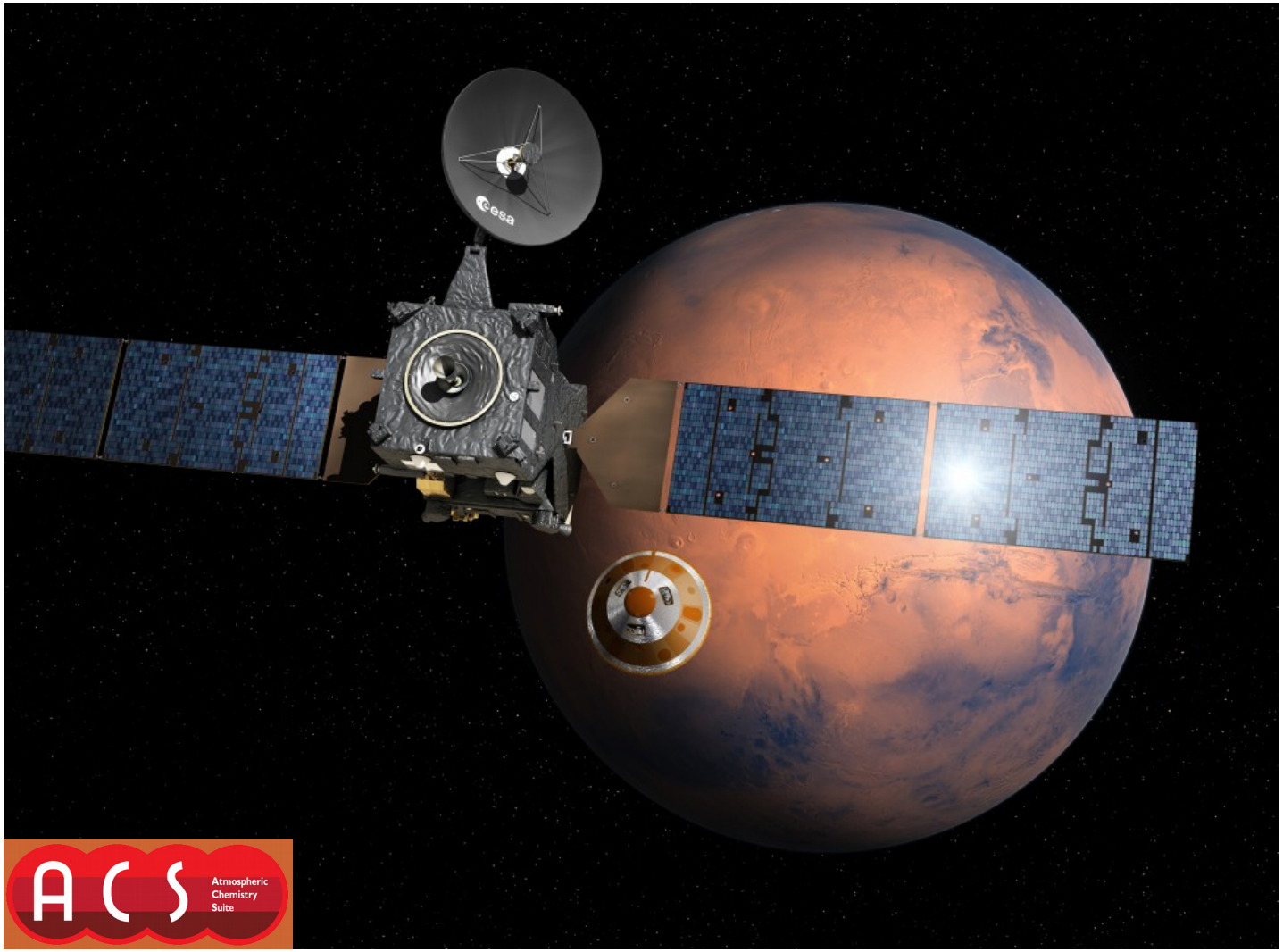
Thermal structure and aerosol content in Mars' atmosphere from TIRVIM on board ExoMars/TGO

