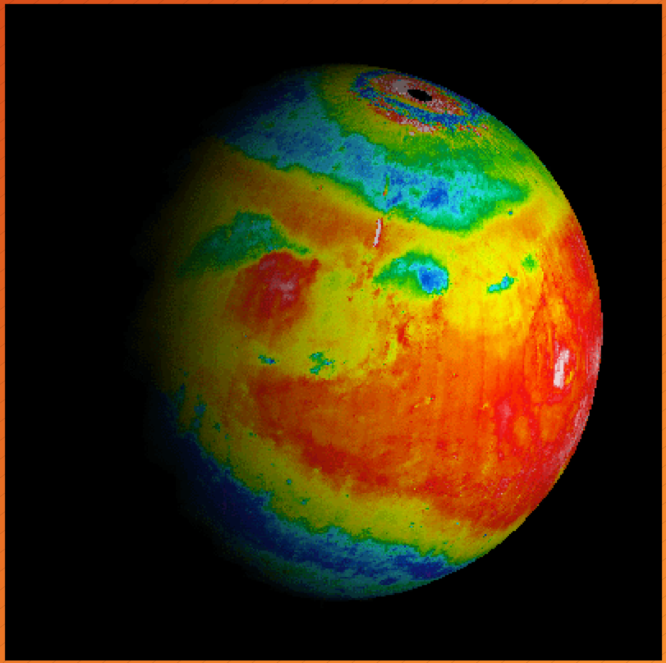
Albedo measurements with PFS



F. Esposito, E. Palomba, L. Colangeli and the PFS team

Albedo measurements with PFS

Remote observations of planetary surfaces are complicated by the surface photometric function and, sometimes, by atmospheric scattering.

The reflectivity of the Martian surface depends both on surface composition and physical properties such as particle size, roughness and porosity.

Viewing geometry also affects the scattering of light from the surface.

Albedo measurements with PFS

The form of the photometric function

Theoretical works derived semiempirical photometric functions from physical laws. Hapke equations have been widely used and have been proven accurate in laboratory and planetary measurements

Hapke function is a complicated expression => simpler photometric functions are faster and more convenient to use

McEwen (1991) demonstrated that deviations between Hapke function and the simpler Lambert or Minnaert expressions are negligible

They can also describe both surface and atmospheric photometric functions

The simple generalised Lambert and Minnaert phenomenological model is used to construct photometrically corrected mosaics from PFS data

Albedo measurements with PFS

The Lambert approach

We measured the Lambert albedo A_L starting from the radiance observed by the Short Wavelength Channel (SWC) of PFS @ 7050 cm^{-1}.

$$A_L = \frac{RD^2}{S \cos(i)}$$

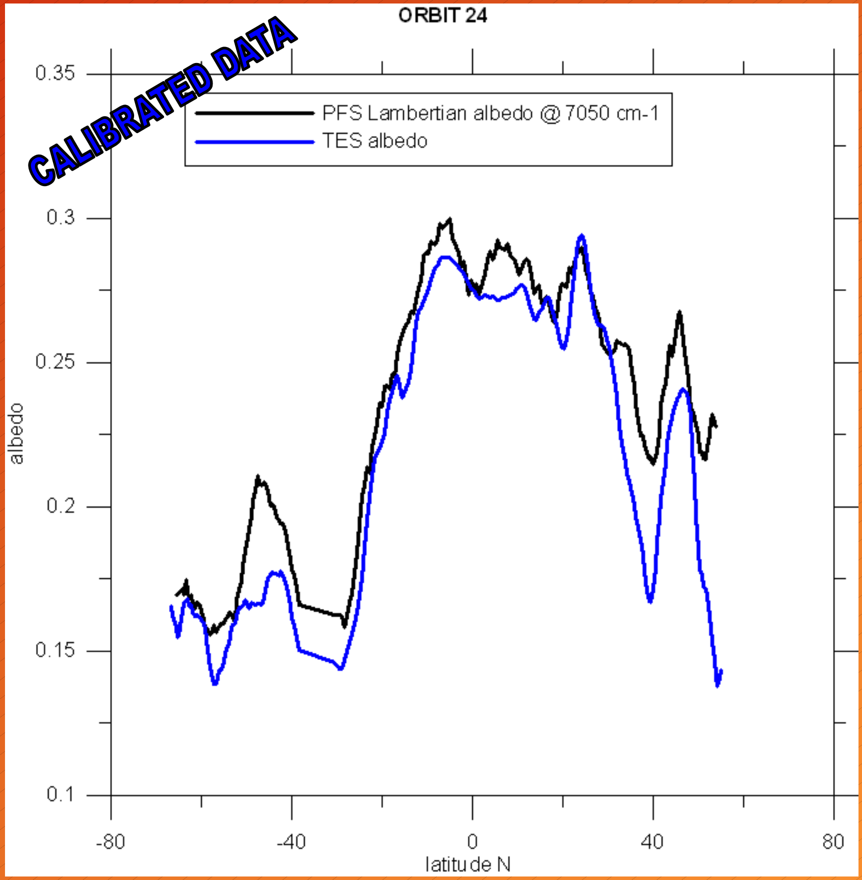
where R is the PFS calibrated radiance, D is the Sun-Mars distance (in A.U.), S is the solar radiance at 1 A.U. and i is the solar incidence angle.

At this frequency there is no major absorption due to atmosphere. Anyway, scattering by micrometer-sized aerosols modifies the continuum of incident and emergent radiation.

Albedo measurements with PFS

The Lambert approach

Comparison with TES Lambert albedo



The match with TES data is very good !

