CARACTÉRISATION DE LA GLACE CO_2 SUR MARS PAR TÉLÉDÉTECTION HYPERSPECTRALE

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SFPT-GH, Porquerolles, May 15th, 2014

Earth

$D_{ES} = 1$ UA

$R_E = 6370$ km

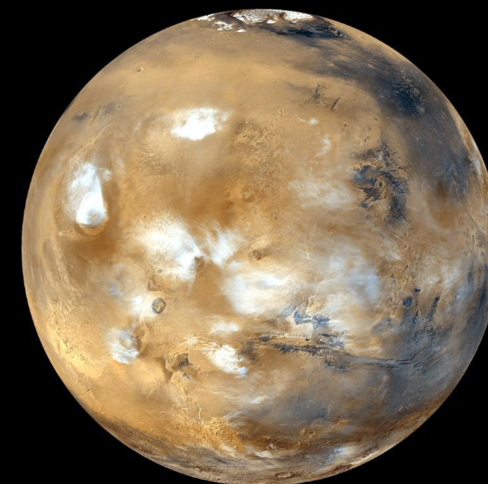
$I_{axe} = 23{,}4°$

$T = 288$ K ($15°C$)

$P_{atm} = 1013$ hPa

Atmosphere : N_2 (78 %), O_2 (20 %), Ar (1 %), ...

Mars



$D_{MS} = 1{,}5$ UA

$R_M = 3390$ km ($0{,}5\ R_E$)

$I_{axe} = 25{,}2°$

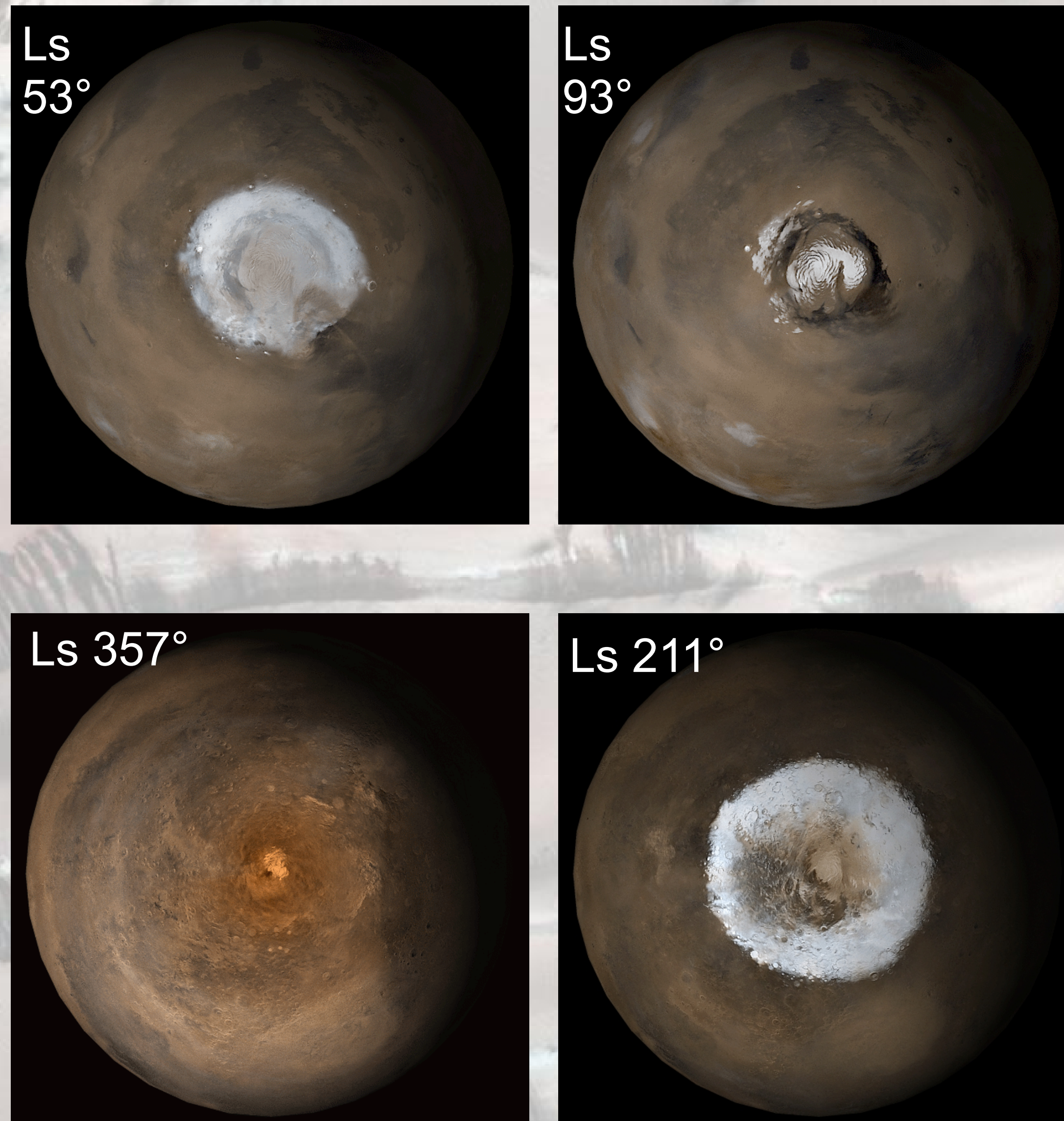
$T = 210$ K ($-63°C$)

$P_{atm} = 636$ Pa ($6.10^{-3}\ P_T$)

Atmosphere : CO_2 (96 %), Ar (2,0 %), N_2 (1,9 %), ...

NORTH

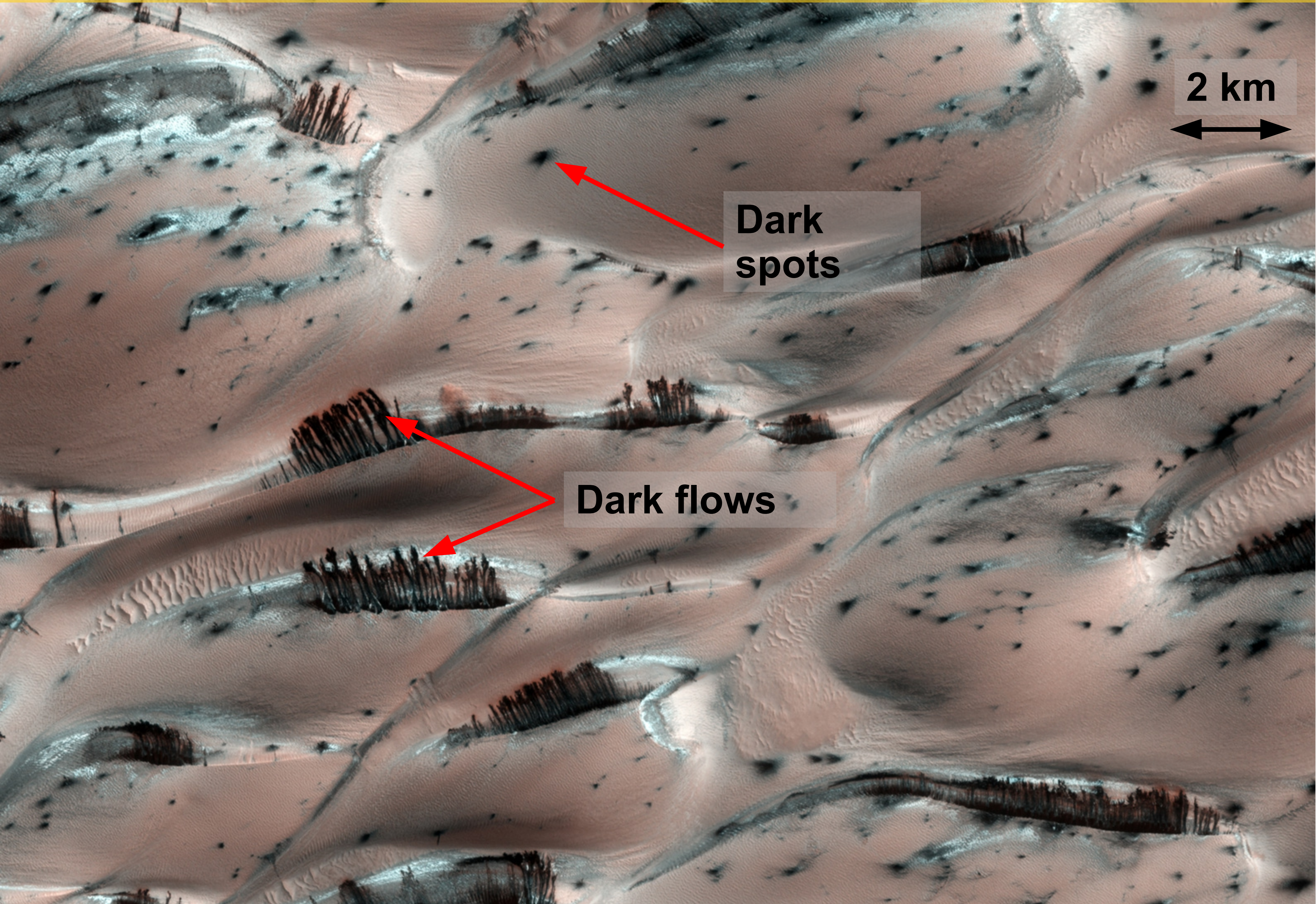
SOUTH



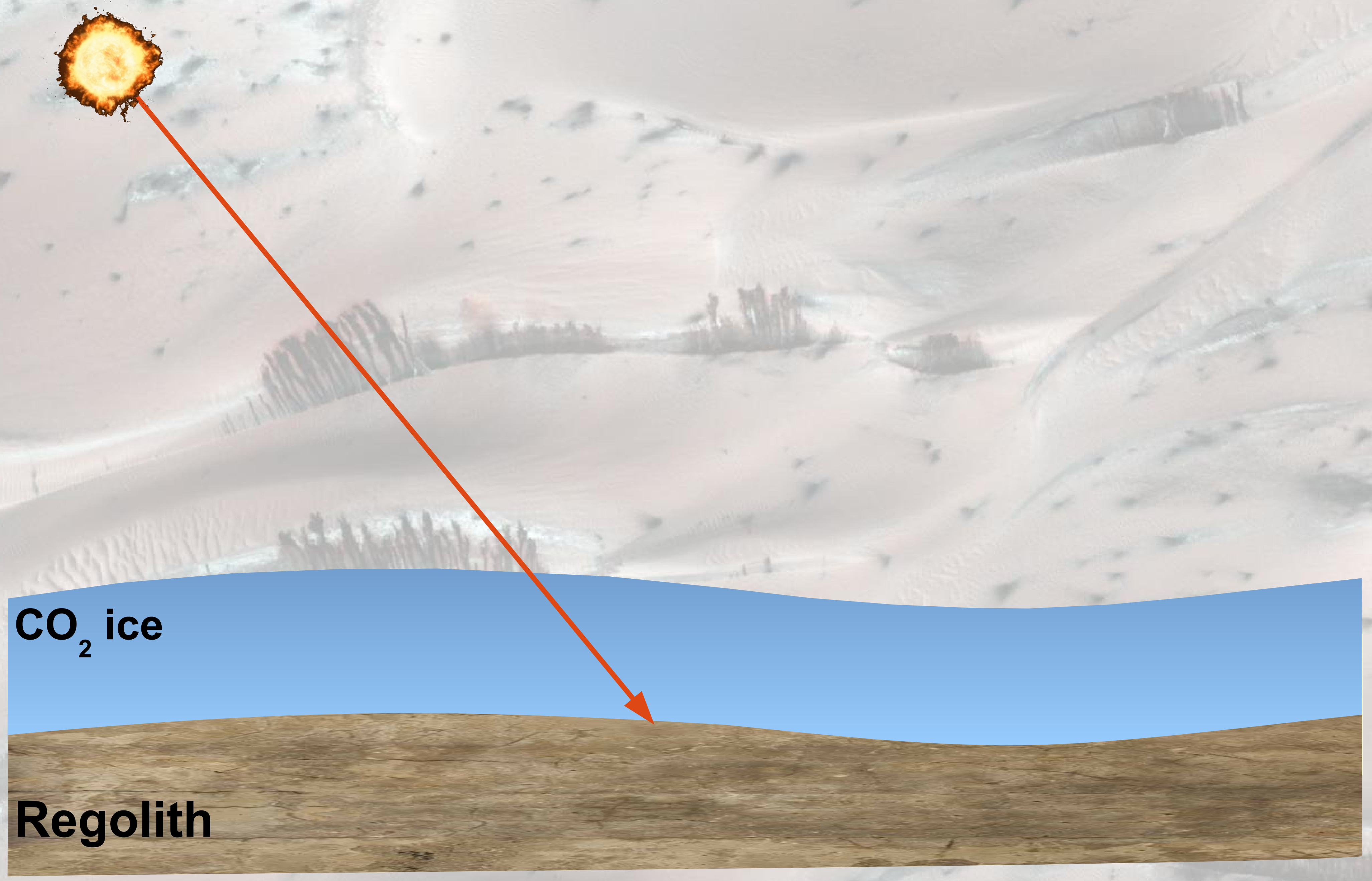
NASA/JPL/MSSS

Seasonal evolution of Mars' polar caps

Introduction



Model : Piqueux, 2003 ; Kieffer, 2006



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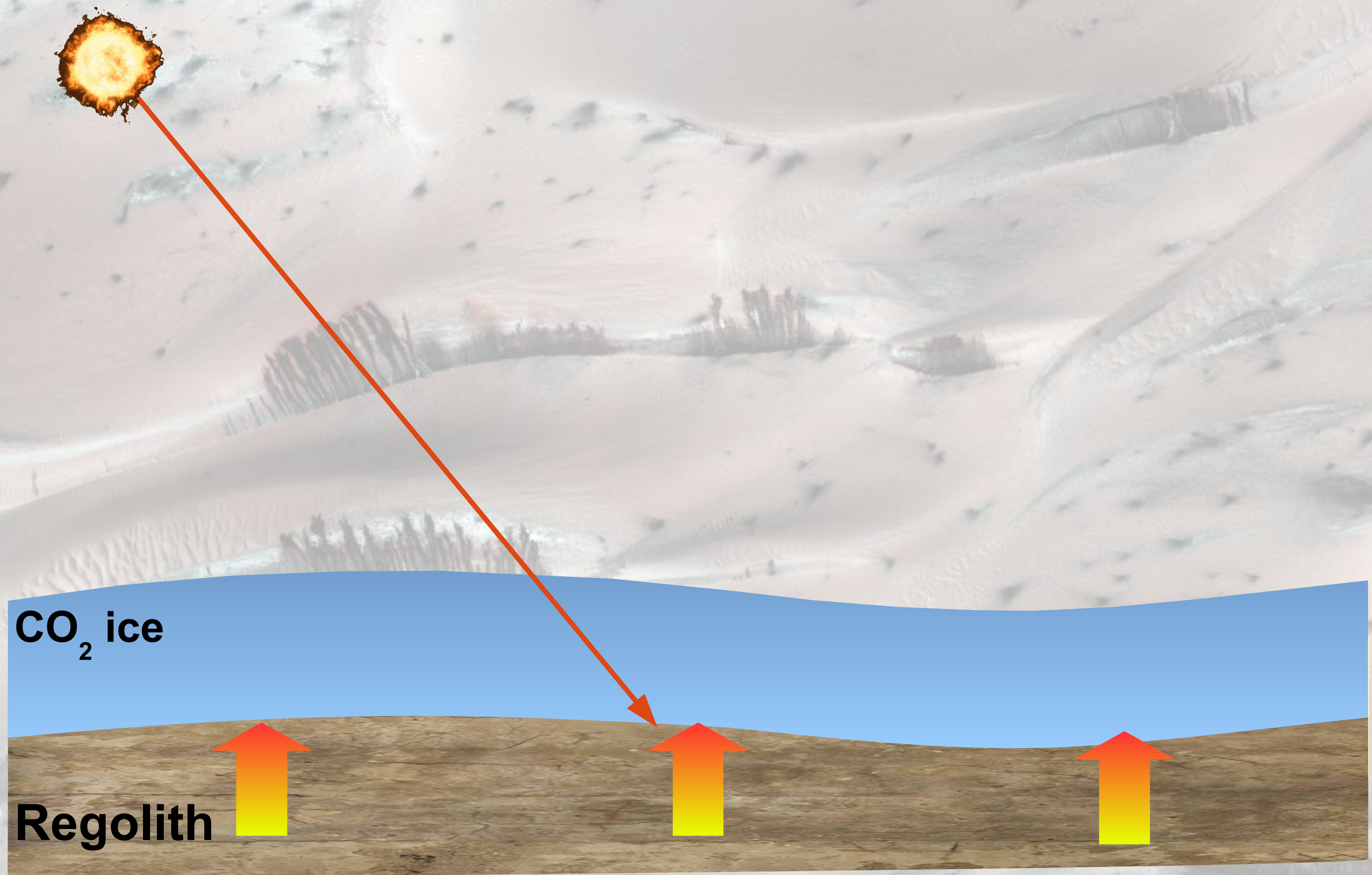

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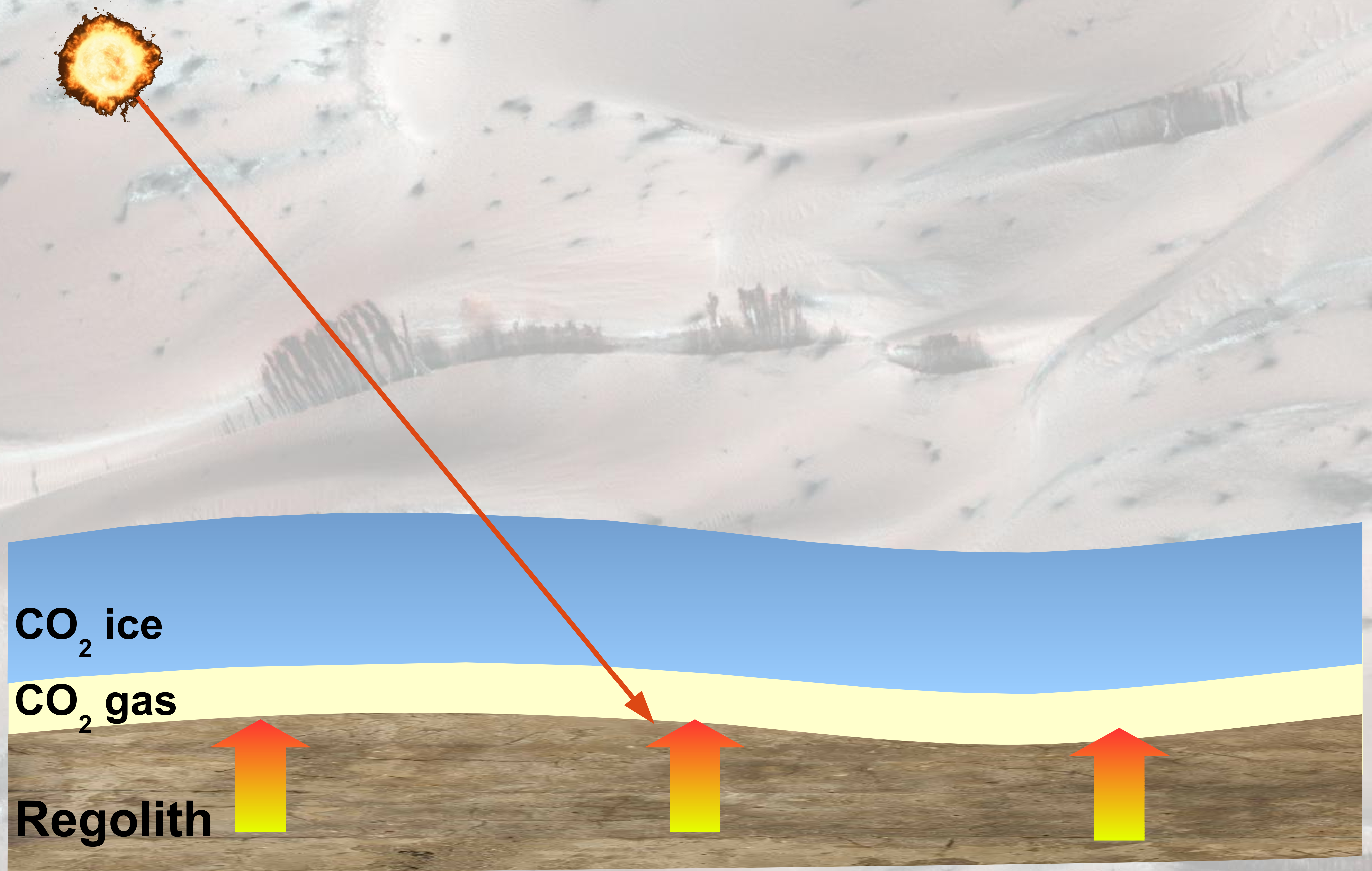