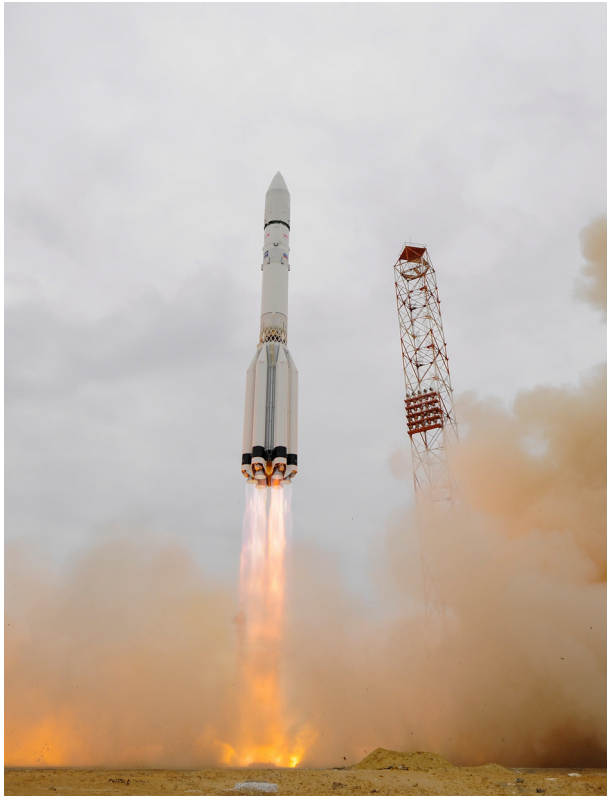


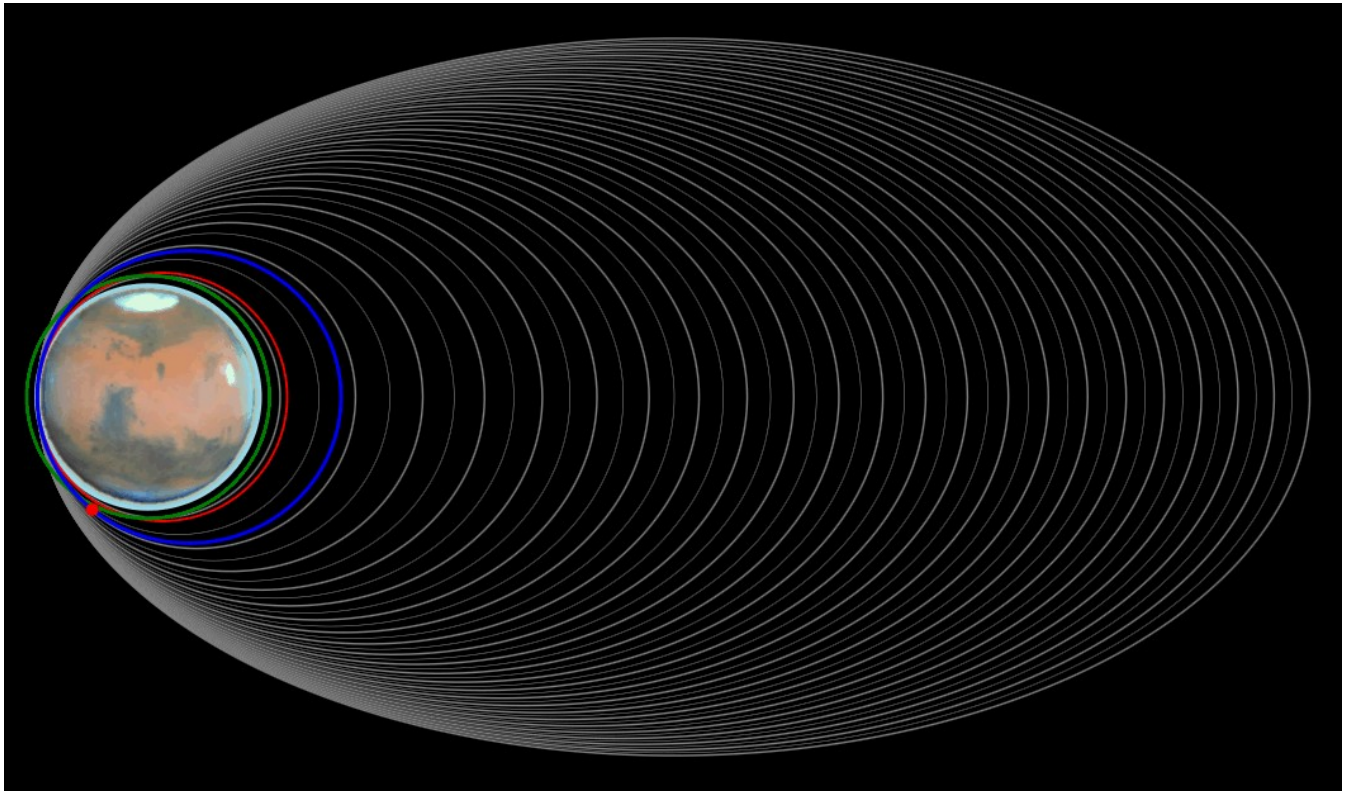
Sandrine Guerlet, LMD – *and the ACS team*

LMD

ExoMars Trace Gas Orbiter (TGO)

Joint ESA-Roscosmos mission. Launched in March 2016, orbit insertion in October 2016. Beween March 2017 and March 2018 : **aerobreaking**





One year to go from a 4-day, elliptical orbit (98 000 x 200 km)...
...to its operational orbit : 2h, circular (400 km), i=74°

