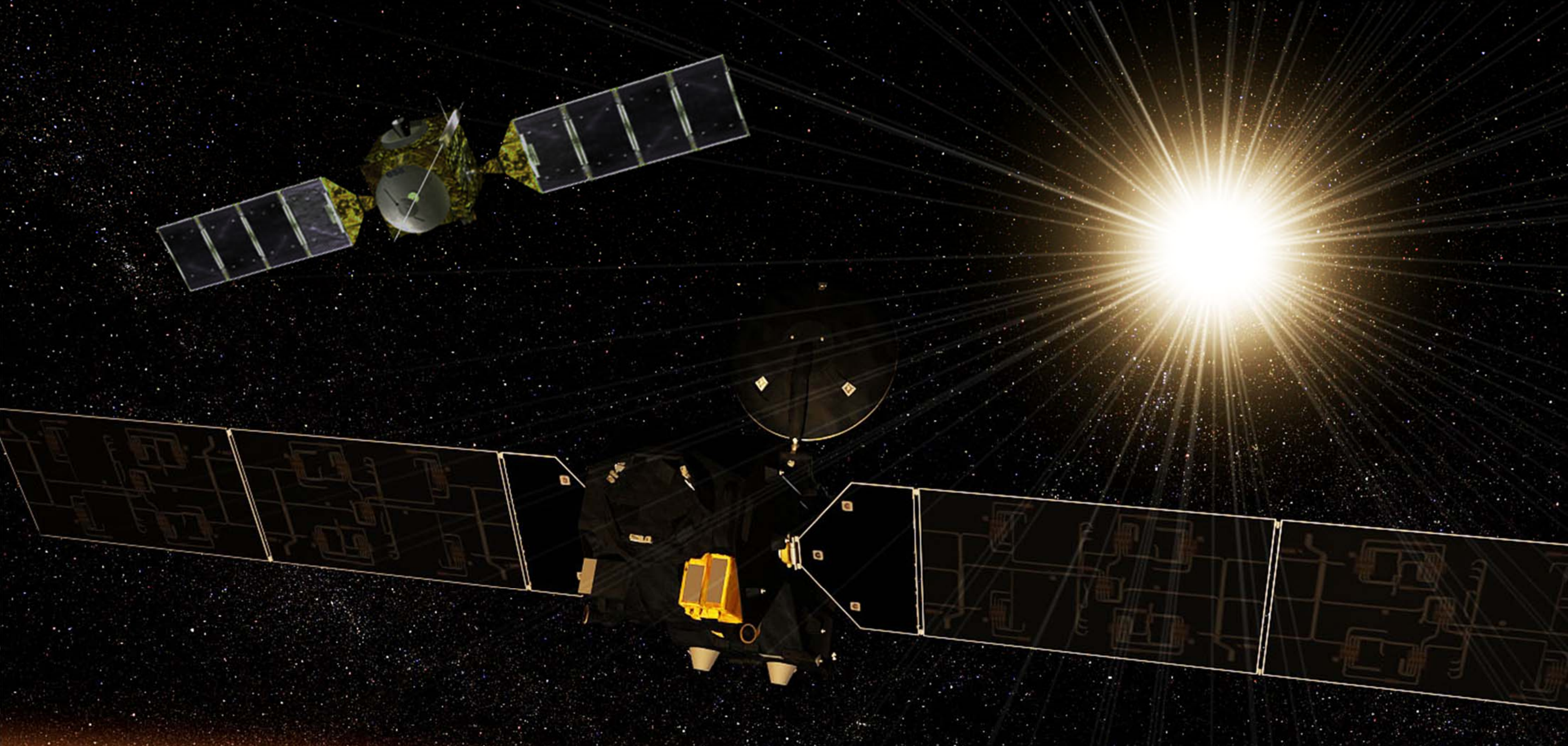
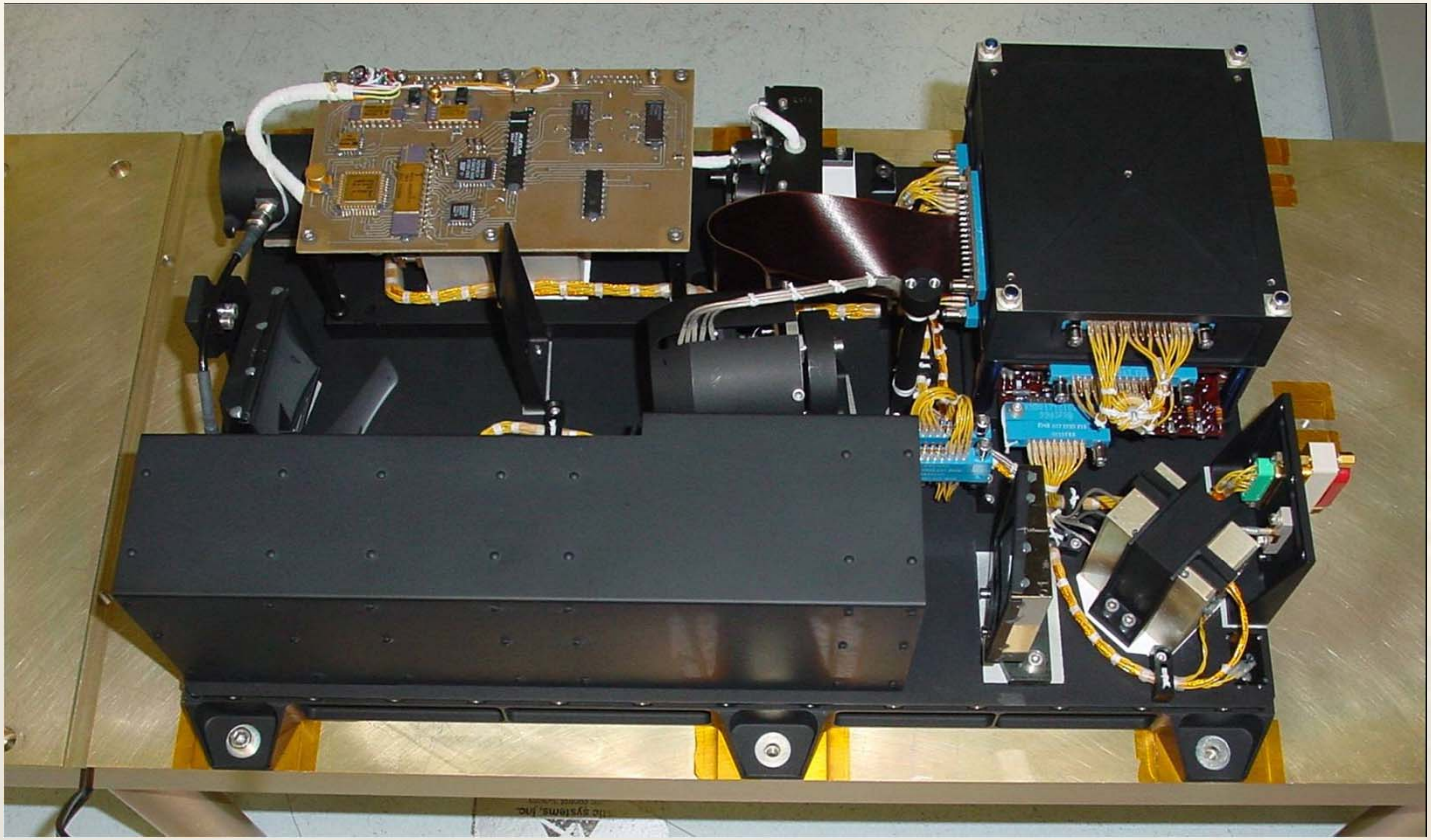


From SPICAM IR to ACS NIR; Dayside Nadir Observations In The Near Infrared

A. Trokhimovskiy, A. Fedorova, F. Montmessin,
O. Korablev, S. Guslyakova, F. Lefevre, J.L. Bertaux

Workshop: “From Mars Express to ExoMars”27–28 February 2018, ESAC Madrid, Spain

SPICAM onboard Mars-Express Mission

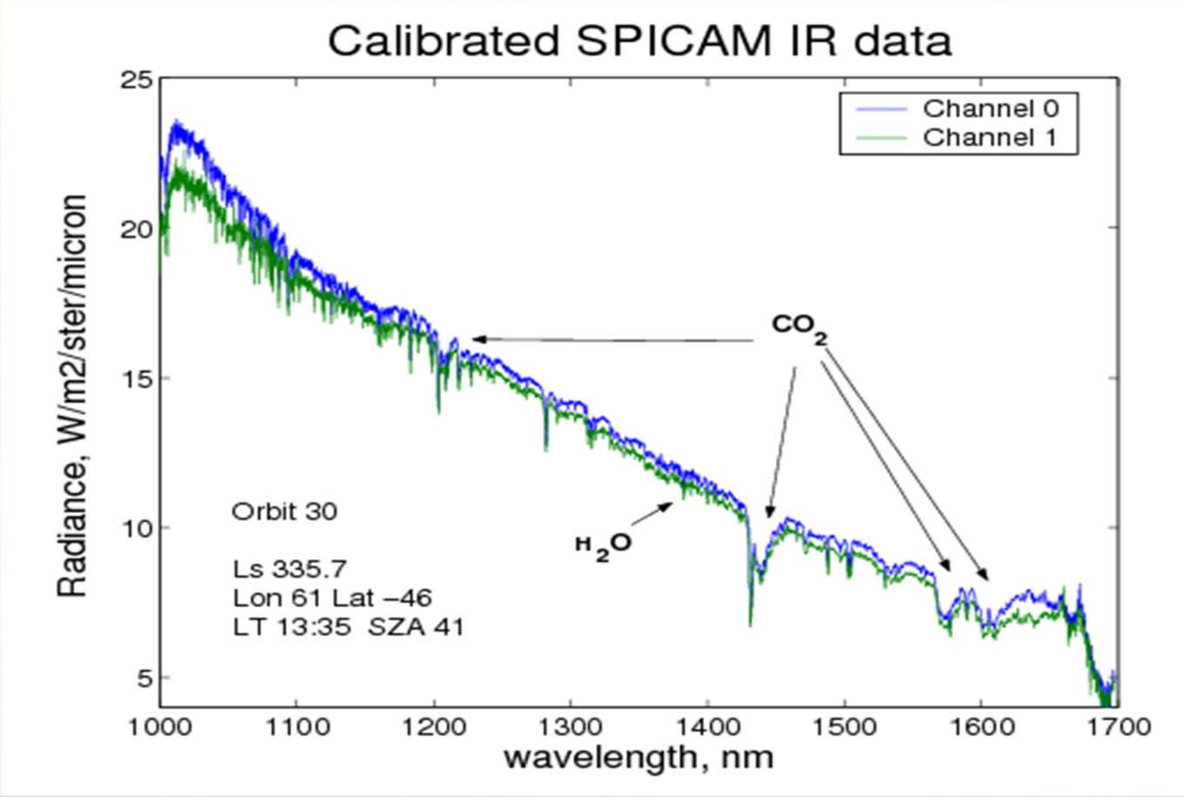


IR spectrometer:	UV spectrometer:
1-1.7 µm	**118-320 nm,**
R~ 2000	**R ~150**
FOV ~0.07° ~ 1-15 km	

SPICAM IR – AOTF spectrometer:

Spectral range:	**1-1.7 µm**
Spectral power: **Spectral resolution**	**R~2000** **0.5-1.2 nm**
FOV nadir **occultation**	**1°** **~0.07°**