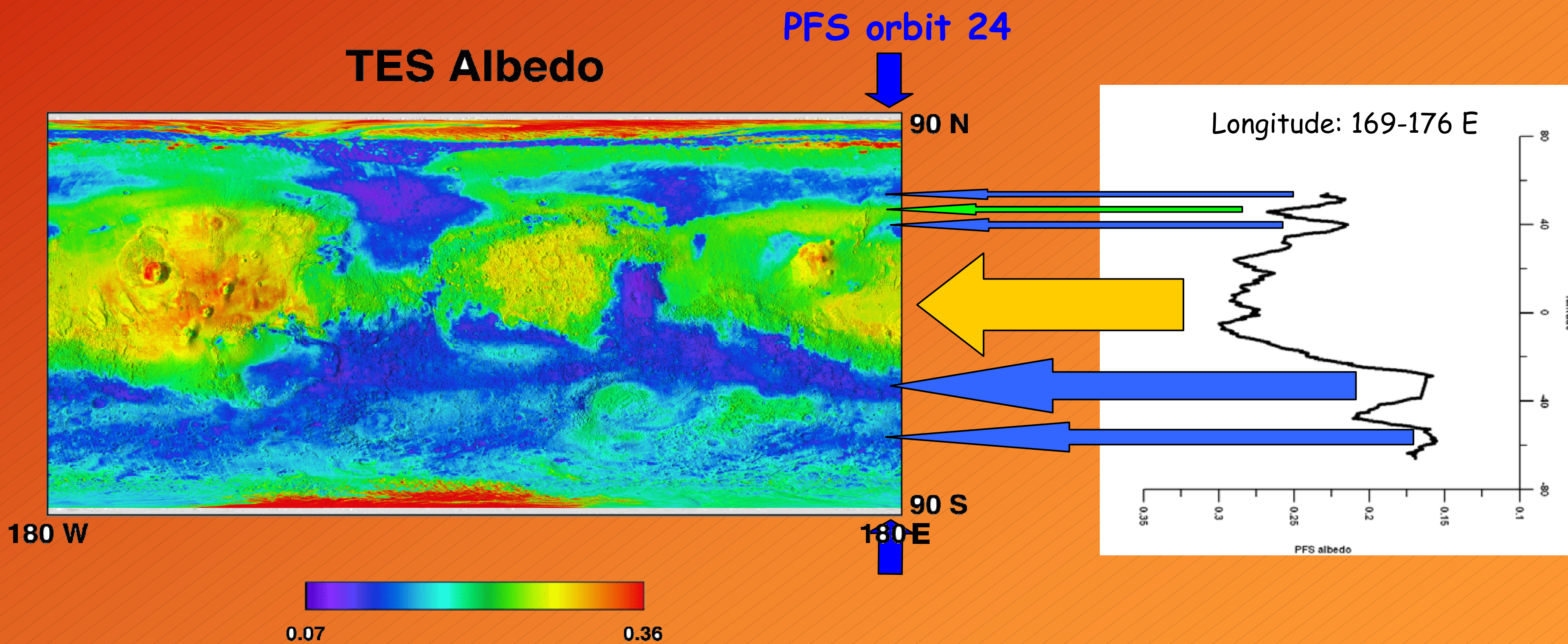
Shape is similar, differences in the average intensity is about 10%

BUT

note that TES albedo is integrated over the spectral range of the VIS/NIR bolometer: 0.3-2.9 μm

Albedo measurements with PFS

The Lambert approach

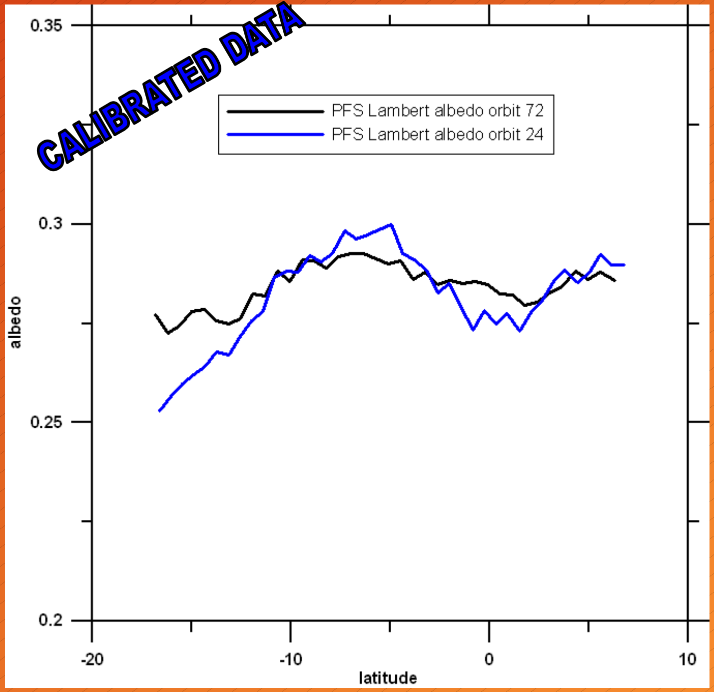


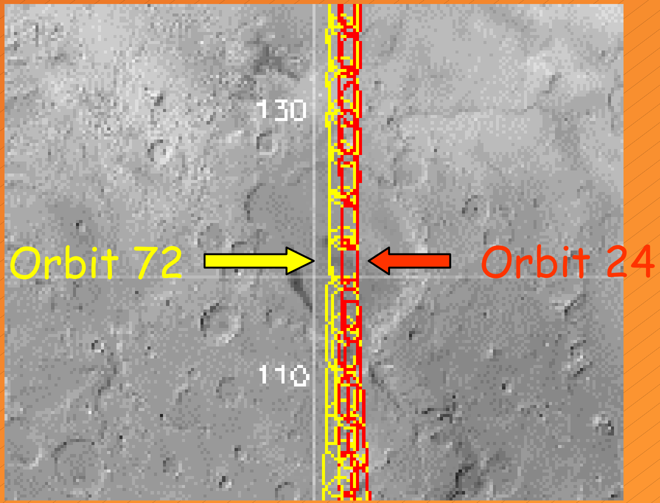
Albedo measurements with PFS

The Lambert approach

Albedo data are reproducible along different orbits.

PFS orbits 24 and 72 overlap between about -20 and 0 deg latitude N.





