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Introduction

Martian polar caps have huge impact on atmosphere of Mars, defining key processes in Martian atmosphere, such as water cycle and CO₂ cycle [1]. It is crucial to know micro and macro parameters of ices on both polar caps in order to fully understand processes in Martian atmosphere and have some insights to history of Mars. There are huge number of papers [2-6] describing retrievals of number of ice microparameters such as grain size, dust wt%, water wt% and layer thickness from IR observations of Martian polar caps, since CO₂ and water ice have easily distinguishable features in this spectral diapason. All of them used mapping spectrometers like OMEGA or CRISM with good spatial resolution and good spectral diapason, but poor spectral resolution. We use SPICAM-IR: IR spectrometer with spectral diapason from 1 to 1.7 μm and has resolving power of ~2000 [7]. This instrument can clearly resolve all sharp spectral features of CO₂ ice in its diapason on surface of Mars. SPICAM-IR performed continuous observations of Mars for 8 Martian Years, and now it is the only IR instrument on the orbit of Mars performing observation of polar caps.

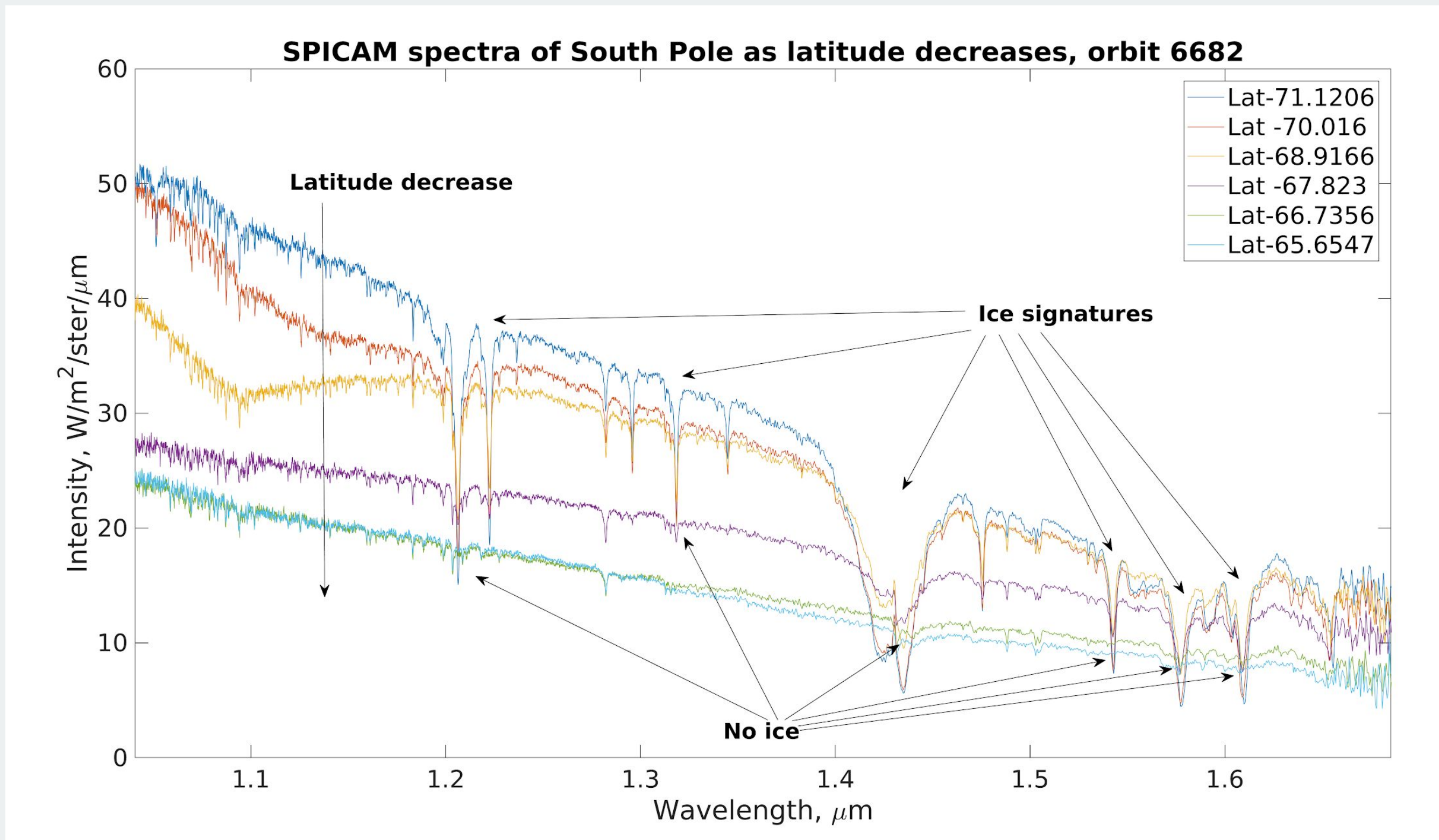


Figure 1. Example raw SPICAM-IR spectra over the south pole of Mars.

Obtaining reflectance

Atmospheric correction

In order to obtain a reflectance spectrum, we need to correct our data for atmospheric absorption and divide it by solar radiance as shown on figure 2. We use CAVIAR solar spectrum, HITRAN 2016 [8] and MCD 5.3 [9] for automatic correction of gaseous CO₂ and water vapour absorption in Martian atmosphere. We also correct minor wavelength shift in data.