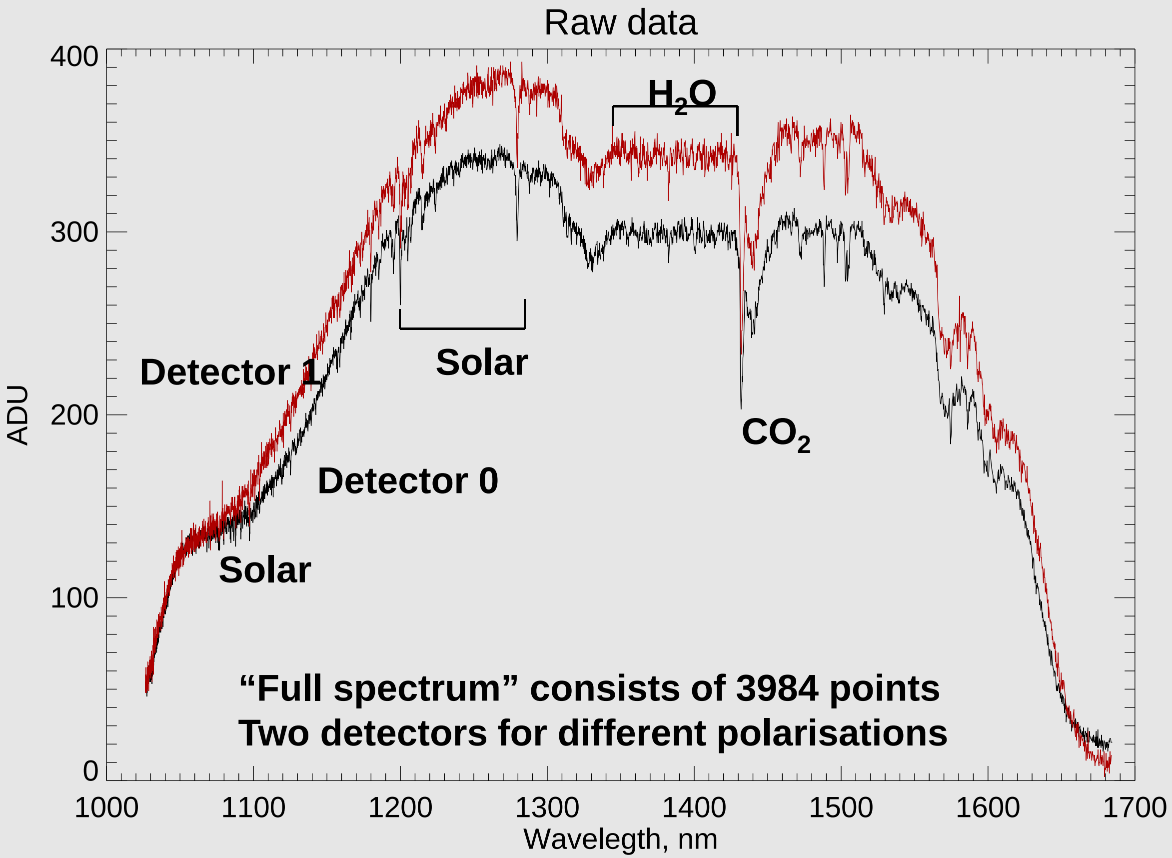
- **Nadir viewing (day side)**
  - H_2O abundance at 1.38 µm
  - H_2O and CO_2 ices
  - O_2 dayglow – ozone tracer
- **4147 nadir sessions ~ 2100 hours**



SPICAM First Observations

ESOC, SOWG 15 January 2004

- 1 Nadir pass orbit 8
- Orbit 8, 2004 Jan 09, Ls=330, MY 26



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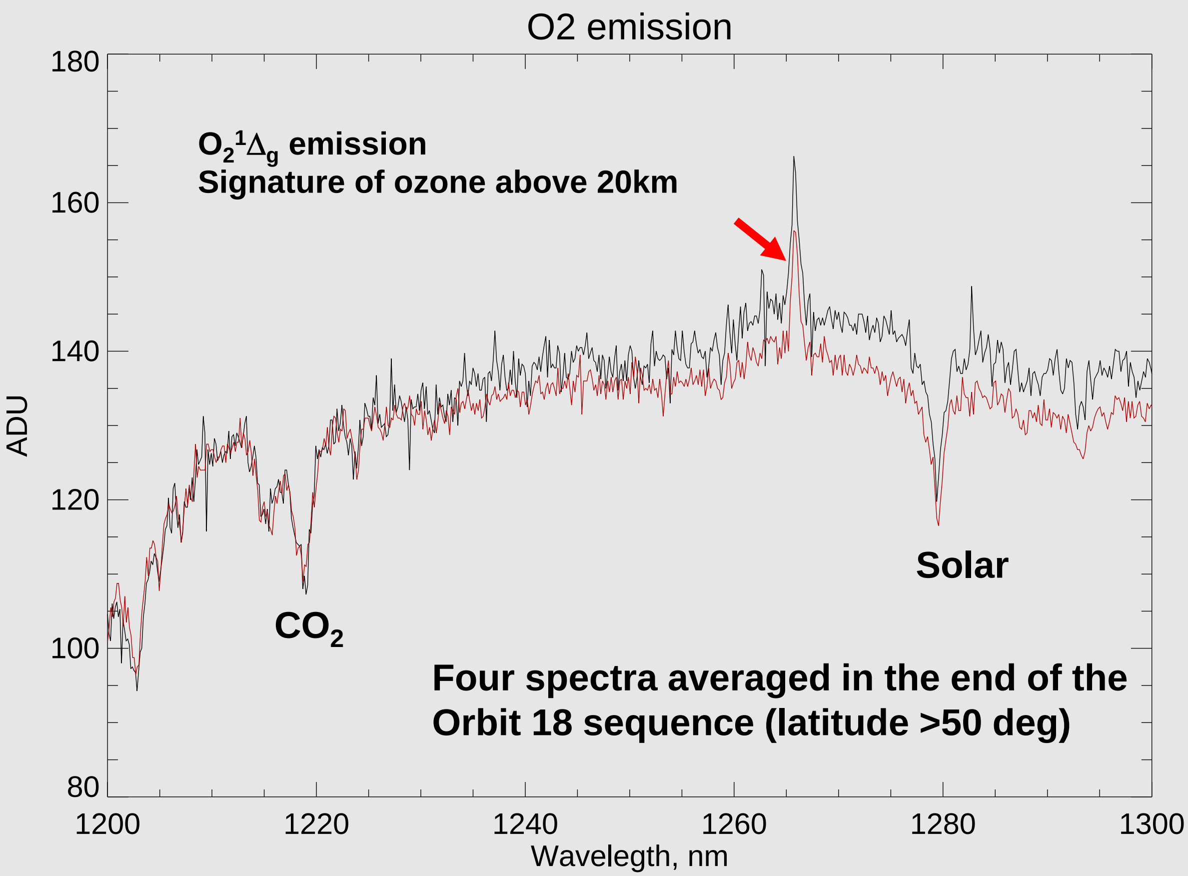


The O_2 emission in 1.27 µm on Mars

The dayside

The O_2 emission at 1.27 µm is produced by UV dissociation of ozone

$$O_3 + h\nu \longrightarrow O(^1D) + O_2(a^1\Delta_g)$$

$$220 \text{ nm} < \lambda < 320 \text{ nm}$$

The emission was predicted after the ozone discovery in atmosphere of Mars in spectra recorded by UV spectrometer onboard of Mariner-7 (Barth, 1971). For the first time the emission was detected by Noxon et al. (1976) by means of ground-based telescopes.

Deactivation of the emission:

1) The emission at altitudes >20-25 km

$O_2(a^1\Delta_g) \longrightarrow O_2(X^3\Sigma_g)$ + $h\nu$ (τ ~ **4566 s**)

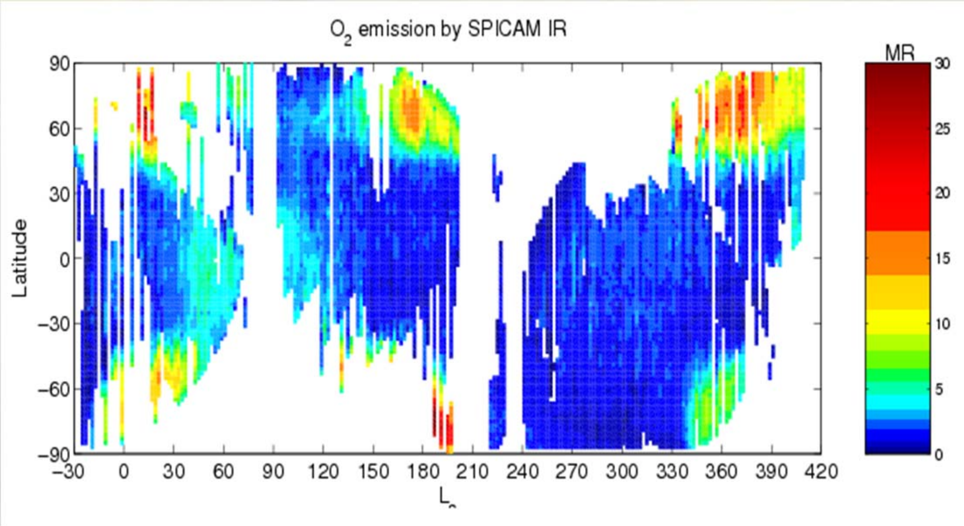
2) Deactivation through collision with CO_2 CO_2 (<20 km)

$O_2(a^1\Delta_g) + CO_2 \longrightarrow O_2(X^3\Sigma_g) + CO_2$

($k_2 \sim 10^{-20}$ cm^3 s^{-1})

First seasonal distribution by SPICAM

from January 2004 (L_s=330°) to May 2006 (L_s=50°)
(Fedorova et al., 2006)

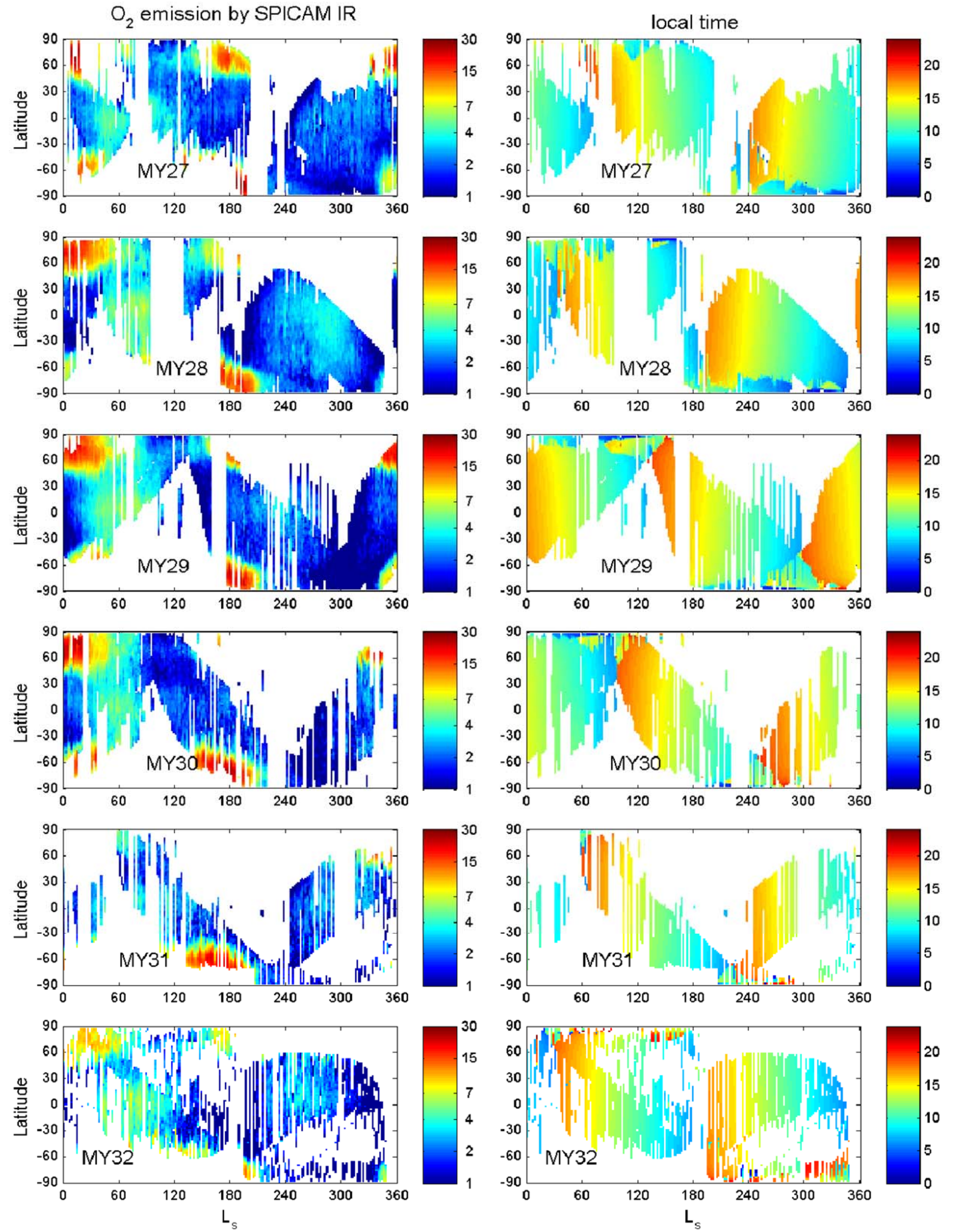


Long term observation of the $O_2(a^1\Delta_g)$ emission

Seasonal distribution in MegaRayleigh (MR) from MY27 to MY32 by SPICAM (2004-2015)