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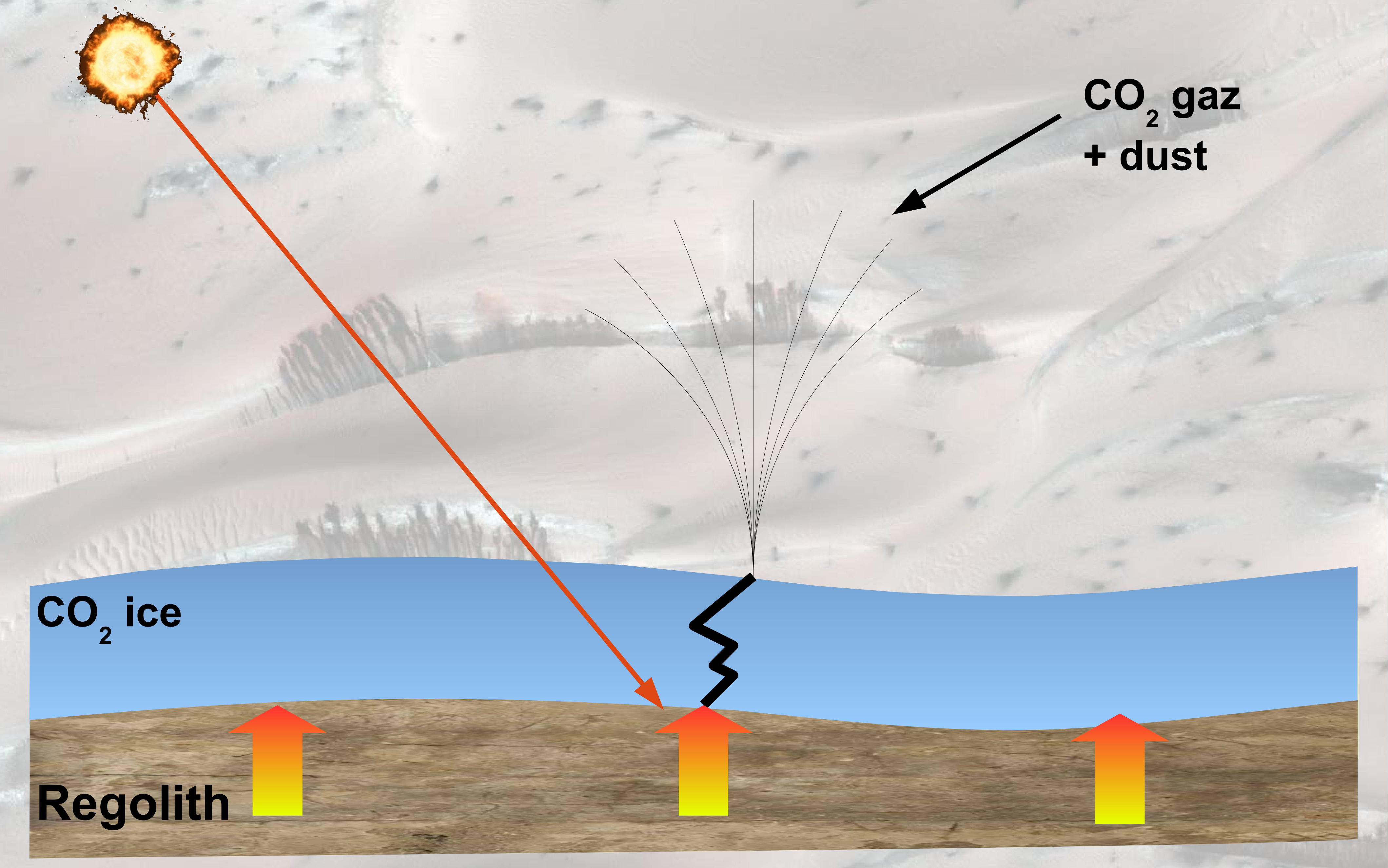

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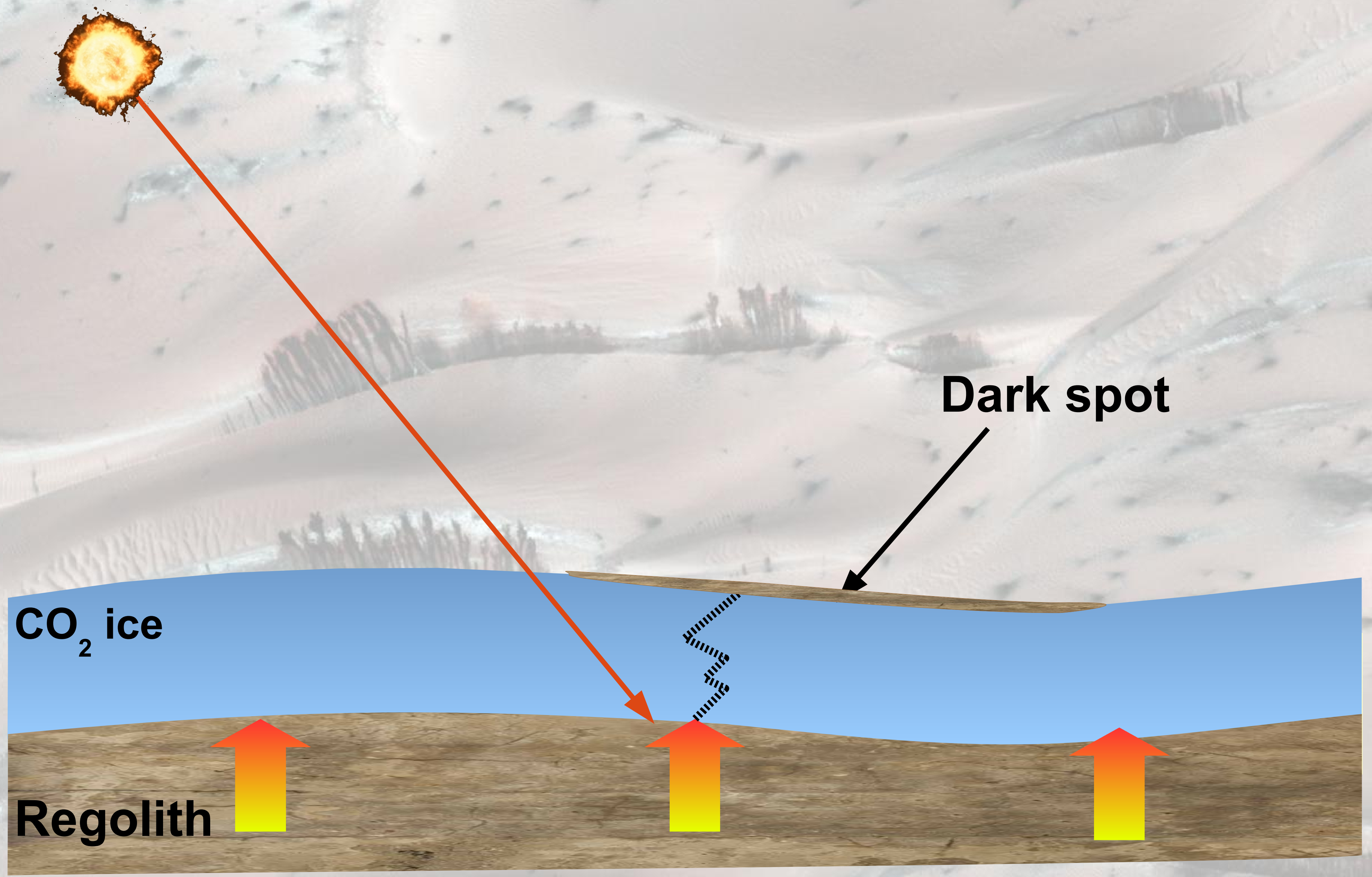
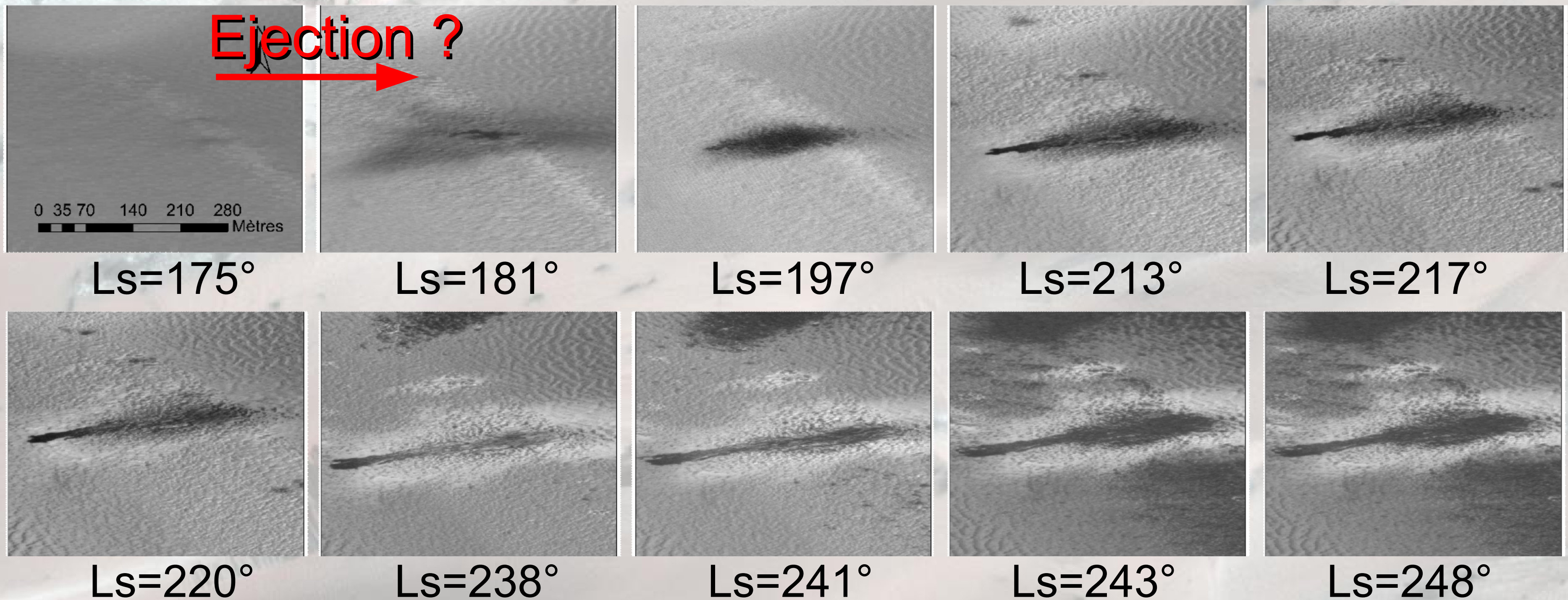
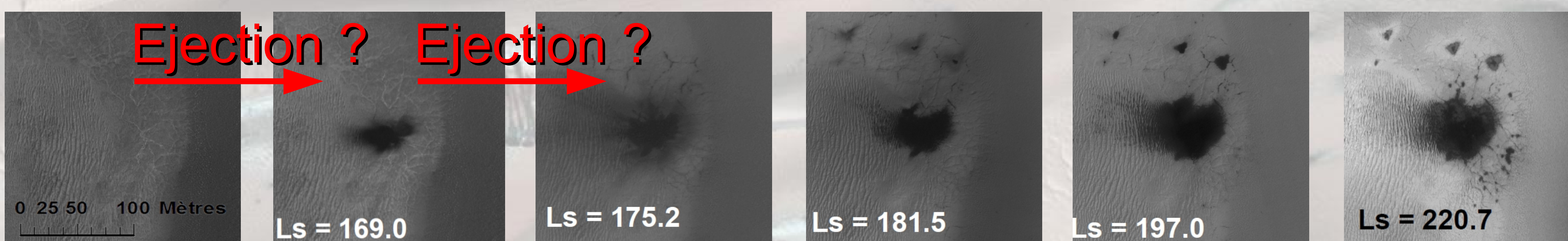


Introduction

Spring, MY 28. localisation : -72,01°N ; 179,78°E





- **Are spectral data compatible with Kieffer's model ?**
- **What is the state of CO_2 ice ?**

Purpose :

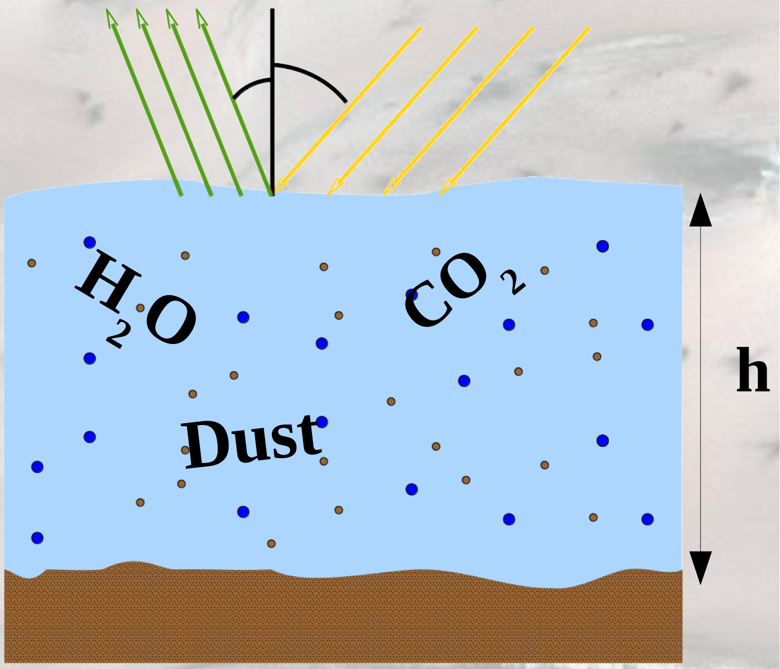
→ **<u>Surface state</u> and its evolution ?**

Translucent CO_2 ?

Contamination ?

Observations :

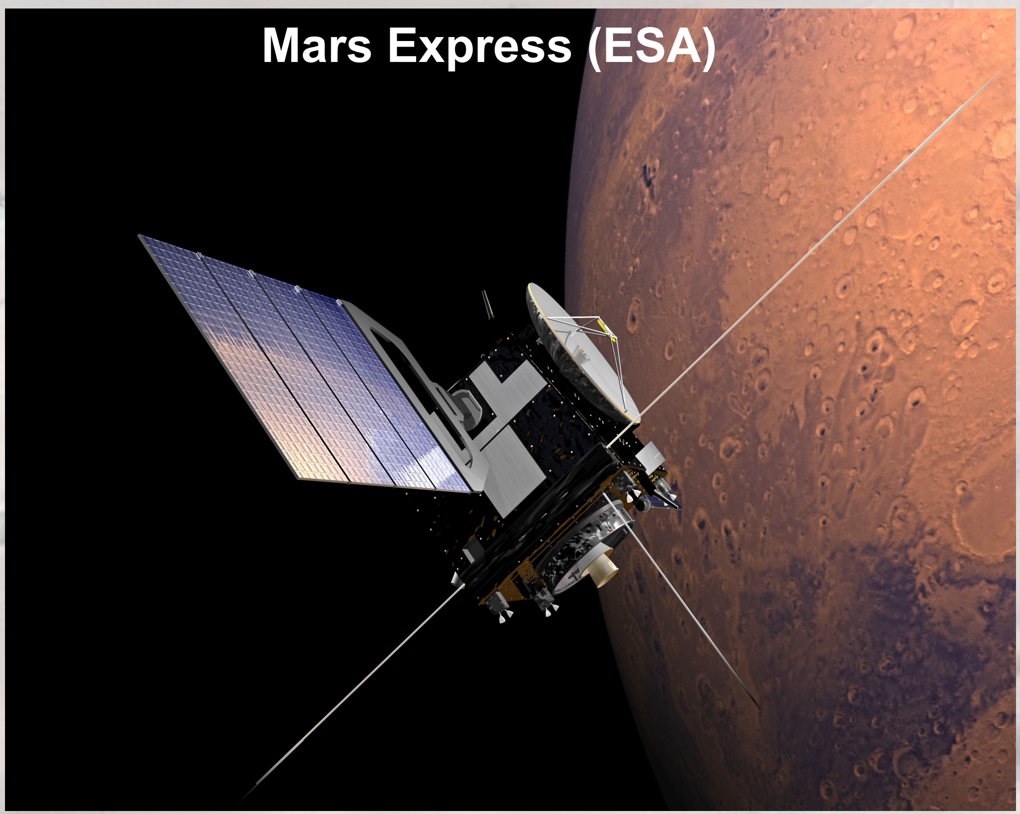
- Imaging spectrometers (MRO/CRISM)
- High resolution imaging (MRO/HiRISE)



Tool:

Radiative transfer inversion

Spectro-imaging instruments on Mars:



OMEGA :

On board Mars Expess (ESA)

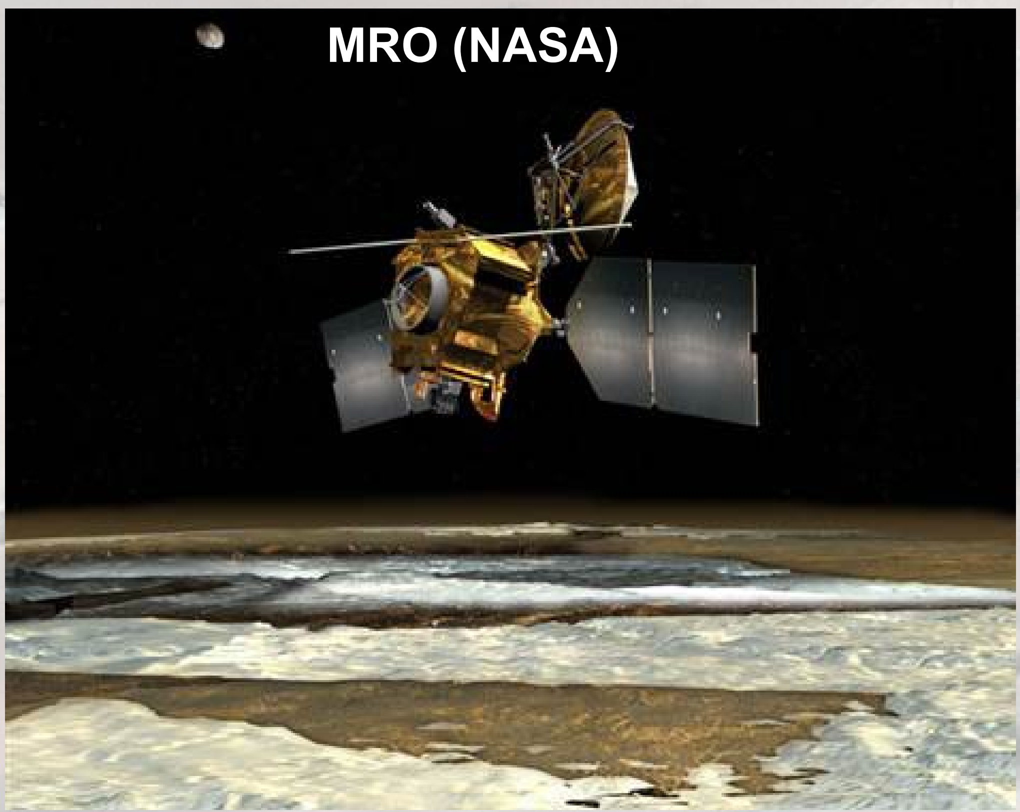
(since 2004)