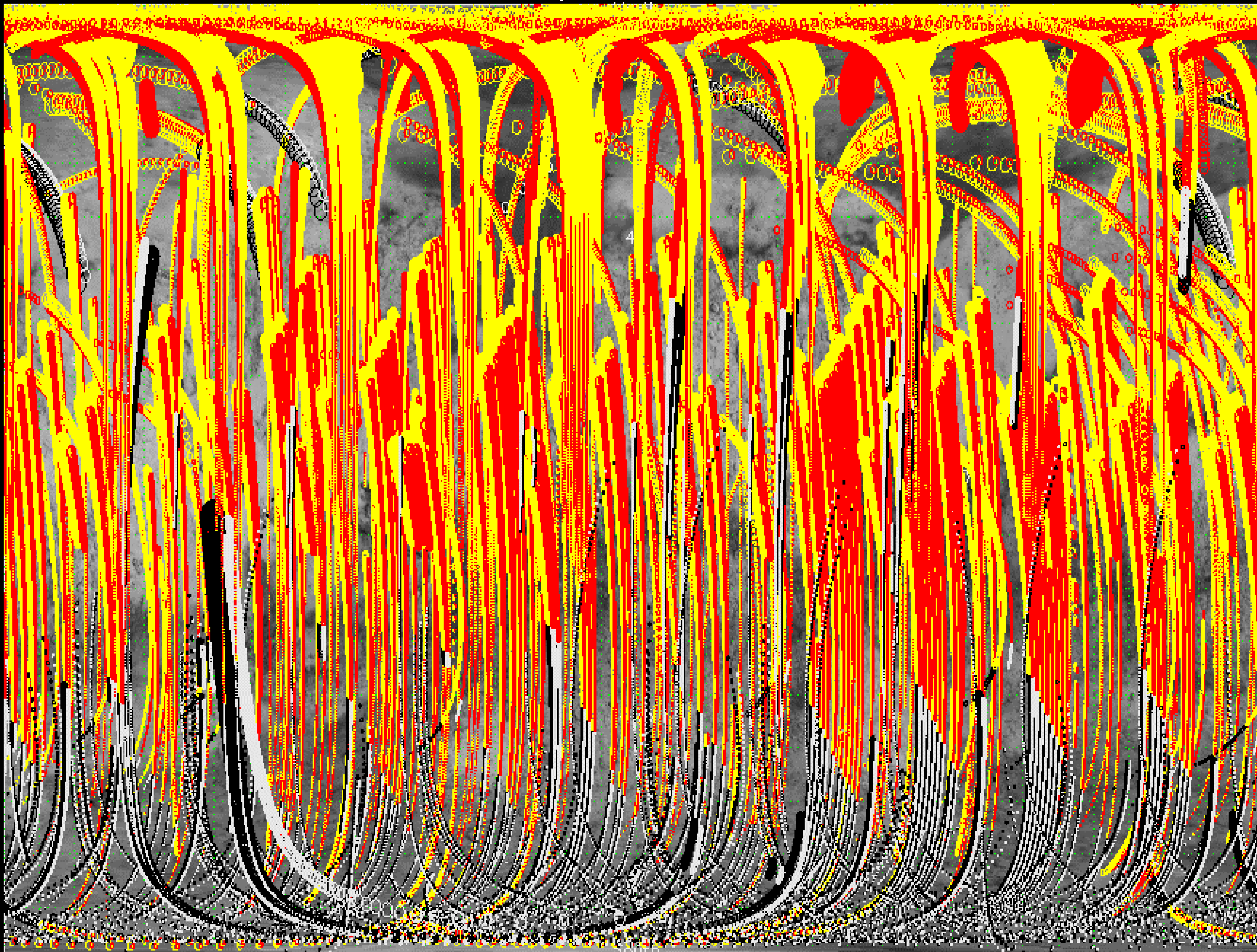
Albedo measurements with PFS

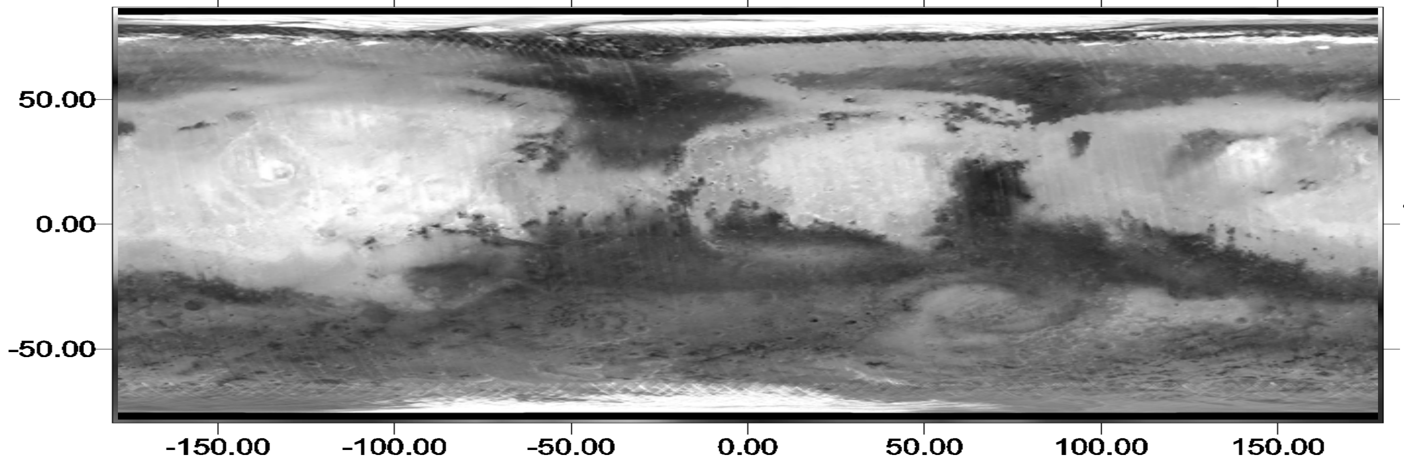
We analysed the first 10 months of PFS SWC RAW data in order to produce an albedo map of the covered regions of the planet.