1) Constraint to the $O_2(a^1\Delta_g)$ quenching coefficient by CO_2
2) Study of interannual variations of the O_2 dayglow
3) Study of correlation with water vapor observations

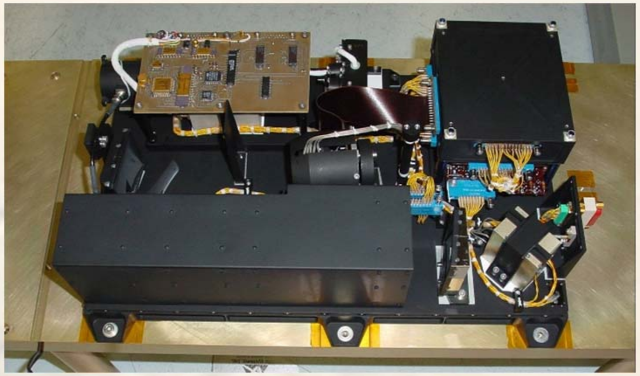
Guslyakova et al. 2016



Mars water vapor abundance from SPICAM IR dayside observations

Solvable topics:

- •Spatial distribution
- •Global and seasonal trends
- •Interannual and spatial variations
- •Correlation with atmospheric parameters and dust load
- •Comparison between instrument and missions

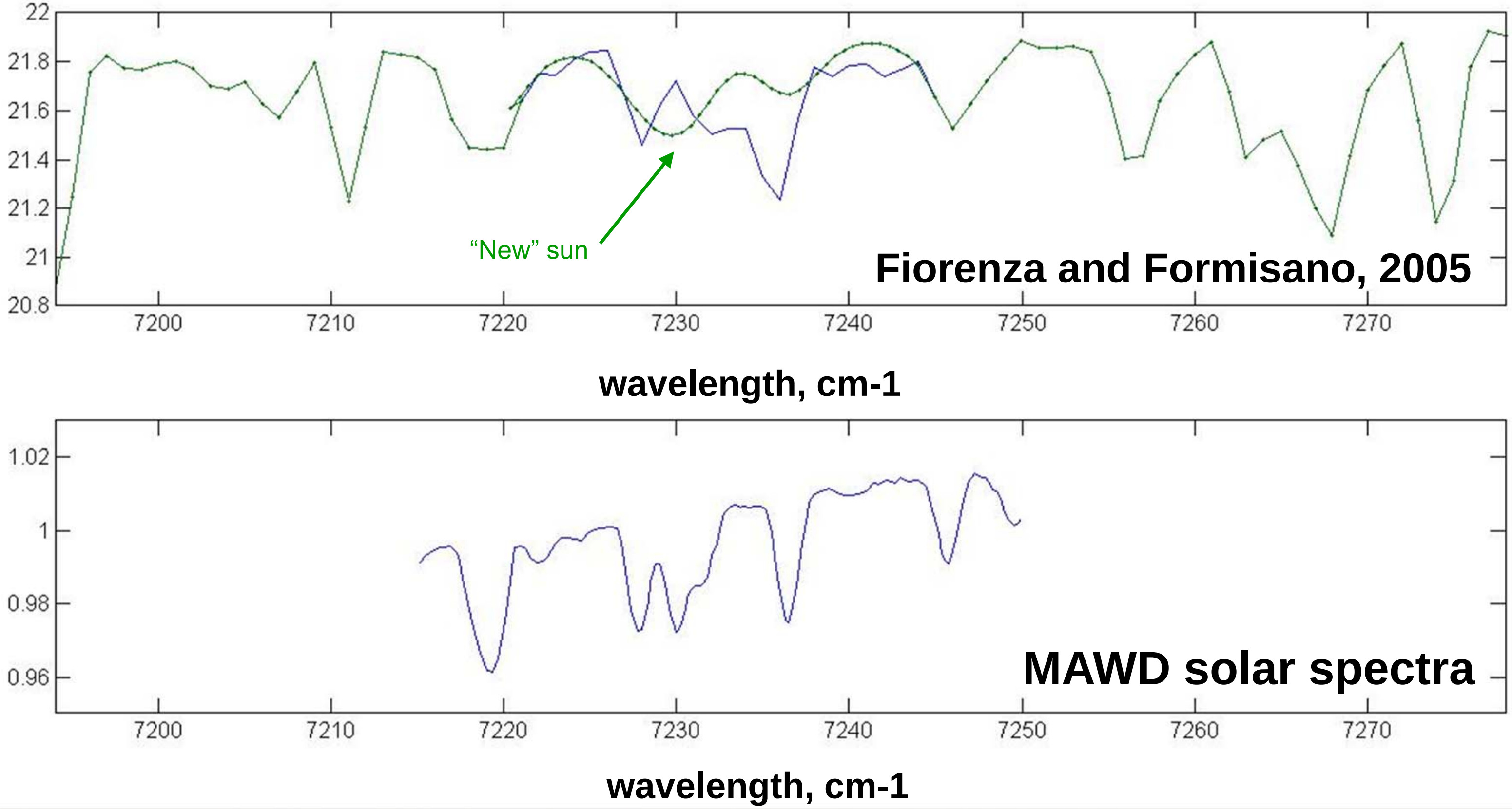


Retrievment procedure (version 2012):

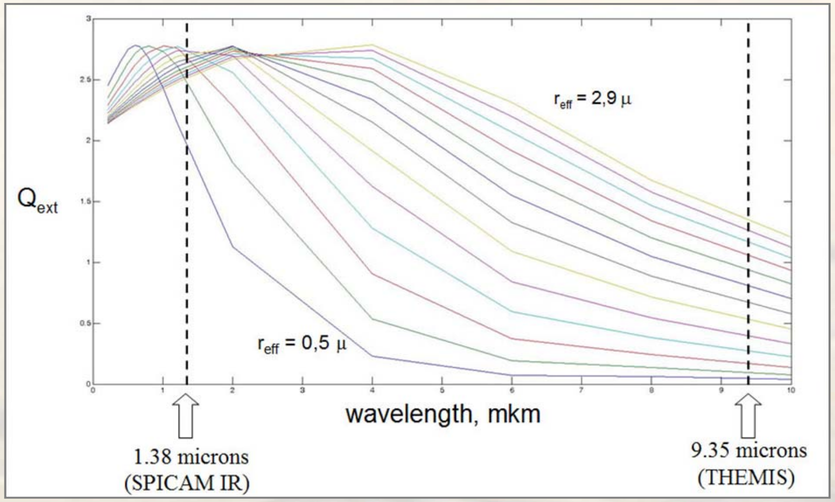
- •Assuming constant value of H_2O in the atmosphere below saturation level, and decrease according to saturation curve above it
- •Solar spectrum (Fiorenza and Formisano, 2005) with MAWD data correction
- •Spectroscopic database: HITRAN 2004 (no major changes in later versions)
- •Martian Climate Database V4.3 (to have a comparison with other datasets)
- •Liny-by-line calculations
- •Dust account (SHDOM, scaled THEMIS dust and ice data)

Trokhimovskiy et al. (2015), Montmessin et al. (2017)

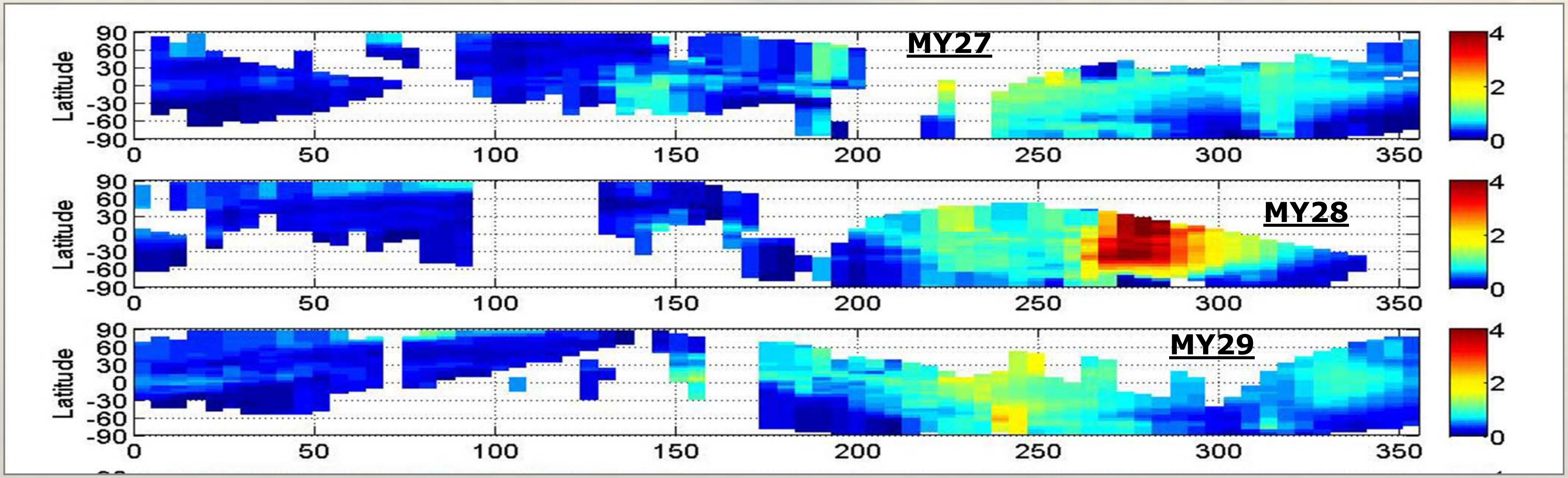
Solar spectra with correction



Dust optical depth and ice optical depth from THEMIS (Mars Odyssey) 1075 cm-1 and 825 cm-1 (M. Smith)

