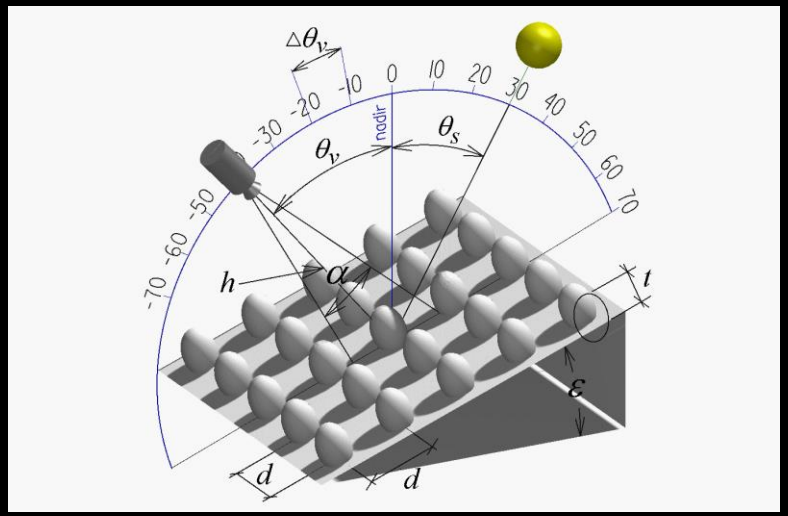
Soil BRDF models: different approaches



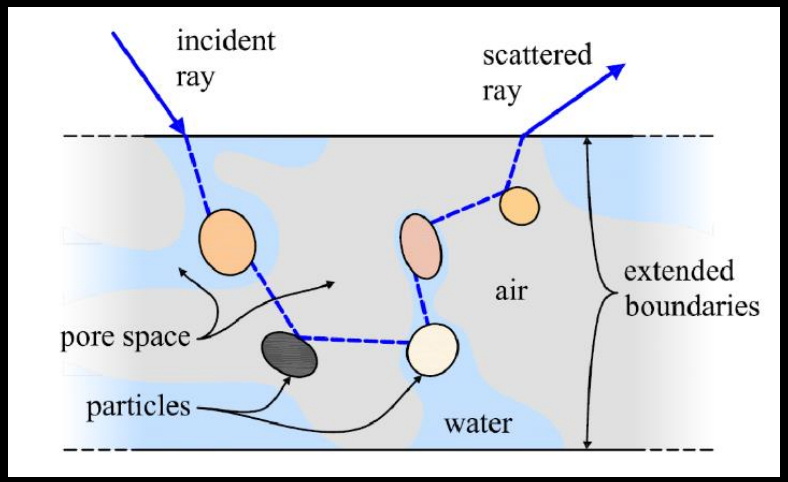
Layer models



Radiative transfer equation



Geometrical models



Ray tracing models

Soil BRDF models: different approaches

Model	Water content	Surface roughness
Layer	Ångström (1925), Lekner & Dorf (1988), Bach & Mauser (1994), Tian and Philpot (2015), **Bablet et al. (2018, 2019)**	
Geometrical		Cierniewski (1987), Cierniewski & Verbrugghe (1997), Cierniewski & Karnieli (2002)
Radiative transfer	Sadeghi et al. (2015)	Hapke (1981, 1984), Despan et al. (1999), Chappell et al. (2006), Wu et al. (2009), Johnson et al. (2013), **Labarre et al. (2017, 2019)**
	Jacquemoud et al. (1992), Yang et al. (2011), Pommerol et al. (2013)	
Ray tracing	Kimmel & Baranoski (2007)	**Labarre et al. (2017)**