This study is important:

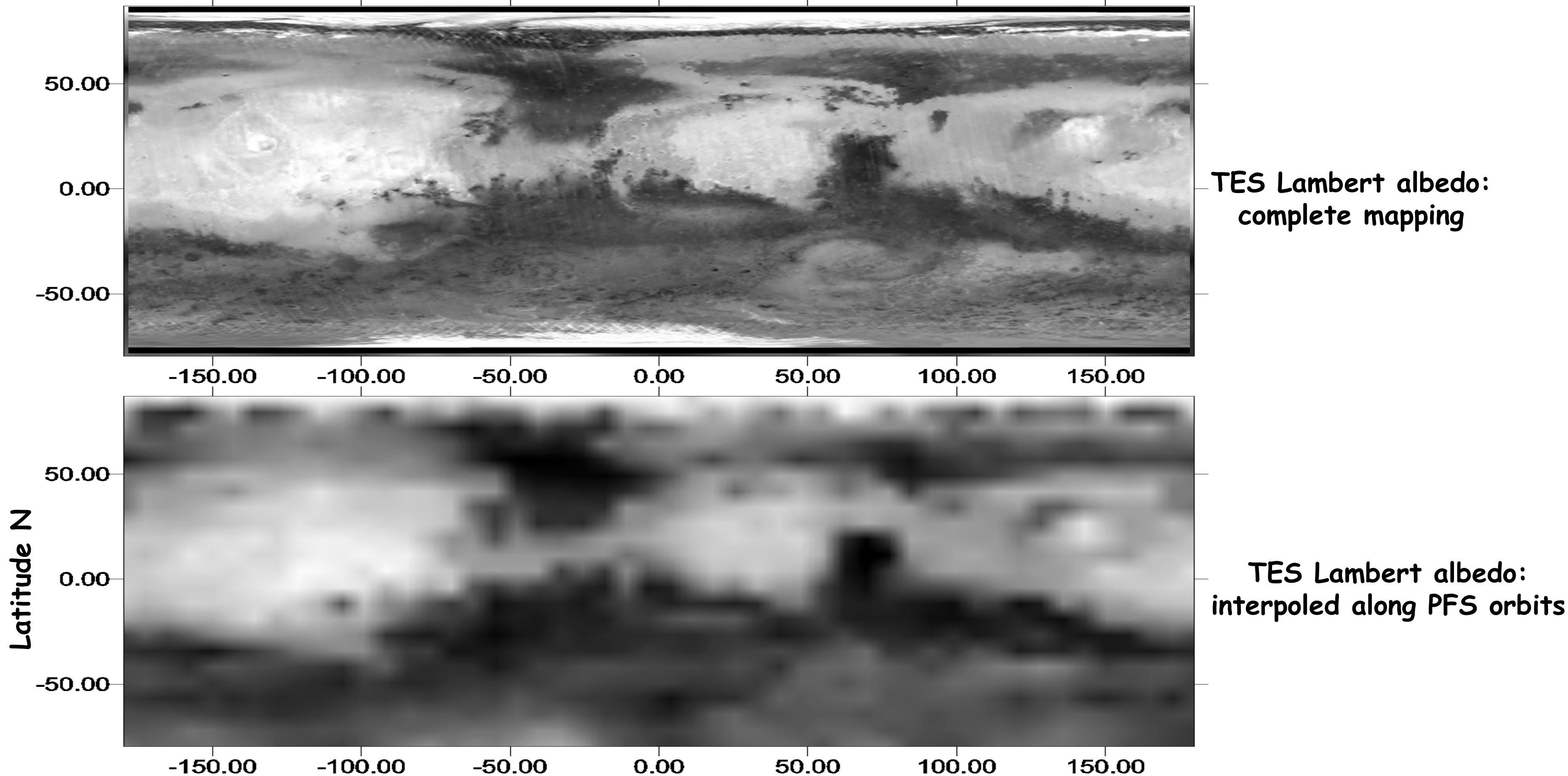
- to check the PFS capability in the observations of the planet's surface
- to investigate the nature of the surface materials through photometric studies
- as a preliminary work, which will be followed by a quantitative investigation on calibrated data (when they will be available) revealing possible changes in the upper surface due to the redistribution of mobile fines