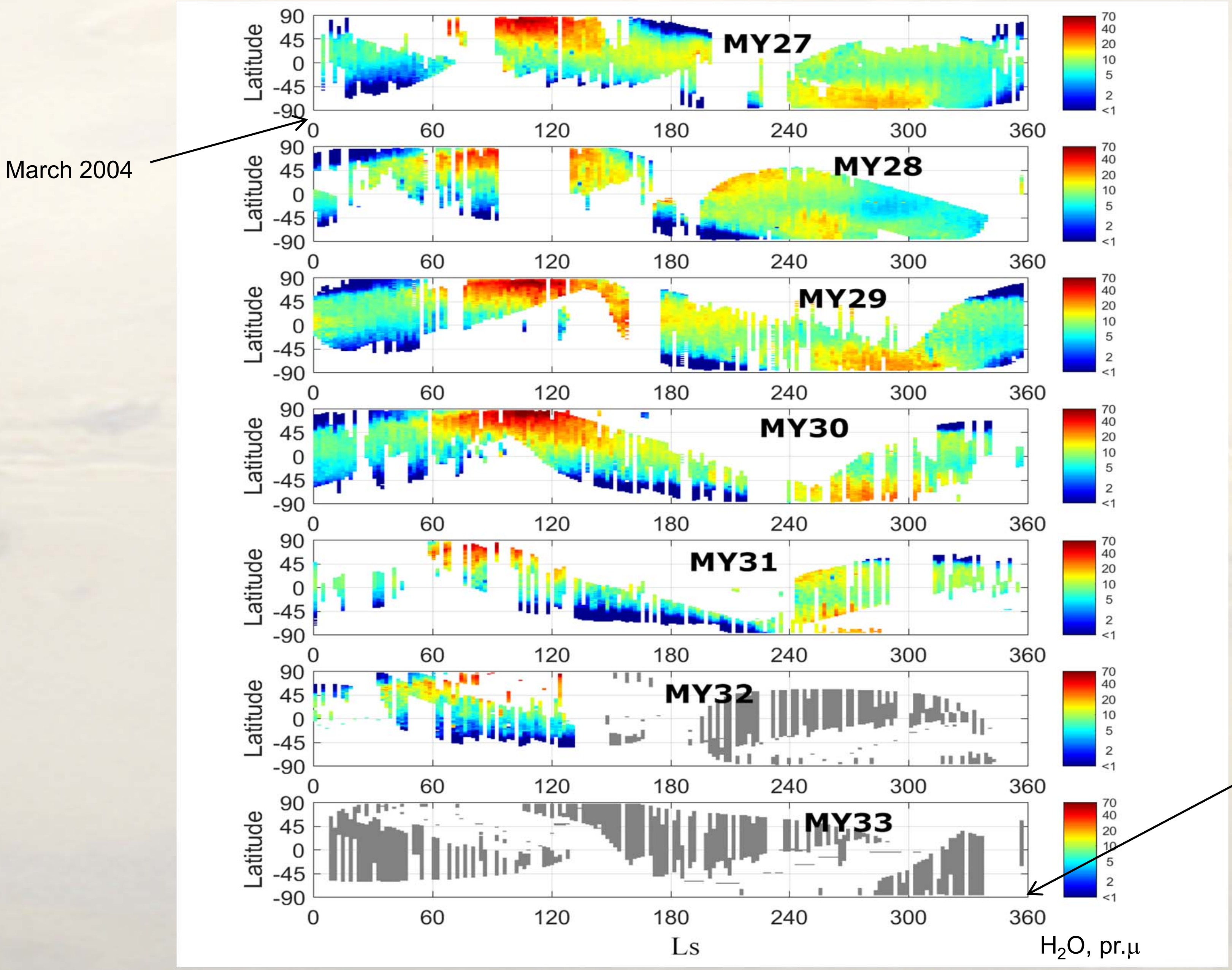


Extinction coefficients for different wavelengths and particles sizes

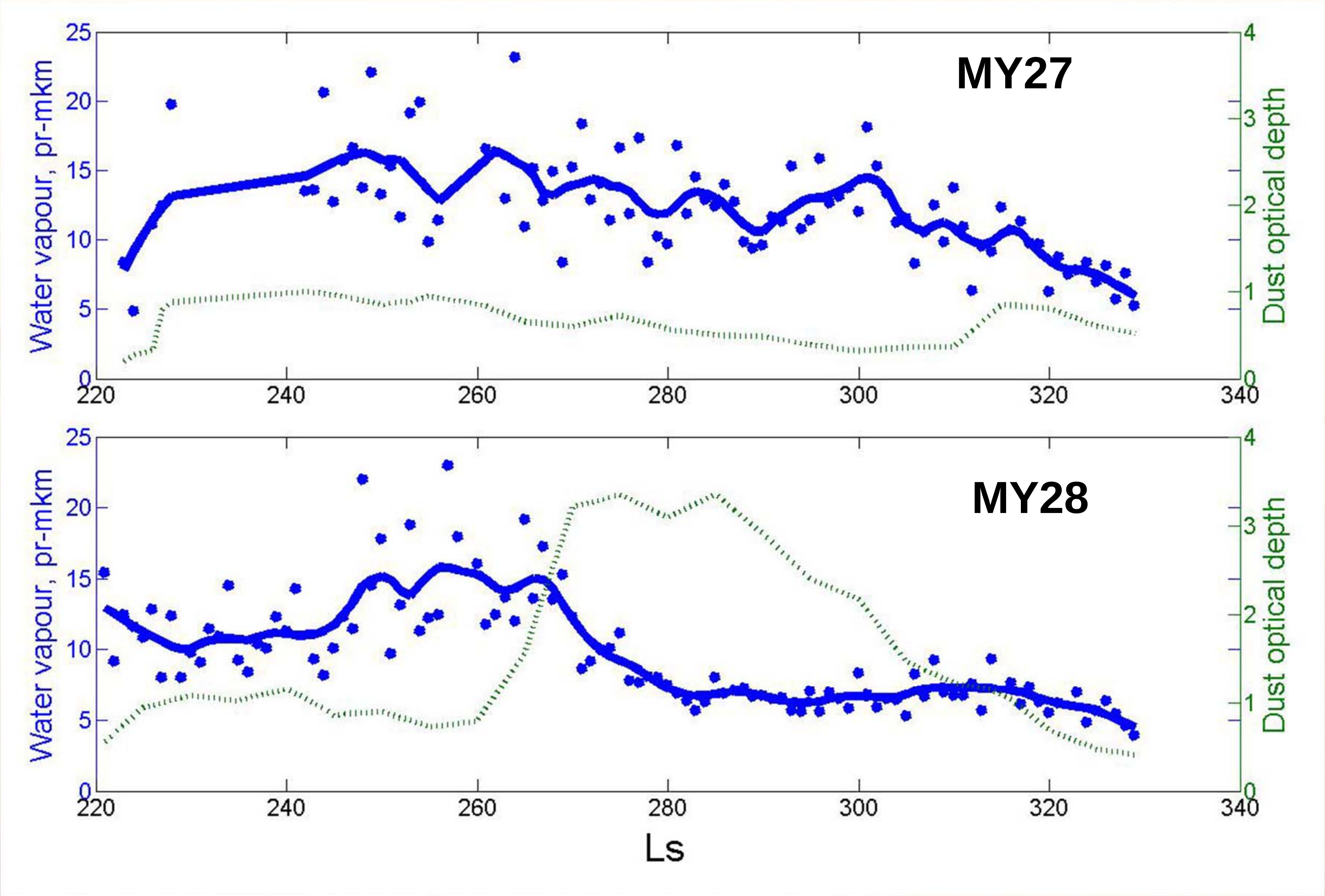


Dust optical depth for 1,38 μ

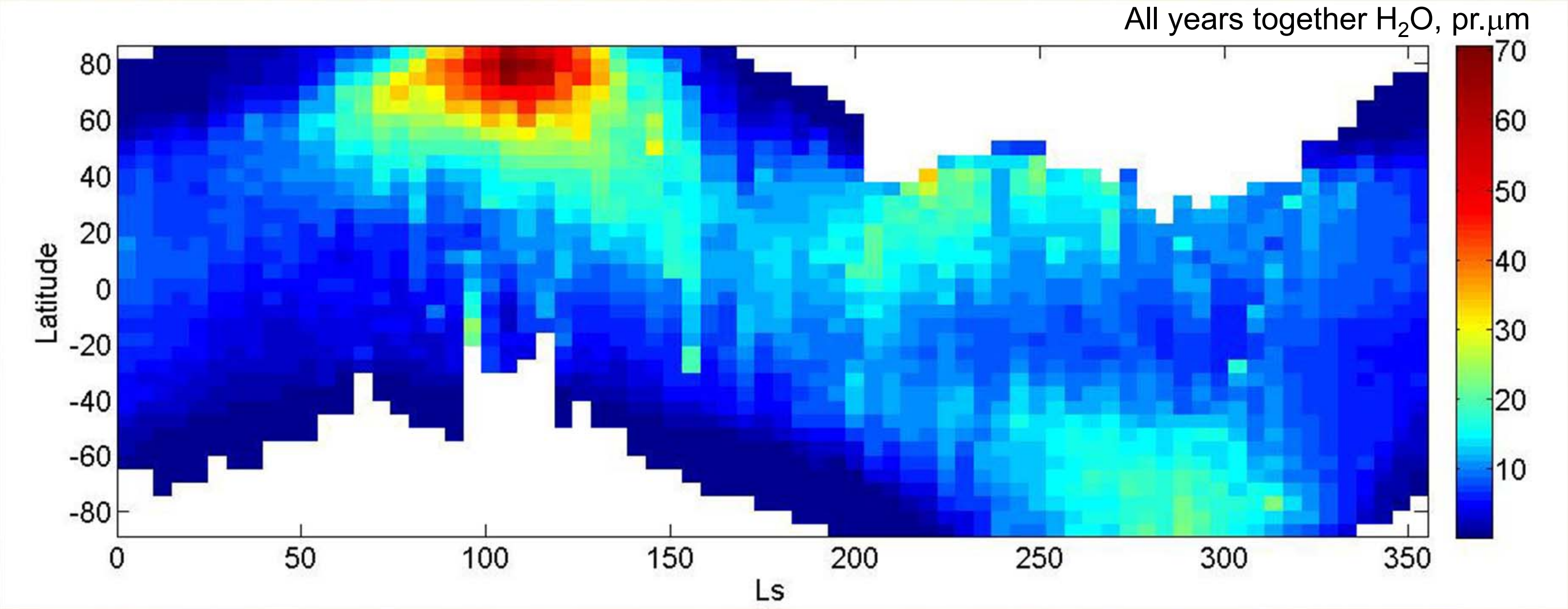
A seasonal map of the H_2O distribution by SPICAM (v.2012)



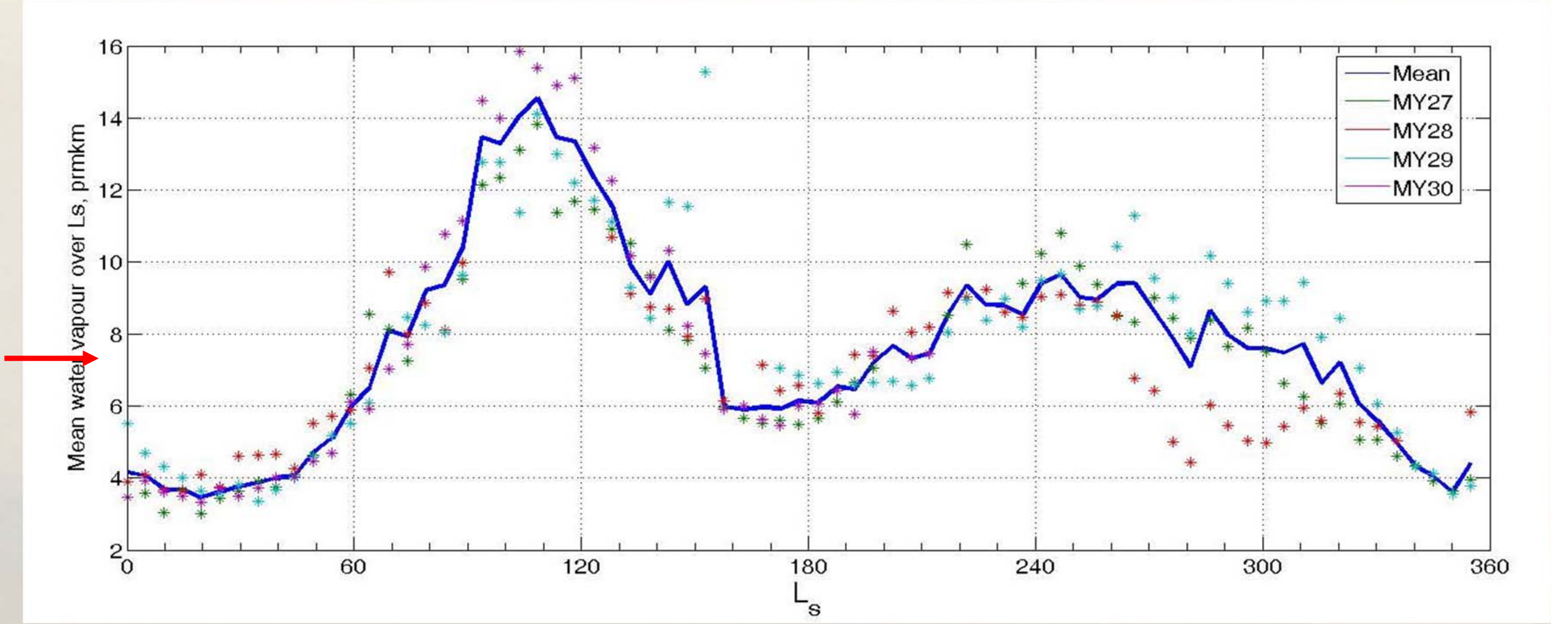
Example of water vapour loss during global dust storm at MY28
(seasonal dependence for H_2O averaged on latitude stripe (-45:-55))