Range :
VIS: 500-1000 nm
IR: 1000-5200 nm (256 bands)

Resolution :
7 nm/band (VIS) - 14-23 nm/band (IR)
300 m/px to 4 km/px (not circular orbit)

Global Mapping

Spectro-imaging instruments



CRISM :

On board Mars Reconaissance Orbiter (NASA) (since 2006)

Range :

VNIR: 362-1053 nm
IR: 1002-3920 nm (438 bands)

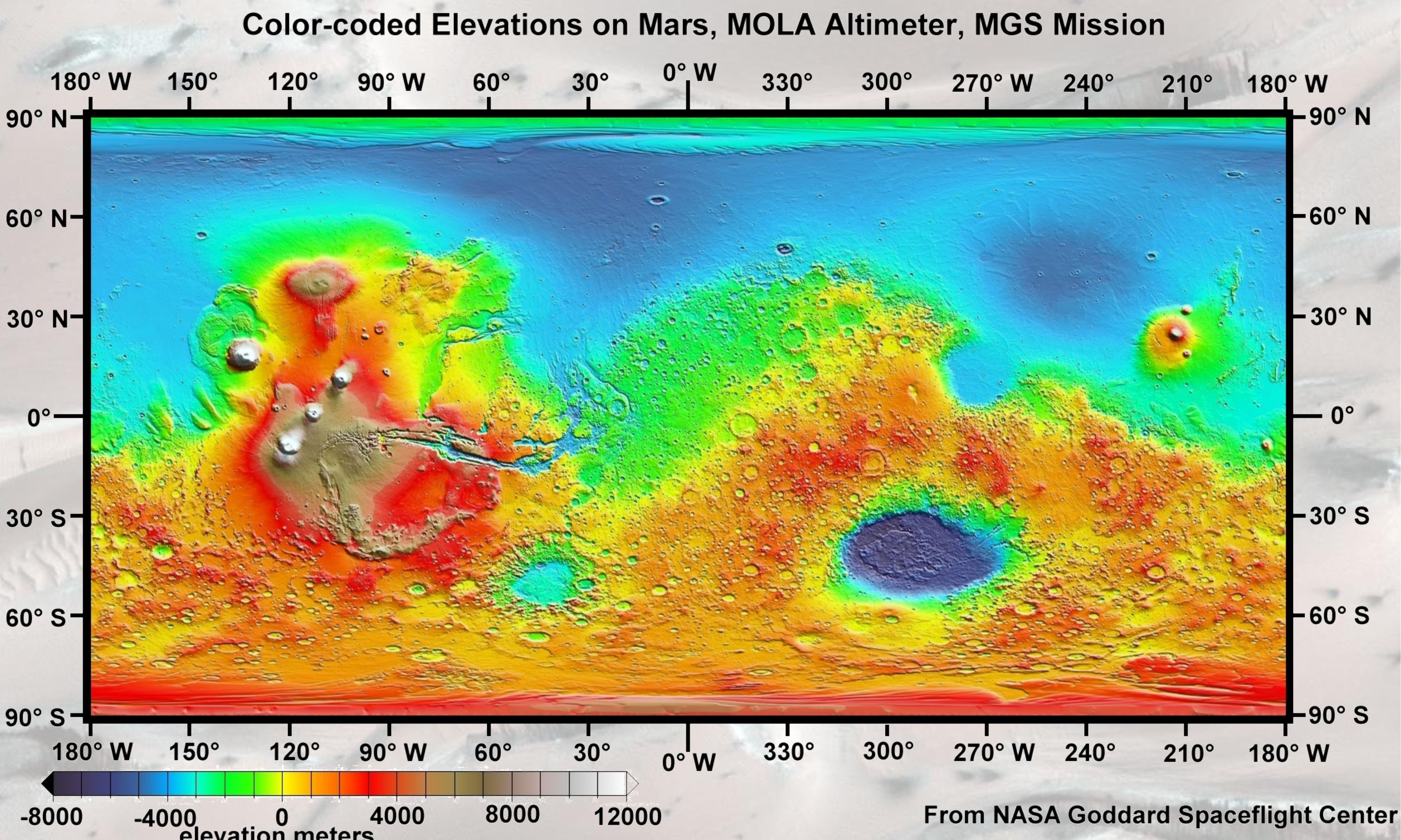
Resolution :

6.55 nm/band
18.4 m/px at 300 km altitude

Targeted studies

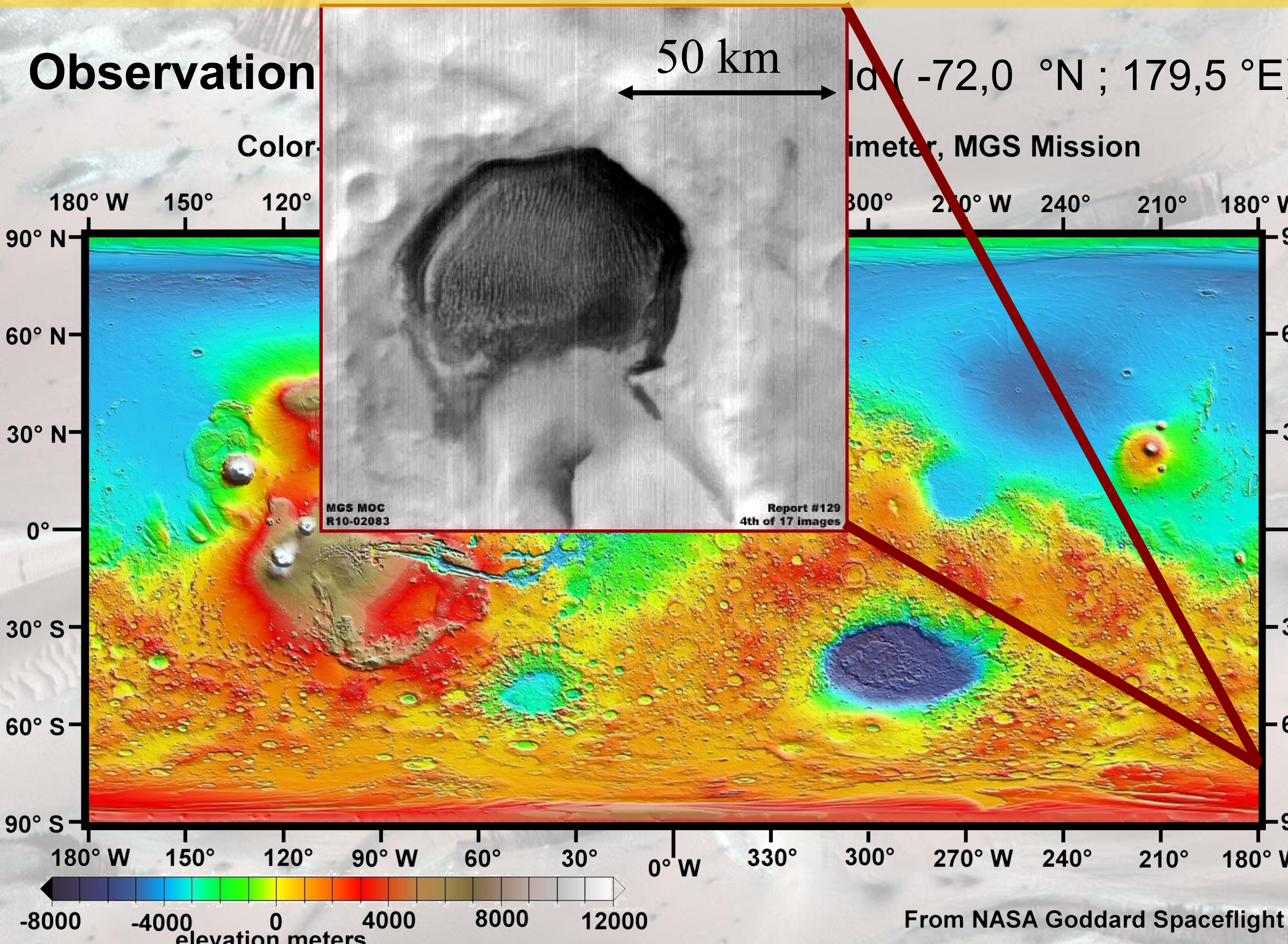
Classic full dataset : **544 channels, 640 × 400 px**

Observation : Richardson crater dunefield (-72,0 °N ; 179,5 °E)



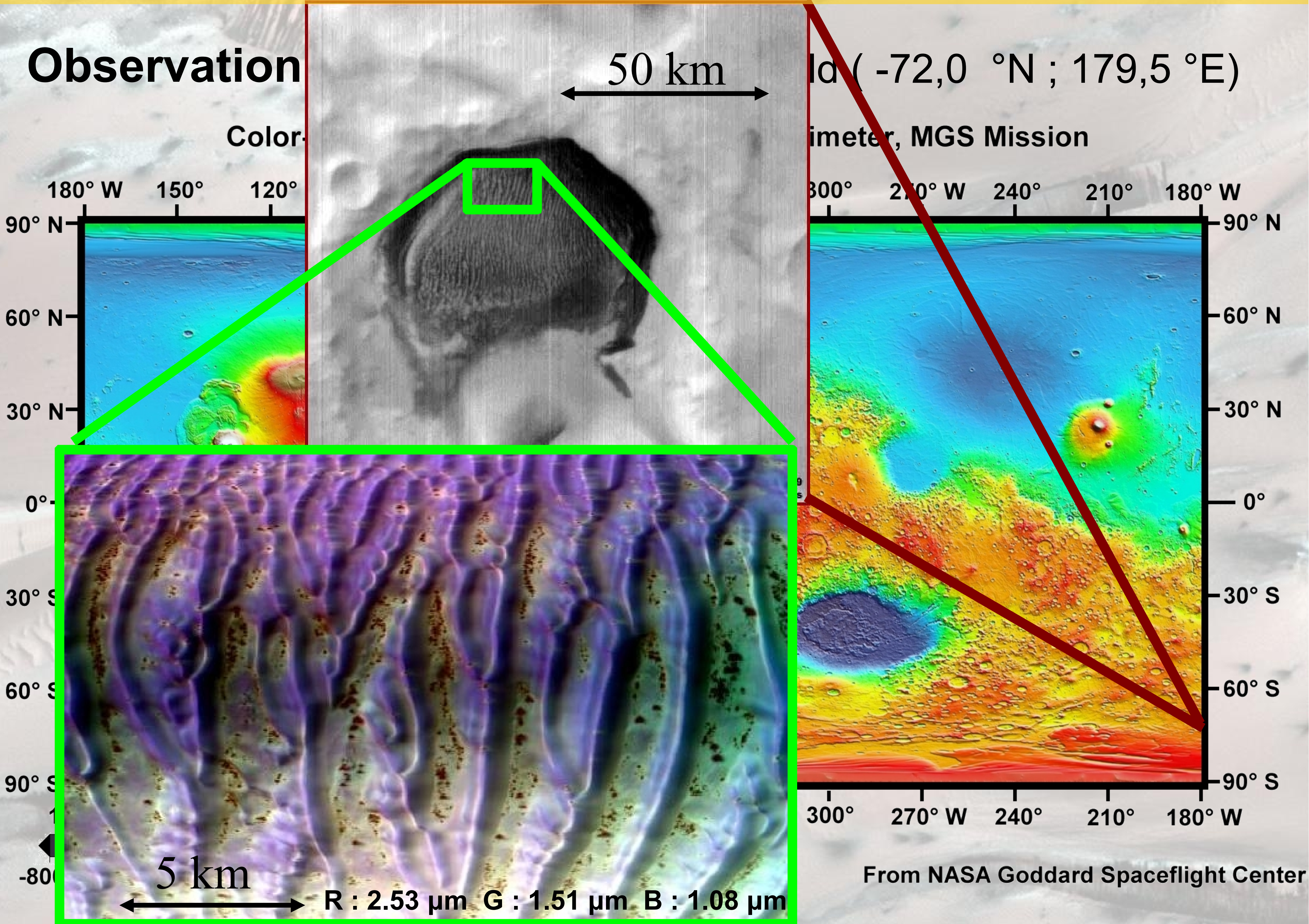
Observation ... ld (-72,0 °N ; 179,5 °E)

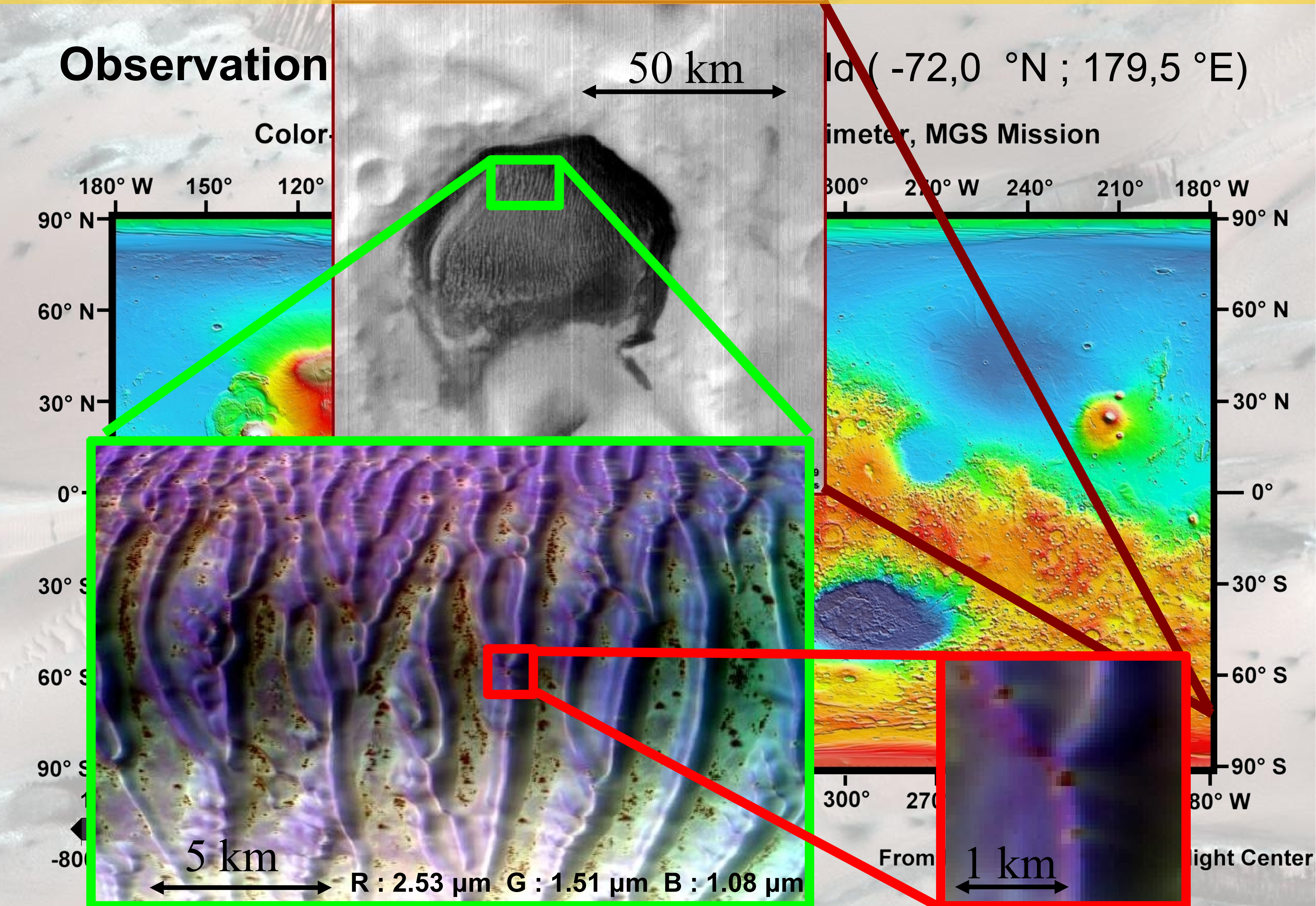
Color- ... imeter, MGS Mission



From NASA Goddard Spaceflight Center

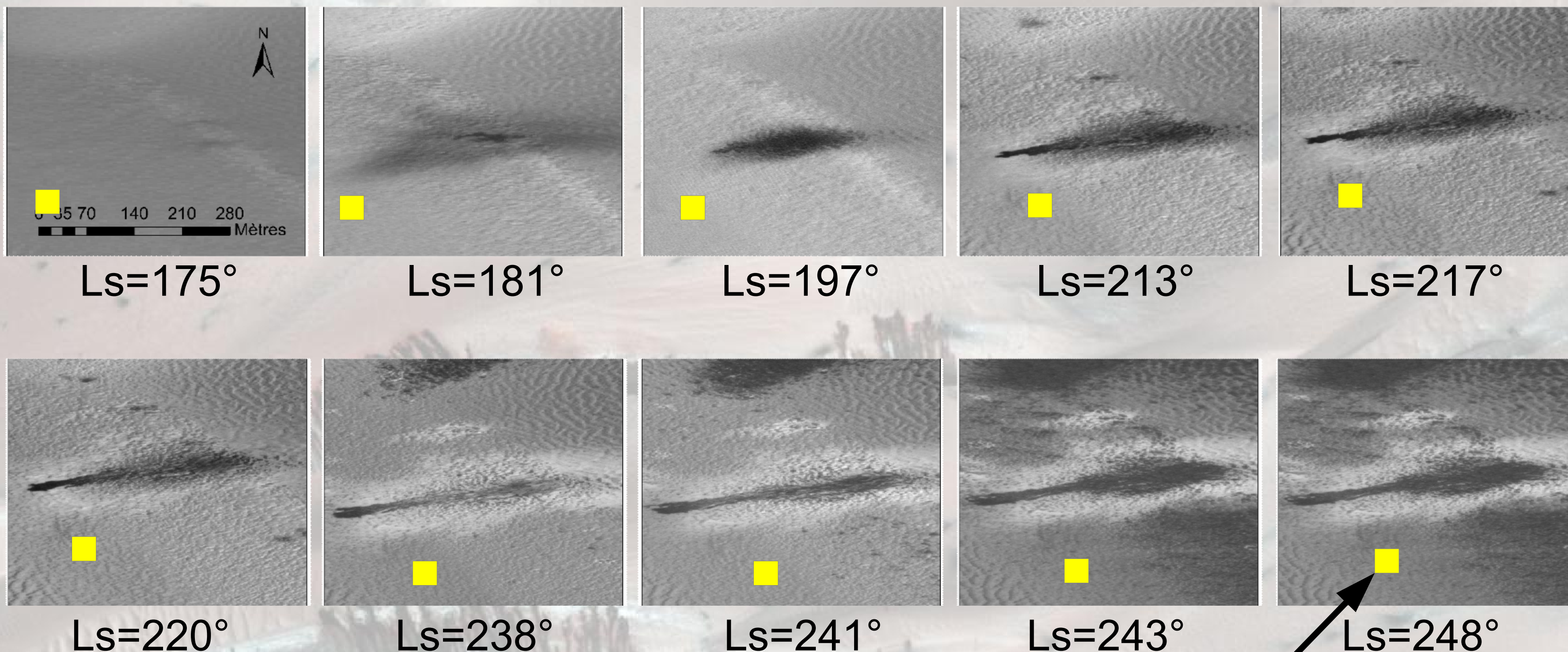
Observation ... ld (-72,0 °N ; 179,5 °E)





Observation
ld (-72,0 °N ; 179,5 °E)
50 km
Color-
imeter, MGS Mission
180° W
150°
120°
300°
240°
210°
180° W
90° N
60° N
30° N
0°
30° S
60° S
90° S
300°
80° W
-800
From
light Center
5 km
R : 2.53 µm G : 1.51 µm B : 1.08 µm
1 km

