MARS SCIENCE WORKSHOP
"FROM MARS EXPRESS TO EXOMARS"

ESAC (ESA), MADRID | SPAIN | 27–28 FEBRUARY 2018

NEW DATASET OF ATMOSPHERIC PARAMETERS RETRIEVED BY PFS-MEX

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THE PLANETARY FOURIER SPECTROMETER

- PFS is an infrared FT spectrometer optimized for atmospheric studies.
- Spectral range: 1.2 to 45 μm. (Thermal+Near Infrared)
- Two spectral channels, SWC (1.16–5.5 μm or 1700–8600 cm^{-1}) and LWC (5.5–45 μm or 250–1700 cm^{-1}).
- Spectral resolution: 1.3 cm^{-1} (FWHM). Sampling step: 1 cm^{-1}
- **IFOV** (FWHM): 1.6° for the SWC; 2.8° for the LWC corresponding to a spatial resolution of 7 and 12 km respectively, when Mars is observed from an height of 250 km (nominal height of the pericenter).

PFS is one of the suite of instruments onboard the **MARS EXPRESS** (ESA) mission

Mars Express launched from Baikonur on **2 June 2003**

Arrived on Mars on **December 2003**

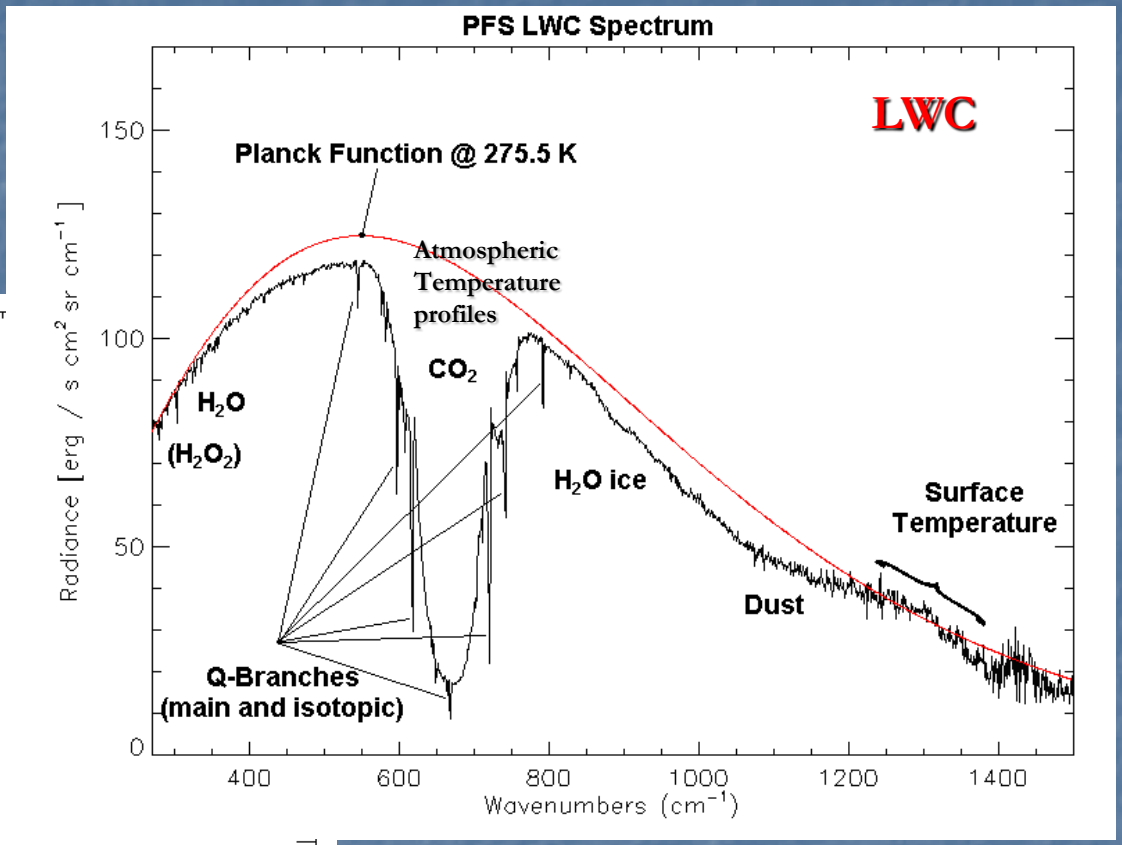
PFS first observation of Mars on January 2004

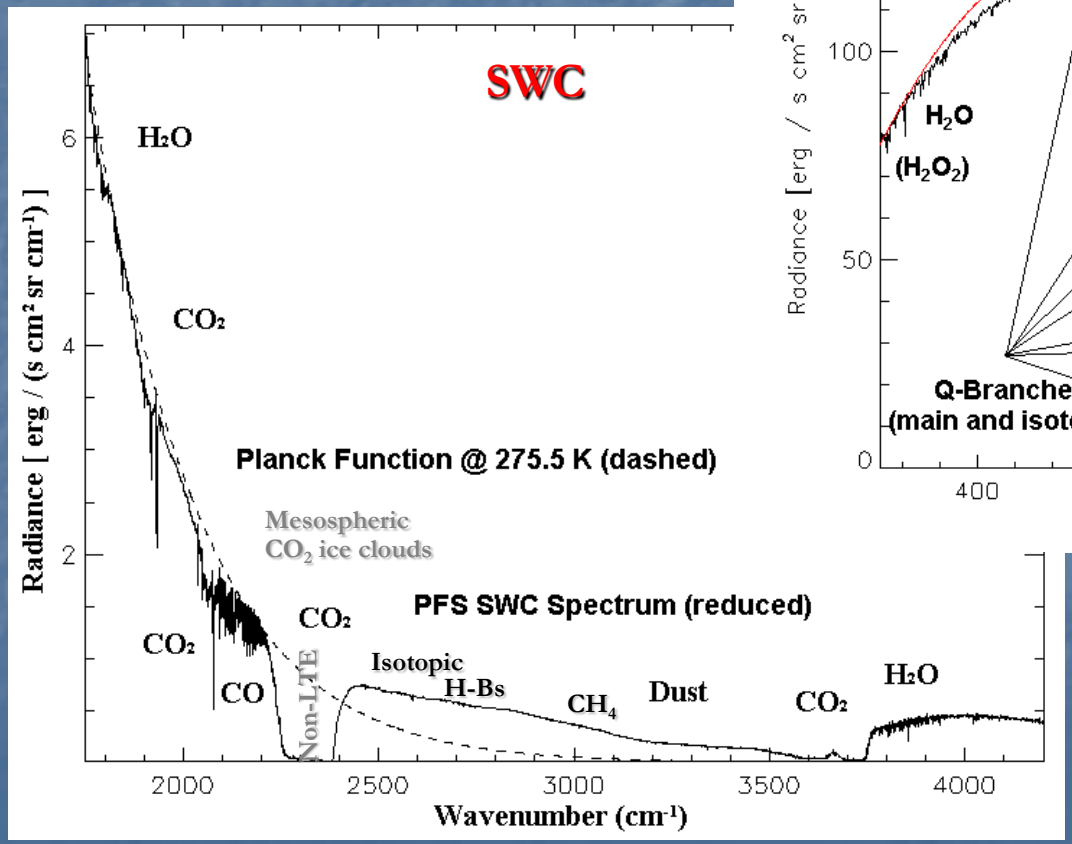
14+ years of atmospheric monitoring

2017-2018 MEx mission extension confirmed

Mission extension till the end of 2020 currently under discussion

EXAMPLE OF PFS SPECTRA

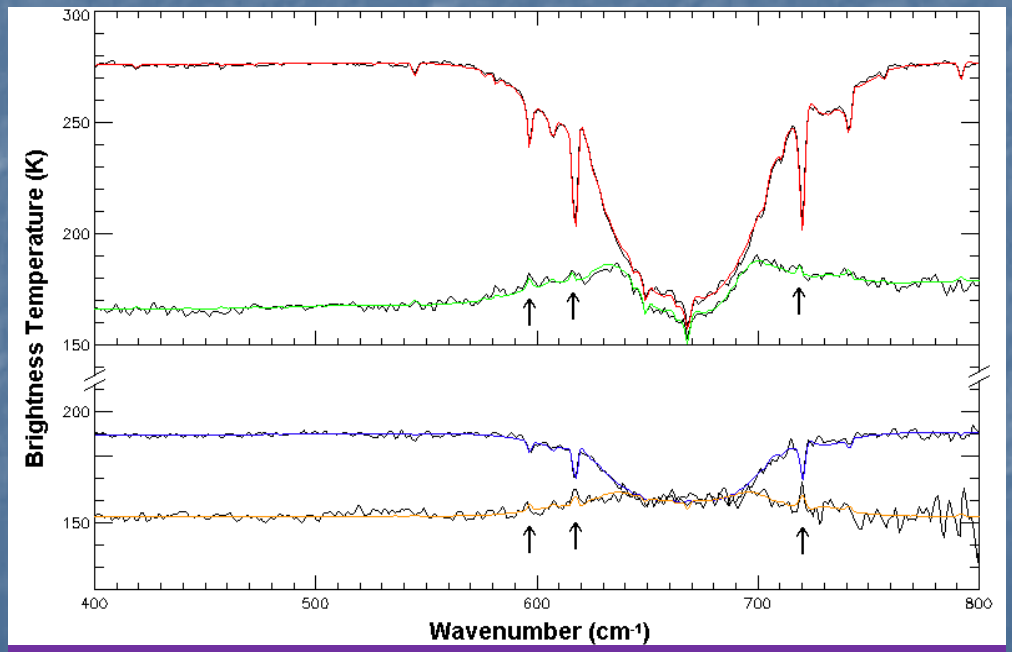




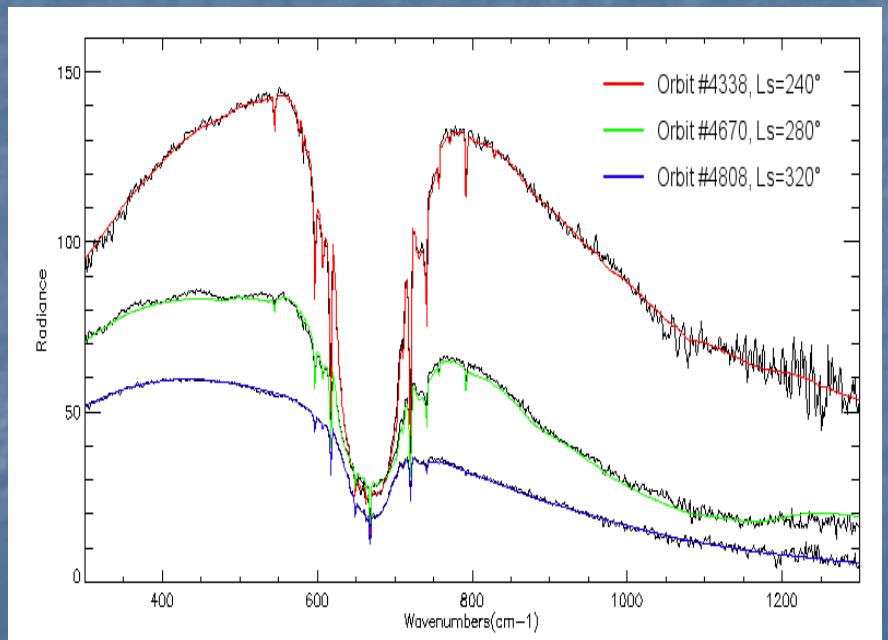
NEW PFS RETRIEVALS

- Temperature vertical profiles surface temperature, water ice and dust opacities
- Improved PFS LWC calibration (Saggin et al., 2011) → whole dataset reprocessed
- Improved and optimized Retrieval code (Grassi et al., 2005; Wolkenberg et al., 2018)
  - Bayesian approach with Levenberg-Marquardt method
  - New definition of Sa matrix
  - Increased max. number of iterations
  - Stabilization gamma parameter varies with iterations
  - New derivation of surface temperature
  - Optimization for dust storms

The relatively high spectral resolution of PFS allows the detection of different thermal gradients in the atmosphere, as demonstrated by the effective modeling in the same spectrum of absorbing and emitting Q-branches.



Typical quality of PFS spectra modeling for different thermal conditions of the atmosphere. Black curves: single spectra measured by PFS. Colored curves: synthetic spectra.