Scientific objectives

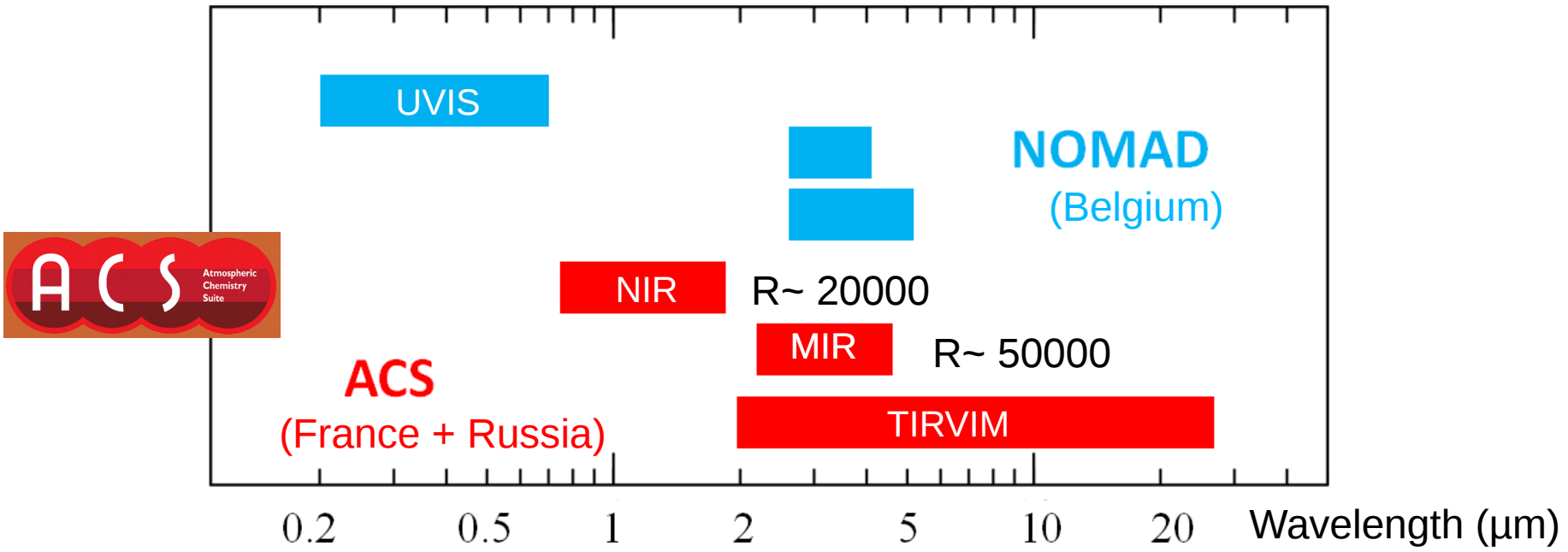
- Detect <u>trace gases</u> such as CH_4, HO_2, H_2S, HCl, SO_2…

  Measure vertical profiles of CO, H_2O, HDO ; aerosols...

  ⟶ High resolution spectroscopy, in UV, NIR and MIR, mostly solar occultations (ACS & NOMAD)

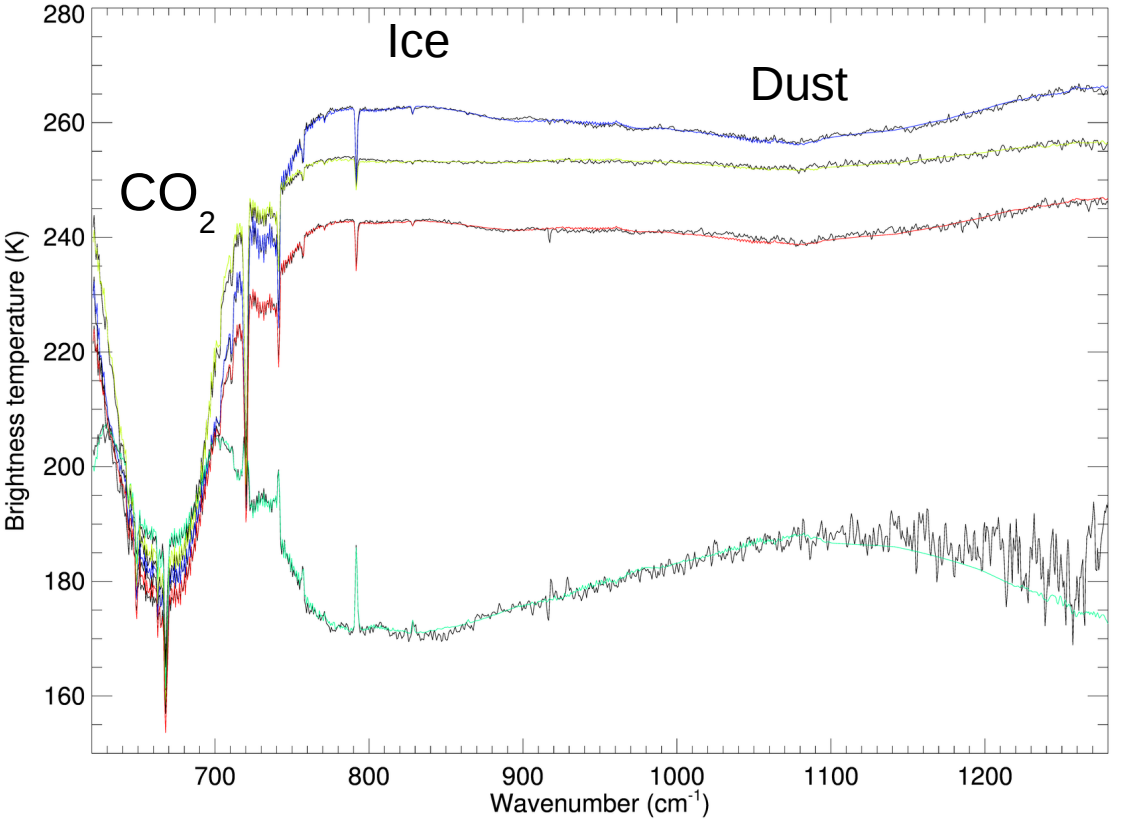
- <u>Climatology</u> : map the thermal structure and aerosol content