Observation :



Spring, MY 28. localisation : -72,008°N ; 179,778°E

CRISM Pixel

Observations are taken at **16:00** local solar time

Method :

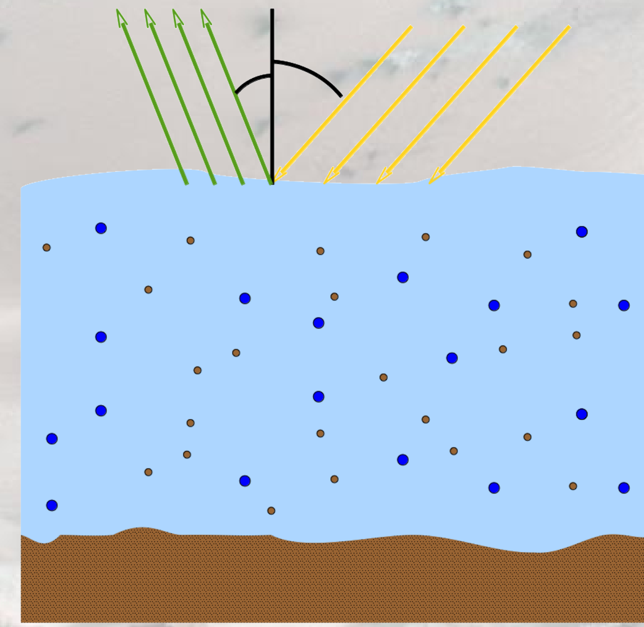
1) Atmospheric correction (Douté *et al.*, 2007b)

- Gas
- Aerosols

2) Radiative transfer inversion in the surface

- Synthetic spectral database
  (improved from Douté & Schmitt, JGR, 1998)
  CO_2 : compact / ~~granular~~
- Inversion

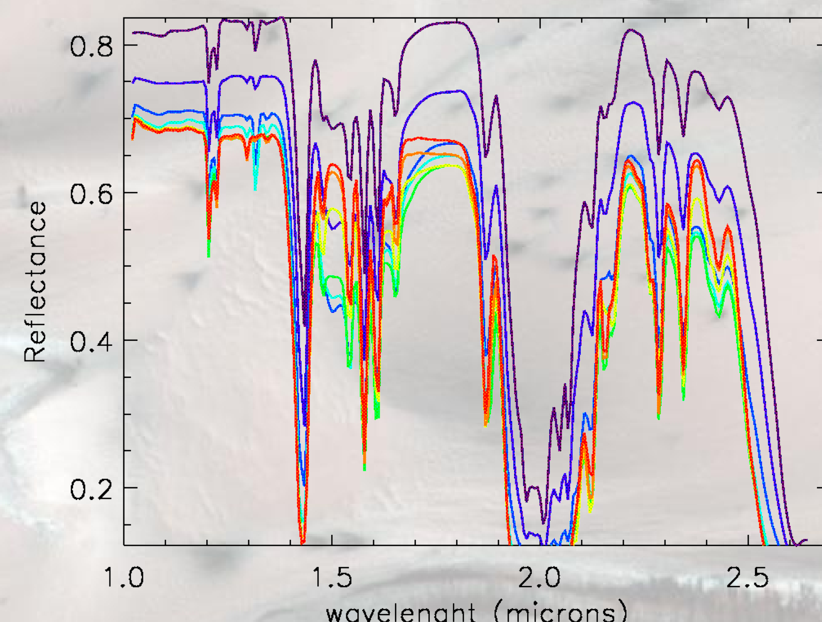
a) Synthetic spectral library



- Laboratory optical constants for CO_2 and H_2O (Schmitt *et al.*, 1998)

- Estimated optical constants for Martian dust (Shkuratov)

~ 250 000 spectra



CO_2 ice slab :

- thickness h

impurities (Dust, H_2O) :

- mass proportions
- grainsizes

a) Synthetic spectral library

- Laboratory optical constants for CO_2 and H_2O (Schmitt *et al.* ,1998)

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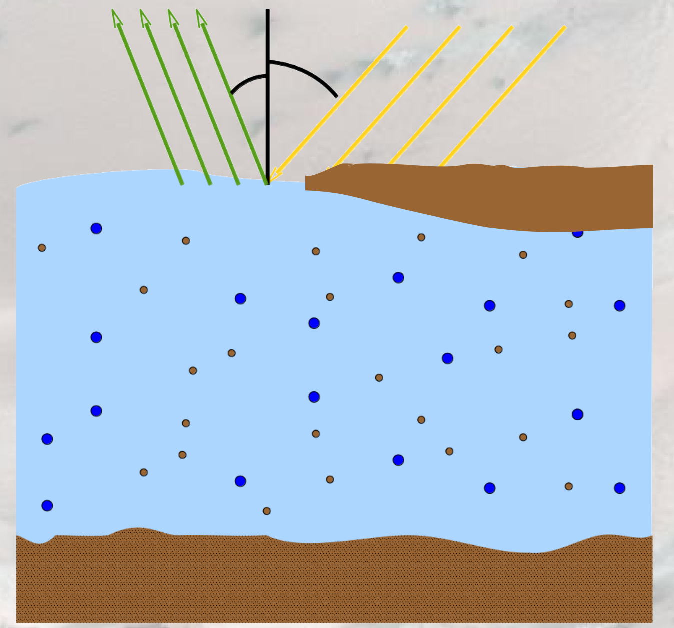


CO_2 ice slab :

- thickness h

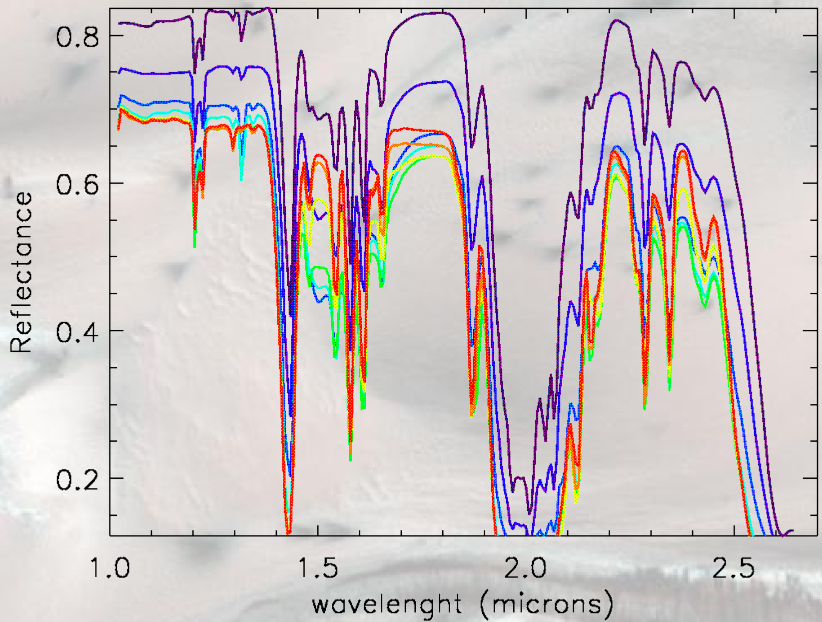
impurities (Dust, H_2O) :

- grainsizes
- mass proportions

Optically thick dust :

- surface proportion

~ 250 000 spectra



a) Synthetic spectral library

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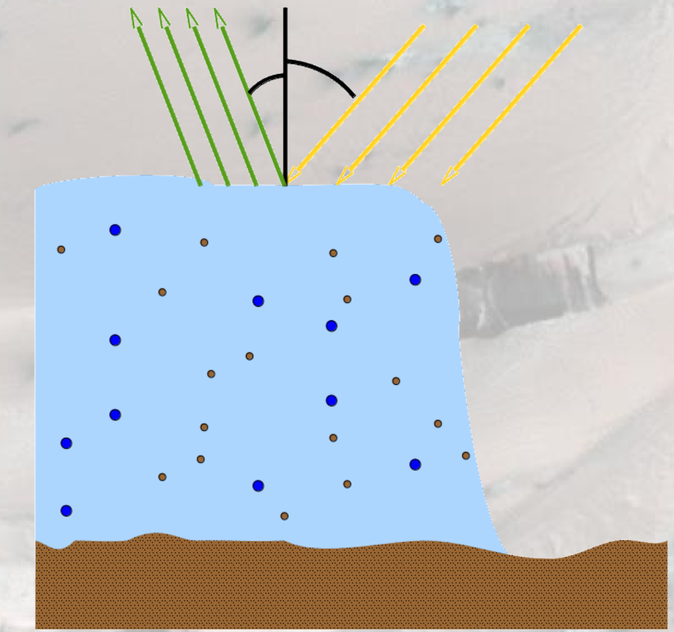

CO_2 ice slab :

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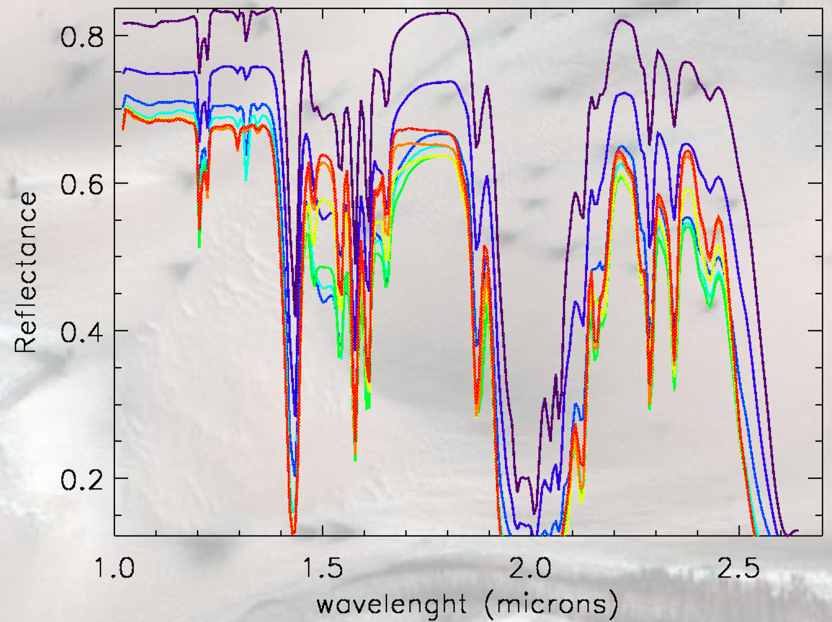


b) Inversion

$$L = \exp\left(-\frac{1}{2} \times {}^{t}(d_{sim} - d_{mes})\,\overline{\overline{C}}^{-1}(d_{sim} - d_{mes})\right)$$

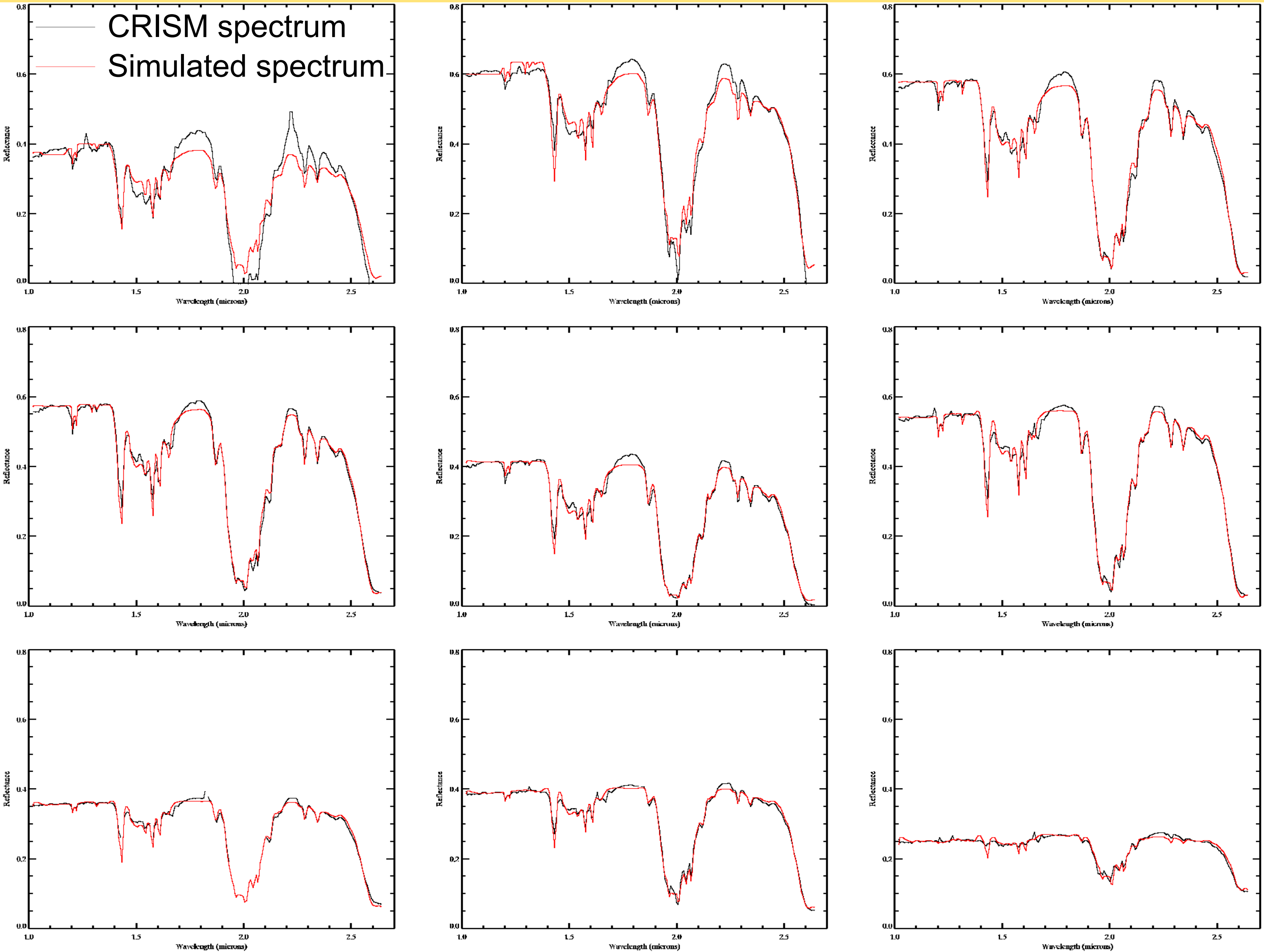
L : Likelihood function (1 = perfect match)

d_{sim} and d_{mes} *:* synthetic and measured spectra

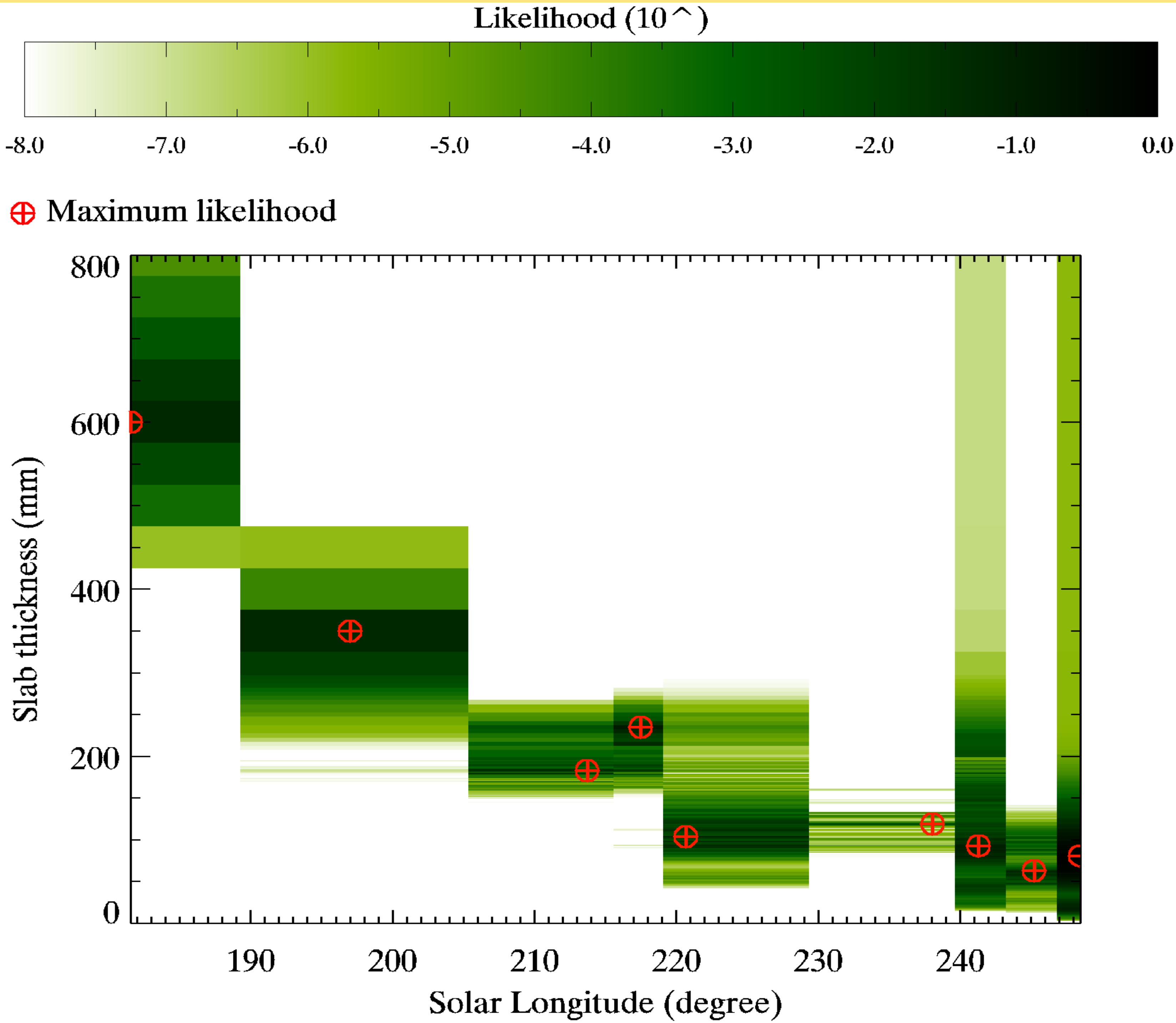
$\overline{\overline{C}}$: covariance matrix : uncertainties

- CRISM noise
- Atmospheric corrections (level + slope)