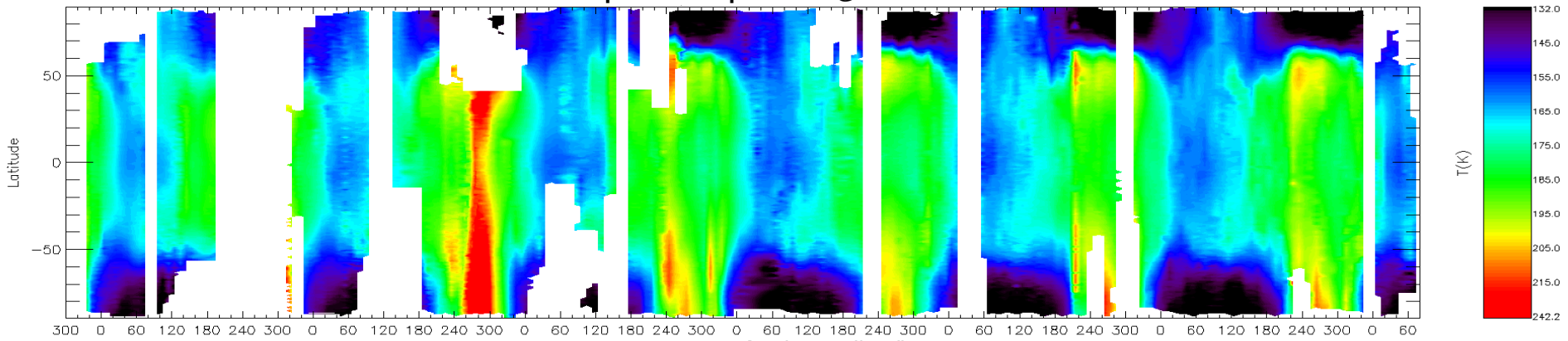


Typical quality of PFS spectra modeling during global dust storm (MY28). Black curves: single spectra measured by PFS. Colored curves: synthetic spectra.

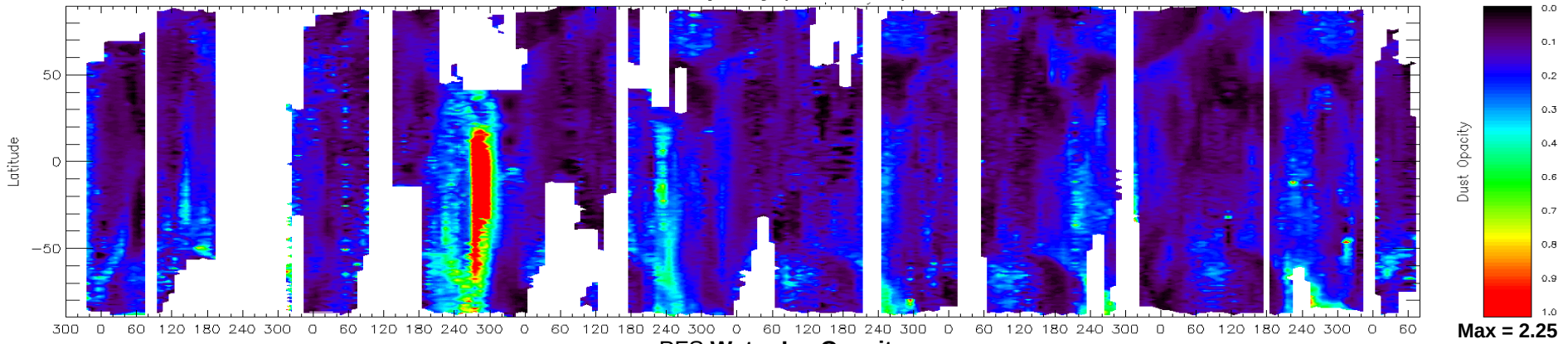
12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

MY 26 | MY 27 | MY 28 | MY 29 | MY 30 | MY 31 | MY 32 | MY 33

Atmospheric Temperature @ 0.5 mbar

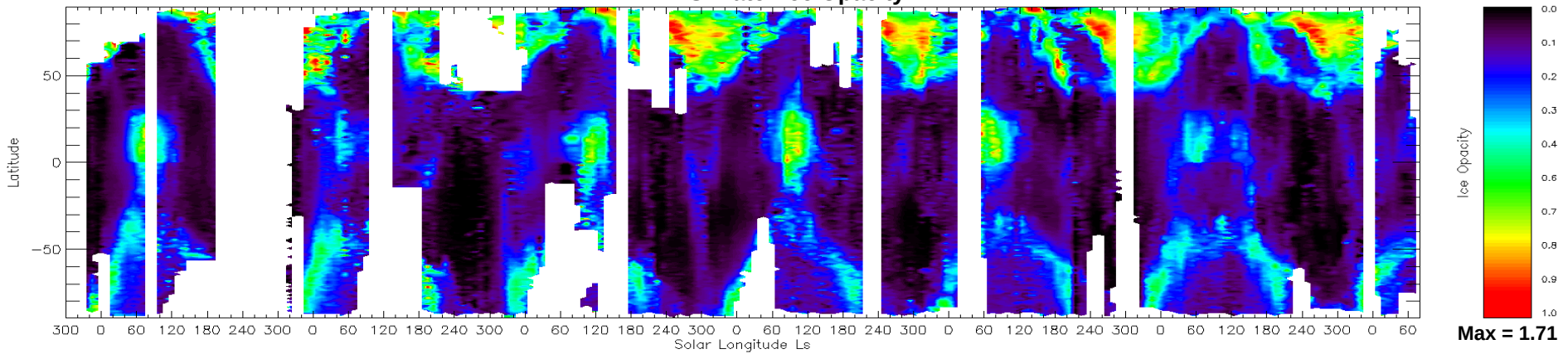


PFS **Dust Opacity** (normalized)



Max = 2.25

PFS **Water Ice Opacity**



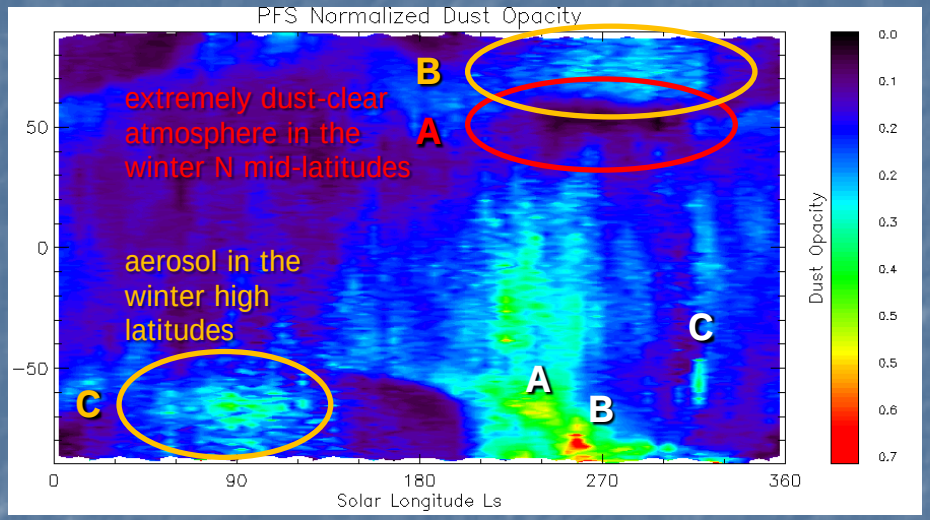
Max = 1.71

12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

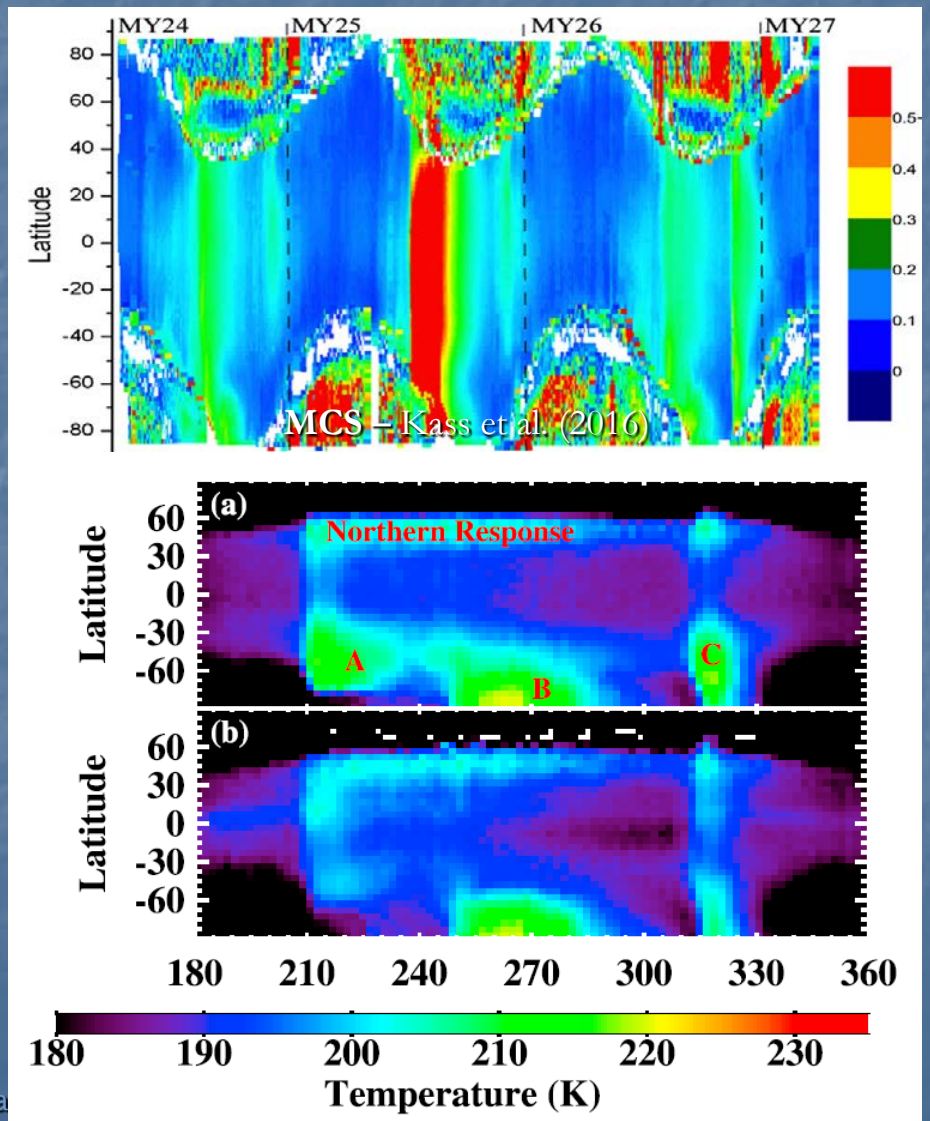
SUCCESSFUL RETRIEVAL OF DUST AND ICE OPACITIES IN THE POLAR REGIONS

DUST

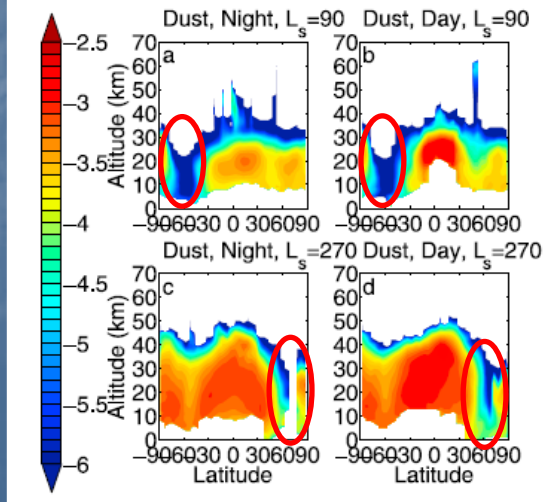
PFS



TES - Horne et al. (2009)



MCS-MRO – Heavens et al. (2011, 2014)



The region of extremely dust clear air in the winter tropics has also been observed by MCS-MRO.