Annual water vapour cycle by SPICAM IR



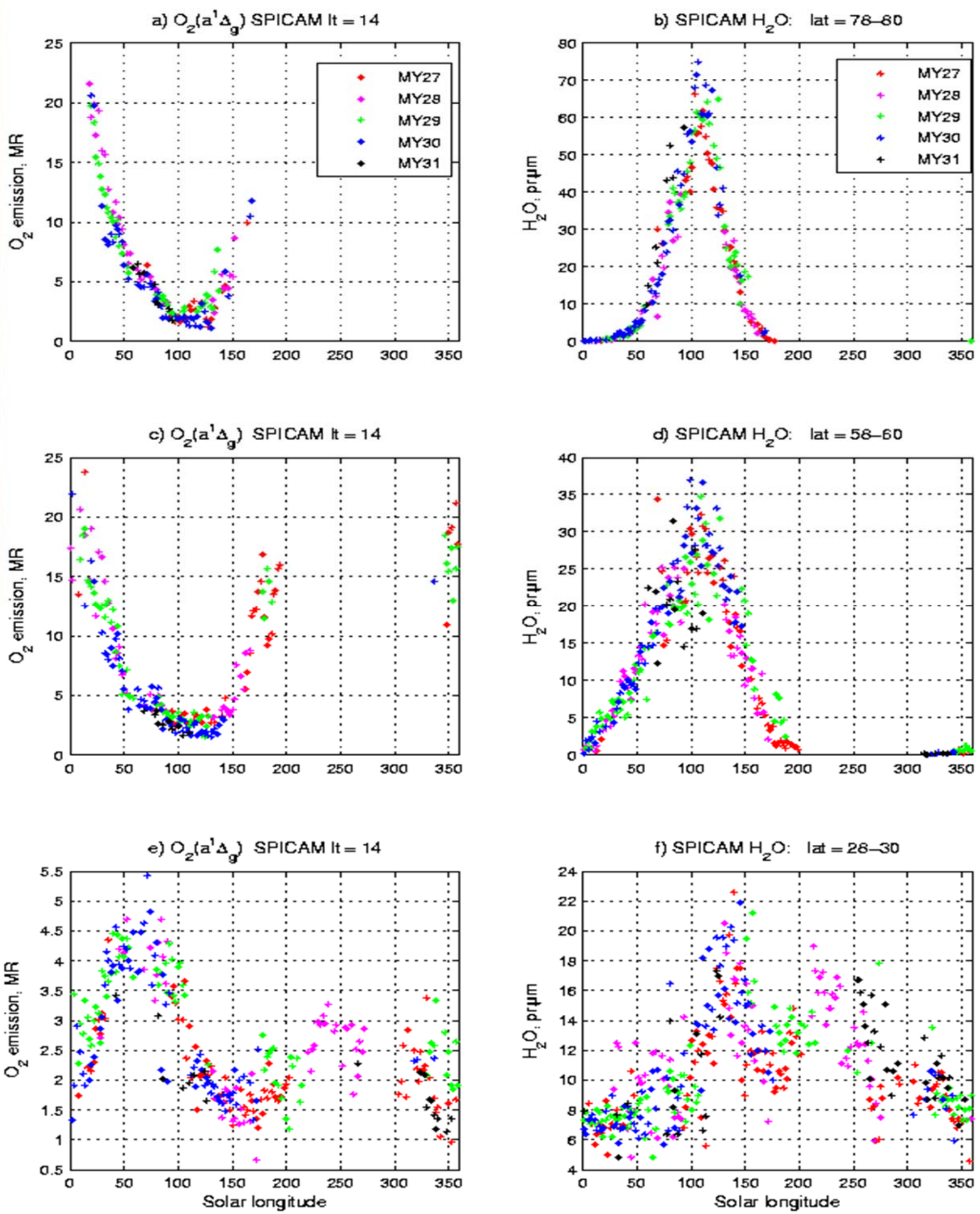
1 km³ of ice



Comparison with H_2O

Northern hemisphere

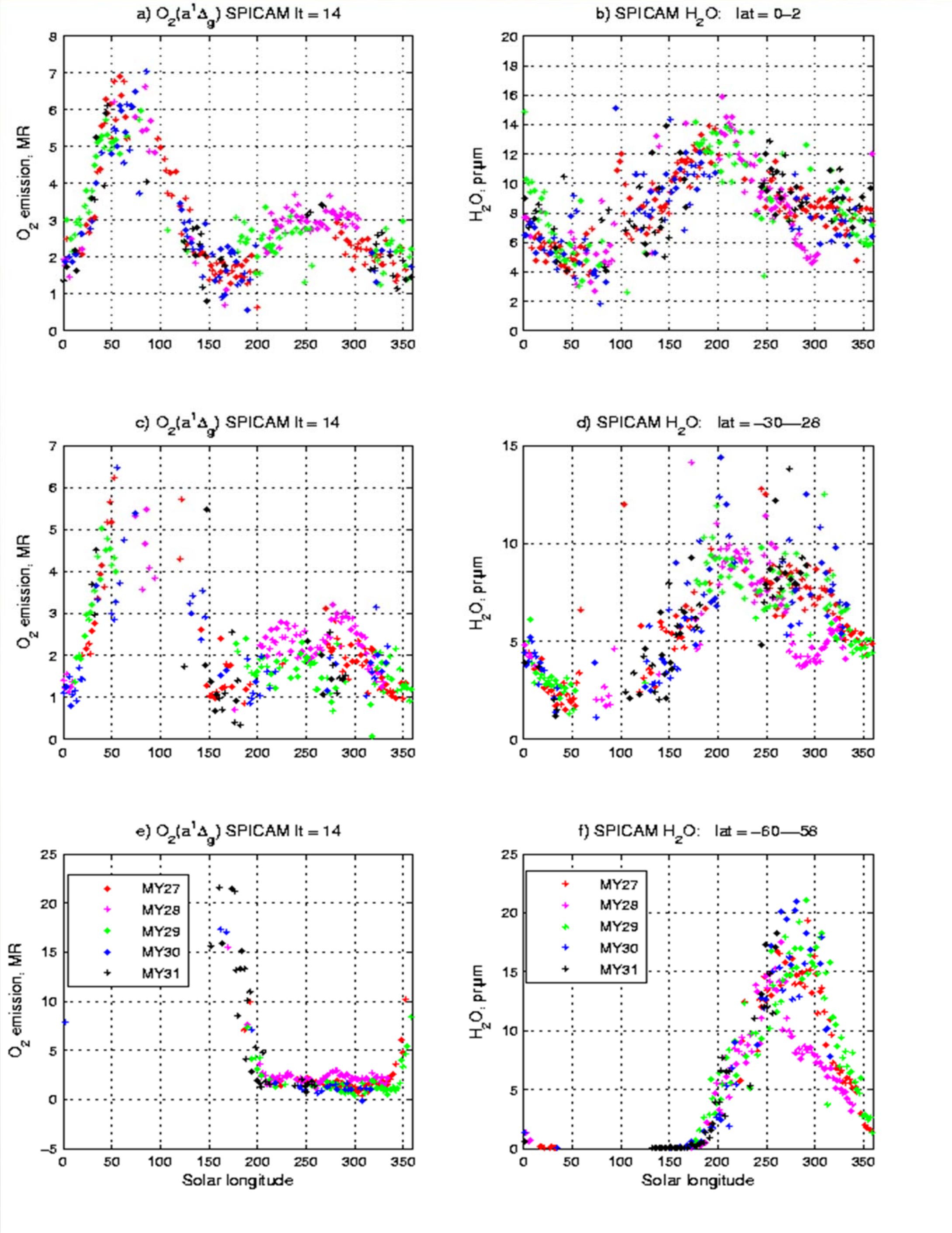
H_2O abundance for MY27-31



Comparison with H_2O

Equator and southern hemisphere

H_2O abundance for MY27-31

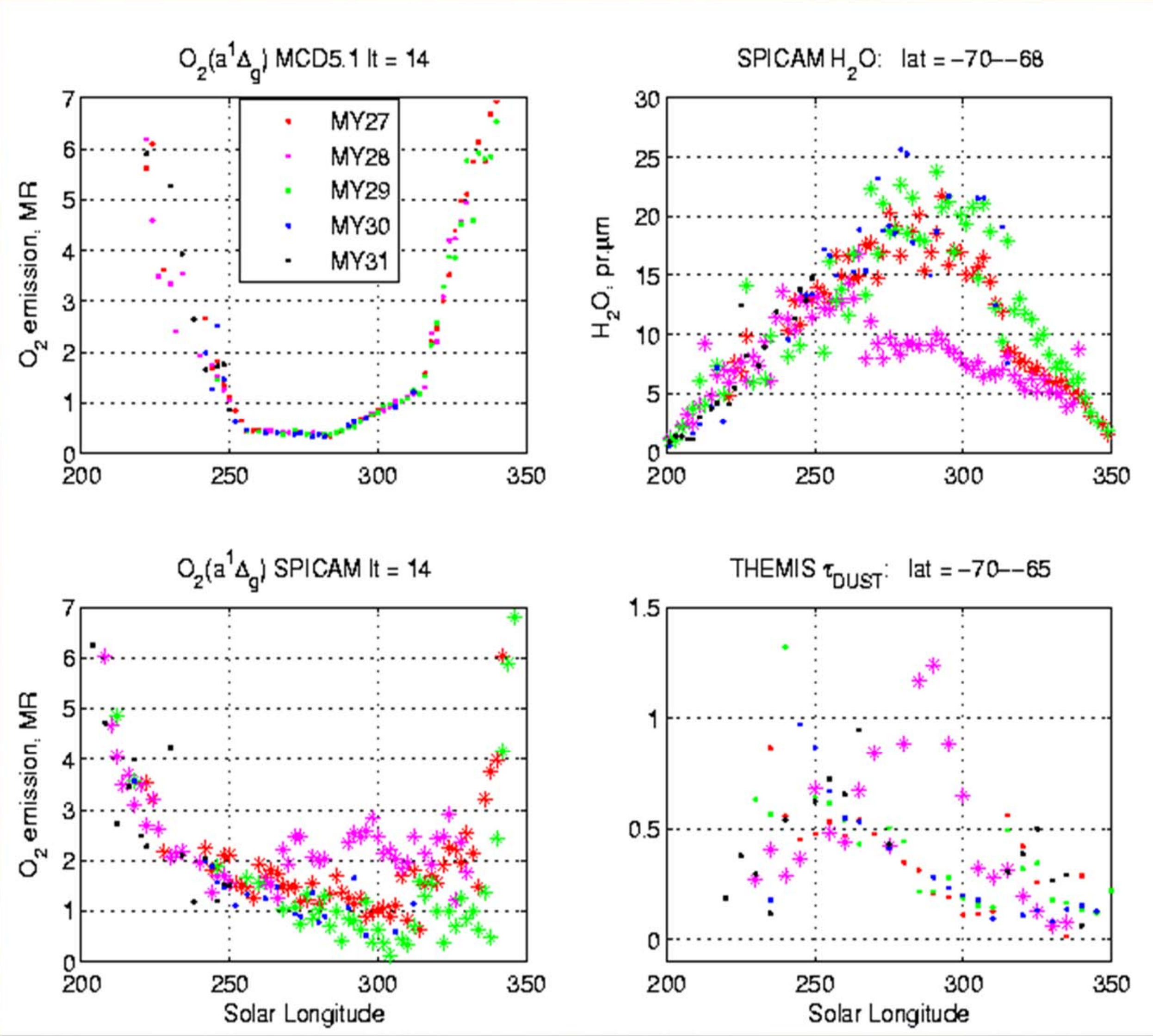


The dust influence

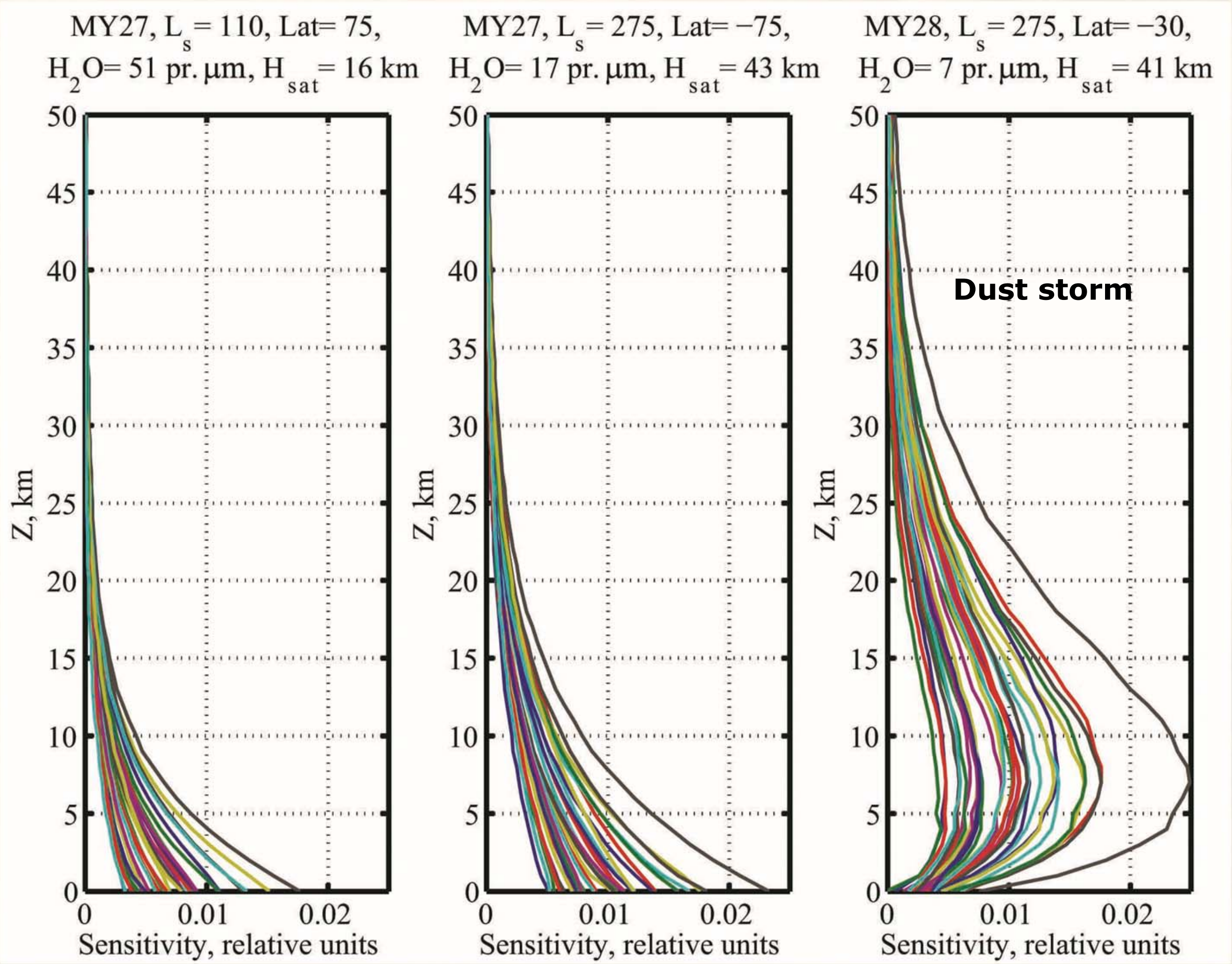
- The maximum of the $O_2(a^1\Delta_g)$ emission in MY28 during the global dust storm is anticorrelated to a minimum of the H_2O column.

- the observed decrease of H_2O during the global dust storm cannot be fully attributed to the masking effect of dust, and indicates a real decrease of water amount near or above the surface.

- the $O_2(a^1\Delta_g)$ emission is larger during the global dust storm supports the idea that the smaller H_2O abundance retrieved by SPICAM during the storm are real.