  ⟶ Thermal infrared channel of ACS (=TIRVIM), **nadir** observations.



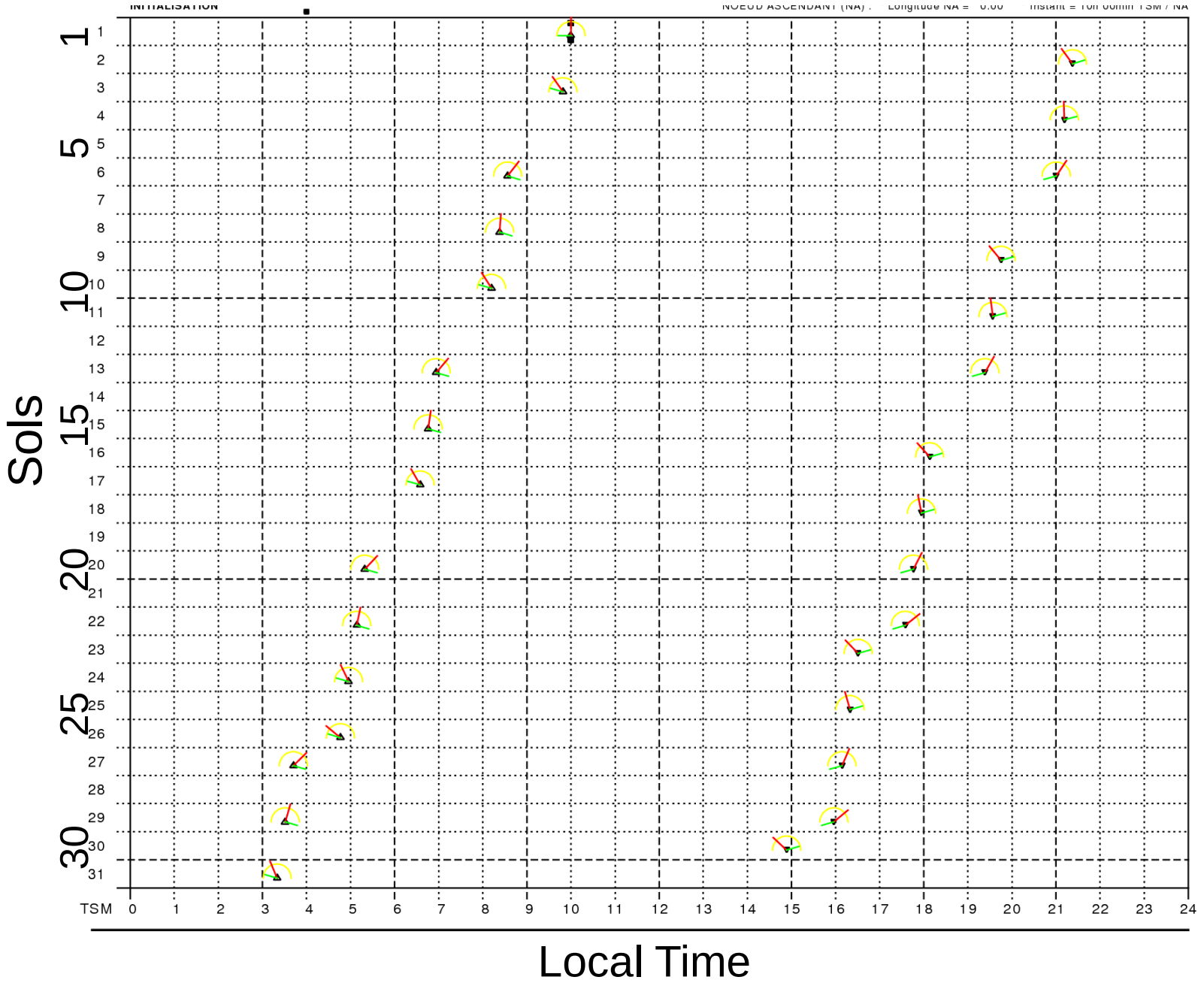
ACS - TIRVIM

- Fourier-transform spectrometer covering 1.7–17 µm (620 – 5000 cm^{-1})
- Compared to MGS/TES : better spectral resolution (1.2 versus 6 cm^{-1})
- Compared to Mex/PFS : better sensitivity.
- Advantage of PFS : wider coverage of the CO_2 band (250 – 1700 cm^{-1}) while TIRVIM starts at 620 cm^{-1}.