PFS Observations up to October 24 2004   LWC – SWC

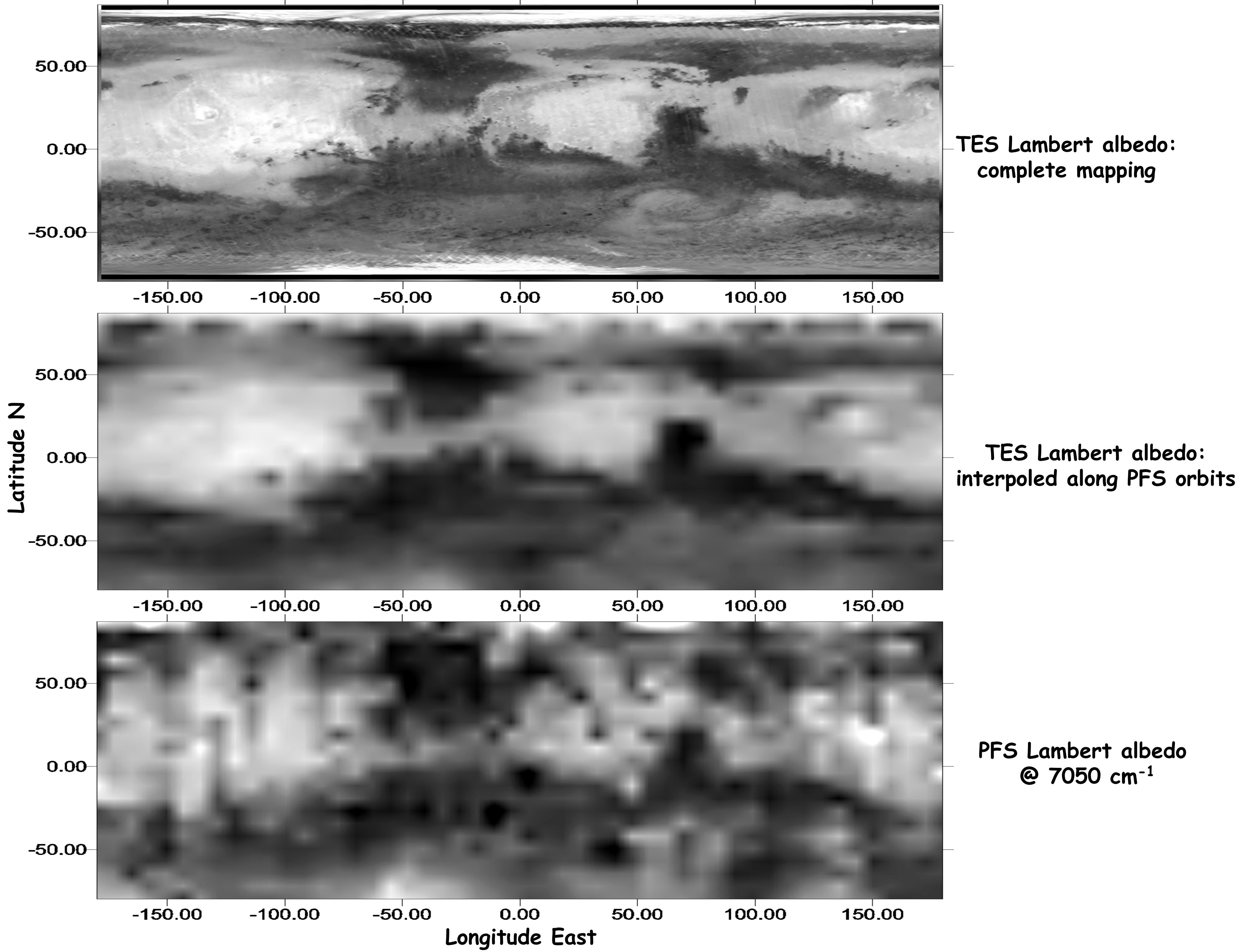




TES Lambert albedo:
complete mapping



50.00
0.00
-50.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
TES Lambert albedo:
complete mapping
Latitude N
TES Lambert albedo:
interpoled along PFS orbits



TES Lambert albedo: complete mapping
TES Lambert albedo: interpoled along PFS orbits
PFS Lambert albedo @ 7050 cm-1
Latitude N
Longitude East
50.00
0.00
-50.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00

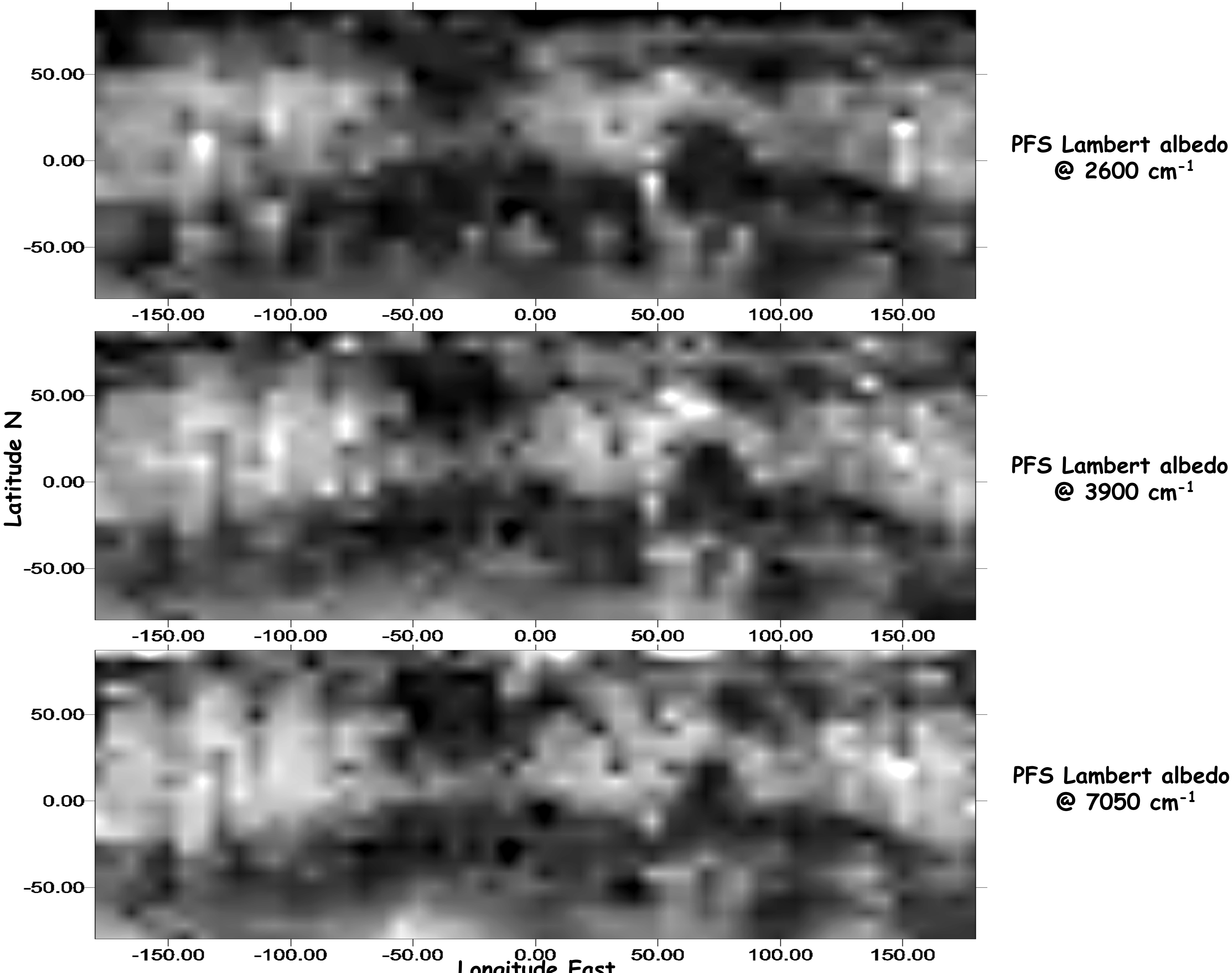
Albedo measurements with PFS

The Lambert approach

We measured the Lambert albedo A_L also @ 2600 and 3900 cm^{-1} for comparison.

At these frequencies there is no major absorption due to atmosphere, too.

At 2600 cm^{-1} the thermal component in the PFS spectra becomes important.



50.00
0.00
-50.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
PFS Lambert albedo @ 2600 cm-1
PFS Lambert albedo @ 3900 cm-1
PFS Lambert albedo @ 7050 cm-1
Latitude N
Longitude East

Photometry of Mars
The Minnaert approach

The Minnaert approach is more general than the Lambert's one and it is demonstrated that, especially at small phase angles, it adequately mimics the photometric behaviour of particulate surfaces.

The Minnaert photometric function *f*(*i,e,g*) is:

$$f(i,e,g,\lambda) = B_0(g,\lambda)(\cos i)^{k(g,\lambda)} \cdot (\cos e)^{k(g,\lambda)-1}$$

where *i, e and g* are the incidence, emission and phase angles, respectively.
k is the limb-darkening parameter and varies with phase angle and wavelength.
At zero phase angle B_0 is the normal albedo.