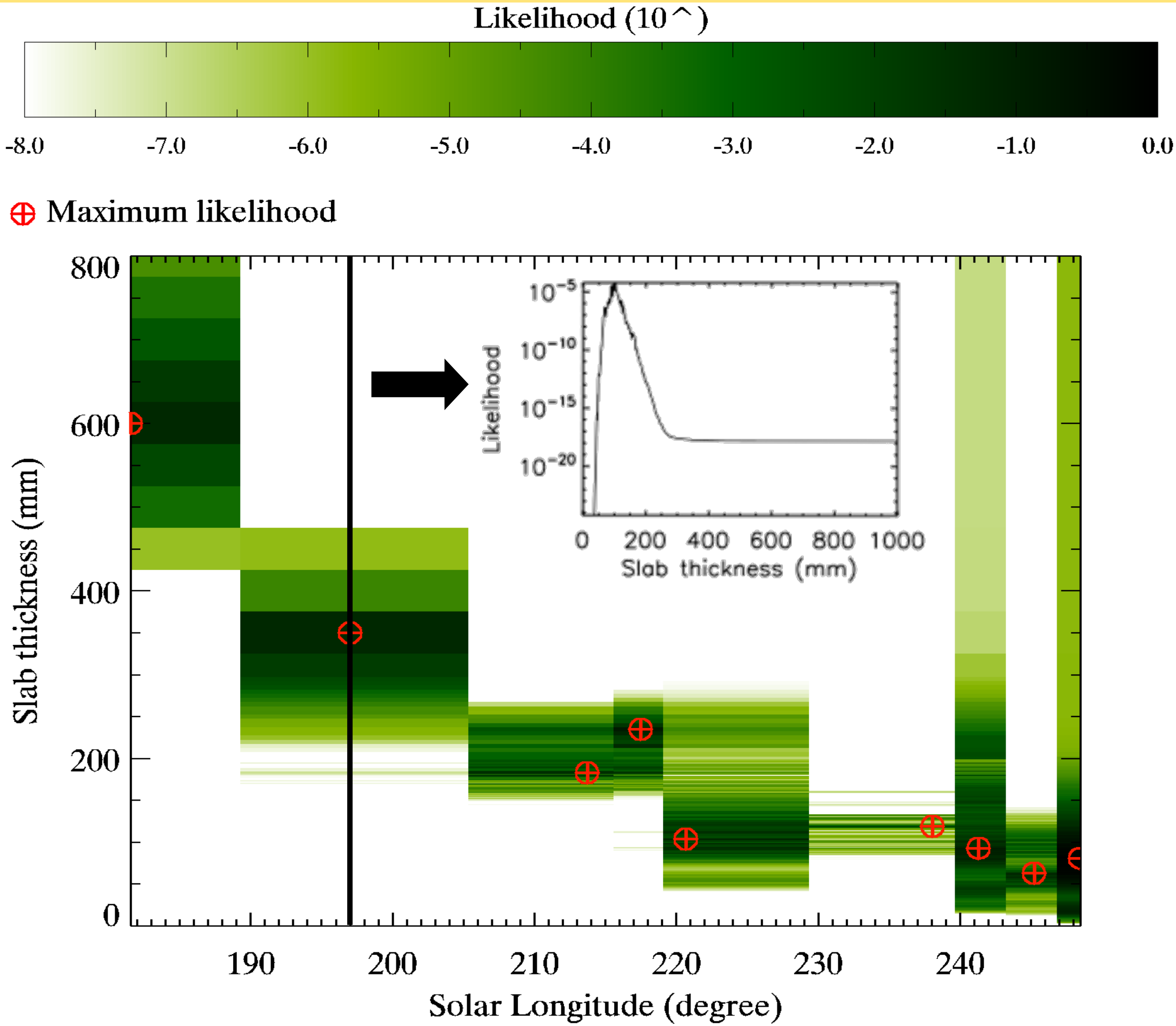
Results : fits



Results : thickness

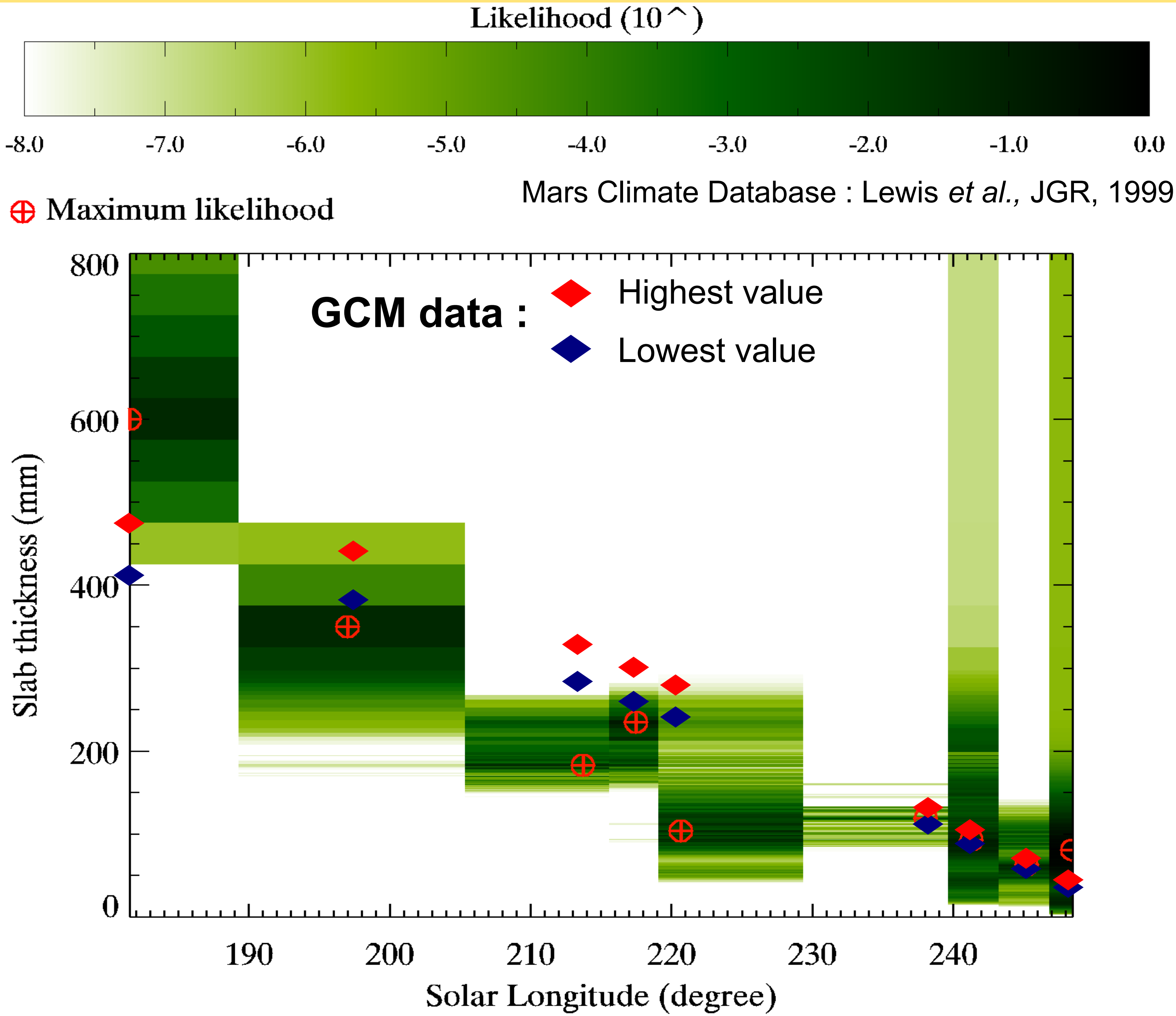


Results : thickness

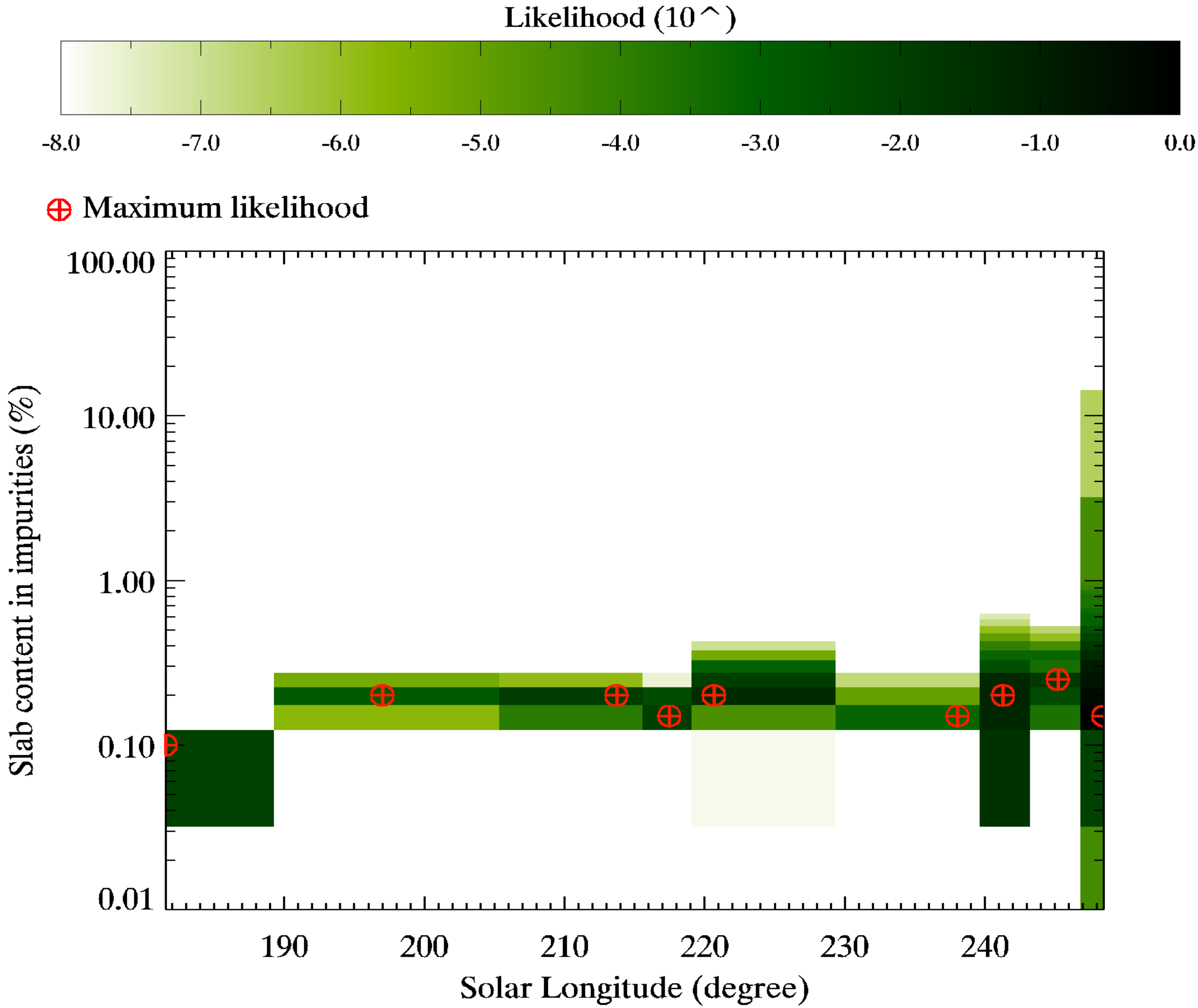


F. ANDRIEU *et al.* : Inversion for CO_2 ice state on Mars.

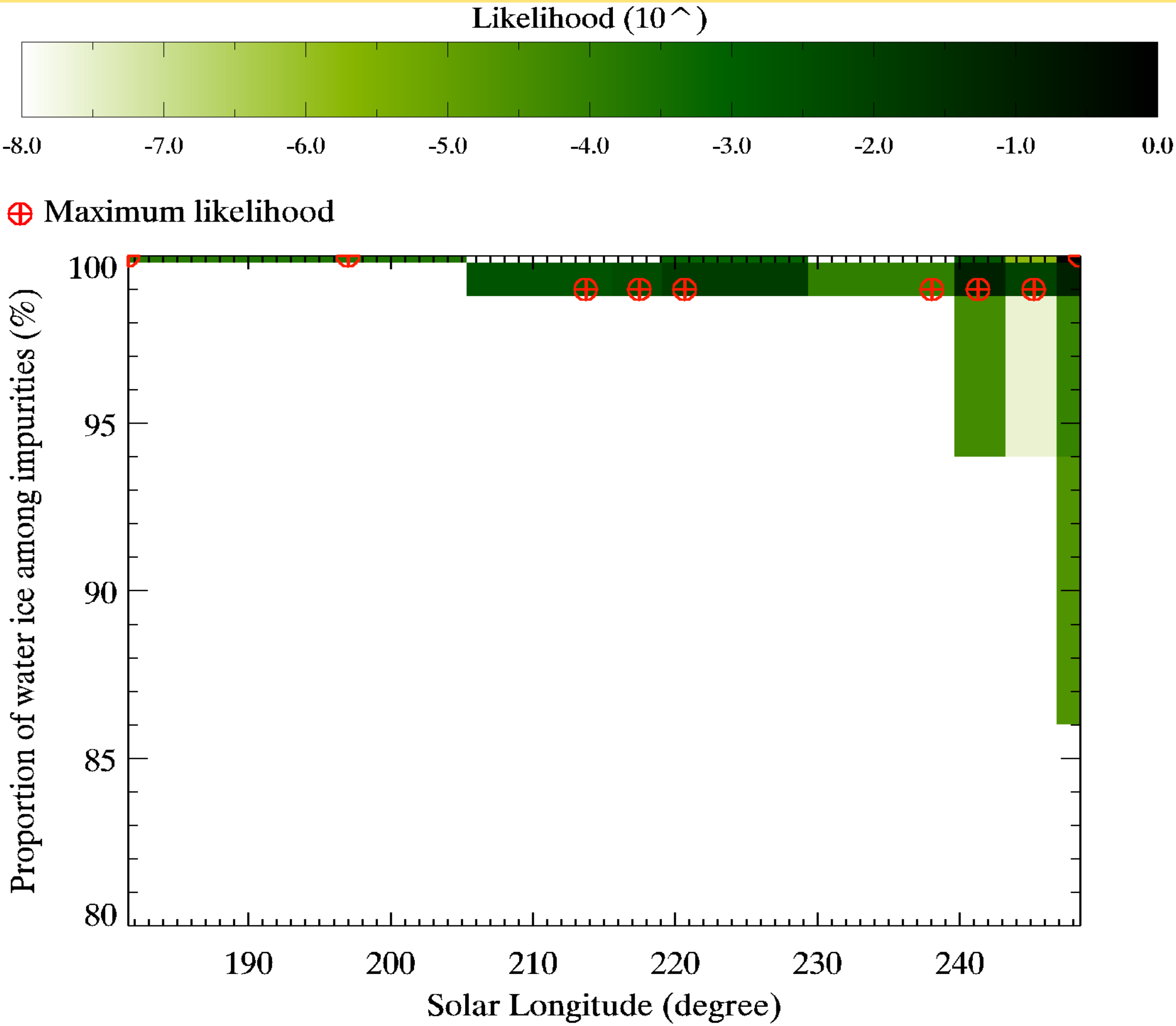
Results : thickness



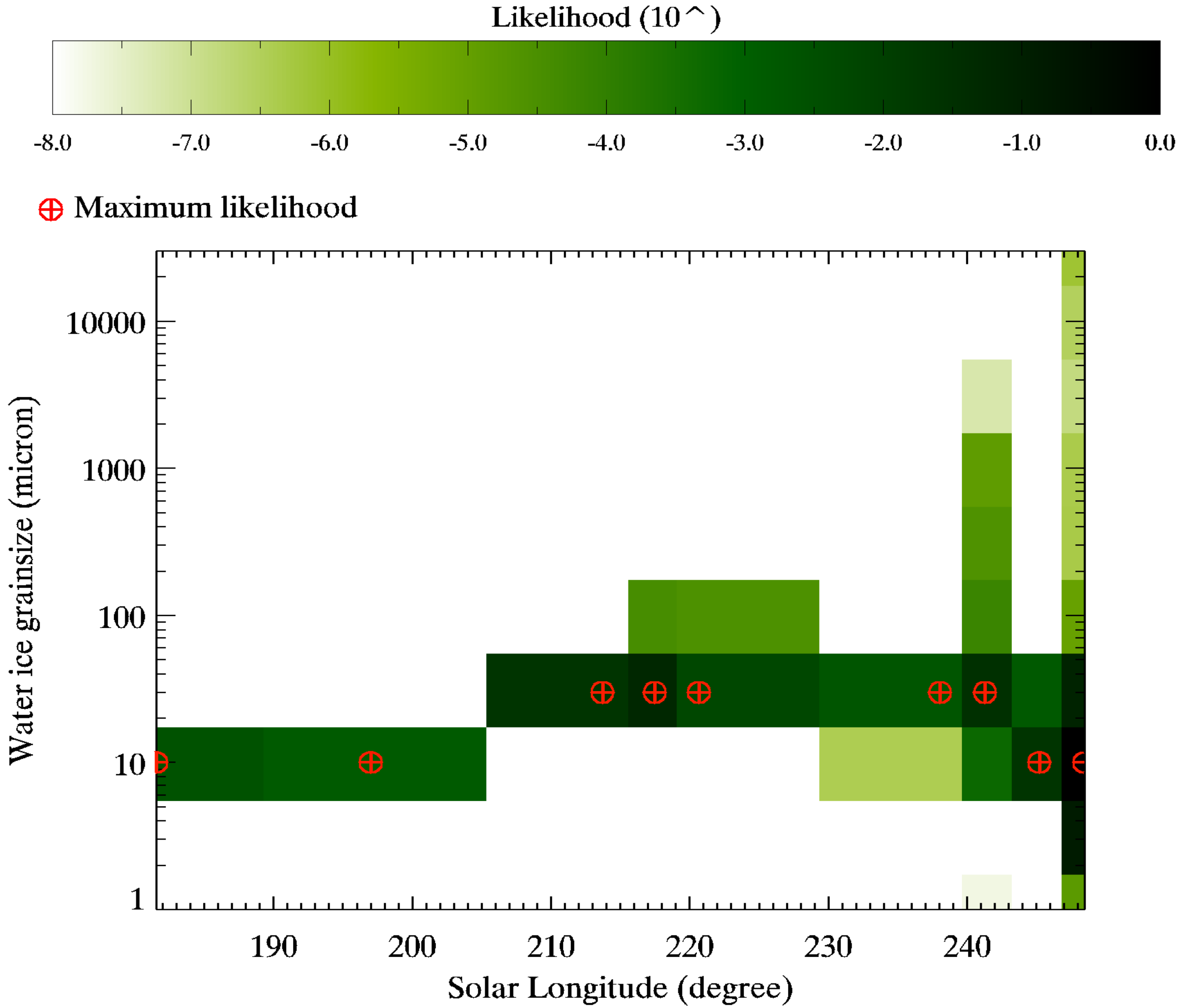
Results : impurities $\%_{wt}$



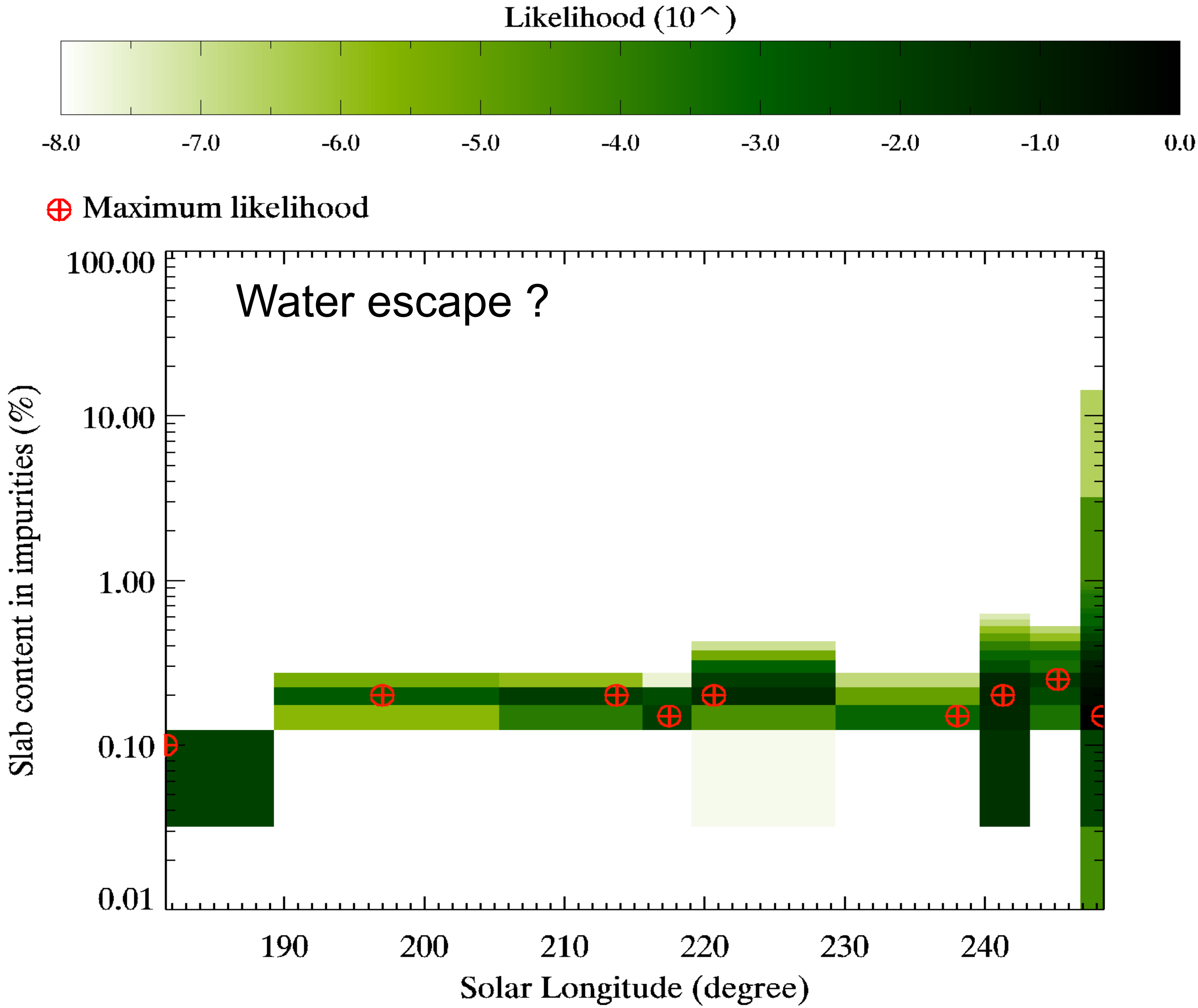
Results : H_2O contents



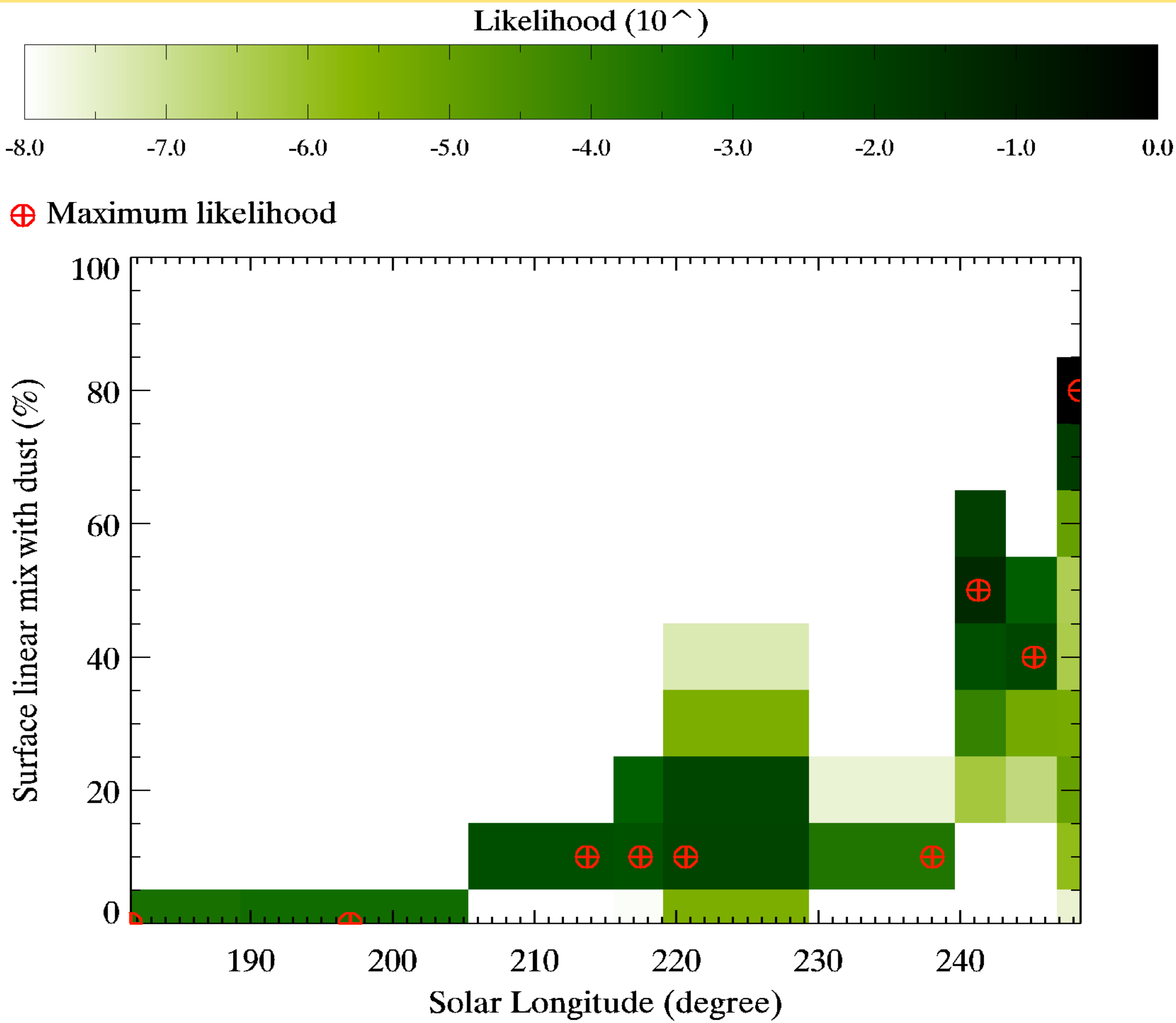
Results : H_2O grainsize



Results : impurities $\%_{wt}$



Results : surface mix



Results : summary

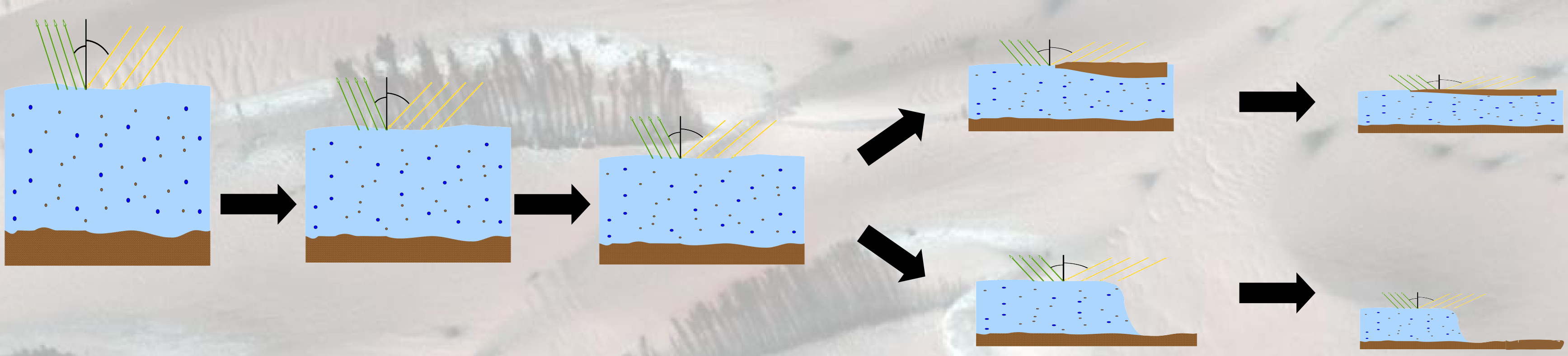