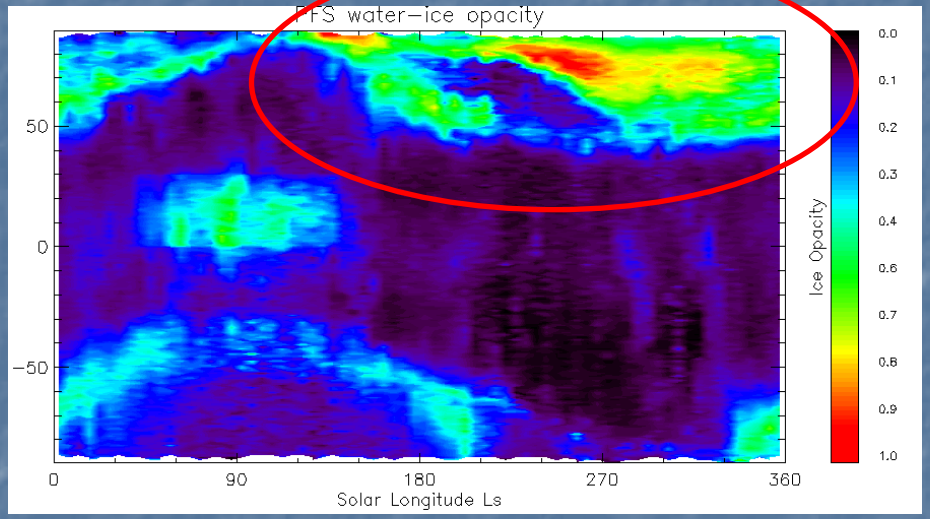
Aerosol in the winter high latitudes also observed by MCS (likely CO_2 ice retrieved as dust)

12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

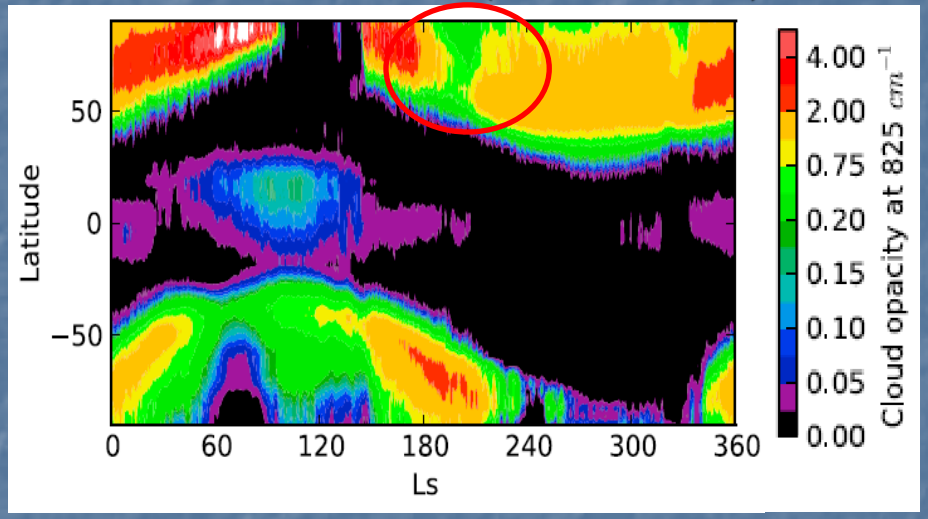
SUCCESSFUL RETRIEVAL OF DUST AND ICE OPACITIES IN THE POLAR REGIONS

ICE

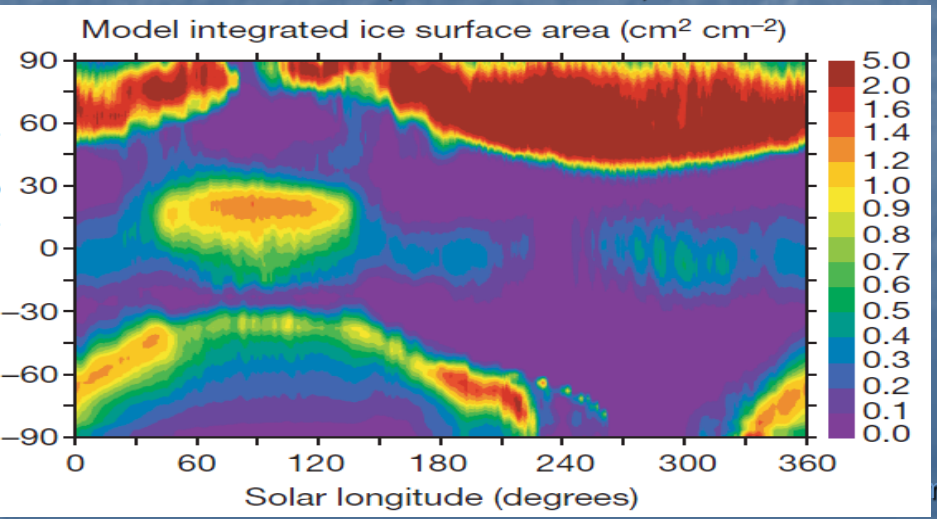
PFS



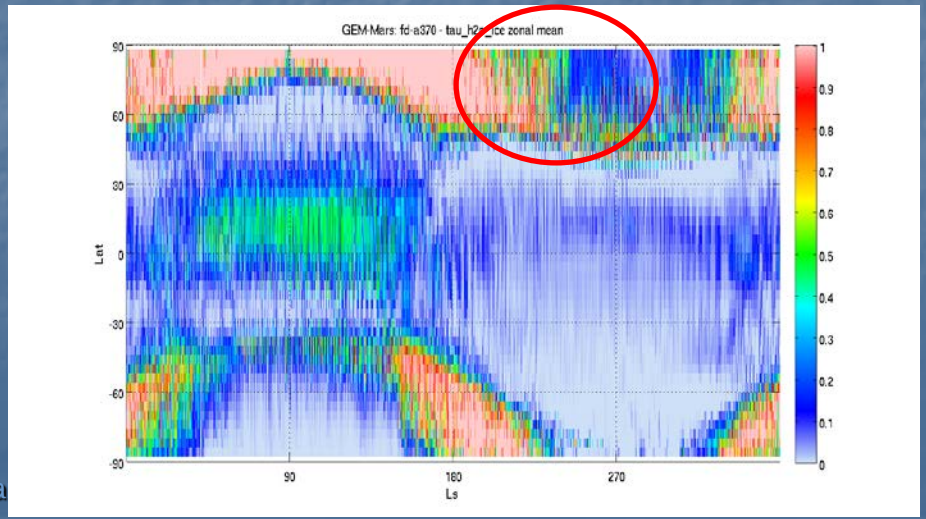
LMD with improved microphysics and radiatively active water ice clouds (Navarro et al., 2014)



LMD (Lefèvre et al., 2008)

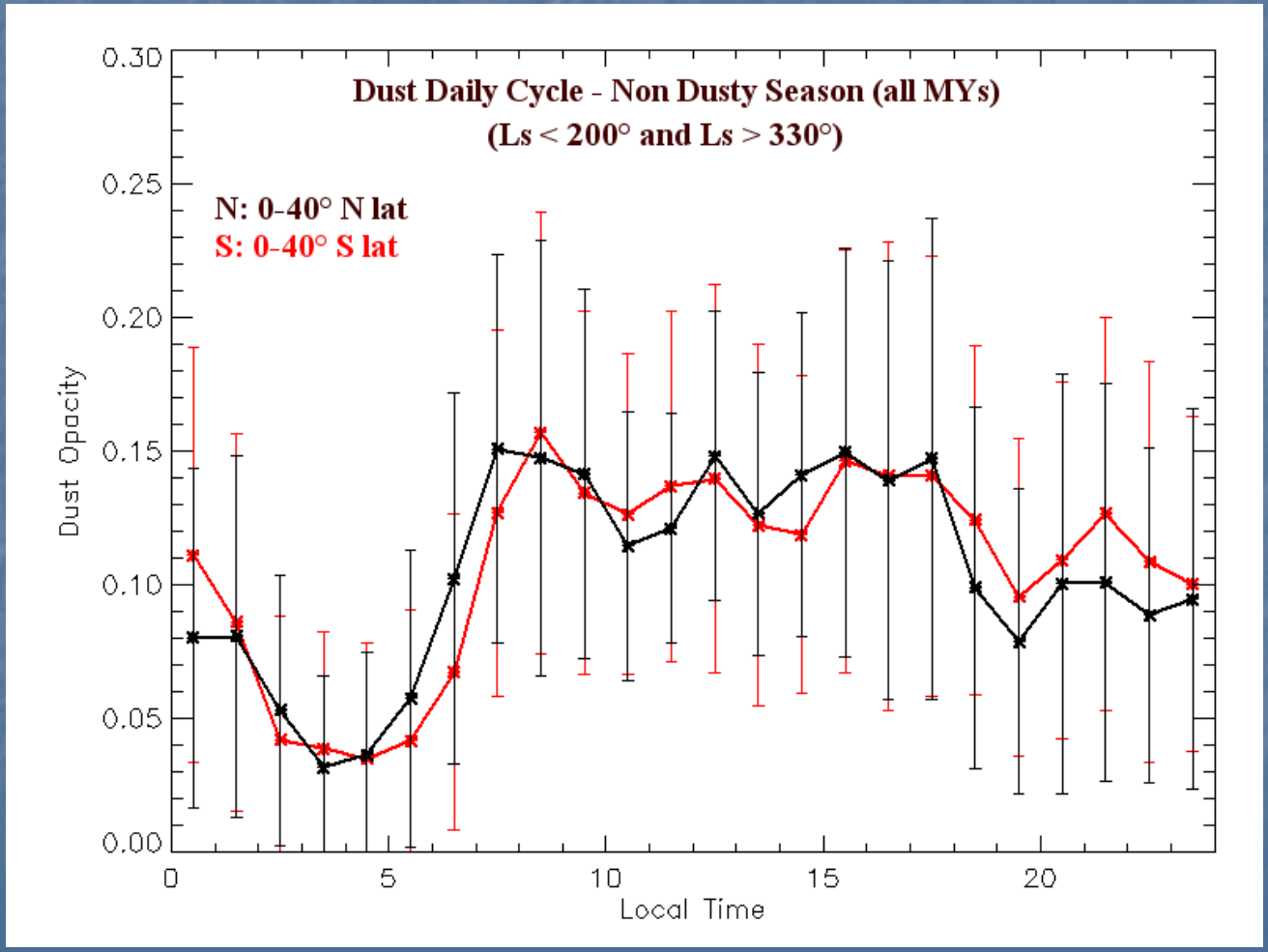


GEM-Mars (Neary and Daerden, 2017)