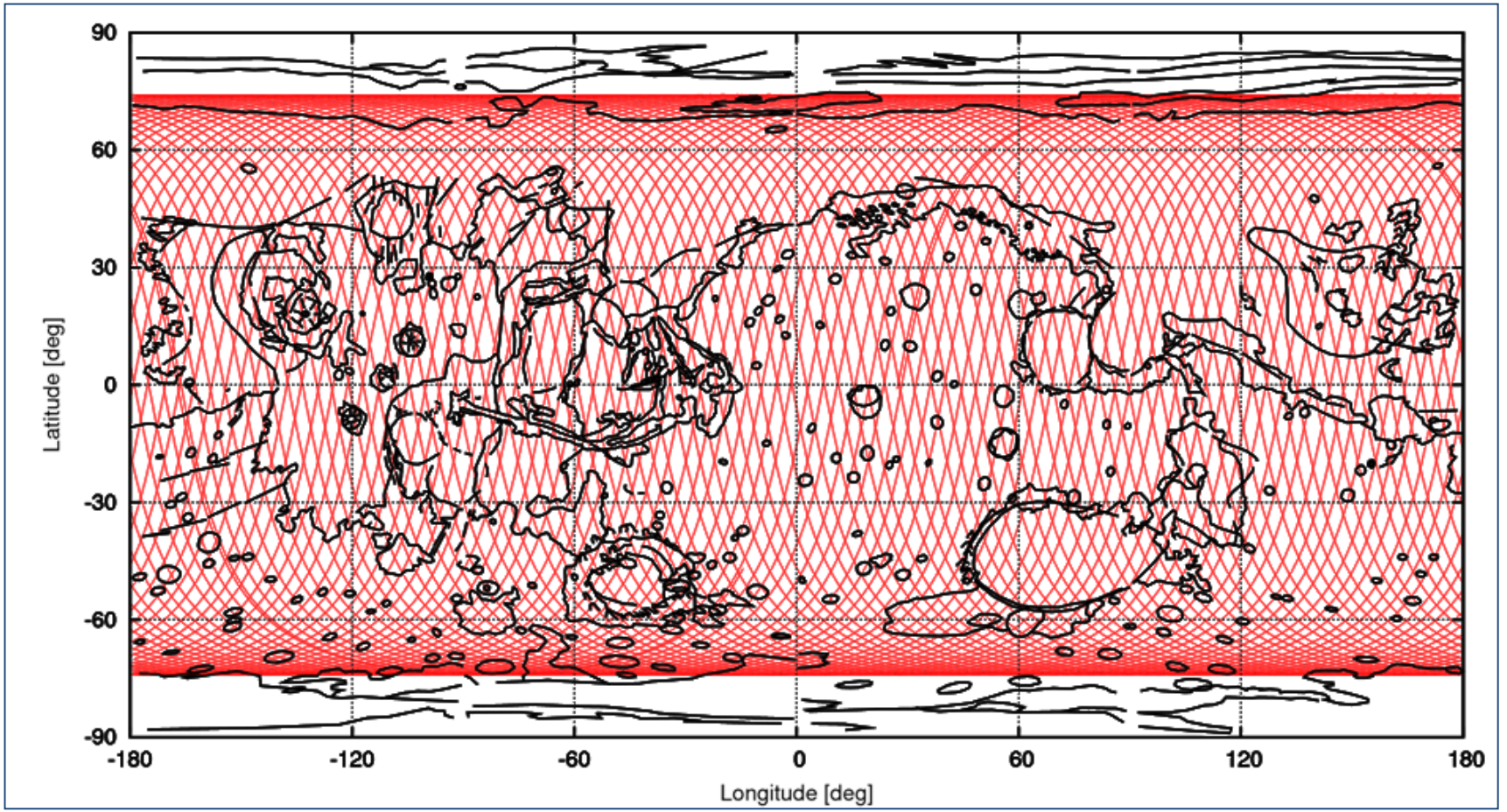


Main advantage : unique sampling of diurnal cycle.

Coverage in local time (nadir observations)



Ground track



One spectrum every 80 seconds (960 per day), full spatial coverage in 7 days.