Presence of a translucent slab

- Slab thickness decreases (consistent with GCMs) **Expected**

- Impurities proportions : constant **Not Expected**

- Water ice grainsize : constant **Expected**

- Optically thick dust proportion : increases **Expected**

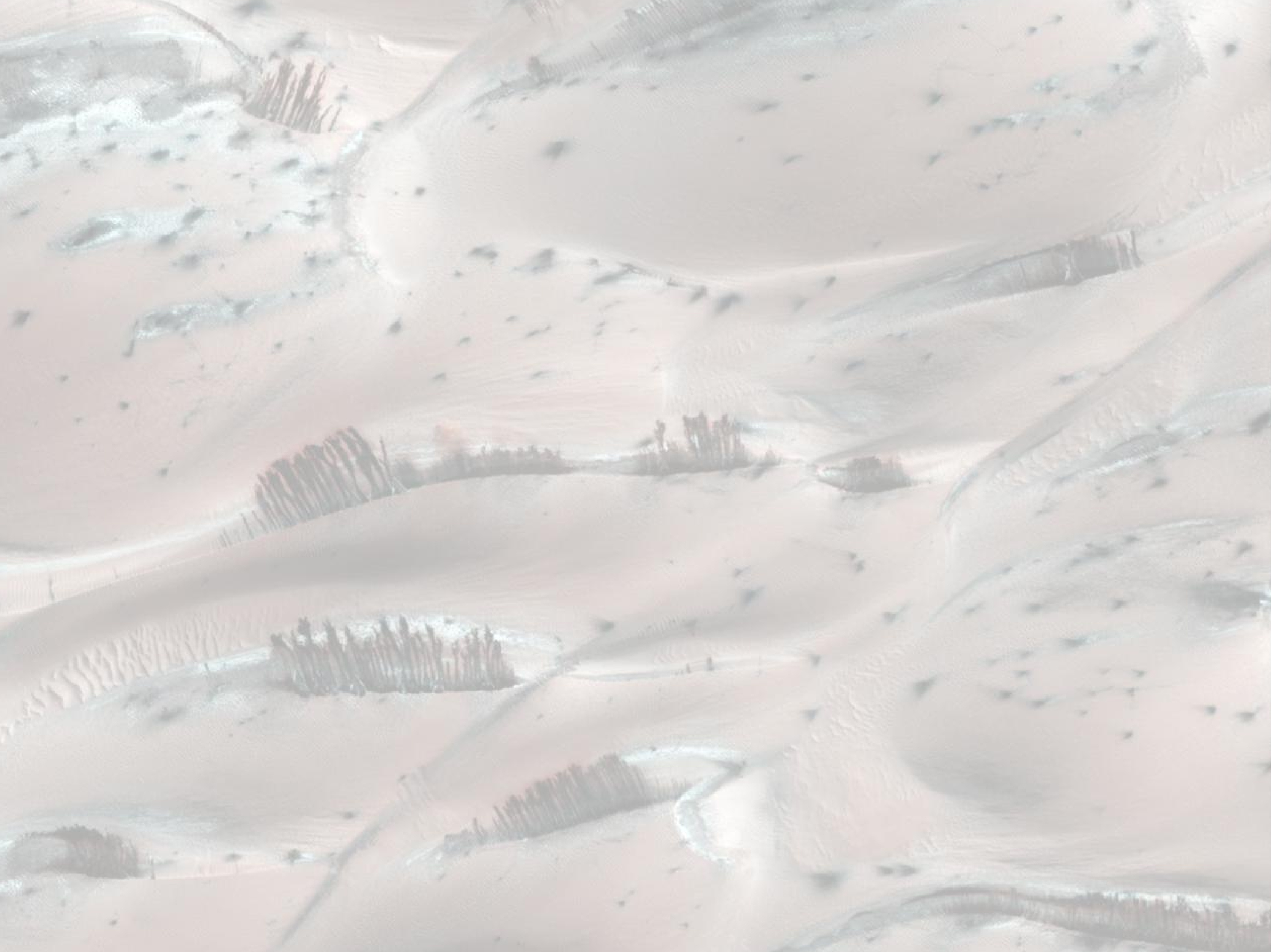


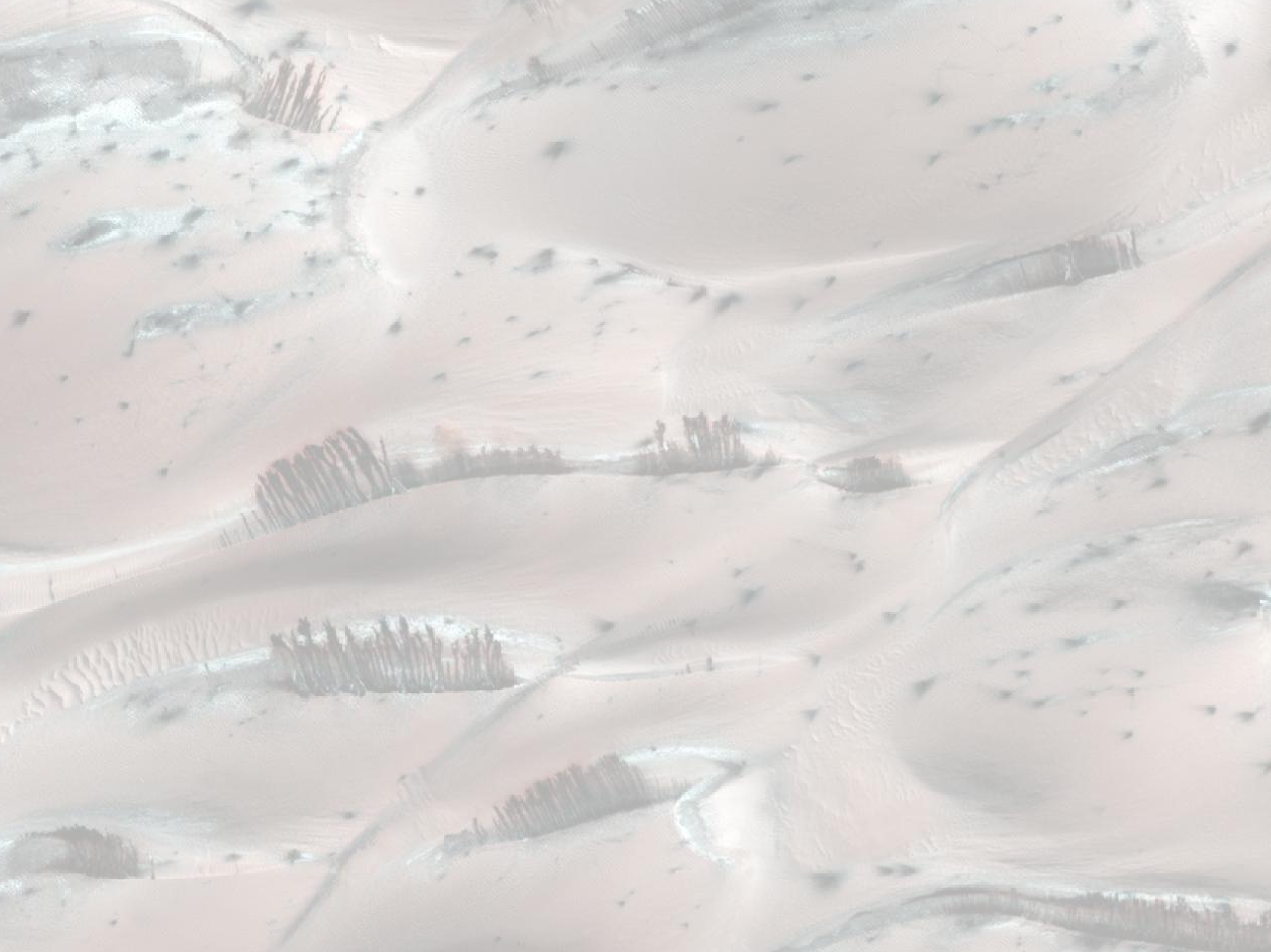
Conclusions :

- data/model agreement
- Dark features consistent with Kieffer (slab ice)

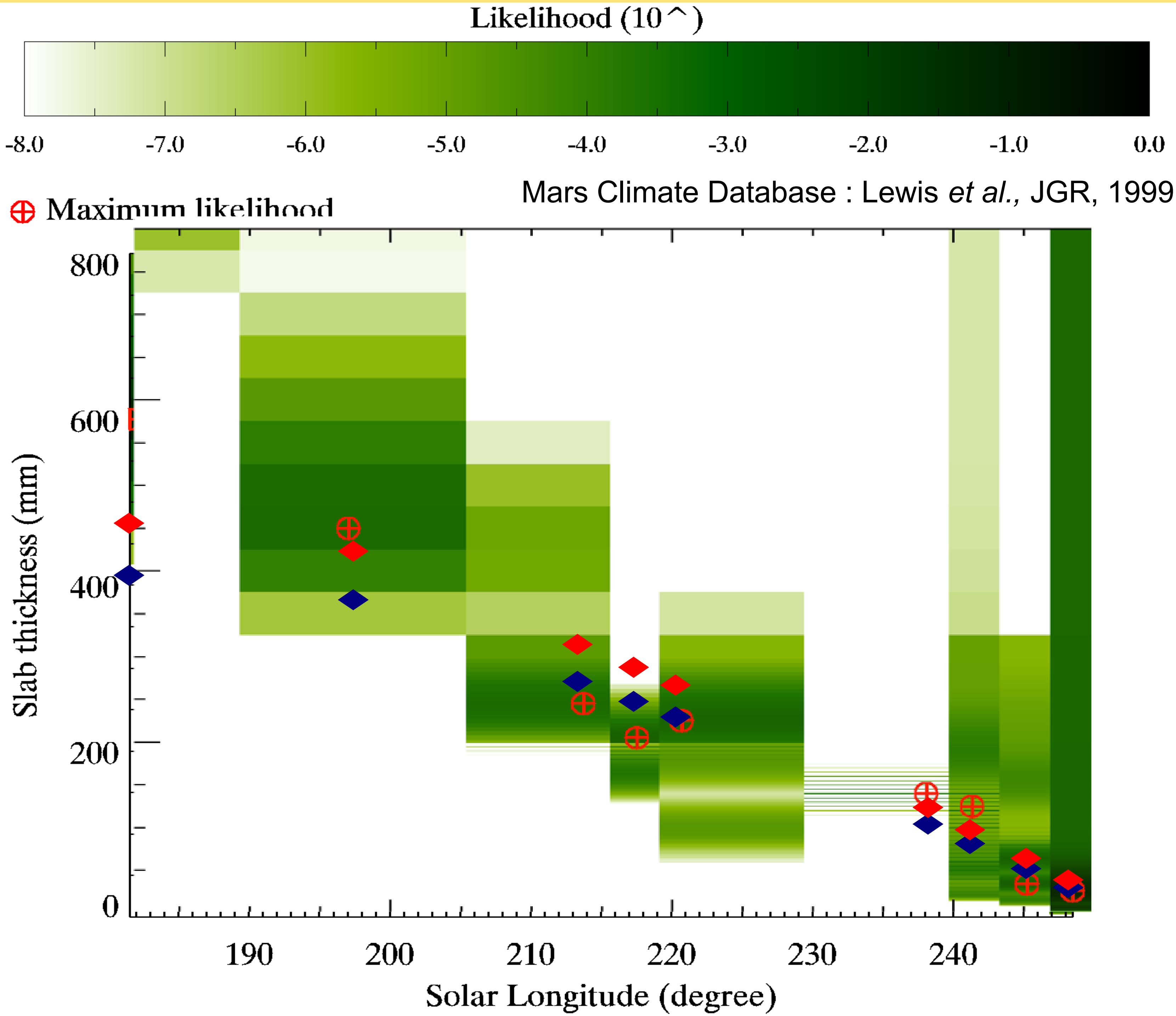
Perspectives :

- **Can be applied to any icy surface** (maps)
- Confirm linear mixing values with HiRISE data





Results : thickness



Sampling :