Sensitivity of SPICAM nadir observations to water vapour vertical distribution

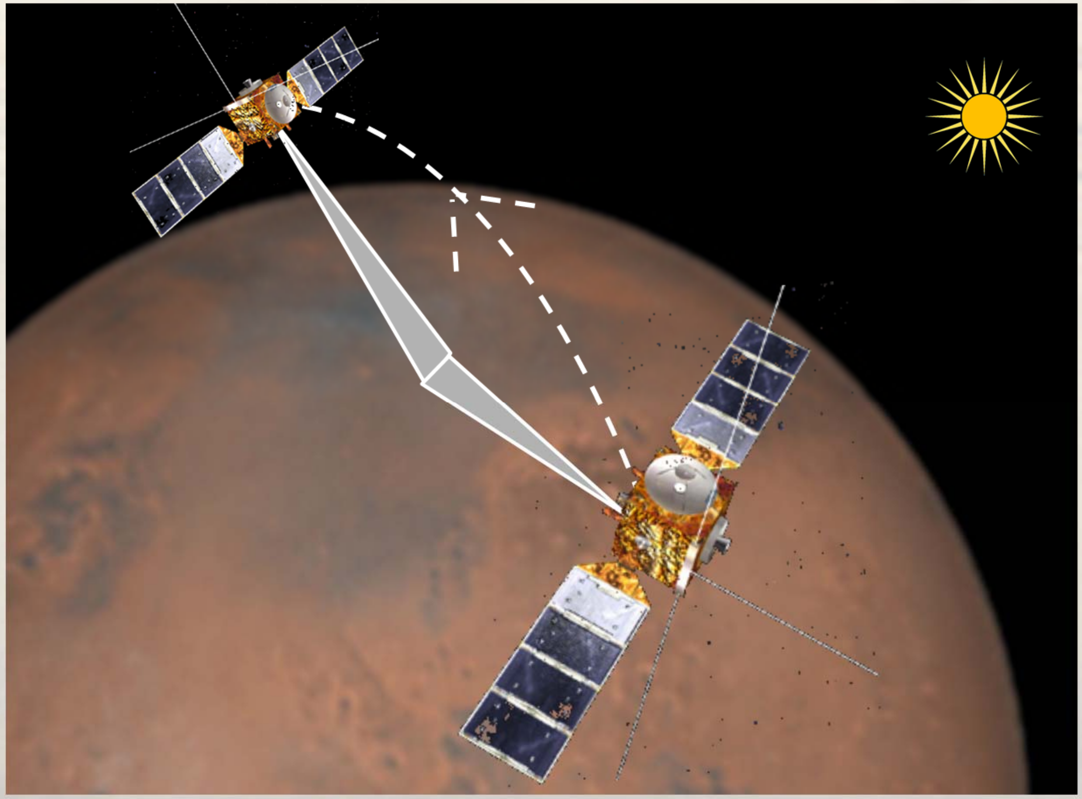


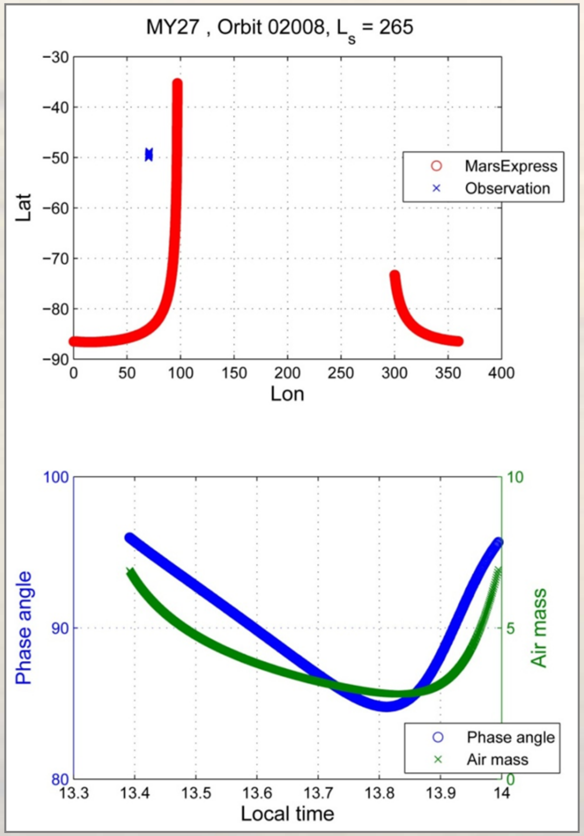
The sensitivity kernels in the 1.38 μm band, a difference between the reference spectrum and the spectrum with additional water at the *j*-th altitude level. Different colors correspond to different wavelengths within the band.

SPICAM EPFs (spot pointing)

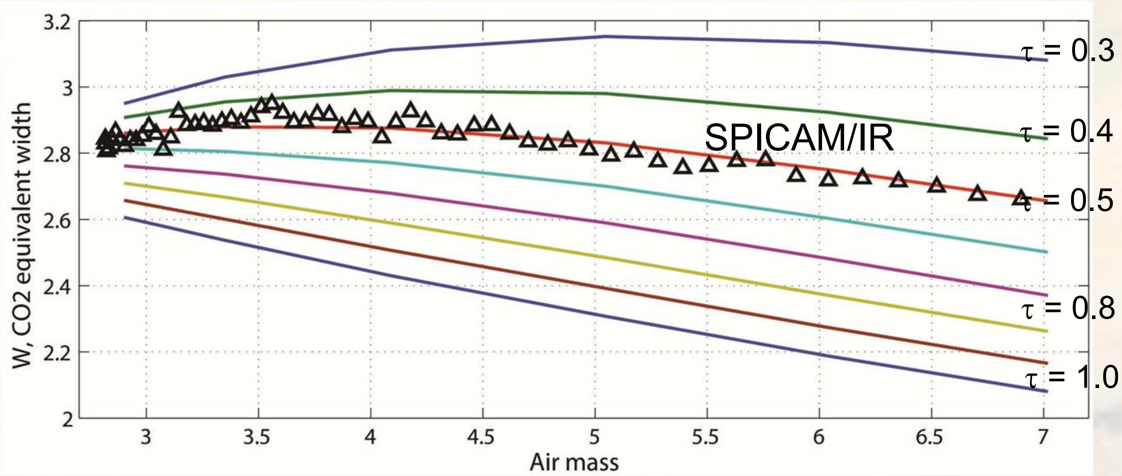
EPF – Emission Phase Functions:

- Pointing at same area in surface
- Wide range of emission and phase angles, almost constant incidence angle
- Use both CO_2 1.43 μ and H_2O 1.38 μ bands
- Fit τ, aerosol height scale, albedo, water abundance, examine vertical distribution of water (**applicable only for certain geometries and dust load**)