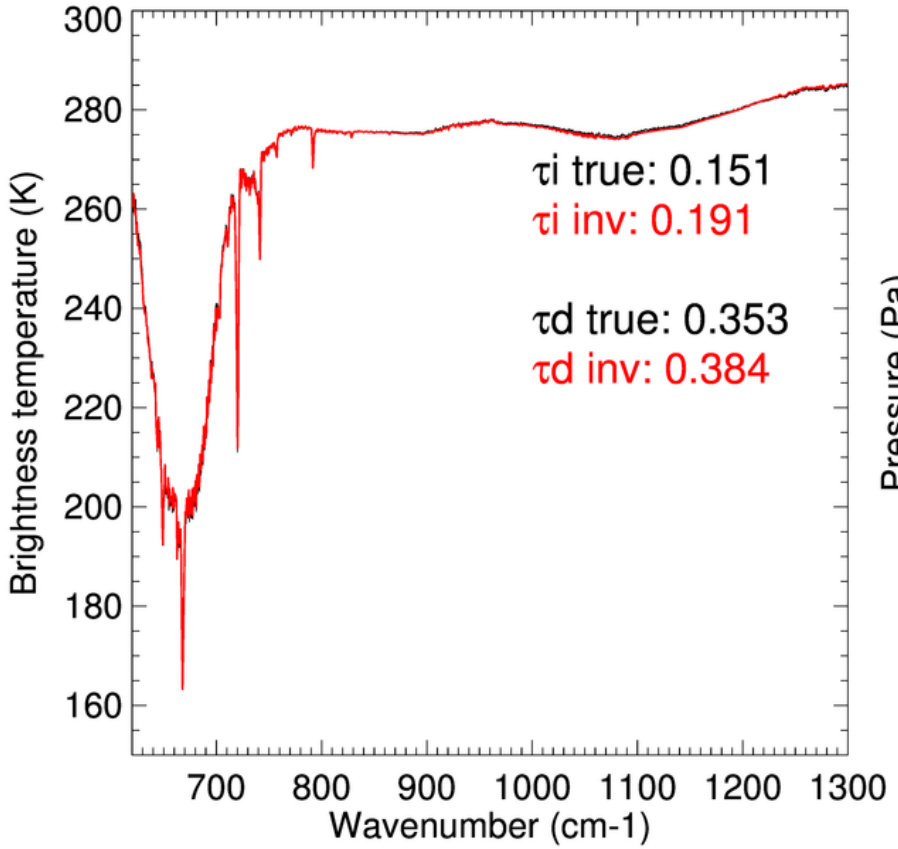
Retrieval algorithm

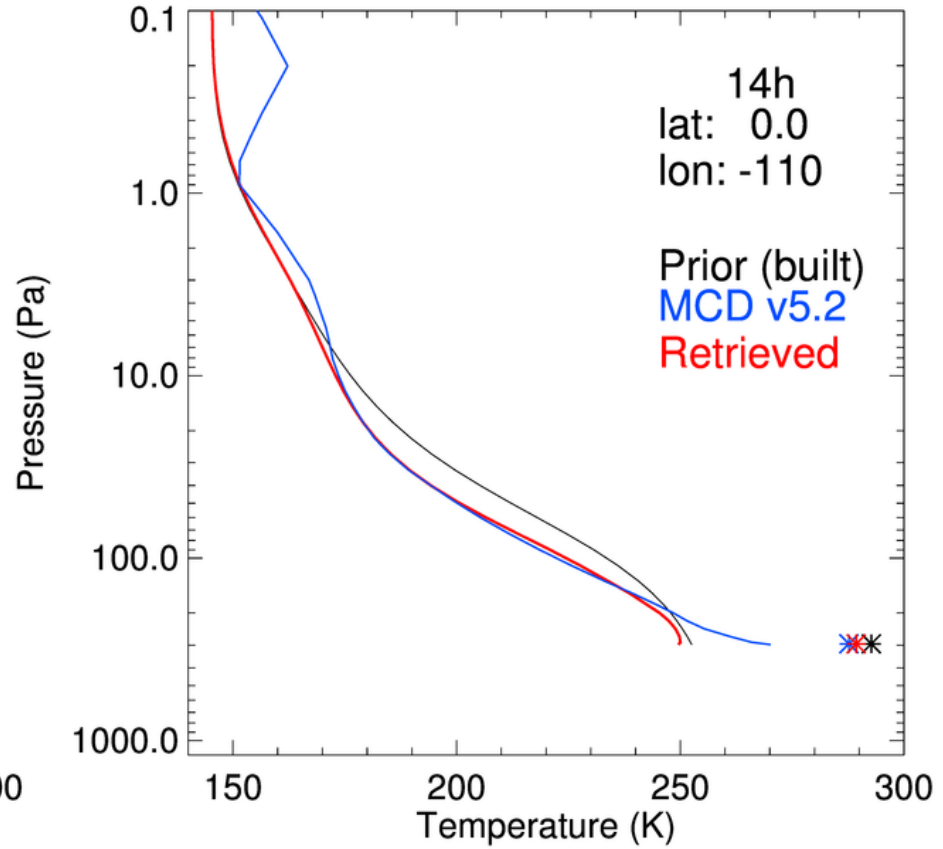
- Line-by-line radiative transfer model
  - Absorption coefficients for CO2 : pre-tabulated at resolution 0.01 cm-1 using the GEISA 2015 linelist.
  - Dust and water ice : single particle size ; scattering neglected.
  - Spectral emissivity map from TES ; surface pressure from MCD.
- Inversion scheme similar to Conrath et al., 2000 for TES observations
  - Optimal estimation method following Rodgers, 2000.
  - Iterative scheme to retrieve surface temperature, atmospheric temperature profile and scaling factors to aerosol profiles.
- A priori values/profiles :
  - A priori temperature profile built from the spectra themselves
  - Aerosol vertical profiles : either from the MCD or « generic » profiles (well mixed dust ; prescribed cloud altitude…)
  - A priori for integrated aerosol opacity taken as entry parameter.