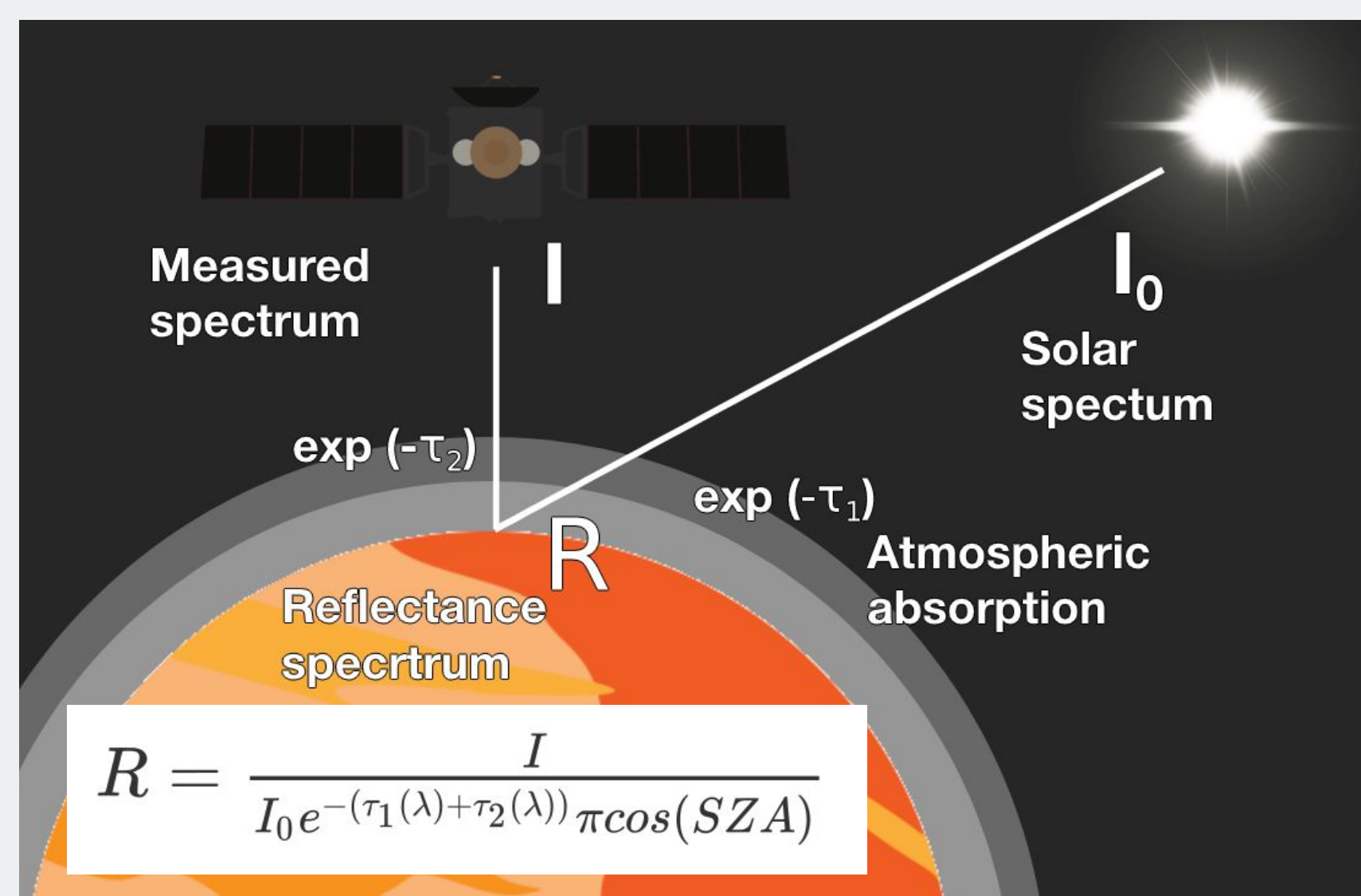


Figure 2. Scheme of SPICAM observations from orbit of Mars.

Since CO₂ ice has sharp feature on 1.4 μm width of which is connected to grain size and abundance of ice on surface, we can make a qualitative measure of grain size on surface using equivalent width of this band:

$$W_\lambda = \int (1 - F_\lambda / F_0) d\lambda$$

F_λ - intensity of absorption line
 F_0 - intensity of continuum

Seasonal map of equivalent width is shown on Figure 4.