→ No unique model validated across a wide range of laboratory/field measurements

A laboratory experiment: the SHINE spectro-gonio-radiometer

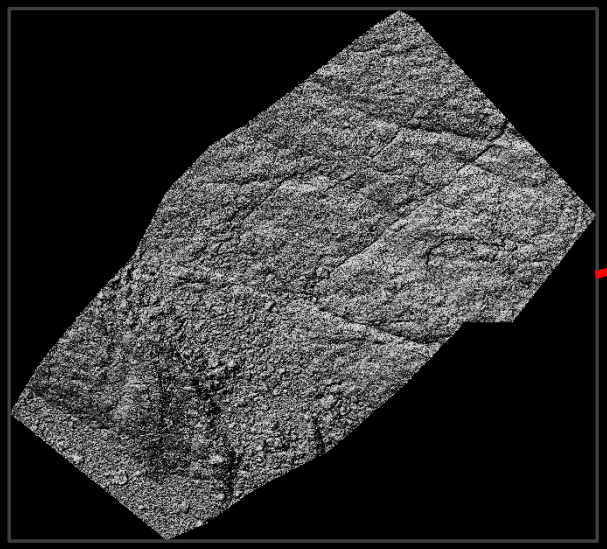
SHINE (*spectrophotometer with variable incidence and emergence*)

→ Measurement of soil BRDF at submillimeter and millimeter scales

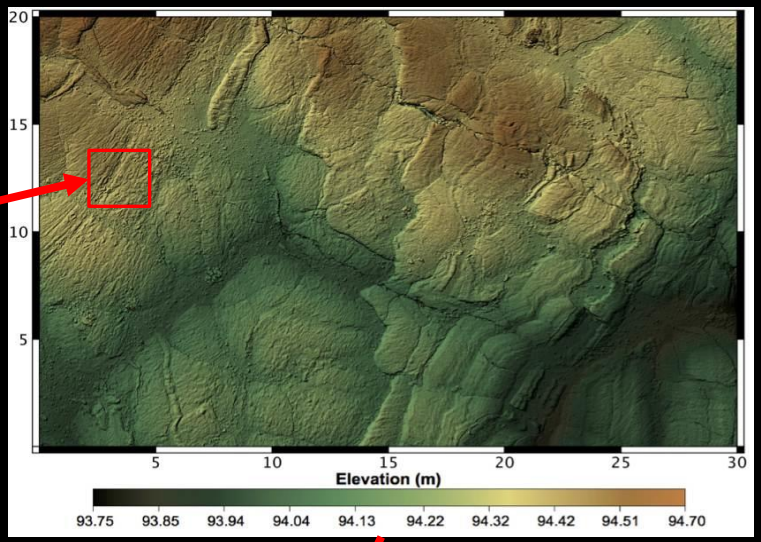
https://cold-spectro.sshade.eu/

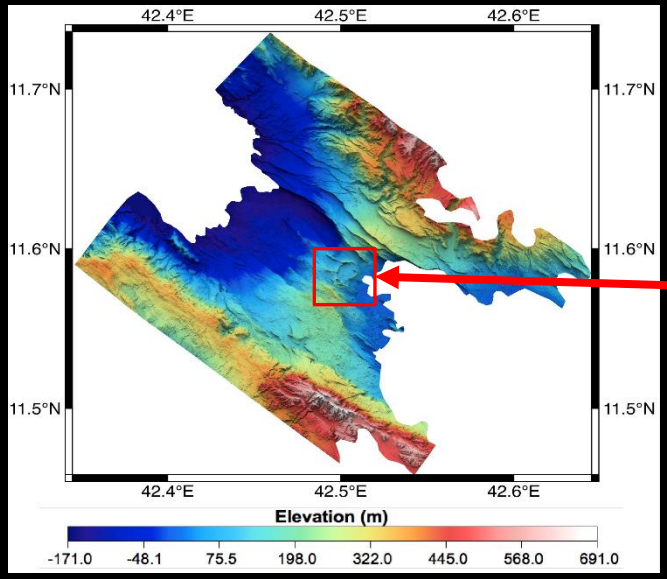
Surface roughness: multi-resolution DTMs (Asal-Ghoubbet rift, Djibouti)

Submillimetric DTM (2 m × 3 m / Δx = 0.8 mm)