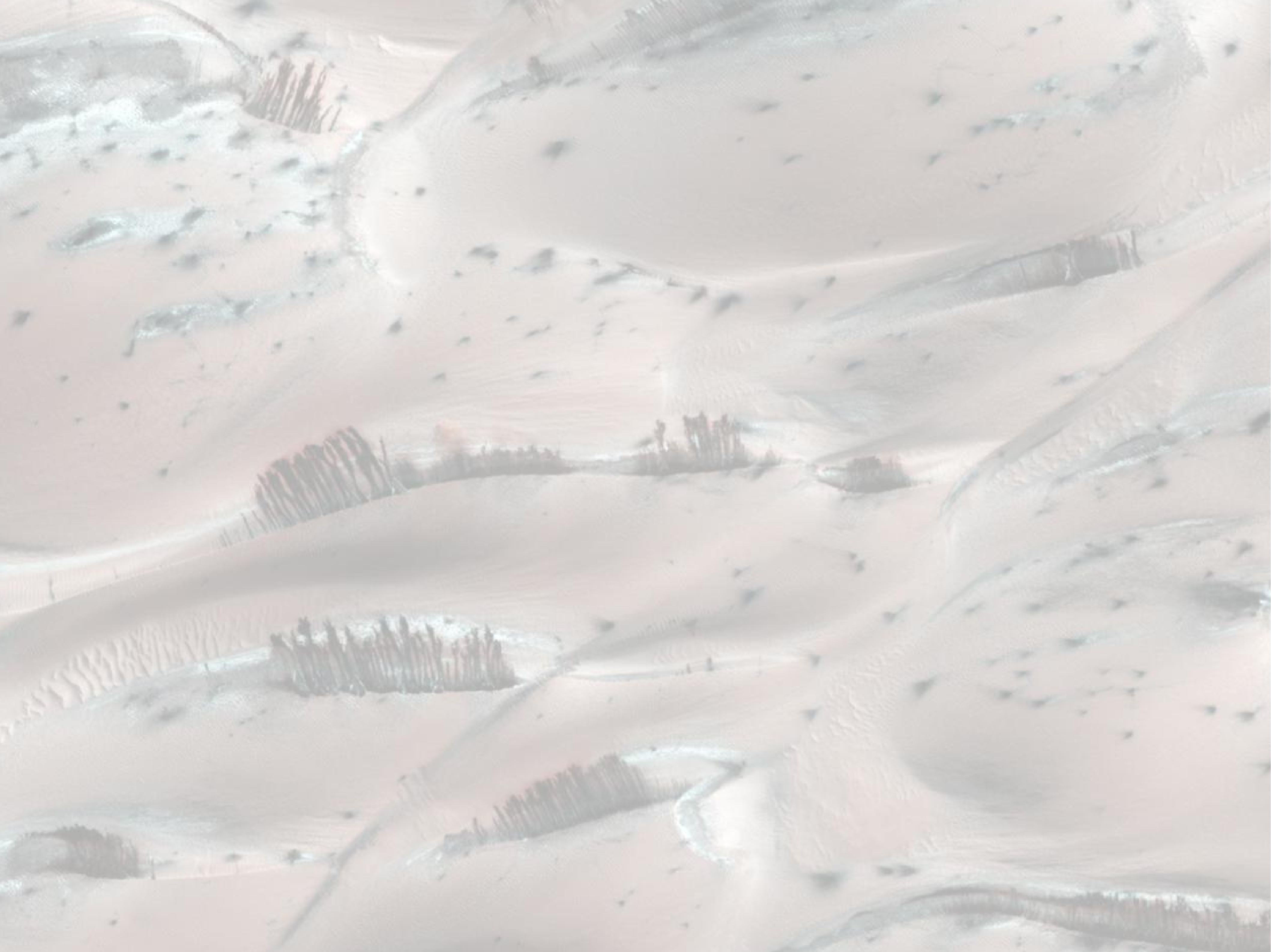
Slab thickness : from 0 to 1000 mm

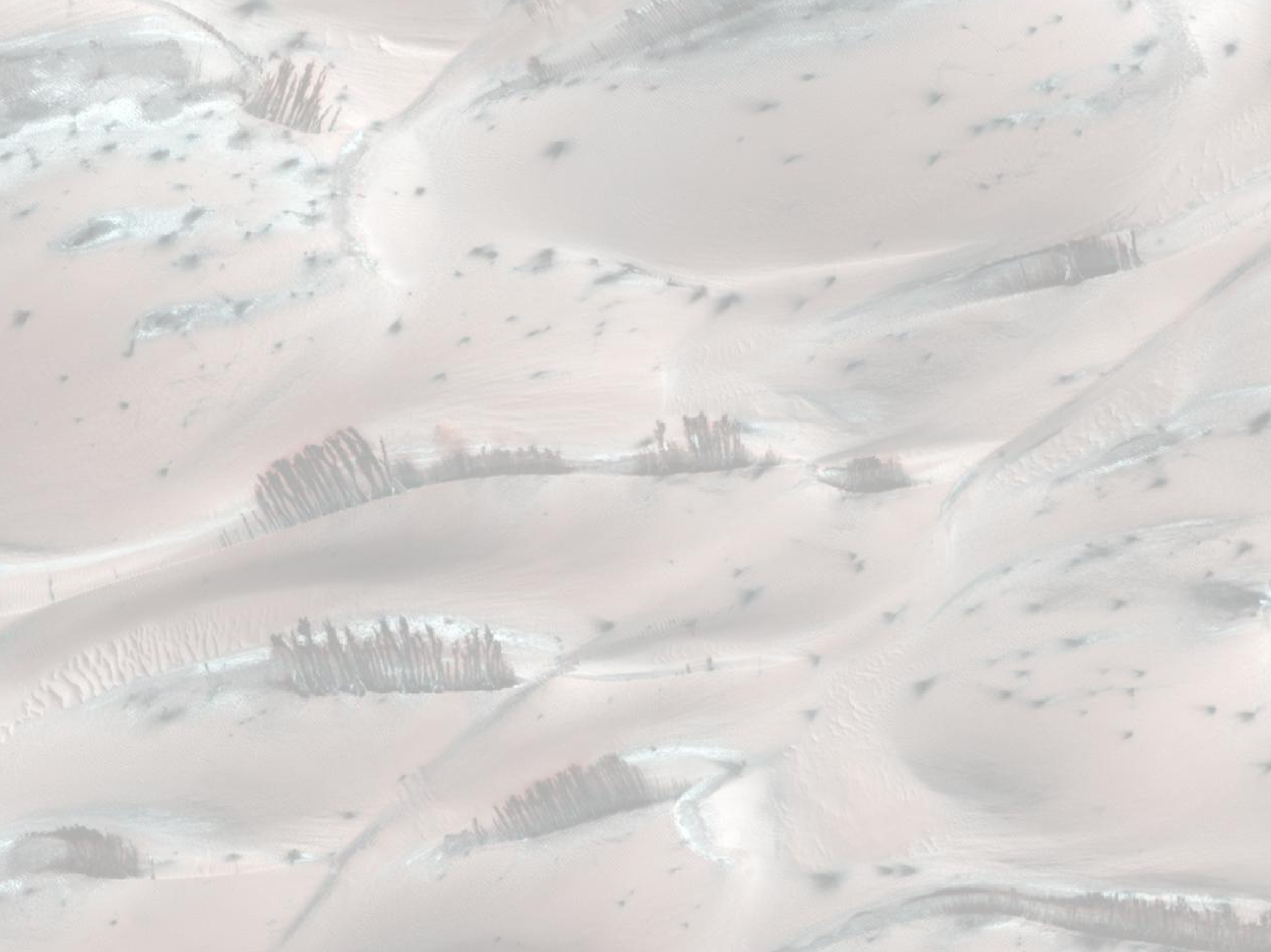
Slab compacity : from 0.9 to 1

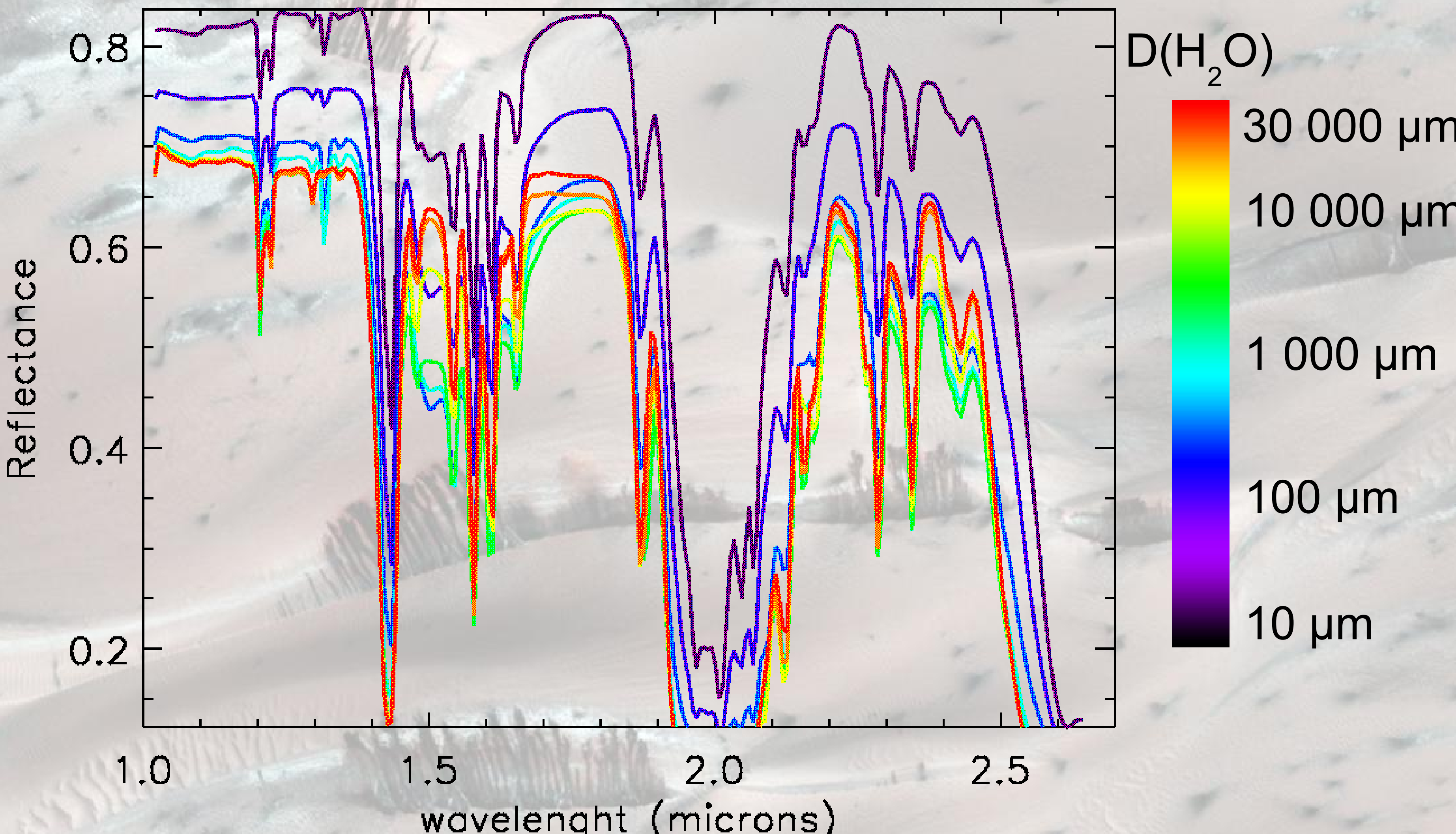
Water ice grainsize : from 1 to 10 000 microns

Water ice proportions among impurities : from 0% to 100%

Proportion of sur surface covered by dust (linear mix) : from 0% to 100%







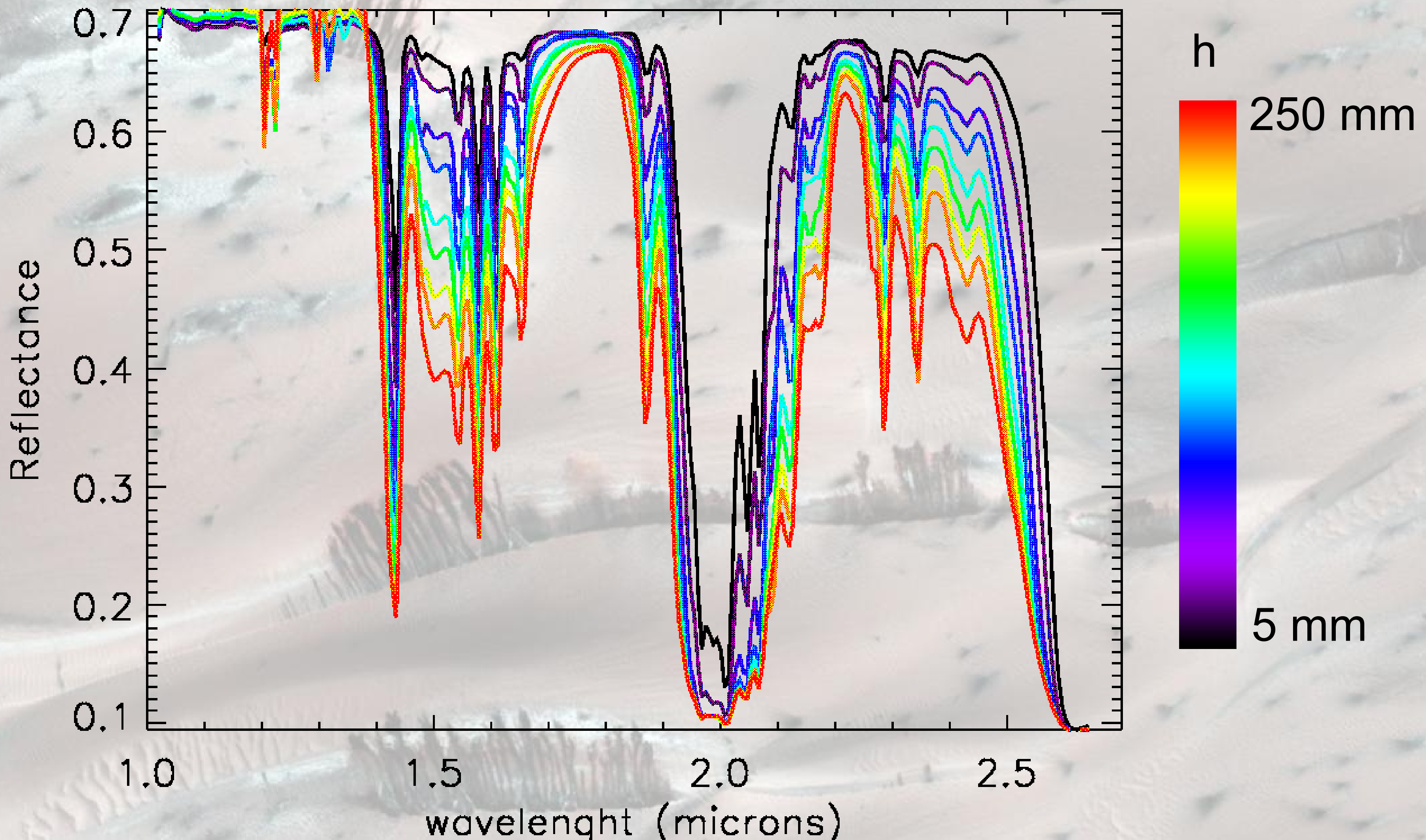
Glace de CO_2 transparente , épaisseur h = 100 mm

Poussière :

- taille de grains : 30 µm
- proportions : 0,01‰

H_2O :

- taille de grains : **variable**
- proportions : 0,99‰



Glace de CO_2 <u>transparente</u> , épaisseur h **variable**

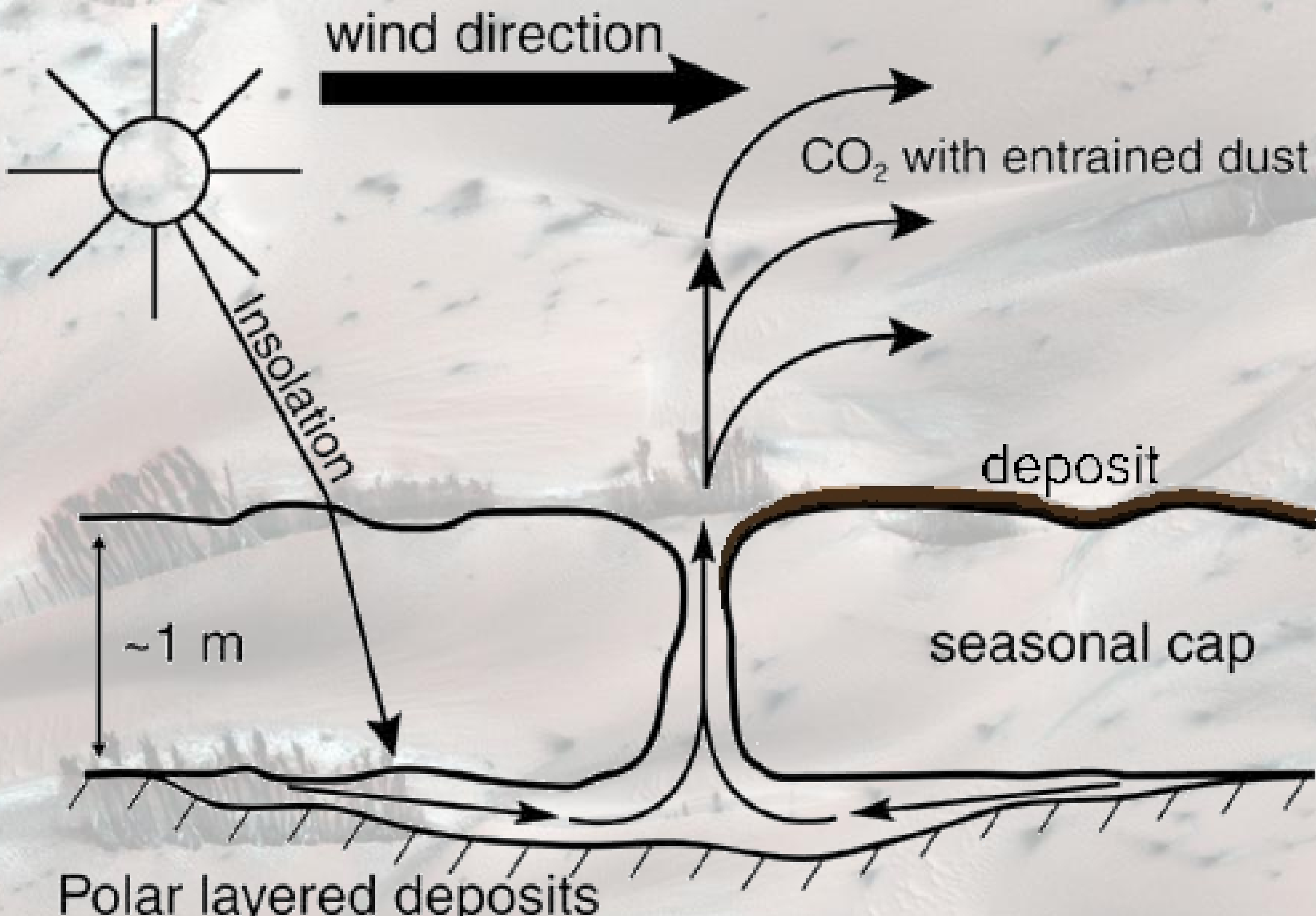
Poussière :