1) EPF orbit 2008, CO2 fitting

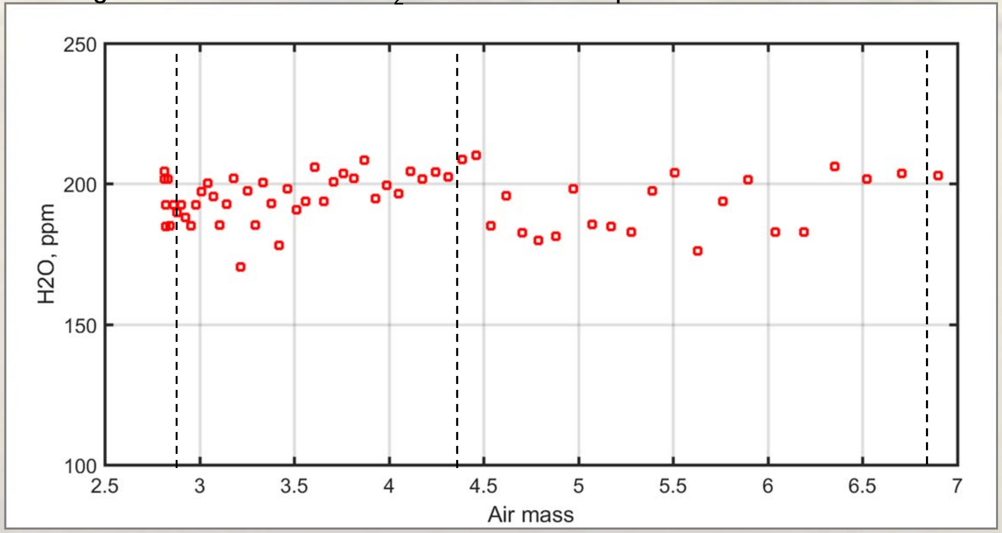


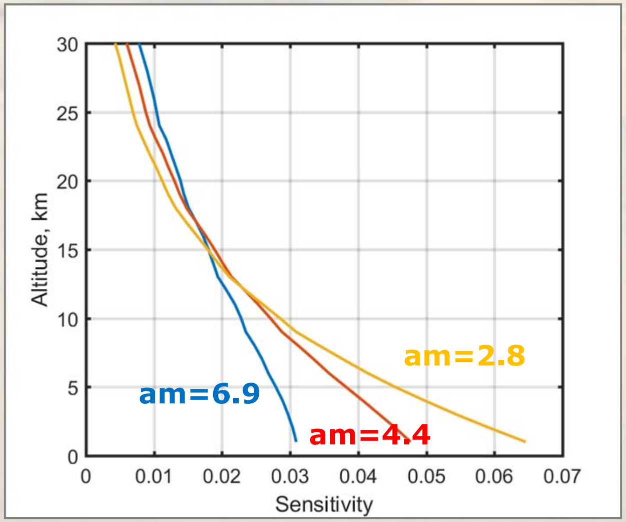
Best fit with:

- t = 0.5 (scaled from THEMIS data is t = 0.44)
- Aerosol height scale Ha=14 km
- Water abundance and Albedo(eta)

2) EPF orbit 2008, water retrieval

Assuming constant value of H_2O in the atmosphere below saturation level (44 km)





No evidences of noticeable deviation from uniform distribution at low altitudes
More orbits wanted at southern hemisphere summer

Mars water vapor abundance from SPICAM IR dayside observations – bulk reprocessing required

Retrievment procedure (version 2012):

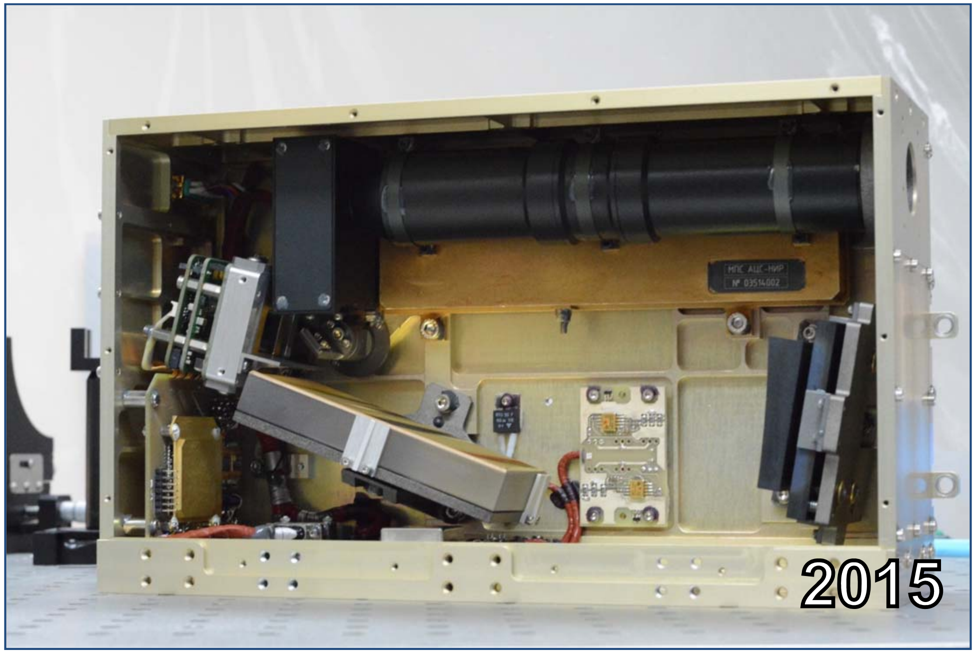
- Assuming constant value of H_2O in the atmosphere below saturation level, and decrease according to saturation curve above it
- Solar spectrum (Fiorenza and Formisano, 2005) with MAWD data correction
- Spectroscopic database: HITRAN 2004, broadening scale factor of 1.7
- Climate from MCD v4.3
- SHDOM, scaled THEMIS dust and ice data

Retrievment procedure (version 2018):

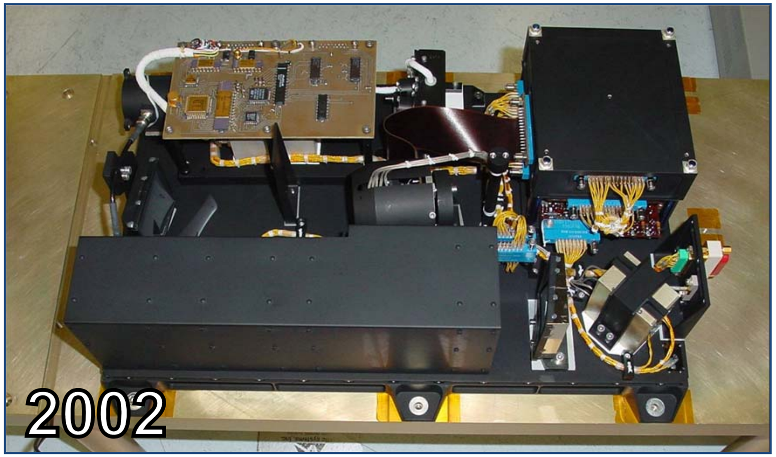
- Constant value of H_2O in the atmosphere below saturation level, and decrease according to saturation curve above it ? / MCD profile
- Solar spectrum from ACS NIR for 1.38 μ range
- Spectroscopic database: HITRAN 2016
- Climate from MCD v5.2 / PFS ? / ACS TIRVIM from mid 2018
- SHDOM, scaled THEMIS dust and ice data / PFS ? / TIRVIM from mid 2018

ACS NIR - Near-IR echelle-AOTF spectrometer

- Spectral range: 0.73 – 1.6 μ (not covered by other TGO instruments)
- Spectral resolving power $\lambda/\Delta\lambda$: ~25 000
- Operation modes: Nadir, Solar Occultation
- FOV: 2°×0.02° nadir, 0.3°×0.02° occultation
- Mass / Power / Data rate: 3.2 kg / 6 W / 0.2 Gbit/day