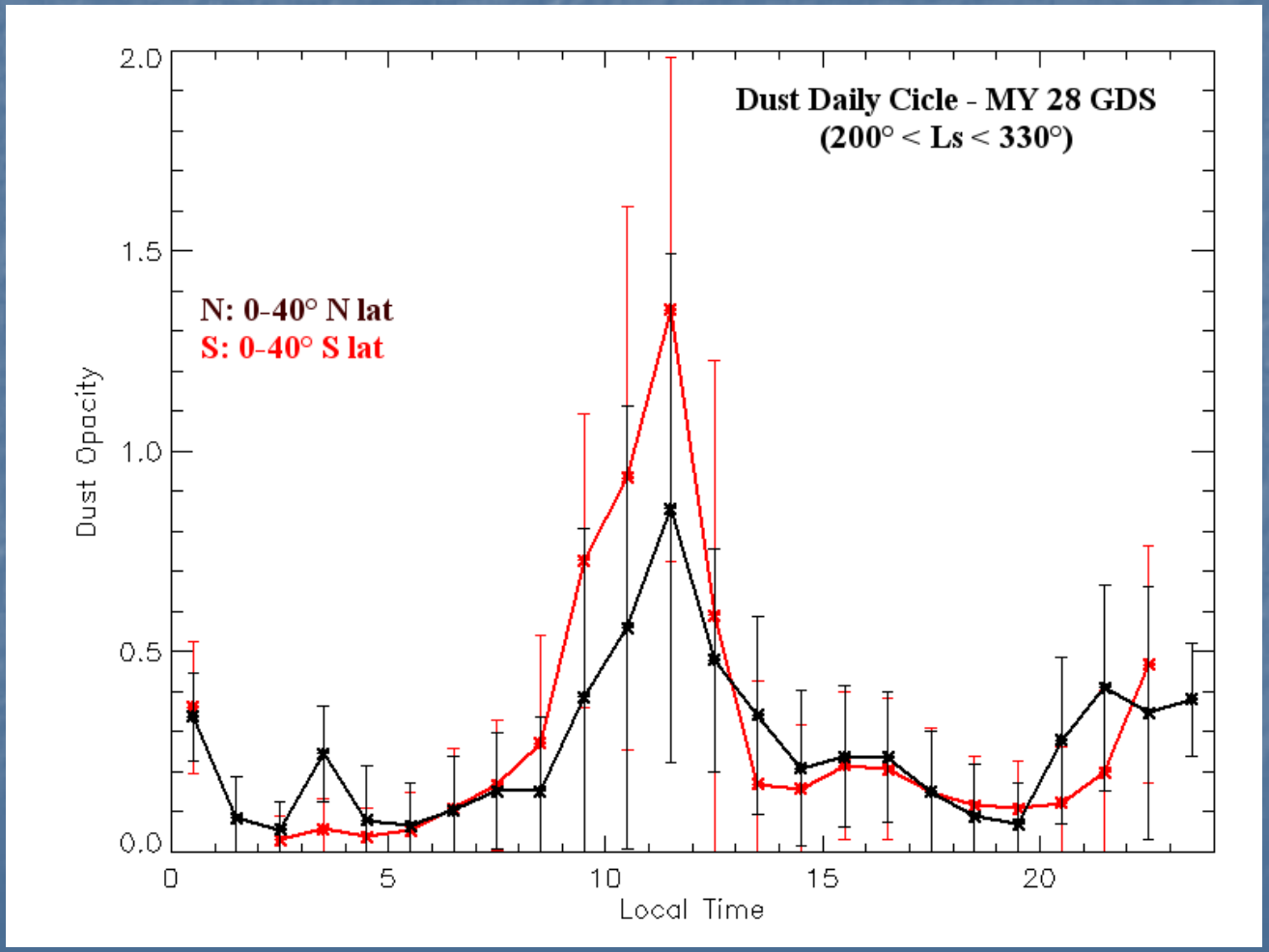
DUST DAILY CYCLE

PFS/MEX PERFORMS OBSERVATIONS AT ALL LTS



DUST DAILY CYCLE

PFS/MEX PERFORMS OBSERVATIONS AT ALL LTS

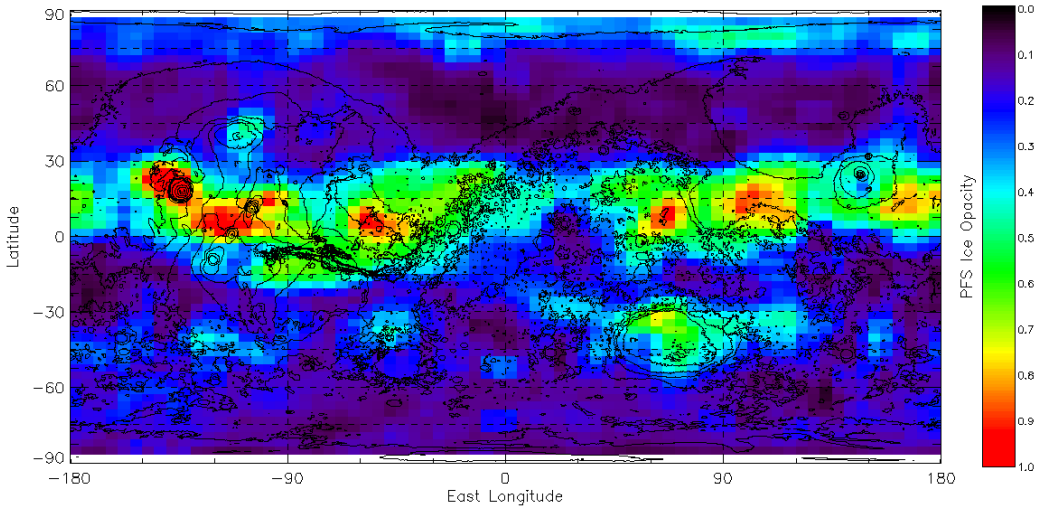


12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

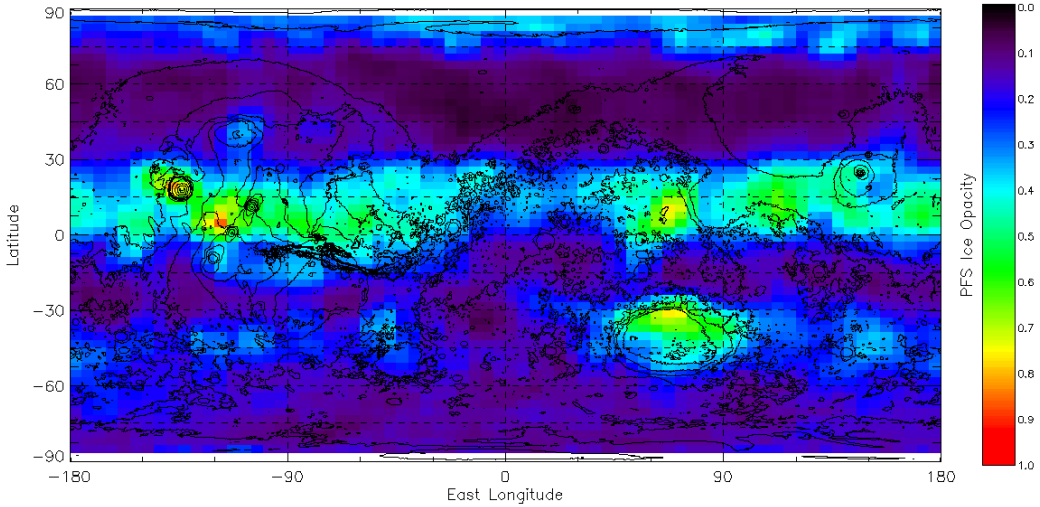
APHELION EQUATORIAL CLOUD BELT

Spatial Distribution and Daily Cycle

Spatial distributions of nighttime clouds at Ls = 60-120



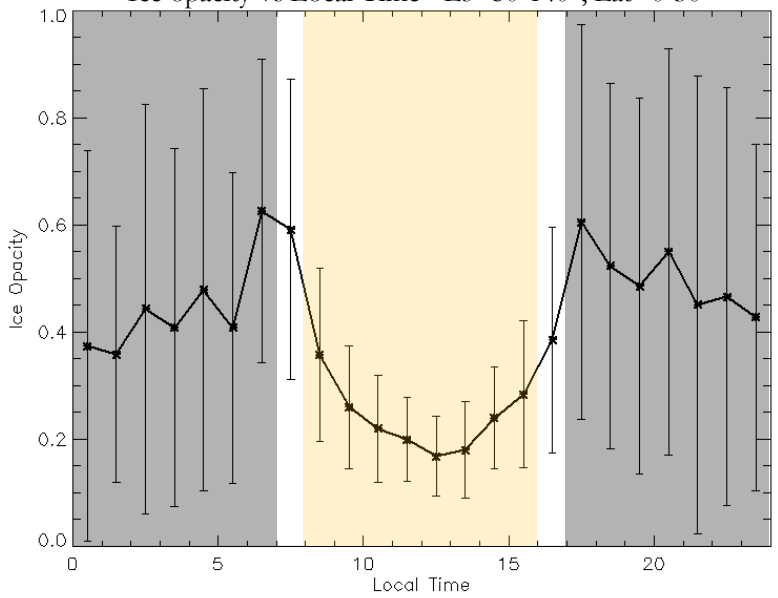
Spatial distributions of daytime clouds at Ls = 60-120



DAILY CYCLE

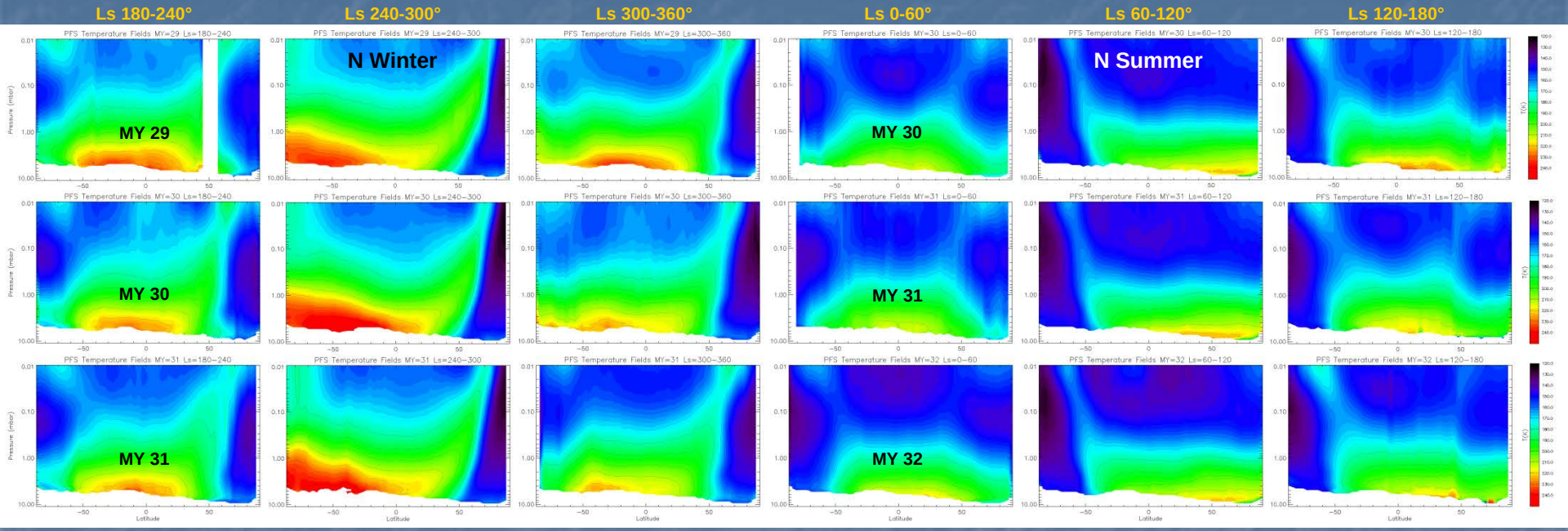
PFS/MEX PERFORMS OBSERVATIONS AT ALL LTS

Ice opacity vs Local Time - Ls=50-140°, Lat=0-30°



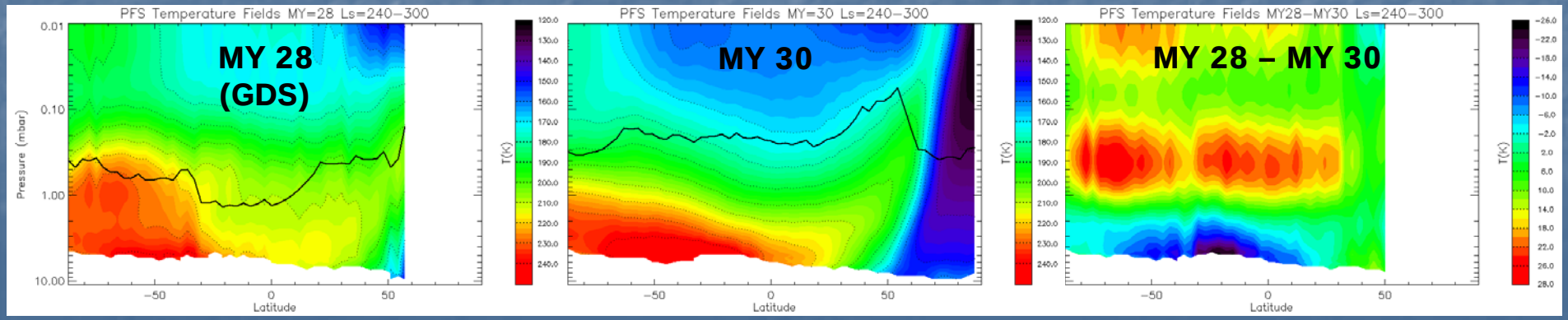
12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