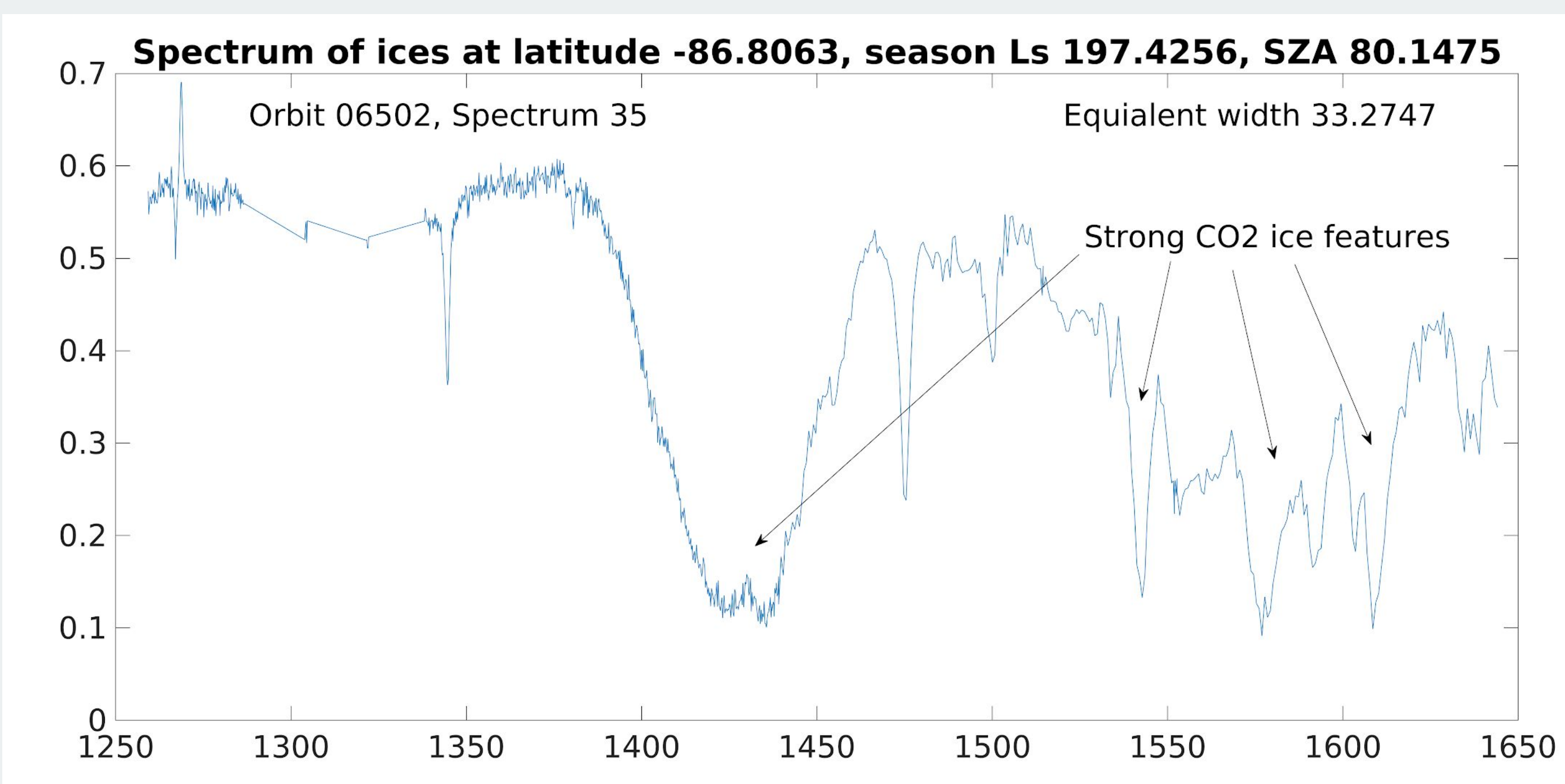