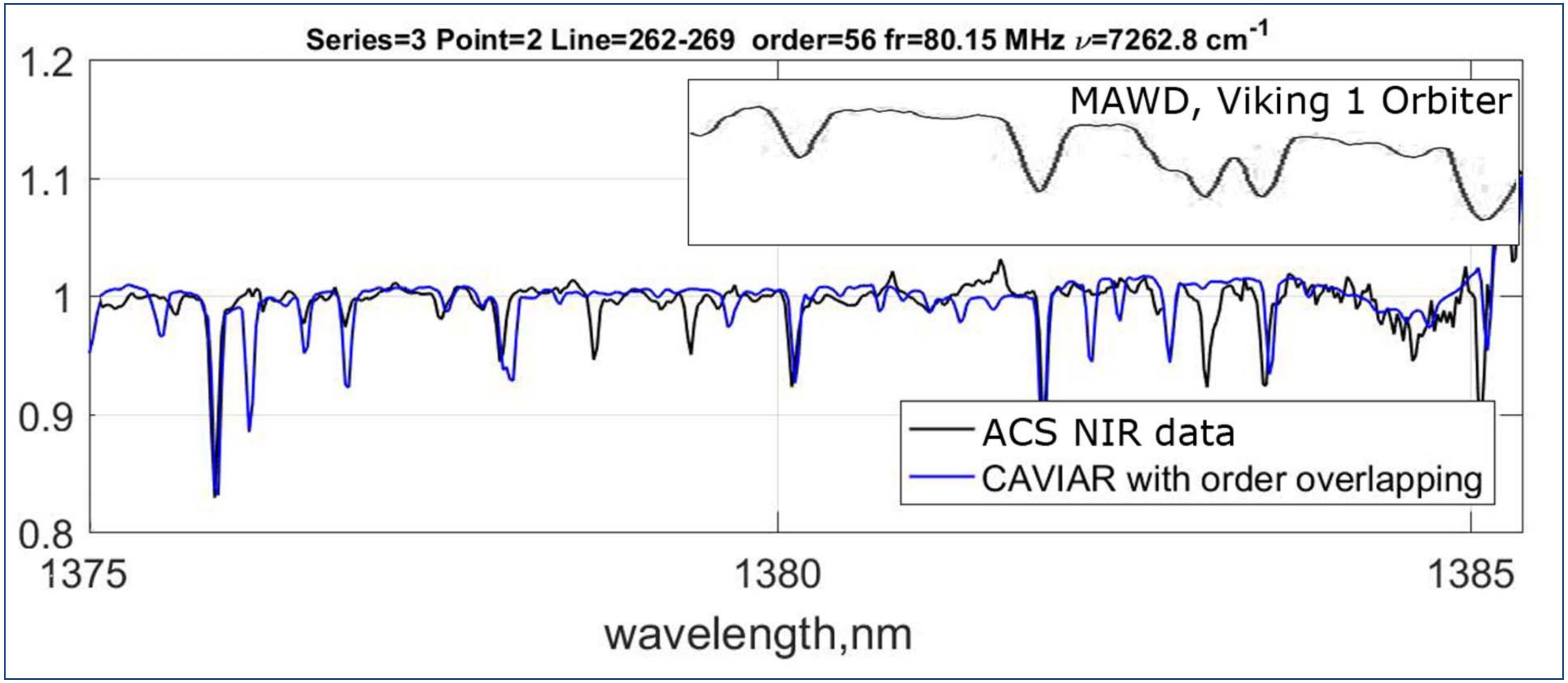


SPICAM IR/MEX,
1 – 1.7 μ, $\lambda/\Delta\lambda$ ~2000



ACS NIR high resolution extraterrestrial solar spectrum

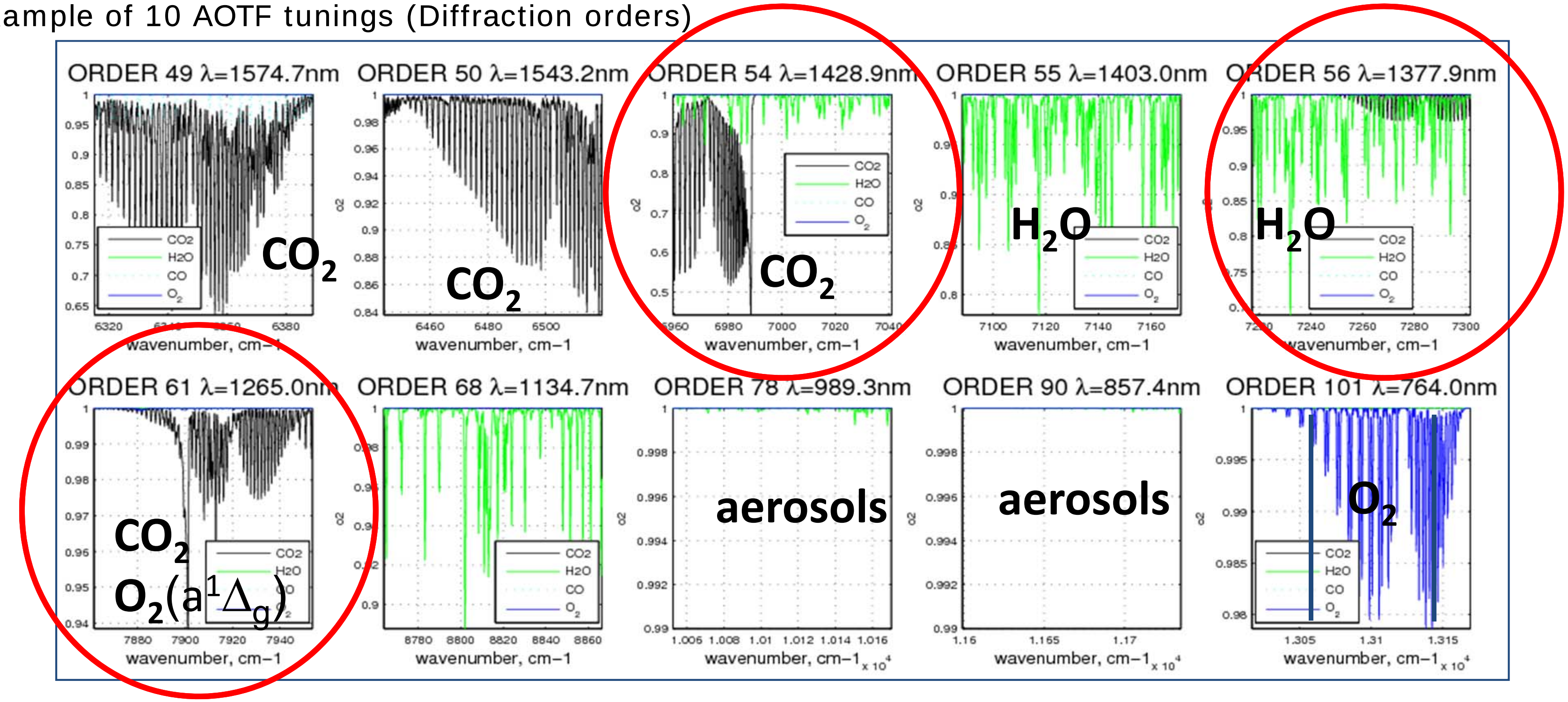
- Measured during TGO cruise to Mars
- Flat field correction in progress
- Comparison with Menang et al. (2013), A high-resolution near-infrared extraterrestrial solar spectrum derived from ground-based Fourier transform spectrometer measurements (CAVIAR dataset) – differences inside water bands



ACS NIR measurements

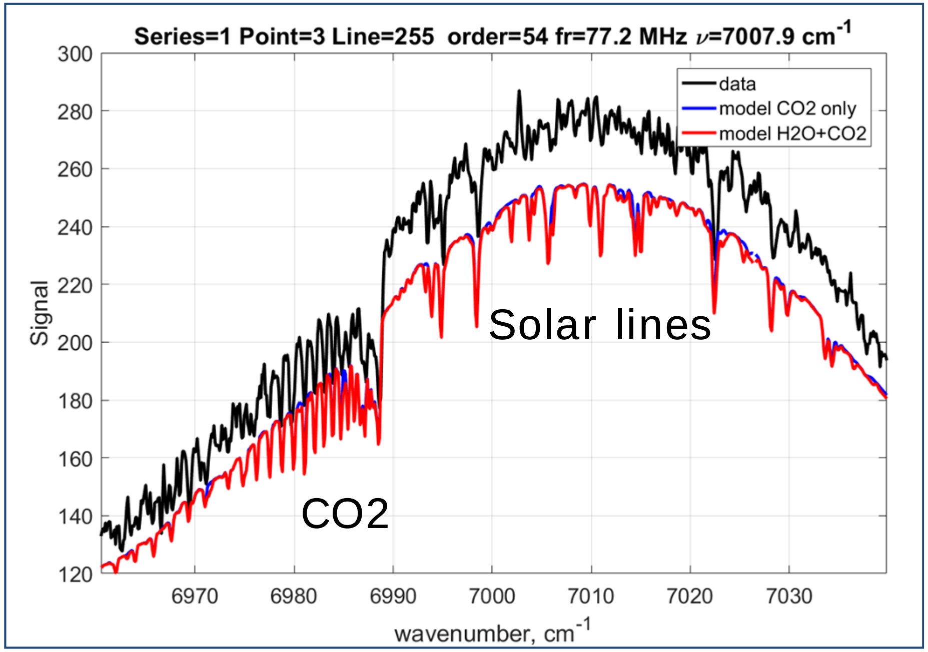
- AOTF/Echelle spectrometer: Principle similar to SOIR/VEx or NOMAD
- Up to 10 orders per one measurement session (10 for SO, 3 for Nadir)
- Onboard averaging 1-96 frames for each order
- Option to do image (640*480) averaging into 1-5 frame stripes

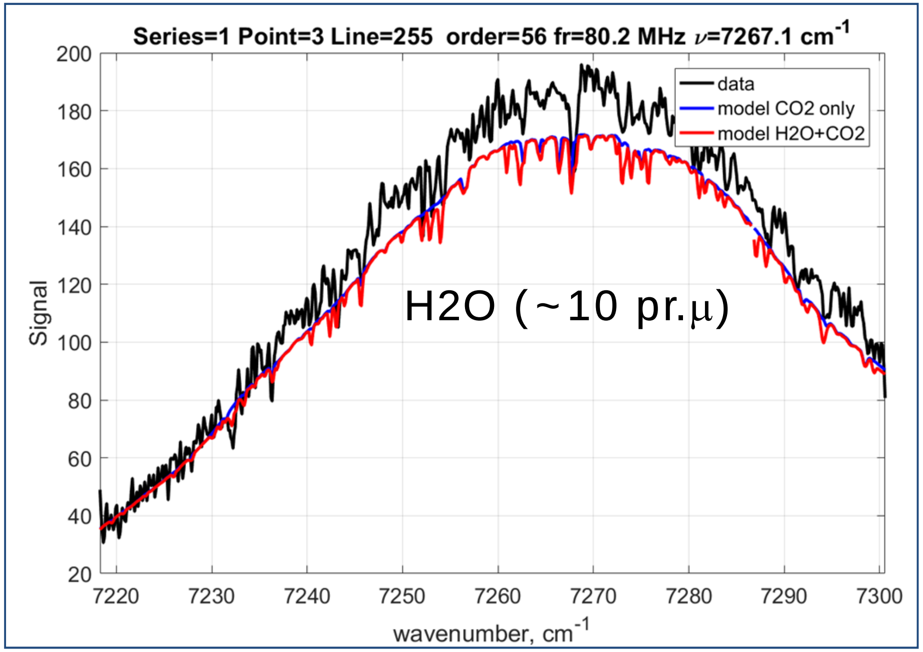
An example of 10 AOTF tunings (Diffraction orders)



ACS NIR first nadir measurements from MCO

- 10 s integration time, low gain, detector Peltier cooler off
- Parameters to be tuned during first days of commissioning (in two weeks from now)



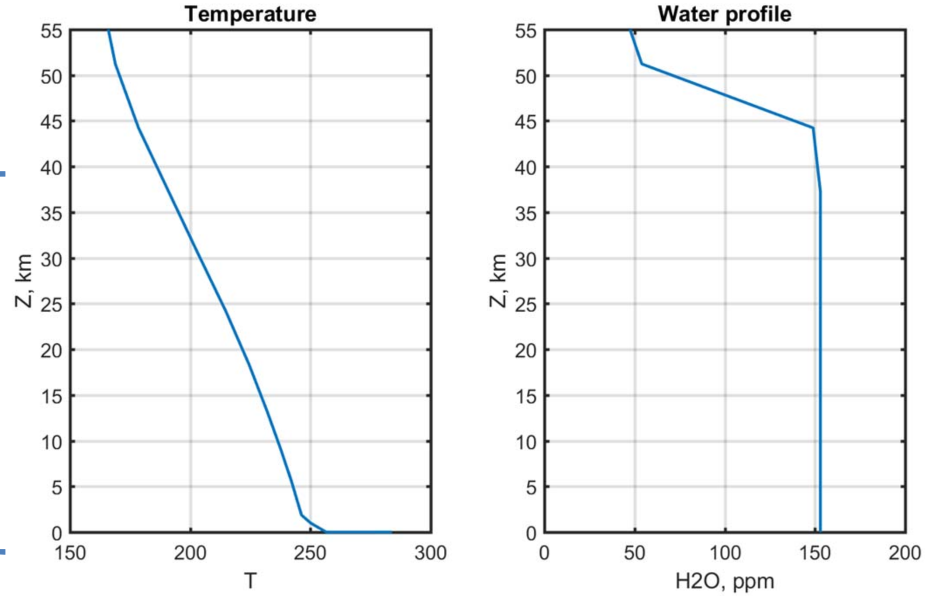


ACS+SPICAM measurements

Column from SPICAM, ACS NIR/TIRVIM

ACS MIR solar occ.

ACS TIRIM nadir



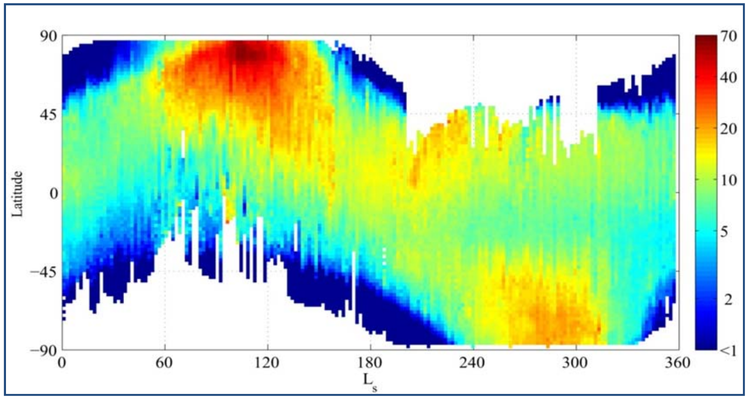
ACS and SPICAM solar occ.

Clues from SPICAM EPF and synergistic retrievals (FM talk)

•Plus aerosols from TIRVIM nadirs and aerosols profiles from occultations

Conclusion

➢ Longest and still growing dataset of O2 emission, water vapour abundance, albedo and saturation level by SPICAM IR/MEX. A bulk reprocessing will be applied with the latest inputs.



➢From now on SPICAM IR should use all dayside possibilities to support joint measurements with ACS NIR – two instruments measuring same wavelength range, and SPICAM can measure slightly higher latitudes (TGO goes max to 74)

➢SPICAM IR can and should perform spot pointing measurements at locations and seasons with expected big dust load. Range of air mass values should be as big as possible.

➢ ACS NIR nadir measurements will be tuned and performed regularly (up to 12 per day)

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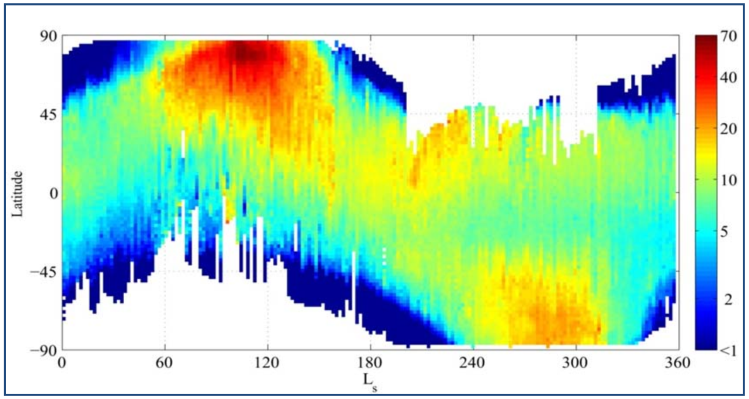

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