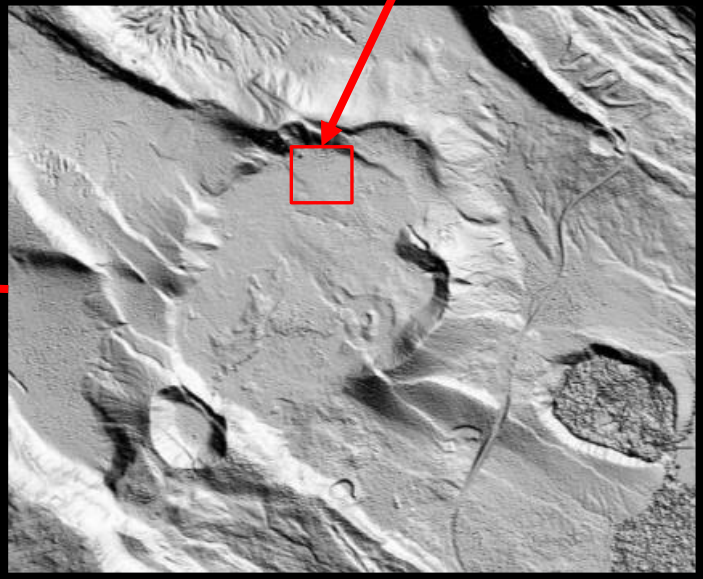


Millimetric DTM (20 m × 30 m / Δx = 3 mm)



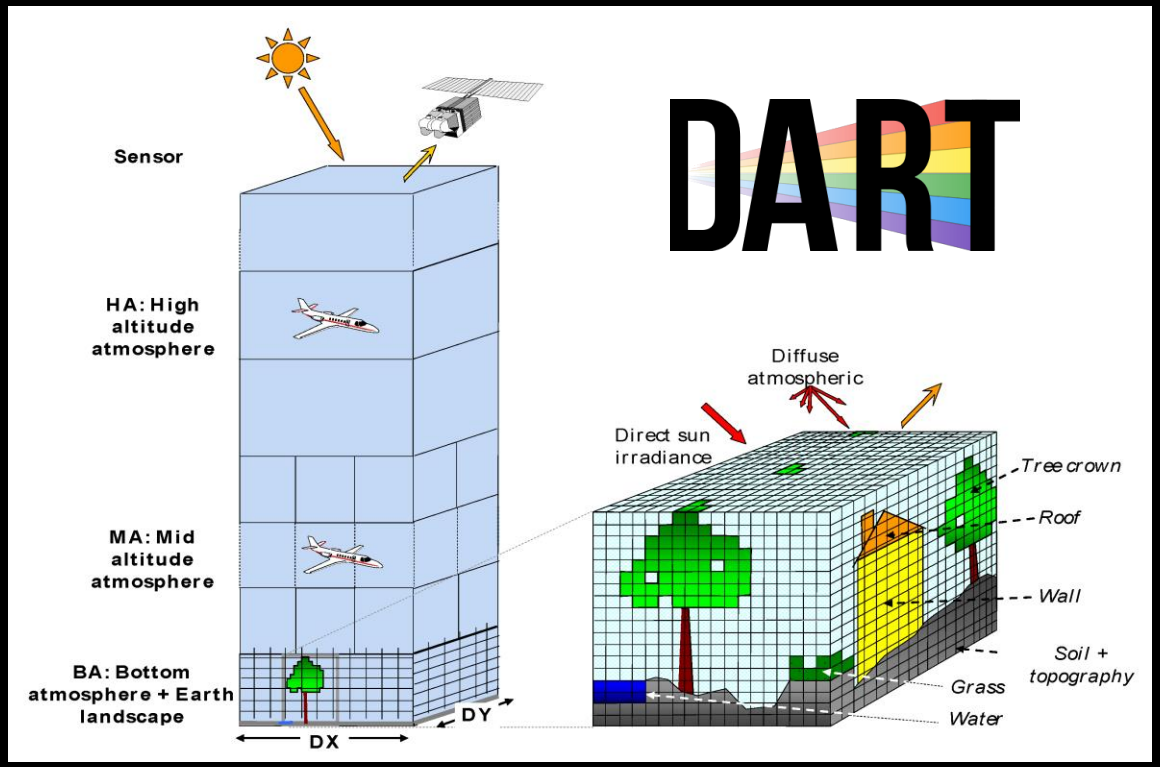


Metric DTM (15 km × 15 km / Δx = 2 m)



Centimetric DTM (4 km × 6 km / Δx = 3-4 cm)

A numerical simulation: the DART model



DART (*discrete anisotropic radiative transfer*)