Synthetic retrievals for Ls=180°

- Set of 720 synthetic spectra computed from MCD outputs at different seasons, local times, latitudes… ⟶ validation of the retrieval algorithm.

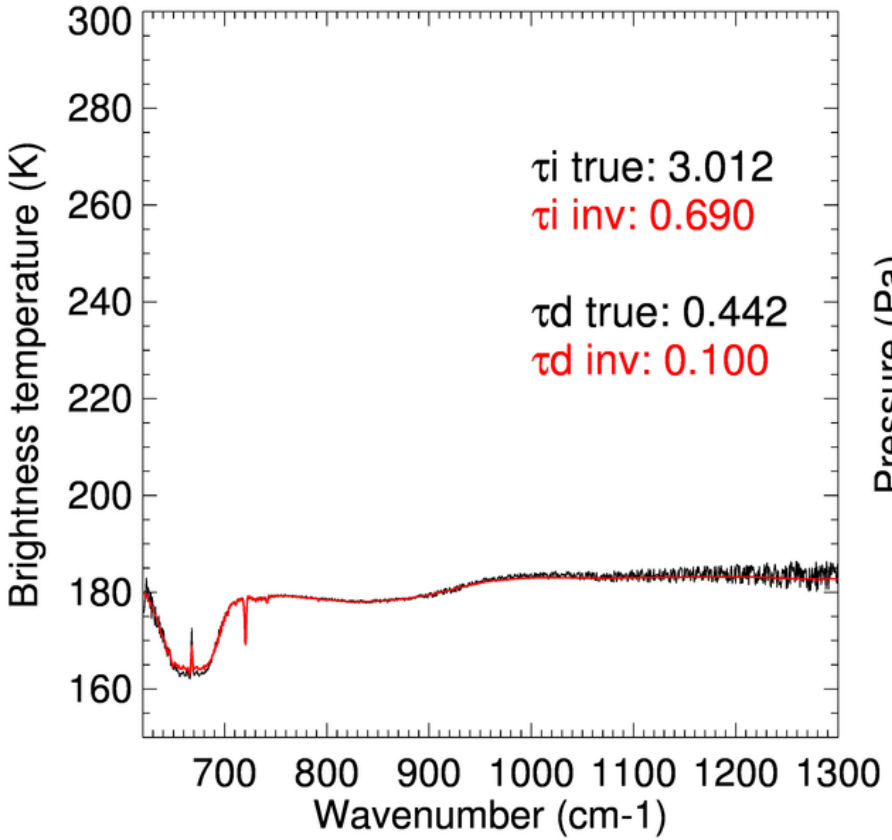
- Best scenario : 2pm, warm surface, strong surface-atmosphere contrast. Temperatures and aerosol content well retrieved.