MARTIAN CLIMATE AND ATMOSPHERIC CIRCULATION



EFFECT OF DUST ON ATMOSPHERIC TEMPERATURES

See Wolkenberg et al. on Wednesday



12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

BUILDING THE MOST COMPREHENSIVE DATABASE OF ATMOSPHERIC PARAMETERS FOR MARS

THE DATASET OF RETRIEVALS PRESENTED HERE IS BEING USED AS INPUT FOR THE RETRIEVAL OF WATER VAPOR AND CARBON MONOXIDE

FULL MULTIPLE-SCATTERING (DISORT-BASED) RT CODE IS USED

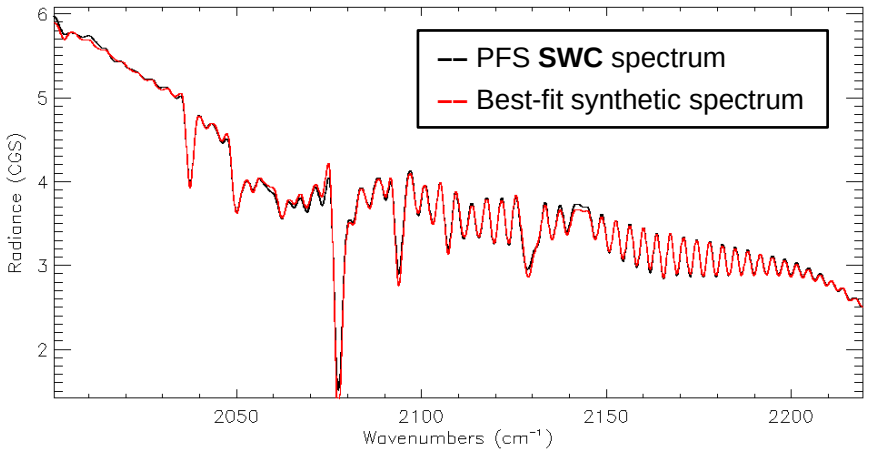
- ✓ **VERTICAL PROFILES OF TEMPERATURES** (0-50 km)
- ✓ **DUST OPACITY** (column-integrated)
- ✓ **ICE OPACITY** (column-integrated)
- ✓ **SURFACE TEMPERATURE**
- ✓ **WATER VAPOR** (MR, pr-um; column-integrated)
- ✓ **CARBON MONOXIDE** (MR; column-integrated)

BUILDING THE MOST COMPREHENSIVE DATABASE OF ATMOSPHERIC PARAMETERS FOR MARS

- ✓ Development and Optimization of retrieval code for H_2O and CO
- ✓ Full DISORT treatment
- ✓ χ^2 minimization (least squares problem)
- ✓ Levenberg-Marquardt approach
- ✓ Self-consistent retrieval: PFS retrievals as input parameters
- ✓ H_2O and CO profiles, Psurf from EMCD5.2
- ✓ HITRAN 2012

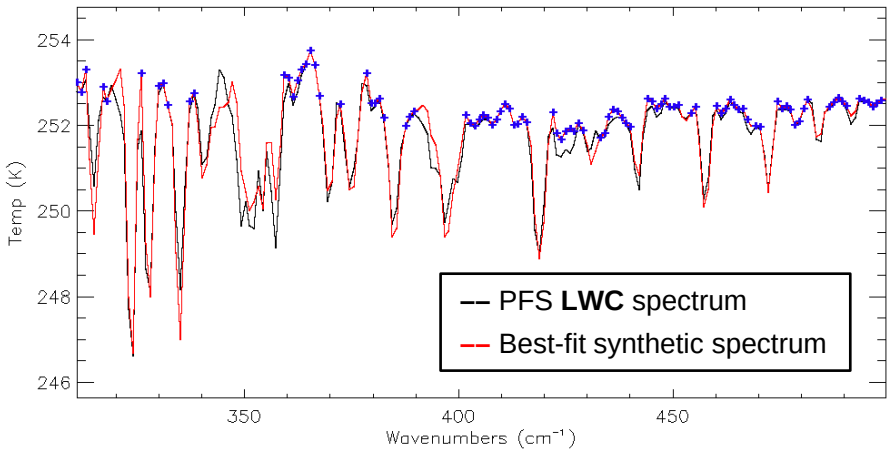
CARBON MONOXIDE

4.7-μm CO BANDS



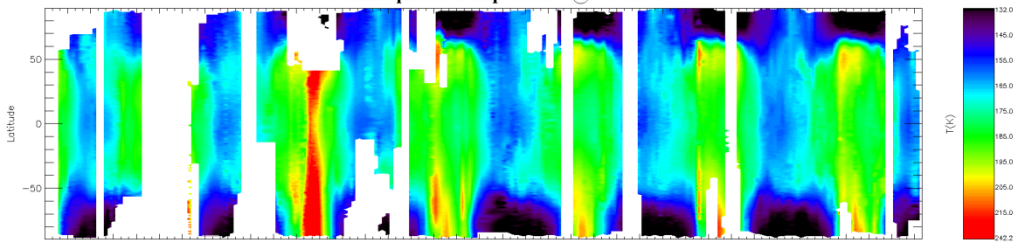
WATER VAPOR

25-μm H_2O BANDS

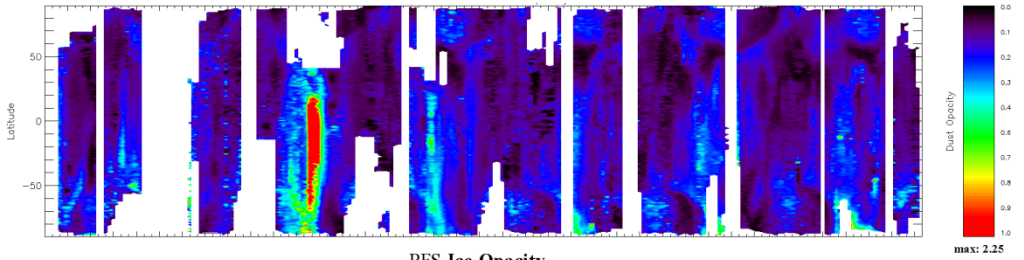


MY 26 | MY 27 | MY 28 | MY 29 | MY 30 | MY 31 | MY 32 | MY 33

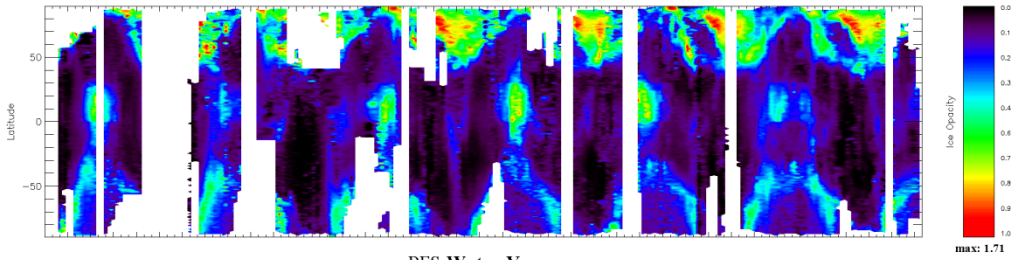
PFS **Atmospheric Temperature** @ 0.5 mbar



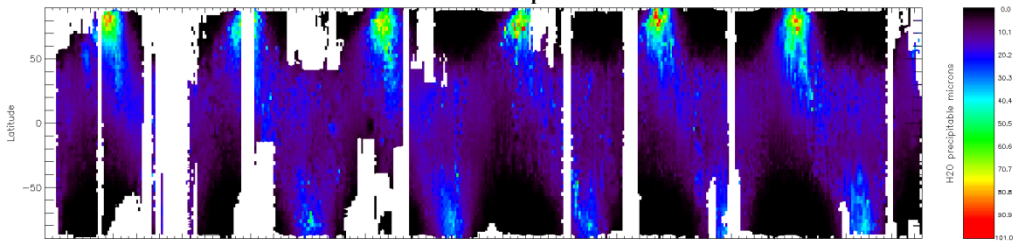
PFS **Dust Opacity** (Normalized)



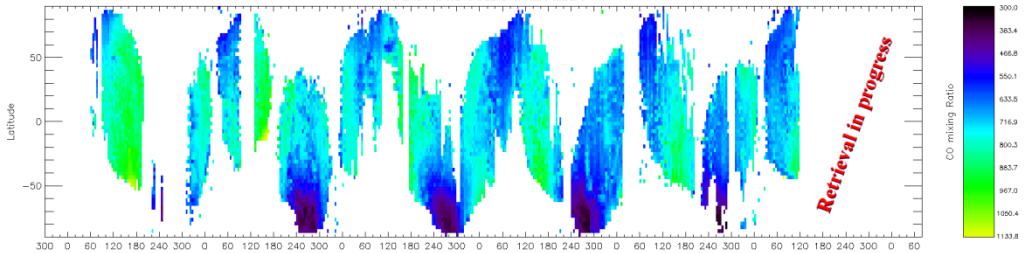
PFS **Ice Opacity**



PFS **Water Vapor**



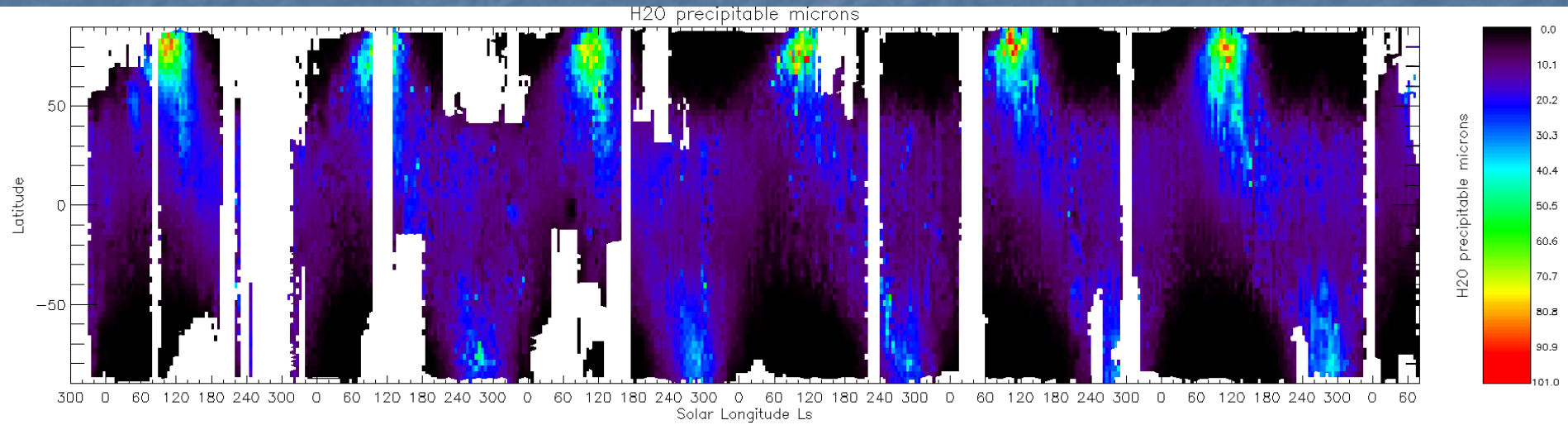
PFS **Carbon Monoxide**



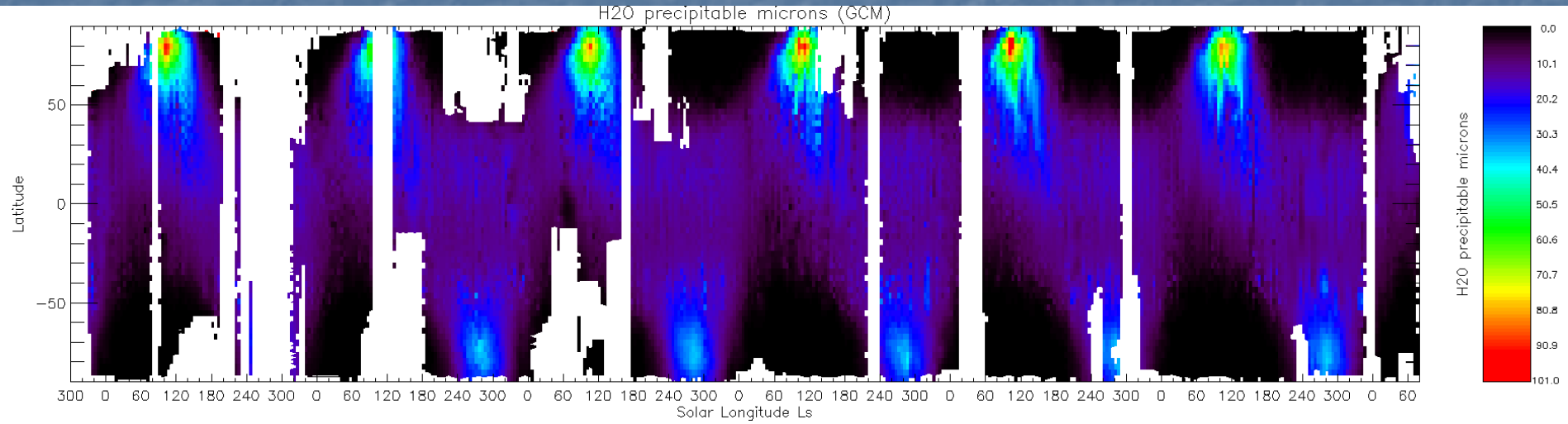
12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