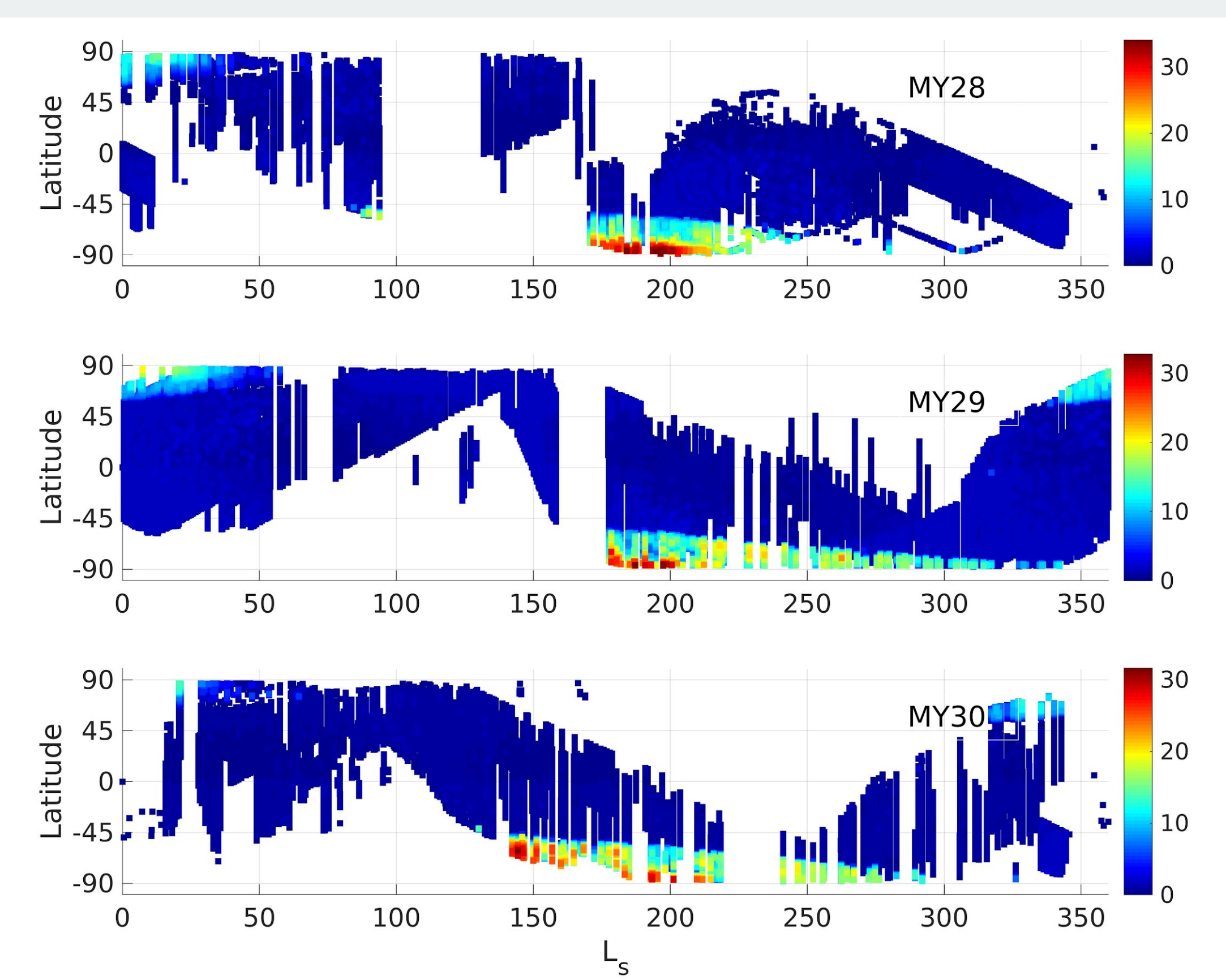