→ Simulation of soil BRDF at centimeter to meter scales

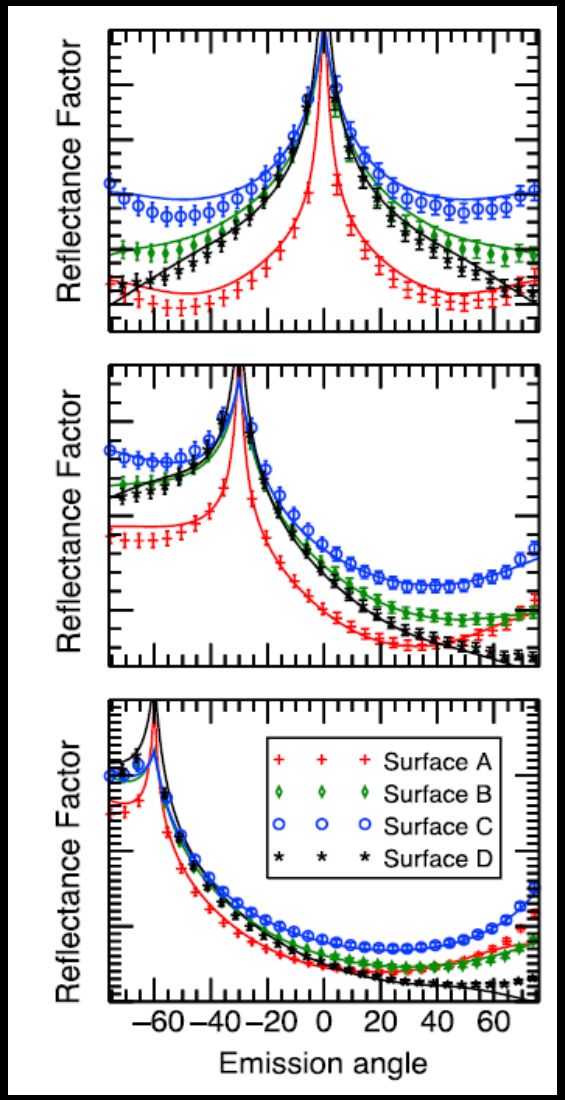
https://dart.omp.eu/

Simulation of soil BRDF: scale / moisture content / surface roughness

i = 0°

i = 30°

i = 60°



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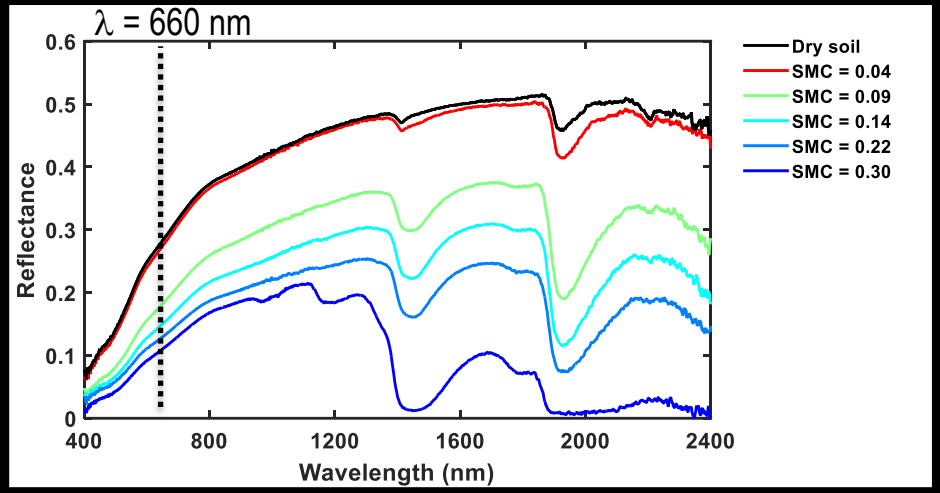