CLIMATOLOGY OF WATER VAPOR

PFS

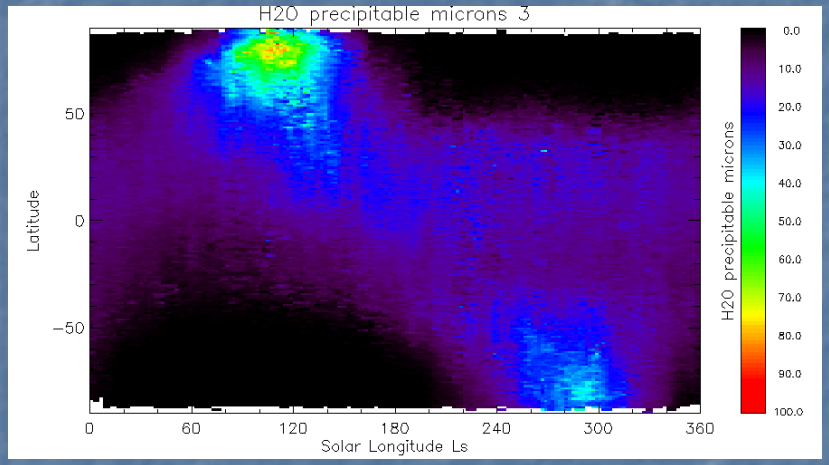


EMCD 5.2

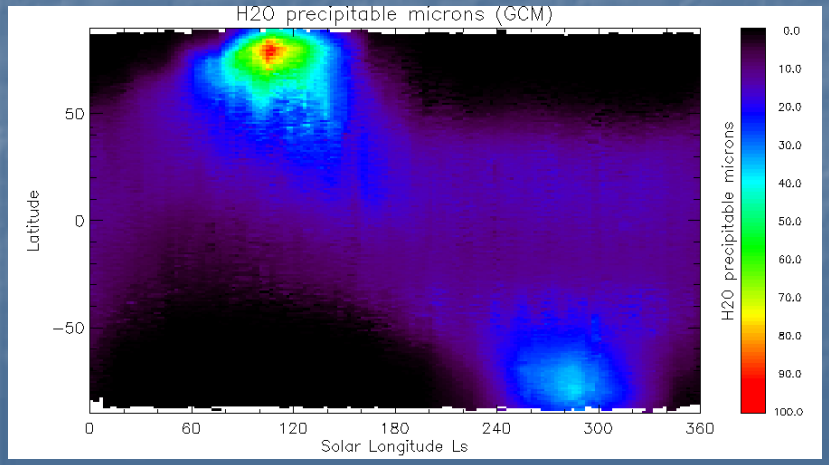


CLIMATOLOGY OF WATER VAPOR

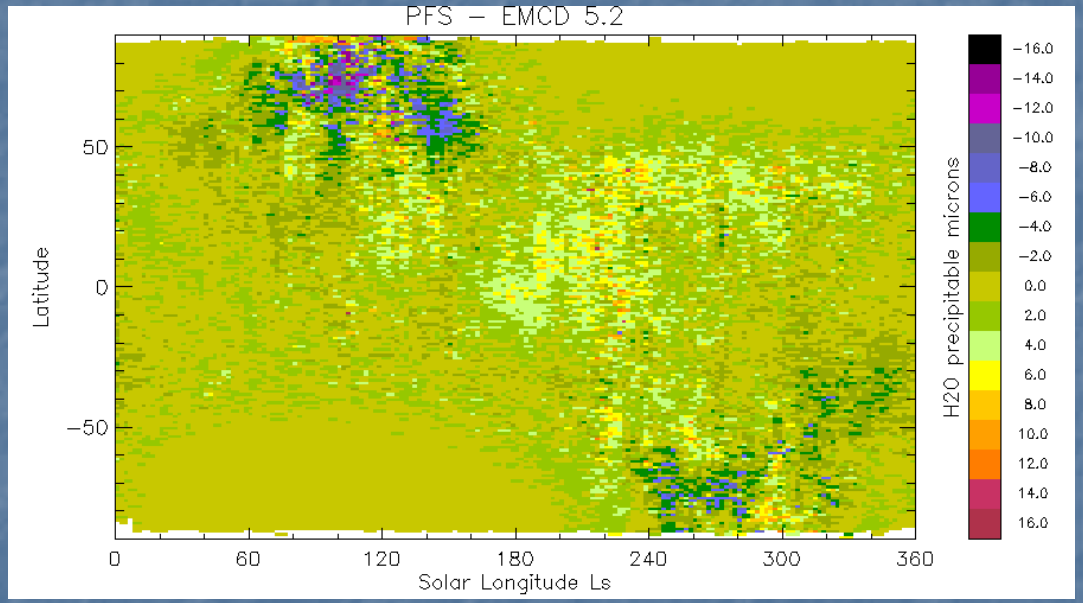
PFS



EMCD 5.2



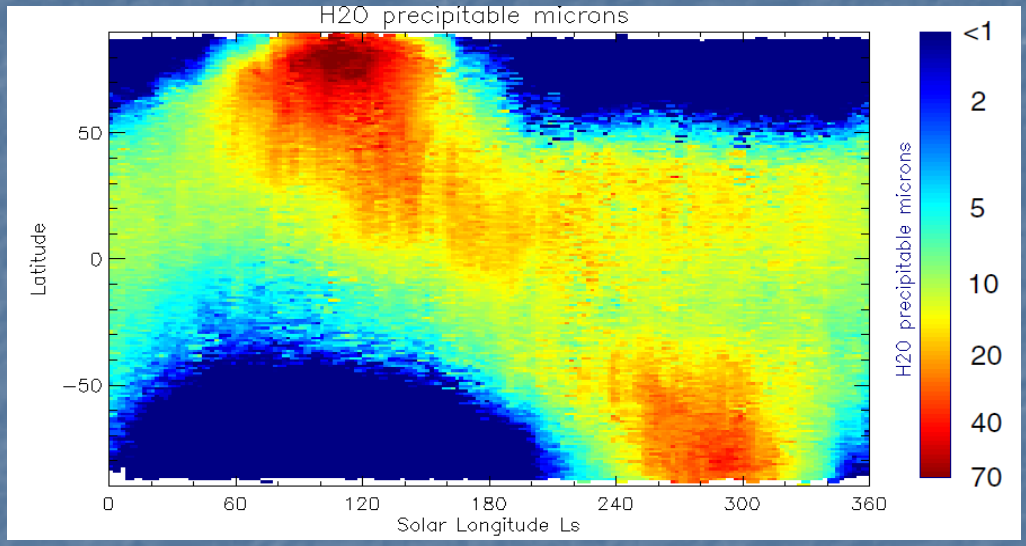
PFS - EMCD 5.2



CLIMATOLOGY OF WATER VAPOR

PFS

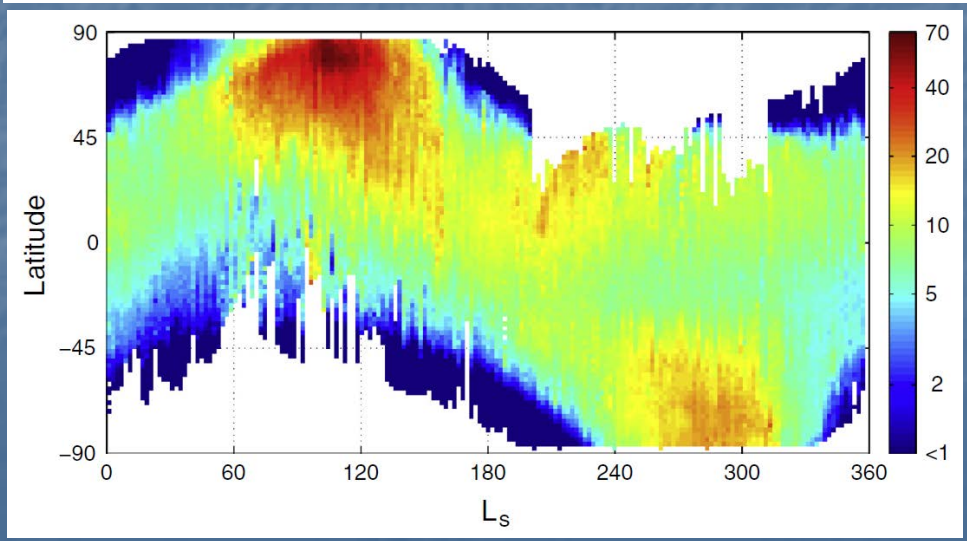
end of MY 26–beginning of MY 33



SPICAM

Trokhimovskiy et al. (2015)

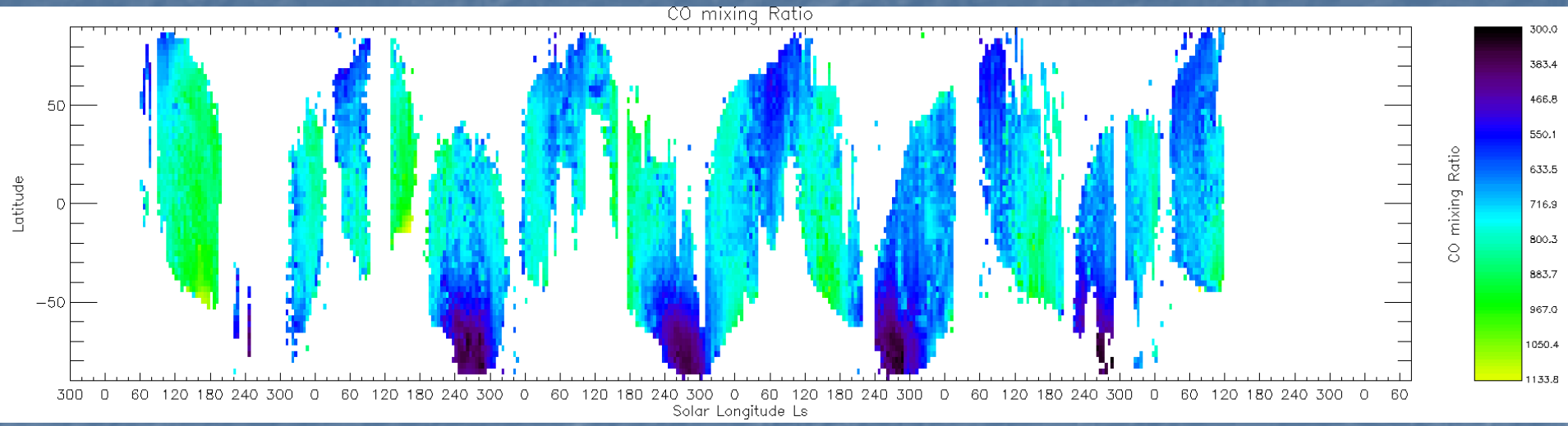
MY 27–31



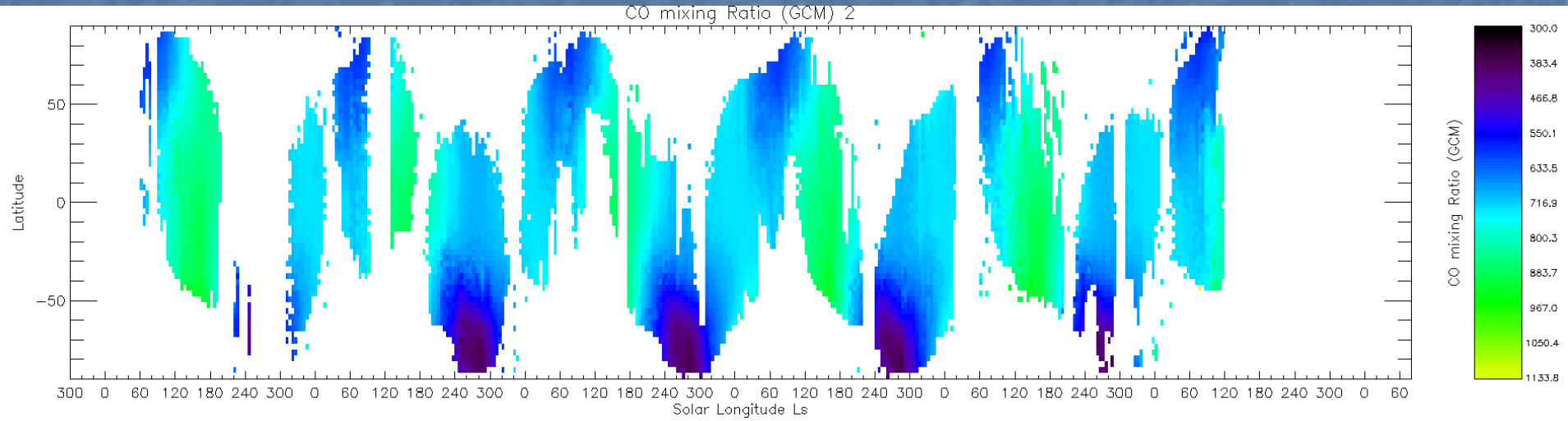
12 YEARS OF ATMOSPHERIC MONITORING BY PFS-MEX