Figure 3. Example of spectrum with big grain size at south pole of Mars.

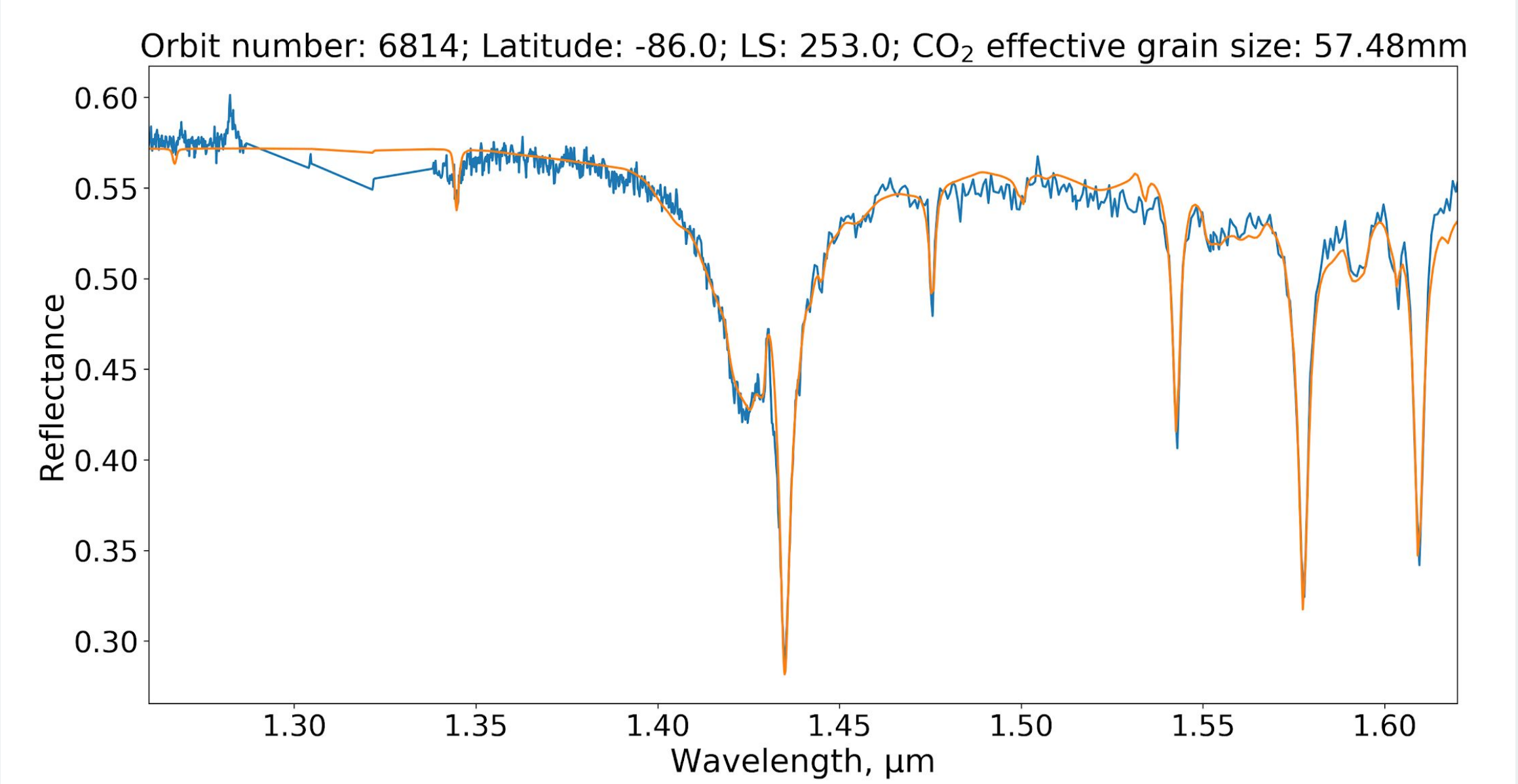
Figure 4. Seasonal map showing distribution of equivalent width of CO₂ ice band over three Martian years.