- taille de grains : 30 µm
- proportions : 0,01‰

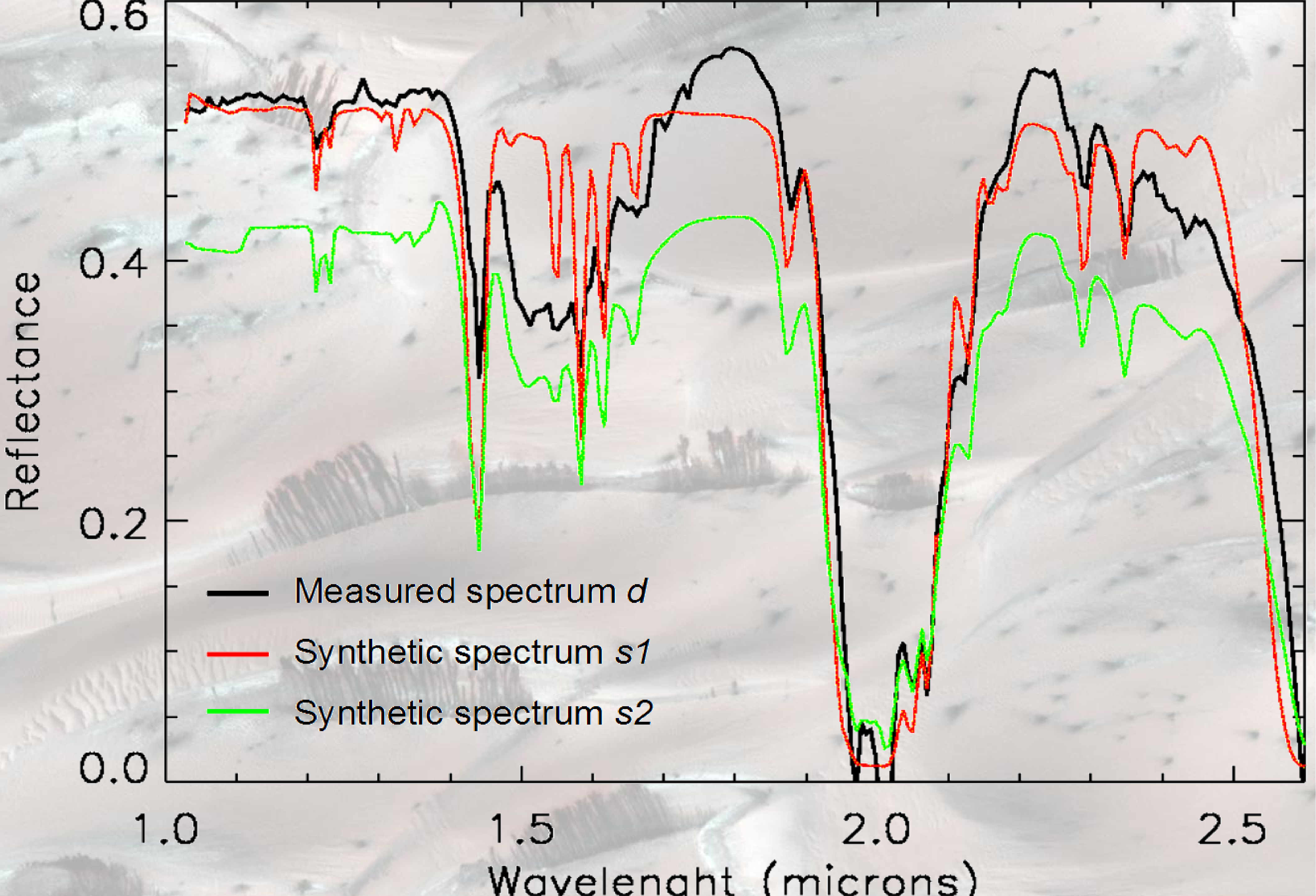
H_2O :

- taille de grains : 100 µm
- proportions : 0,99‰

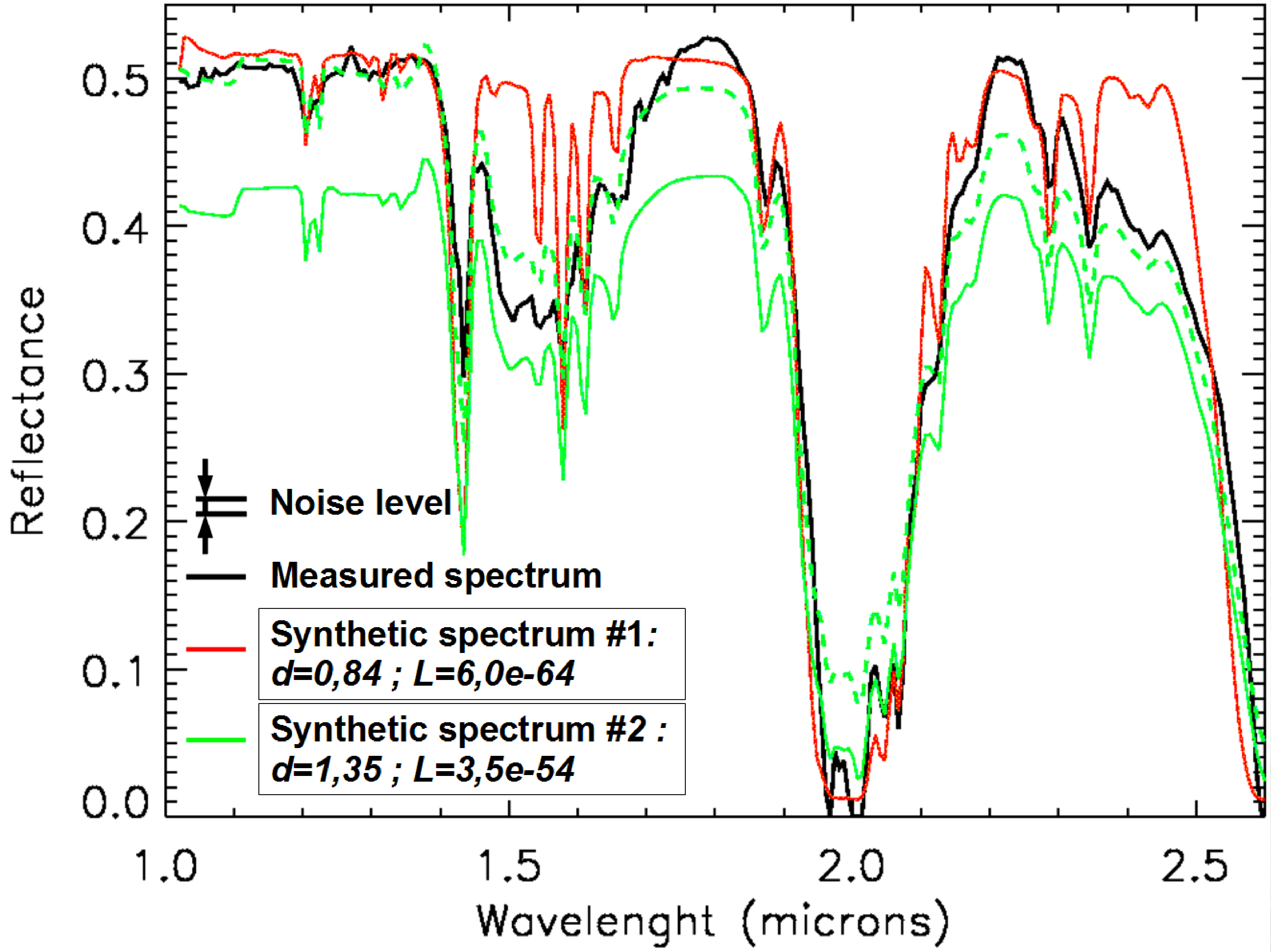
Process :



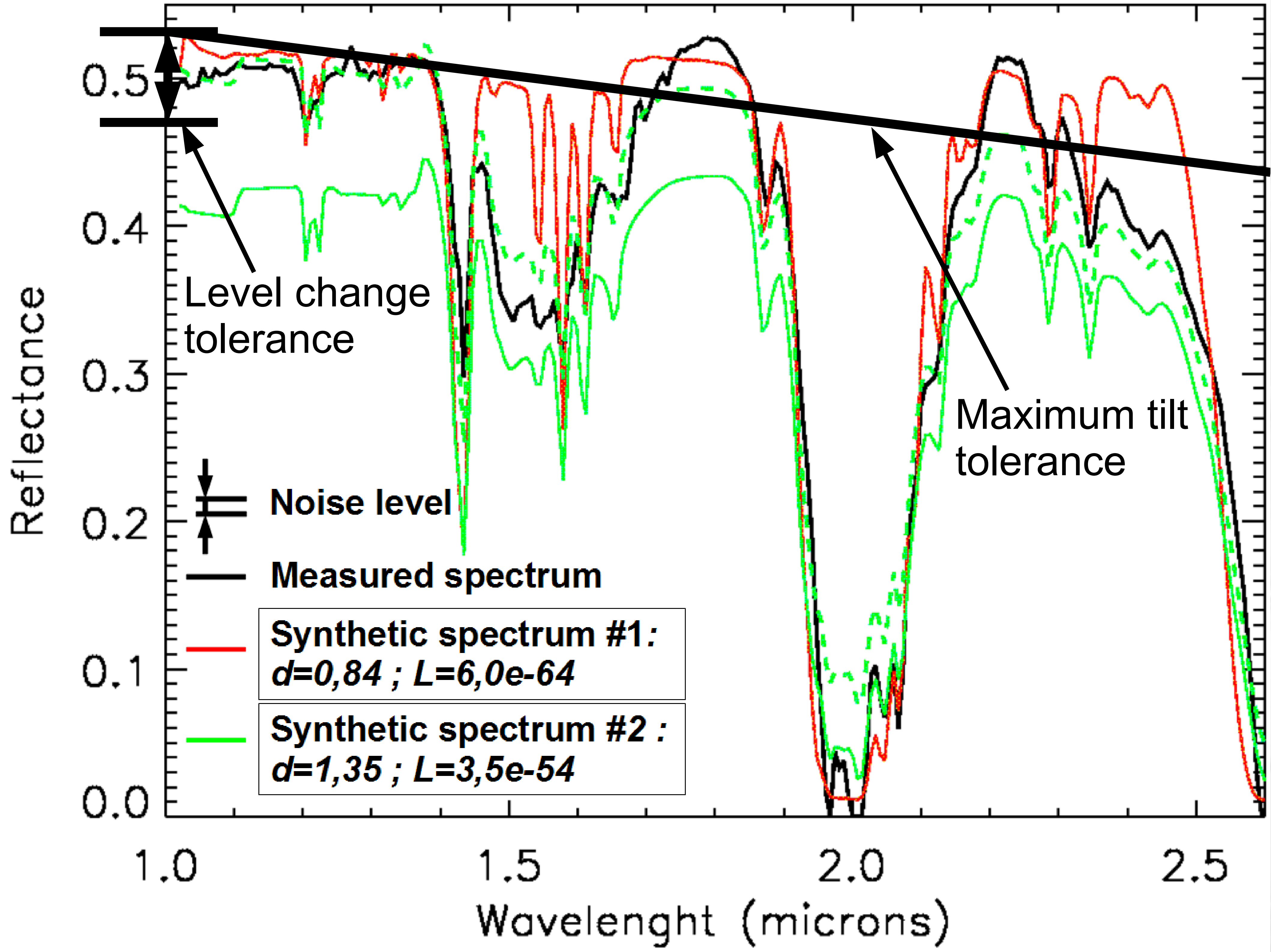
(Piqueux *et al.*, *JGR,* 2003)
(Kieffer *et al.*, *Nature,* 2006)



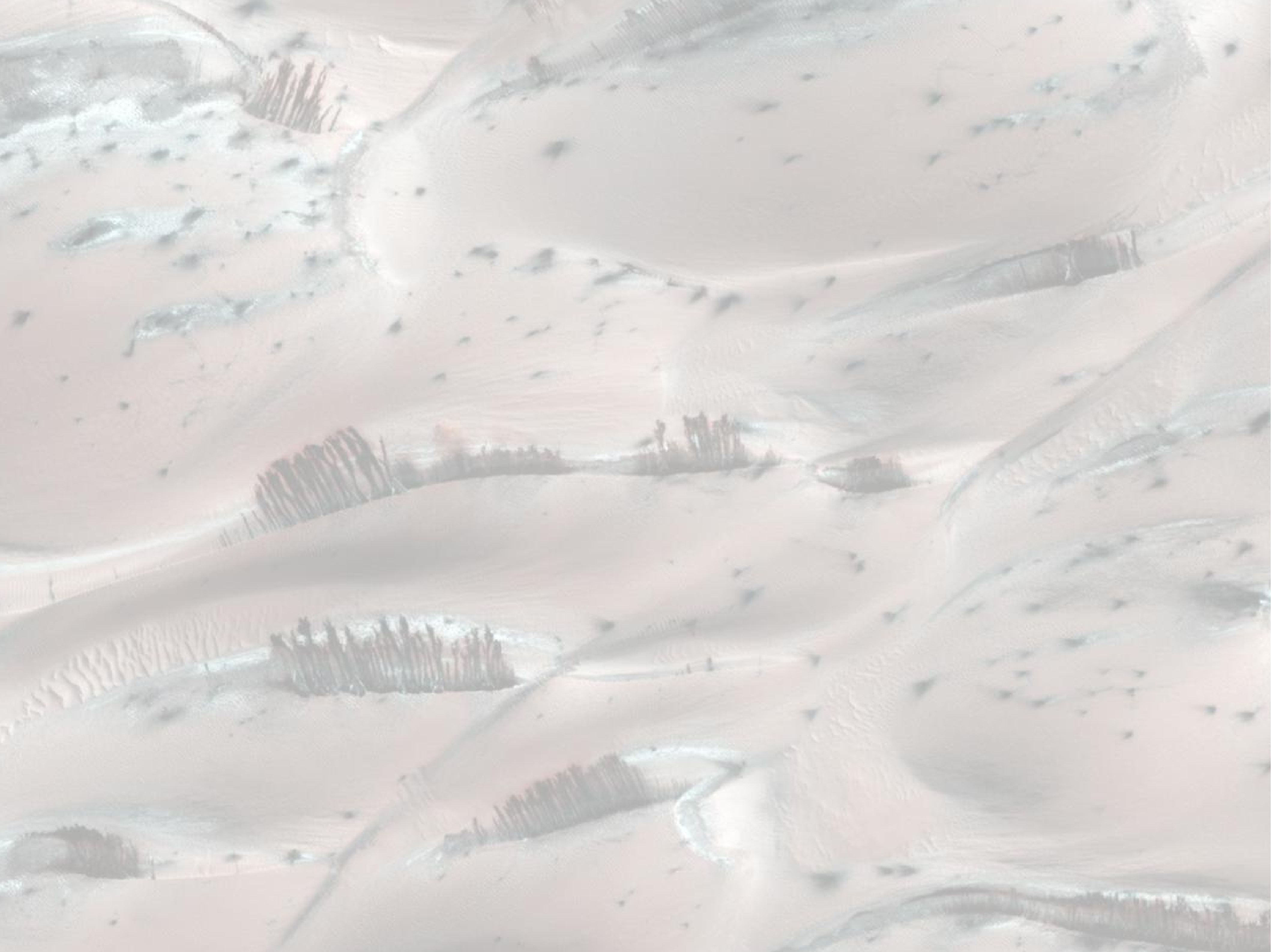
The green synthetic spectrum *s2* seems more accurate



0.5
0.4
0.3
0.2
0.1
0.0
Reflectance
1.0
1.5
2.0
2.5
Wavelenght (microns)
Noise level
Measured spectrum
Synthetic spectrum #1:
d=0,84 ; L=6,0e-64
Synthetic spectrum #2 :
d=1,35 ; L=3,5e-54

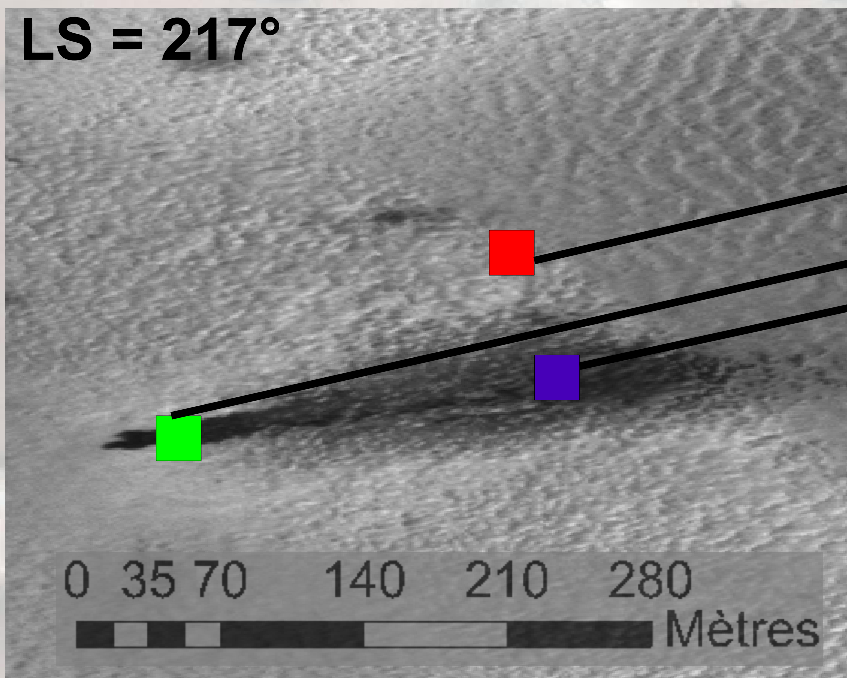


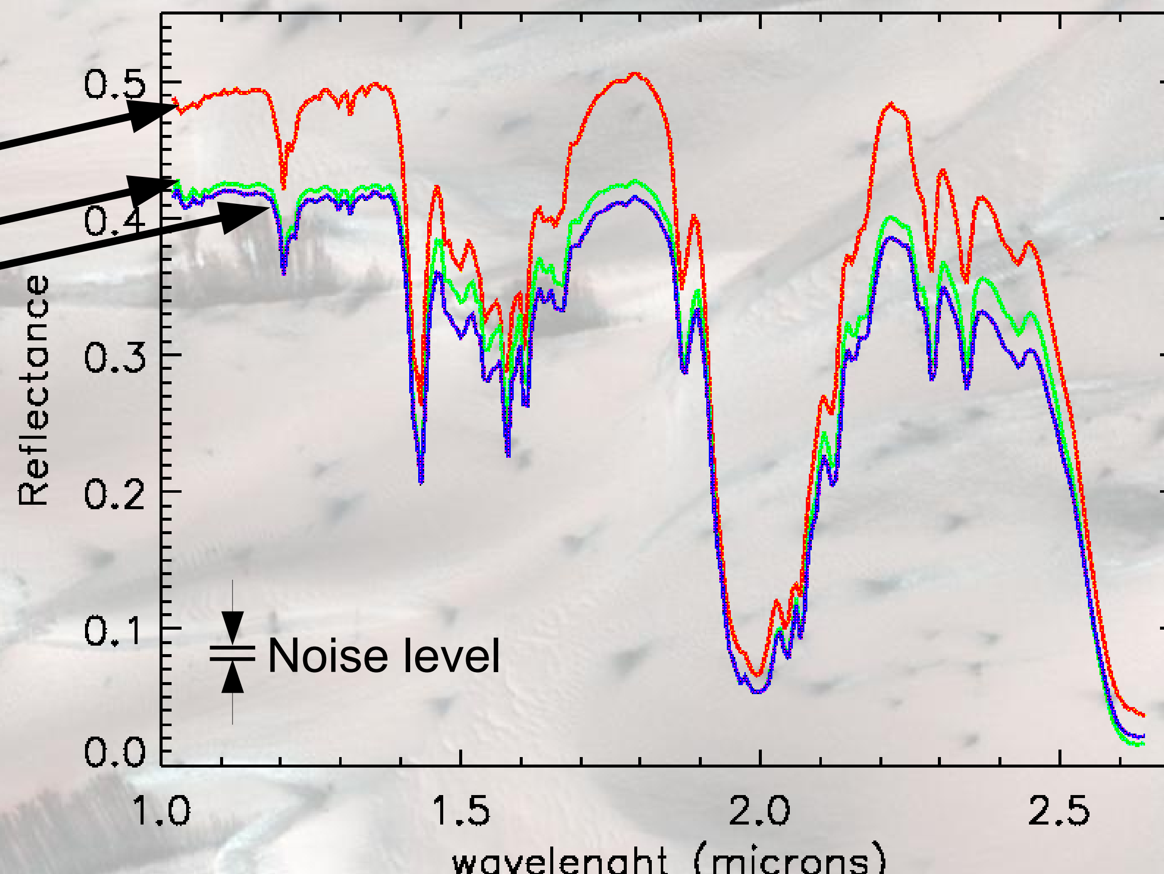
Reflectance
0.0
0.1
0.2
0.3
0.4
0.5
1.0
1.5
2.0
2.5
Wavelenght (microns)
Level change tolerance
Maximum tilt tolerance
Noise level
Measured spectrum
Synthetic spectrum #1: d=0,84 ; L=6,0e-64
Synthetic spectrum #2 : d=1,35 ; L=3,5e-54



Spatial variability :

CRISM measurement





CRISM pixel