CLIMATOLOGY OF WATER CARBON MONOXIDE

PFS

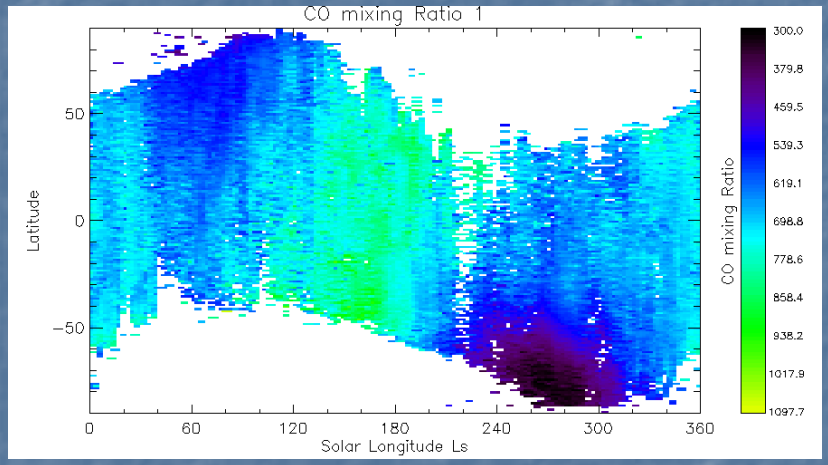


EMCD 5.2

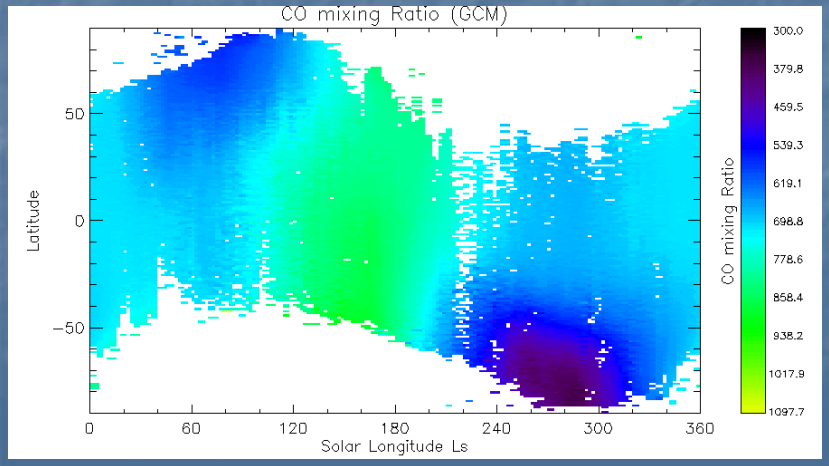


CLIMATOLOGY OF WATER CARBON MONOXIDE

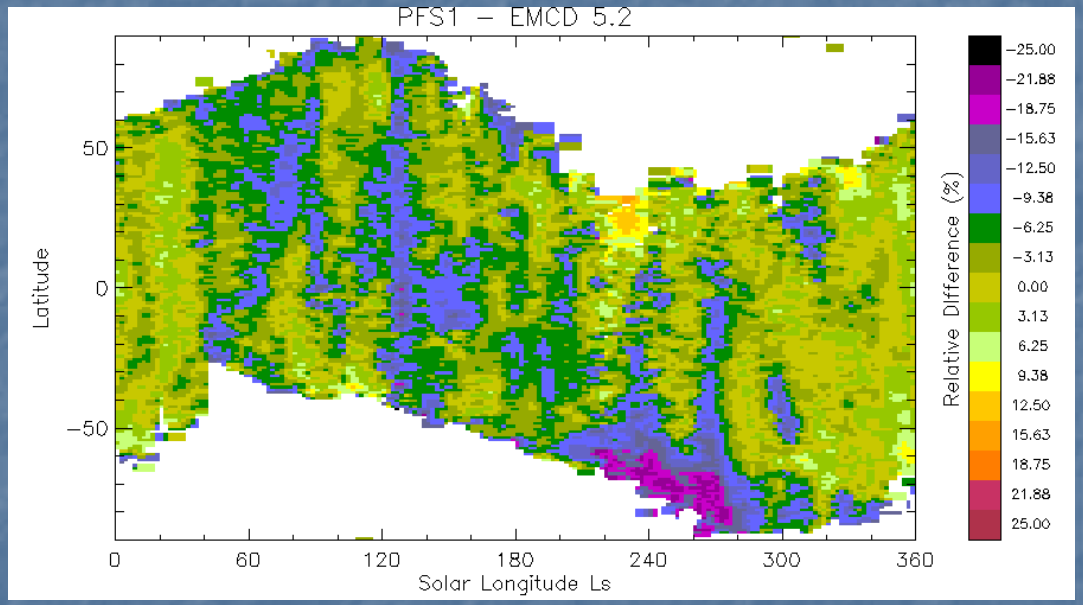
PFS



EMCD 5.2



PFS - EMCD 5.2

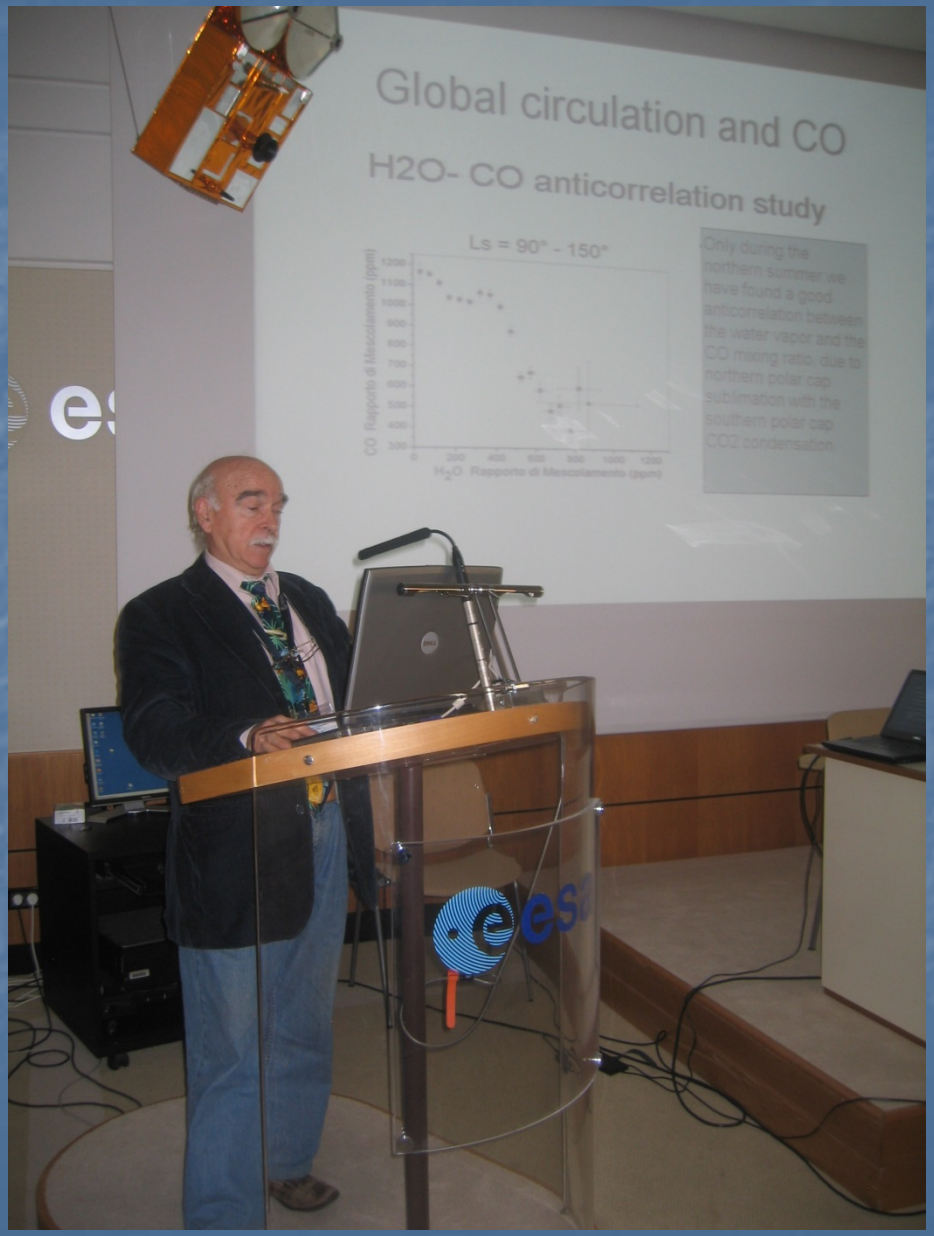


Relative difference (%)

CONCLUSIONS

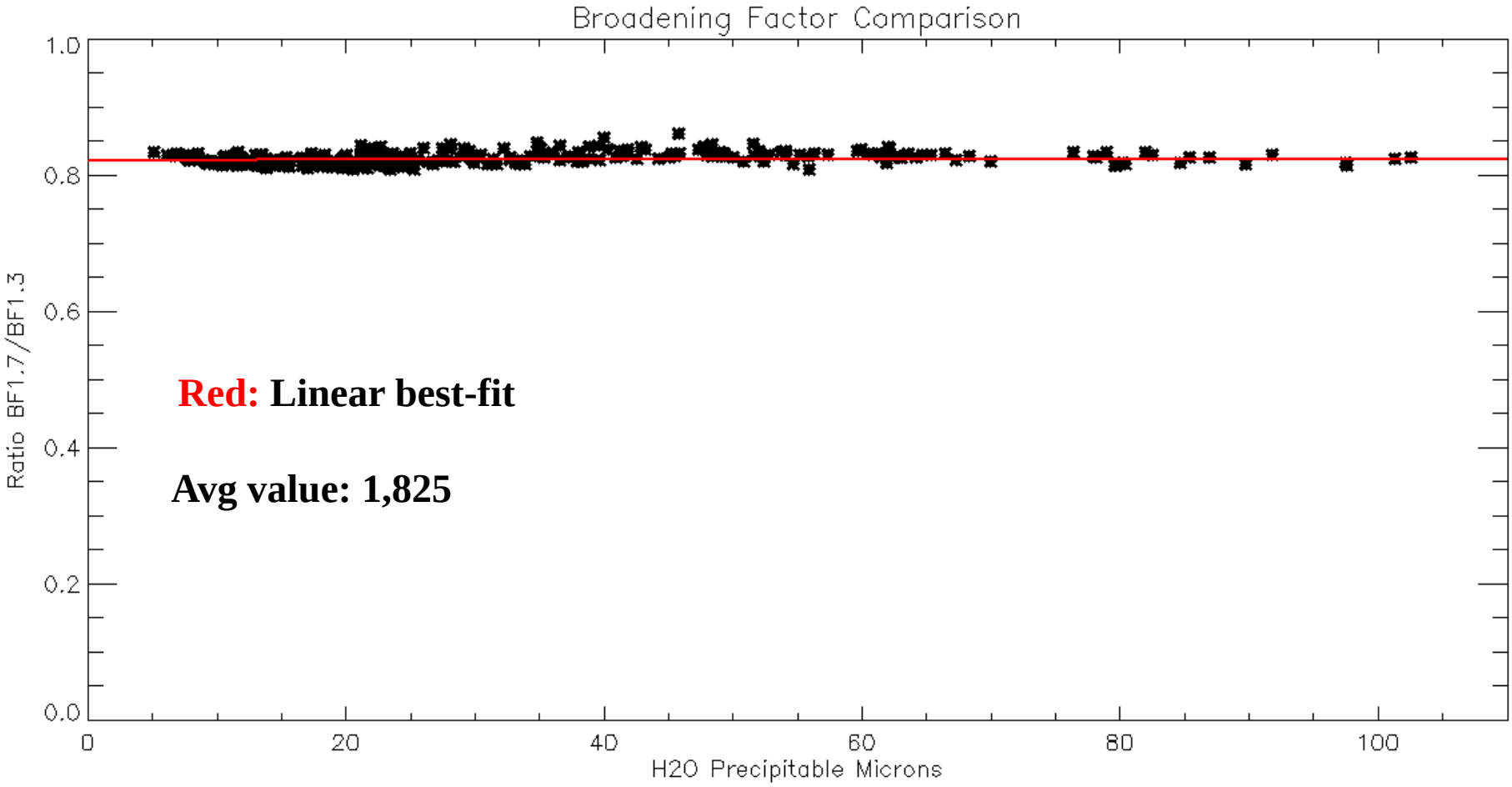
- ✓ After 14+ Years of operations PFS is still working nominally
- ✓ We used PFS-MEx LWC spectra to retrieve atmospheric temperature, and dust and water ice aerosol optical depth.
- ✓ 6+ full Martian years (27-32)… and more will come
- ✓ Successful retrieval in winter polar regions
- ✓ Seasonal, spatial, Interannual, and daily variations
- ✓ Daily "cycle" of suspended dust and ice
- ✓ Dust activity, Q+H rates, GDS in MY28 (see talk by Walkenberg on Wednesday)
- ✓ Climatology of H_2O and CO
- ✓ With unprecedented spatial and temporal coverage and details revealed, this dataset offers new challenges to the GCMs and, at the same time, a new reference for the Mars climate