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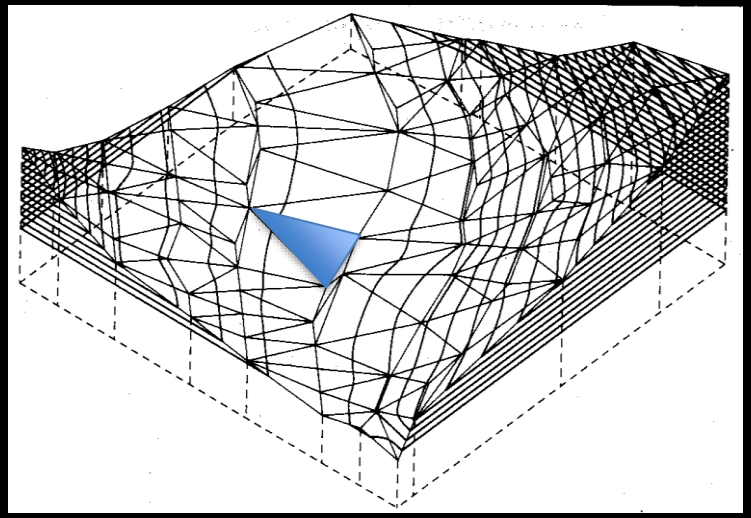
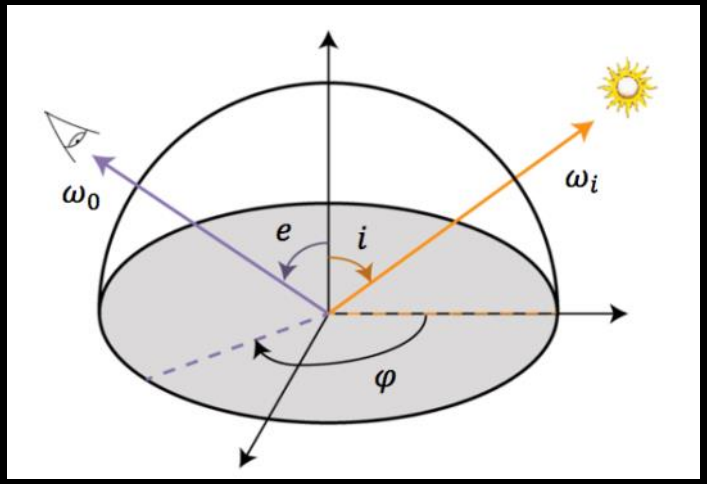


= ?

Inversion of the Hapke photometric model

i = incidence angle (illumination direction)
e = emission angle (viewing direction)
g = phase angle



$$R(i,e,g) = \frac{K(P)}{\mu_0}\frac{w}{4\pi}\frac{\mu_{0e}(\bar{\theta})}{\mu_{0e}(\bar{\theta}) + \mu_e(\bar{\theta})}\left[p(g,b,c)B_S(g,P,B_0) + M(\mu_{0e},\mu_e)\right]\times S(i,e,g,\bar{\theta})$$

Symbol	*Parameter*	*Physical meaning*	*Range*
w	Single scattering albedo	Scattering at the grain scale	[0 ; 1]
B_0	Opposition surge amplitude	Particles opacity	[0 ; 1]
b	Phase function asymmetry parameter	*b*=0 → isotropic scattering *b*=1 → *directional scatering*	[0 ; 1]
c	Phase function backscattering coefficient	*c* > 0 → backward scattering *c* < 0 → forward scattering	[-∞ ; +∞]
P	Porosity	Void fraction	[0 ; 1]
θ	Roughness parameter	Mean slope angle	[0° ; 90°]

Expected results

- A BRDF database of soils at different moisture levels
- BRDF simulations of terrestrial and planetary surfaces at different levels of humidity and roughness
- The validation of a radiative transfer model in direct and inverse mode
- Terrestrial and planetary applications

Position	Name / Surname	Laboratory	Grade / Employer
WP leader	Stéphane JACQUEMOUD	IPGP-PSS	Professeur / U. Paris
WP co-leader	Xavier BRIOTTET	ONERA-DOTA	Directeur de recherche / ONERA
WP member	Alice DUPIAU	ONERA/IPGP	Doctorante / ONERA
WP member	Sophie FABRE	ONERA-DOTA	Chercheur / ONERA
WP member	Cécile FERRARI	IPGP-PSS	Professeur / U. Paris
WP member	Antoine LUCAS	IPGP-PSS	Chargé de recherche / CNRS
WP member	Sébastien RODRIGUEZ	IPGP-PSS	Maître de conférences / U. Paris
WP member	Françoise VIALLEFONT	ONERA-DOTA	Chercheur / ONERA