Photometry of Mars

The Minnaert approach

The quantification of limb-darkening as a function of wavelength and surface albedo gives access to Martian regional properties as a function of wavelength and surface albedo and results in the production of a NIR normal albedo map.

This analysis may contribute to characterize some physical properties, such as surface roughness.

Photometry of Mars

The Minnaert approach

Data in the literature

VIS		NIR	
$k \approx 0.6$	for $g = 0$	k from ~ 0.48 to ~ 1	for $g = 0$
$k \sim 1$	for larger g	$k \sim 1$	for larger g

A linear relation between k and the geometrical albedo exists in the NIR.

Based on laboratory studies (Veverka et al., 1978), it suggests a spectral response of particulate type for the Martian soil (multiple scattering).

Conversely, in the VIS, the value of k is 0.6 independent of albedo and is consistent with a single scattering photometric behaviour in the surface layer.

However, the observed change in the Martian photometry from single to multiple scattering may be partially due to a large contribution of atmospheric scattering above 0.7 μm.

Photometry of Mars
The Minnaert approach

In order to study the variation of *k* in the PFS measurements of Mars we classified the data in 13 classes of albedo.

For each albedo class we classified data again according to phase angles value:

subclass 1 for $0° \leq g < 30°$
subclass 2 for $30° \leq g < 60°$
subclass 3 for $60° \leq g < 90°$

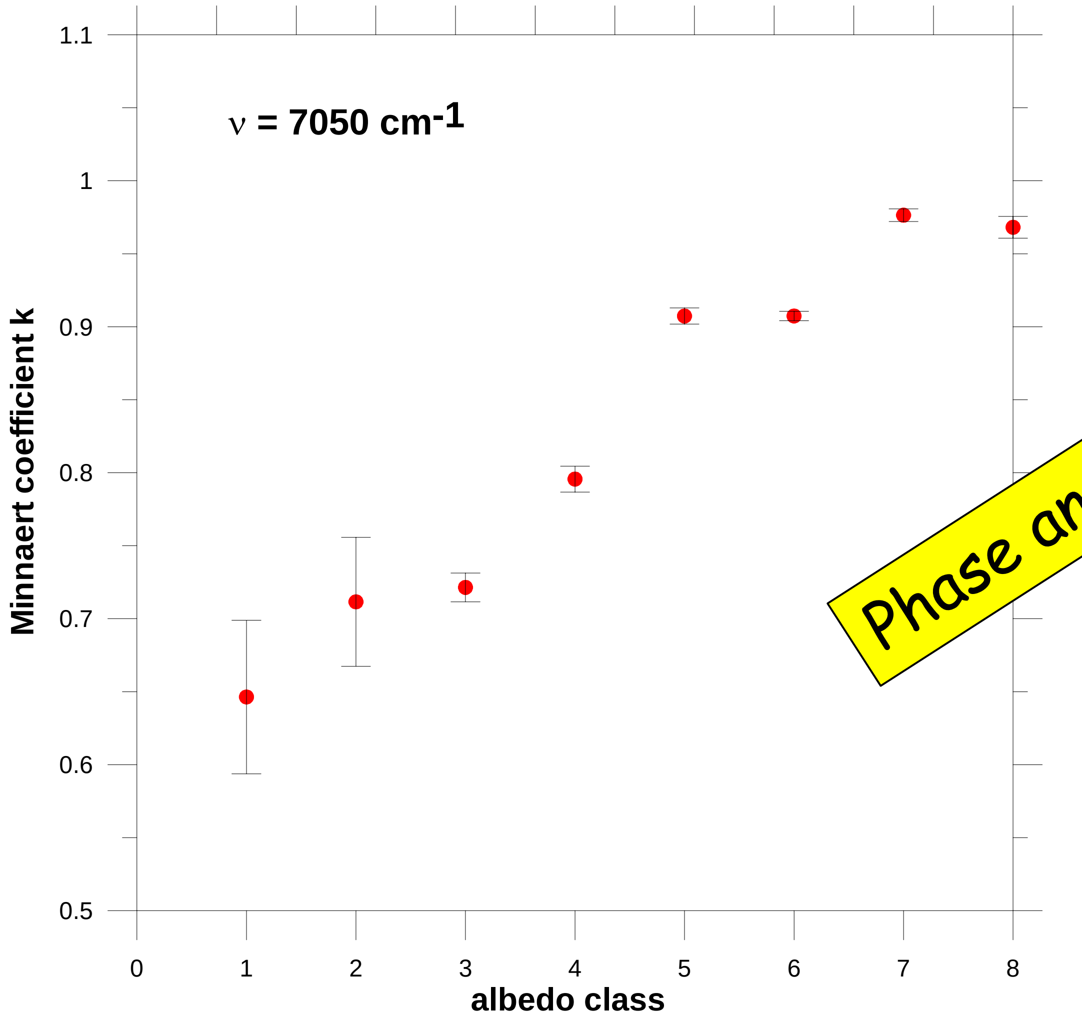
Finally, for each subclass in each class we computed the value of the *k* parameter through the linear regression:

$$\log(S \cdot \cos e) = \log B_0 + k \cdot \log(\cos i \cdot \cos e)$$

where S is the PFS signal extracted at the fixed wavenumbers (7050, 2600, 3900 cm^{-1}).

Photometry of Mars

Minnaert function: $f(i,e,g,\lambda) = B_0(g,\lambda)\cdot(\cos i)^{k(g,\lambda)}\cdot(\cos e)^{k(g,\lambda) - 1}$



Fixing g and λ, we observe that *k* increases with the albedo class.