THANK YOU VITTORIO!



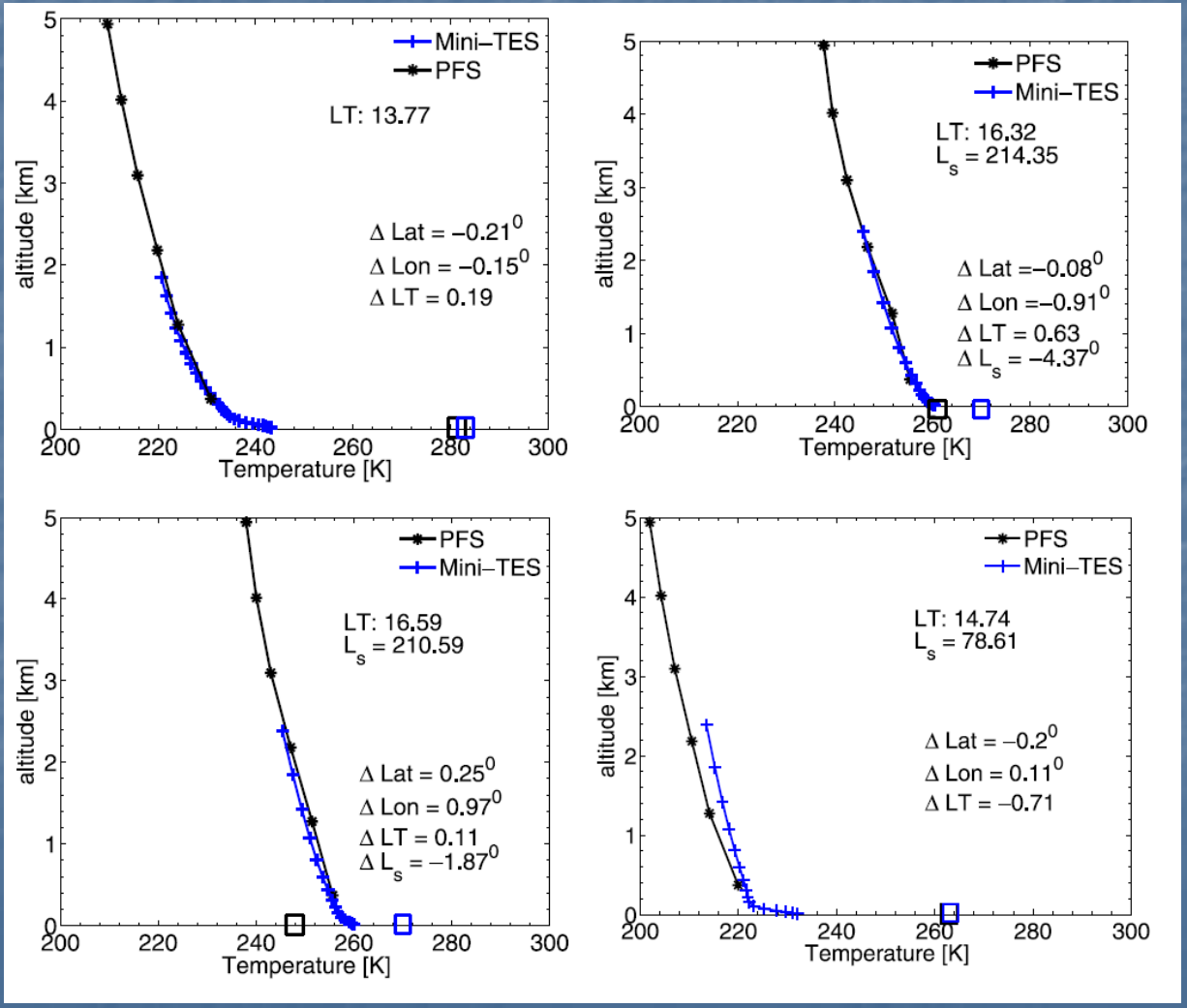
EXTRA

Comparison of H_2O retrievals with different CO_2 broadening Factors



EXTRA (1)

SIMULTANEOUS OBSERVATIONS OF THE MARTIAN ATMOSPHERE BY PFS/MEX AND MINI-TES/MER (Wolkenberg et al., 2009, JGR 114)



Purpose:

Confirm validity of PFS temperature profiles below 5 km by comparing them with the Mini-TES retrievals.

Method:

Temperature profiles retrieved from PFS and Mini-TES were selected according to strict criteria.

Results:

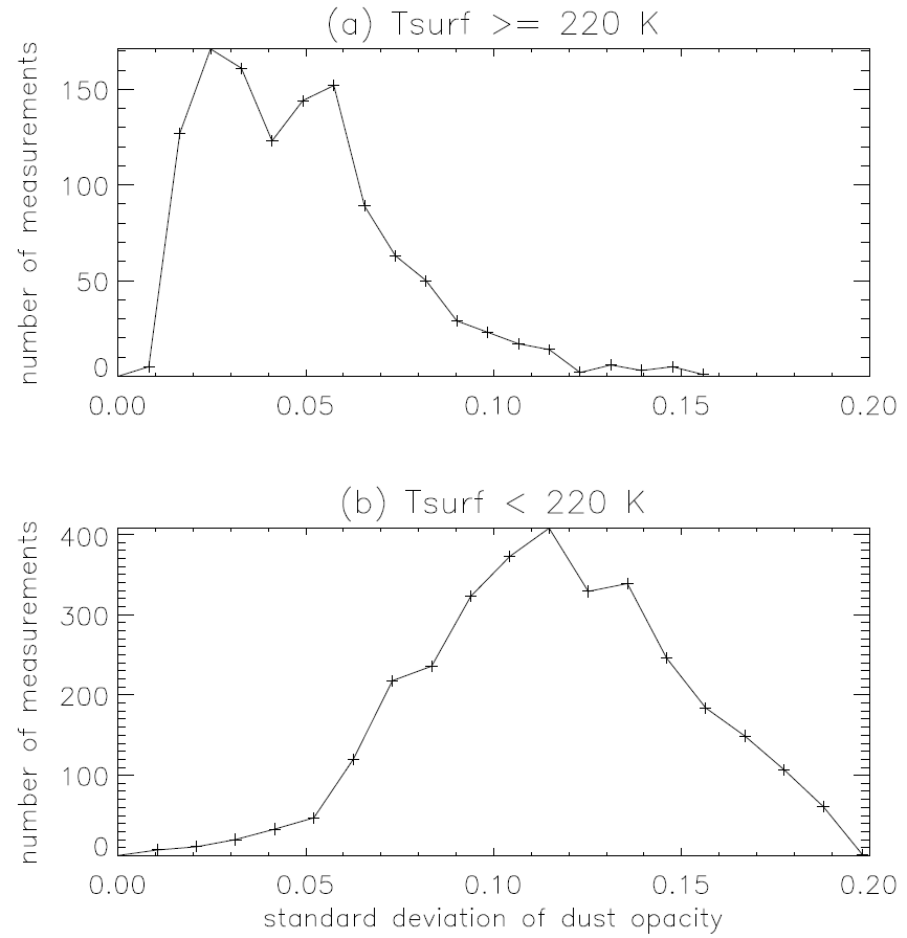
- Retrieval of temperature profiles below 5 km obtained from downward-looking measurements by PFS is largely consistent with upward-looking temp. retrievals from Mini-TES given the different vertical resolutions of the two instruments and their combined uncertainties.
- Temperatures at 370 m were in most cases identical from PFS and from Mini-TES.

EXTRA (2)

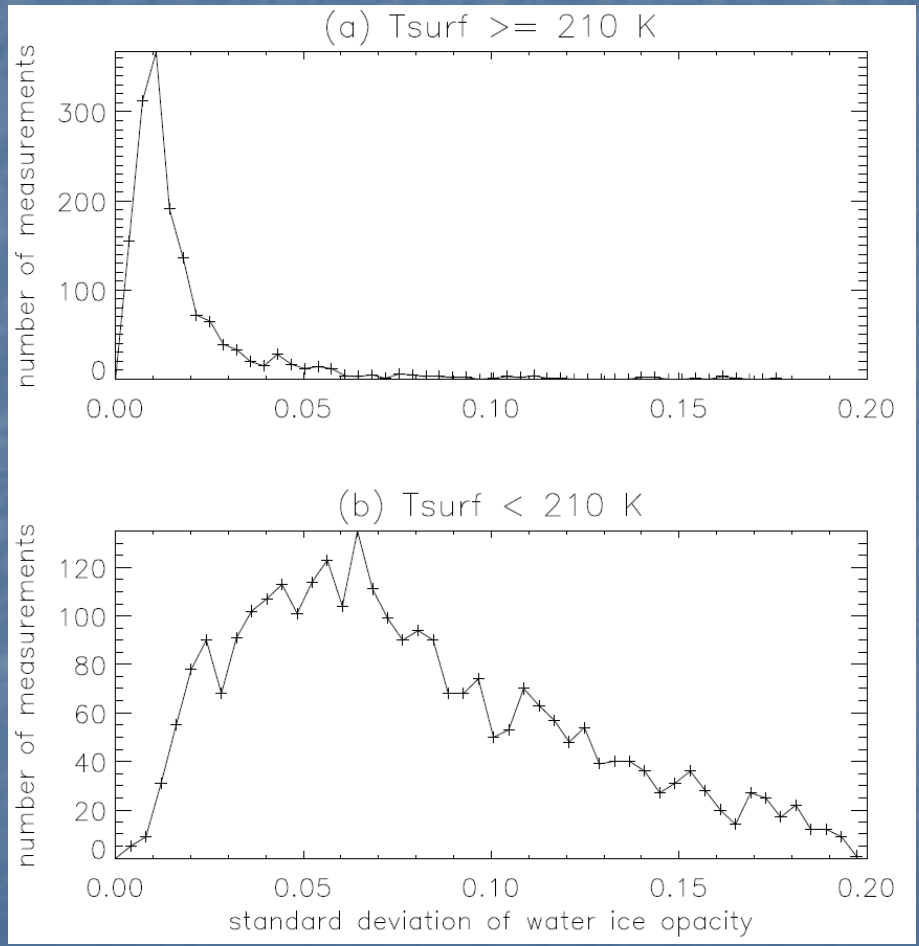
UNCERTAINTIES

Histogram of standard deviation of retrieved opacities

Dust



ICE



- The variance of retrieved opacities is clearly related to the values of the surface temperatures (SNR).
- Larger variances are observed for low surface temperatures, as one would expect.
- Two regimes of standard deviation, based on the surface temperatures.