Choosing model for retrieval

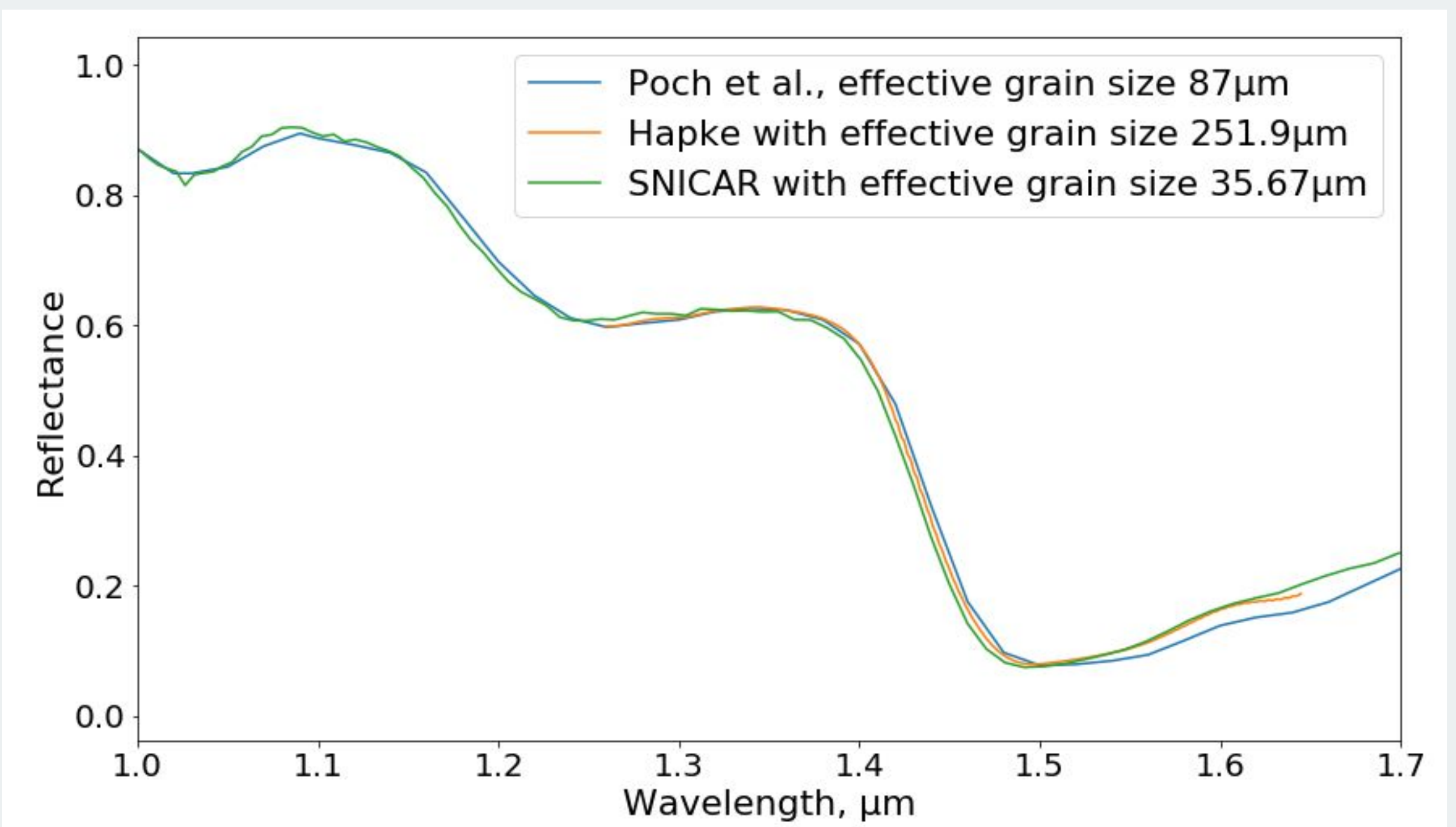
There are only two models with code that is more or less publicly available: Hapke model [9,10,11], which is known for its simplicity and speed, and SNICAR [12], which was for a long time successfully applied for Earth snow studies. Hapke model was used for years in planetary science for modeling different surfaces. It uses simple semiempirical approach to radiative transfer, which is the cause of some controversies [13] over the model results. Nevertheless, we applied Hapke model to retrieve grain size from SPICAM observations, there is an examples of retrieval:

Figure 5. Sample retrieval of CO₂ grain size using linear unmixing with endmembers modeled with Hapke model.



SNICAR is model of snow surfaces, applied on Earth for a long time. It was recently applied to Martian conditions [6] and showed interesting results. Before using SNICAR model, we wanted to compare both model on laboratory spectrum to test both models and to see how good they are. With help of SSHADE database we found few open water ice laboratory experiments, best was Poch et al.[14]. The description of the experiment provided us with grain size distribution of material, layer thickness, observation geometry and temperature of ice. We did set all of this parameters with SNICAR; it is not possible to set layer thickness and grain size distribution, only the mean grain size with our implementation of Hapke model. We did compare the retrievals from two models: effective grains size of sample was 87μm, unmixing using Hapke model results 251.9μm, SNICAR - 35.67μm.

Figure 6. Retrieval of water ice grain sizes using linear unmixing.



Conclusions

We retrieved reflectance from SPICAM nadir measurements and successfully retrieved grain sizes of CO₂ ice from few spectra using Hapke model. Though, there are some controversies around Hapke model, and we tried to retrieve grain sizes from laboratory experiments using also SNICAR model. Retrieval has produced controversial results with Hapke model overestimating grain size and SNICAR underestimating grain size of water ice. Though, it is clearly possible to retrieve a lot of information can be retrieved and mapped properly using one of these models. SPICAM operations are funded by CNES and Roscosmos. The data analysis by A.L., A.F. and O.K. has been supported by the Russian Government grant 14.W03.31.0017.