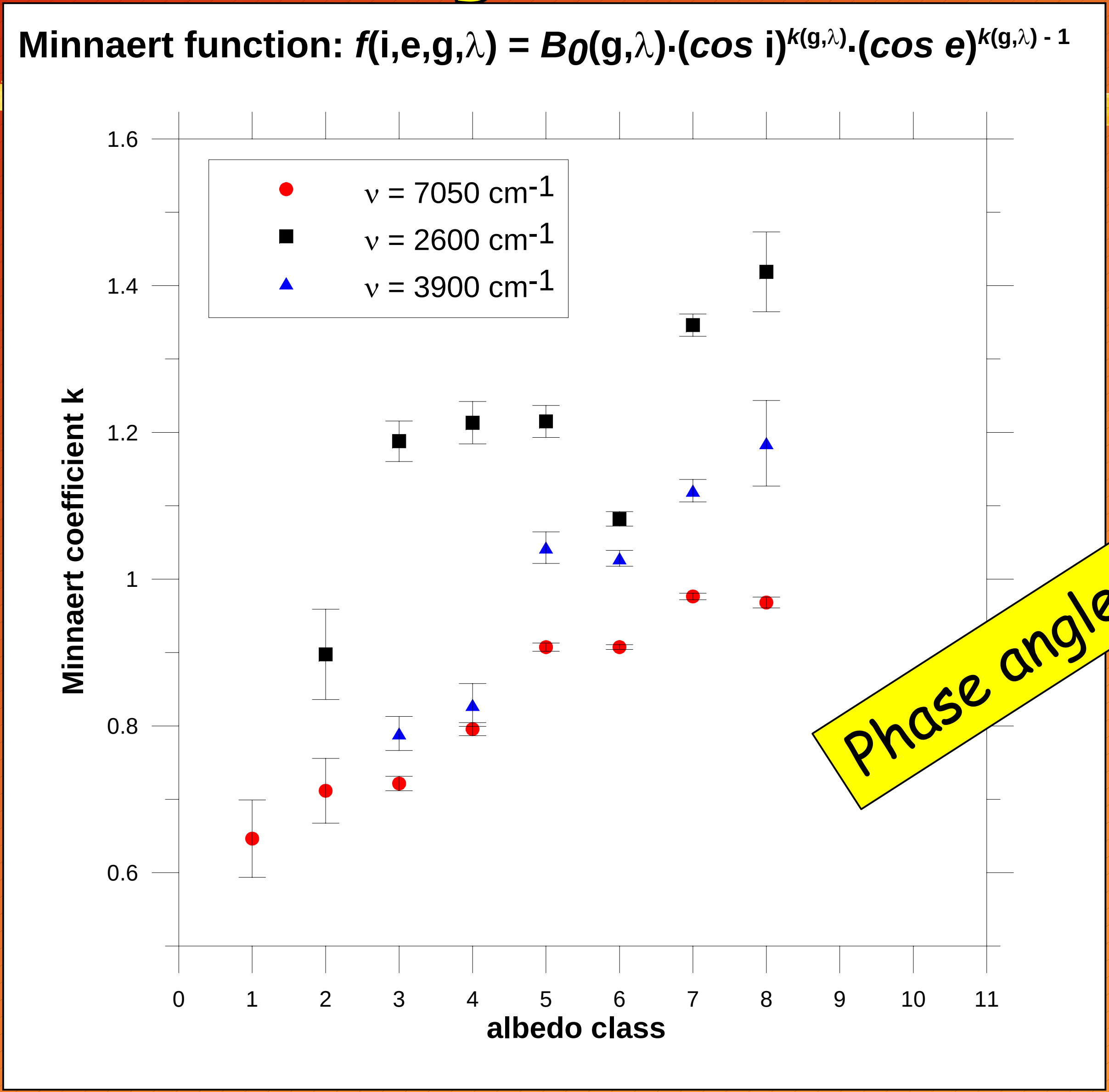
Photometry of Mars
The Minnaert approach

This analysis may contribute to characterise some physical properties, such as surface roughness.

For regions which are members of high albedo classes (≥ 5), k tends to be more uniform at 7050 cm^{-1} (with values around around 0.91 - 0.98) and agrees with the presence of very fine particulate materials.

Photometry of dark areas is more irregular (0.65-0.80) and might result from surface roughness heterogeneity.

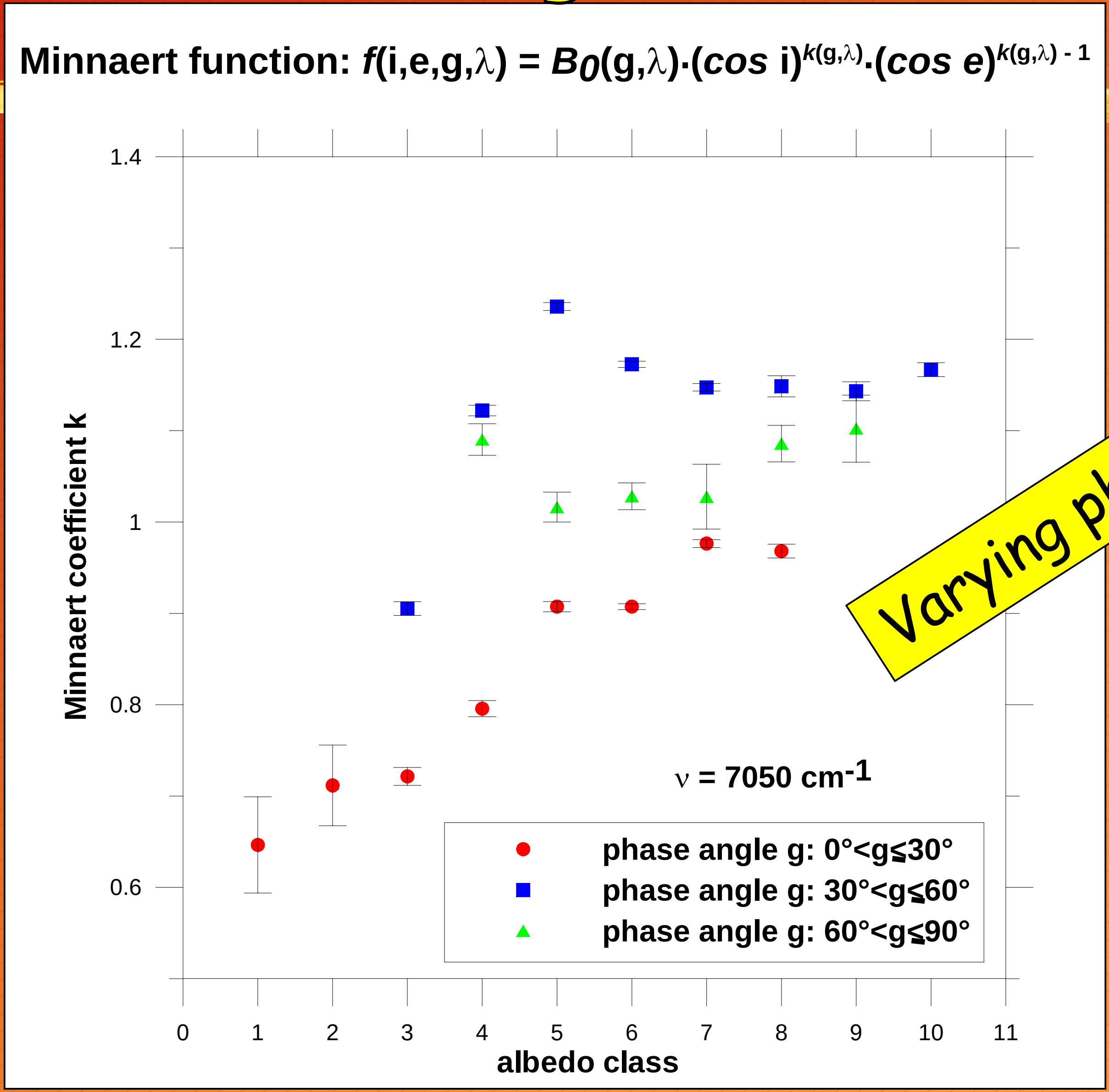
Photometry of Mars



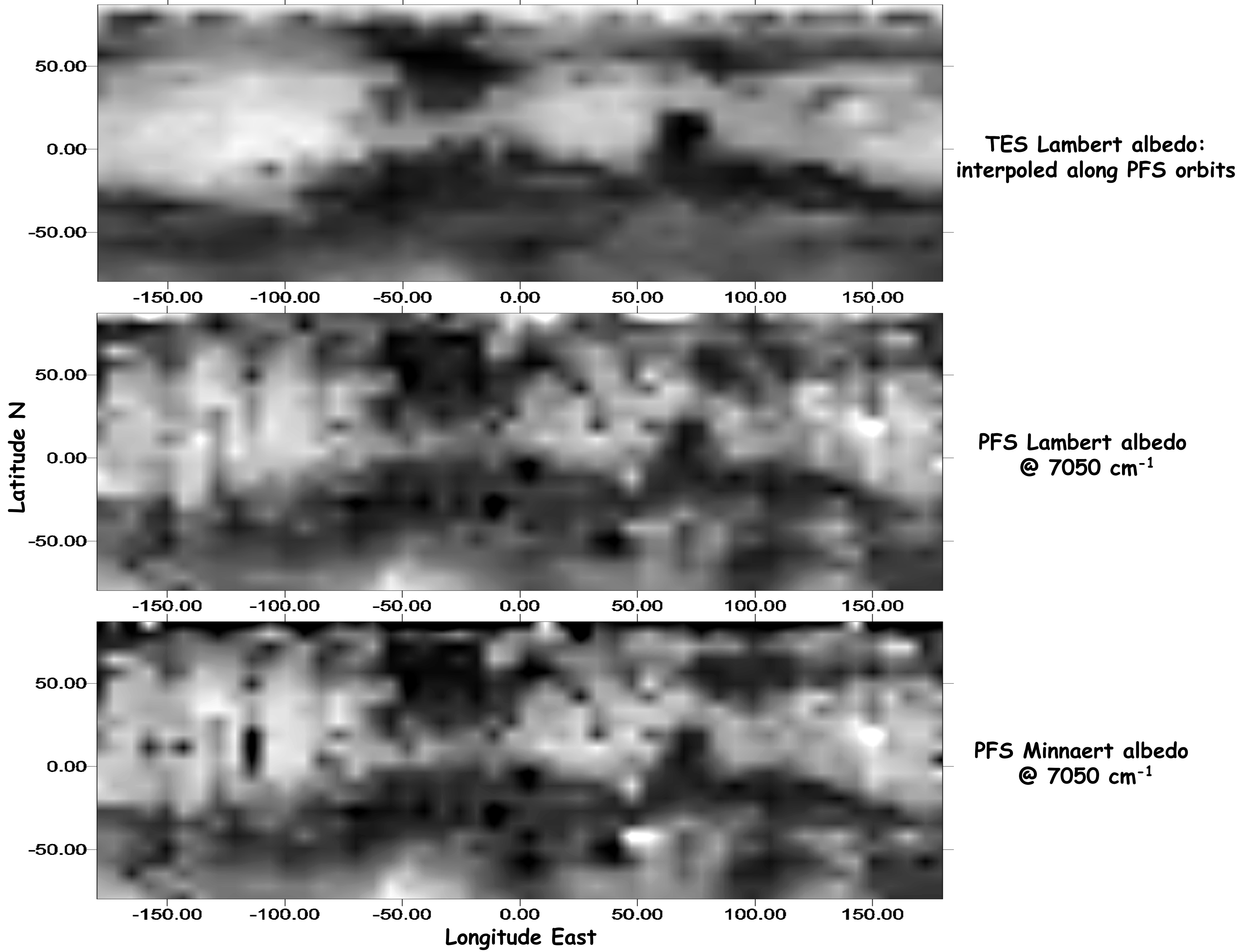
Fixing *g* and the albedo class, we observe that *k* increases with λ.

Photometry of Mars

Except for the lowest albedo class, *k* values tend to about 1 - 1.2.



Varying phase angle


TES Lambert albedo:
interpoled along PFS orbits
PFS Lambert albedo
@ 7050 cm-1
PFS Minnaert albedo
@ 7050 cm-1
Latitude N
Longitude East
50.00
0.00
-50.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00

Conclusions

- We measured the albedo of Mars starting from the radiance observed in the first 10 months by the Short Wavelength Channel (SWC) of PFS at three different wavenumbers: 2600, 3900 and 7050 cm^{-1} following two different approaches: Lambert and Minnaert.

- Calibrated Lambert albedo was compared with TES measurements: data show a good match and indicate the capability of PFS to investigate surface properties.

- The photometric study with the Minnaert approach was used to investigate the nature of surface materials.

After PFS data calibration, this study will be used to investigate possible changes in the upper surface due to the redistribution of mobile fines and for heat balance study.