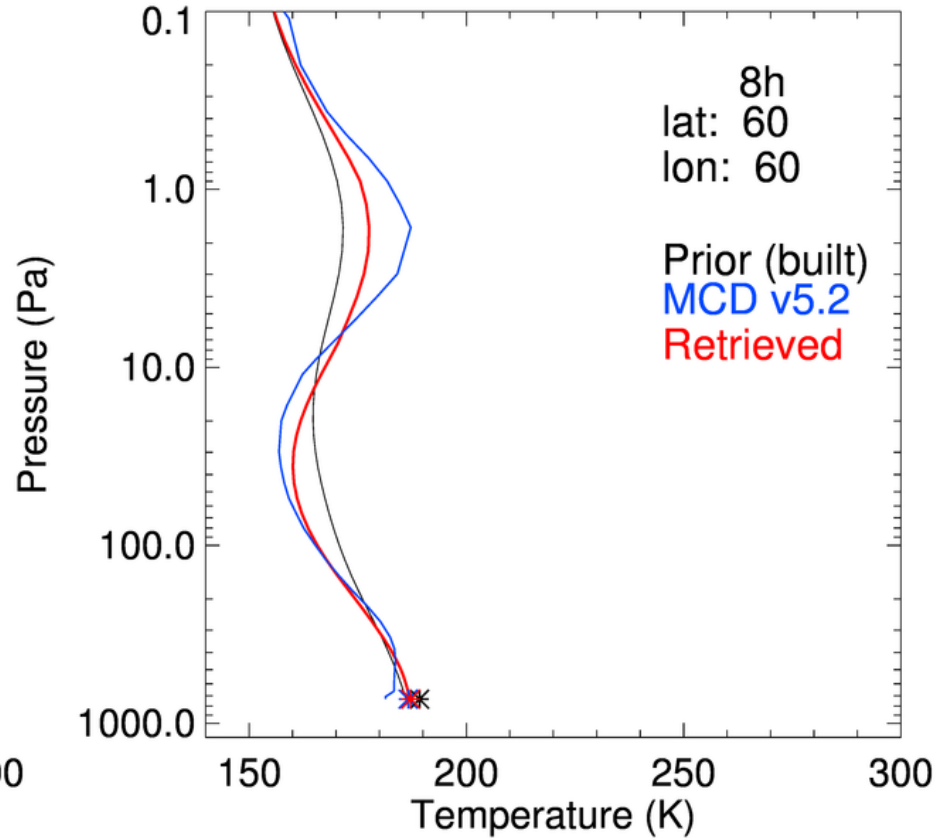




Synthetic retrievals for Ls=180°

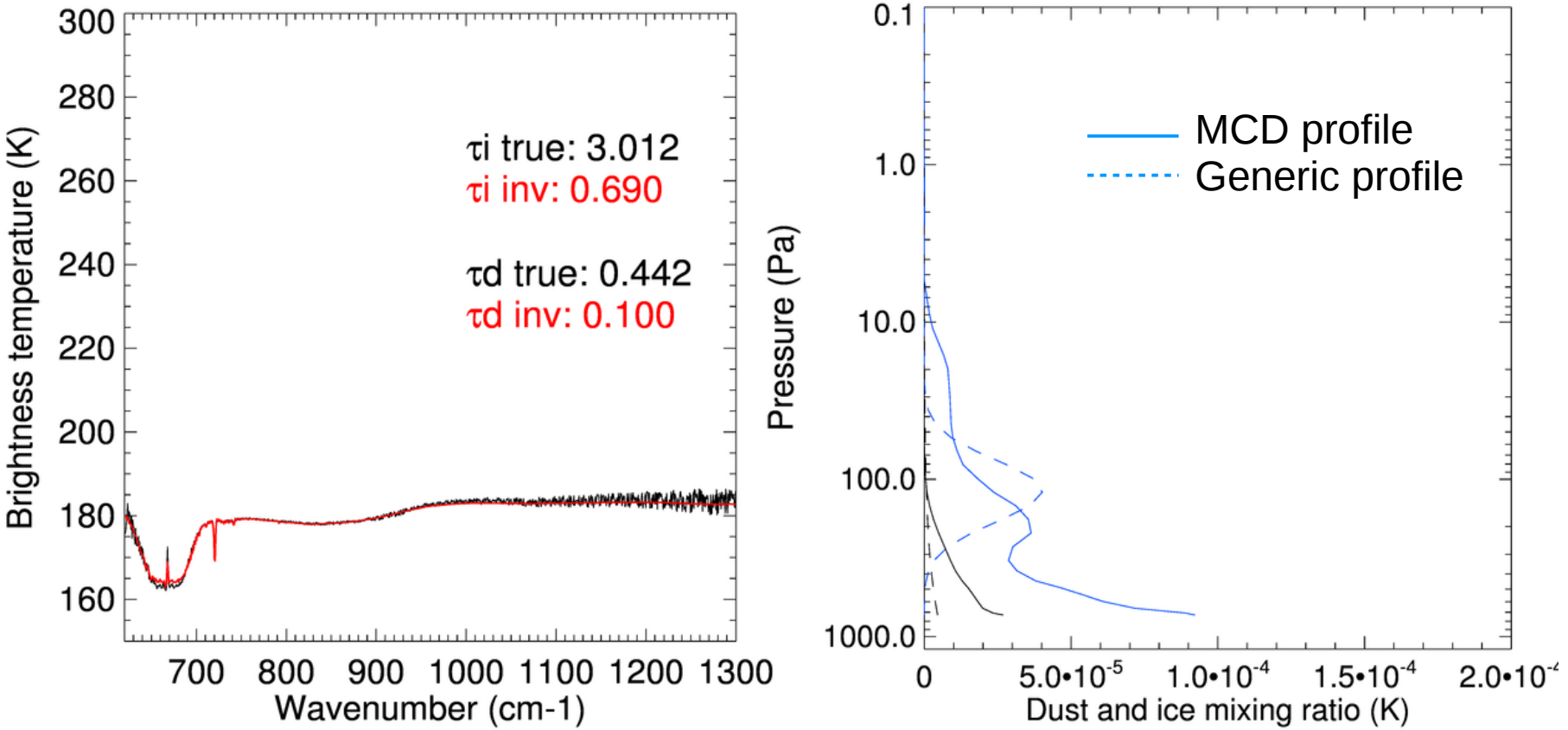
- Temperature profile oscillates ; nadir observations do not fully capture it (vertical resolution ~ 1 scale height).
- Worst case scenario : 8 am (and ~7pm), very low surface-atmosphere contrast ⟶ no dust signature (wrong retrieved opacity).



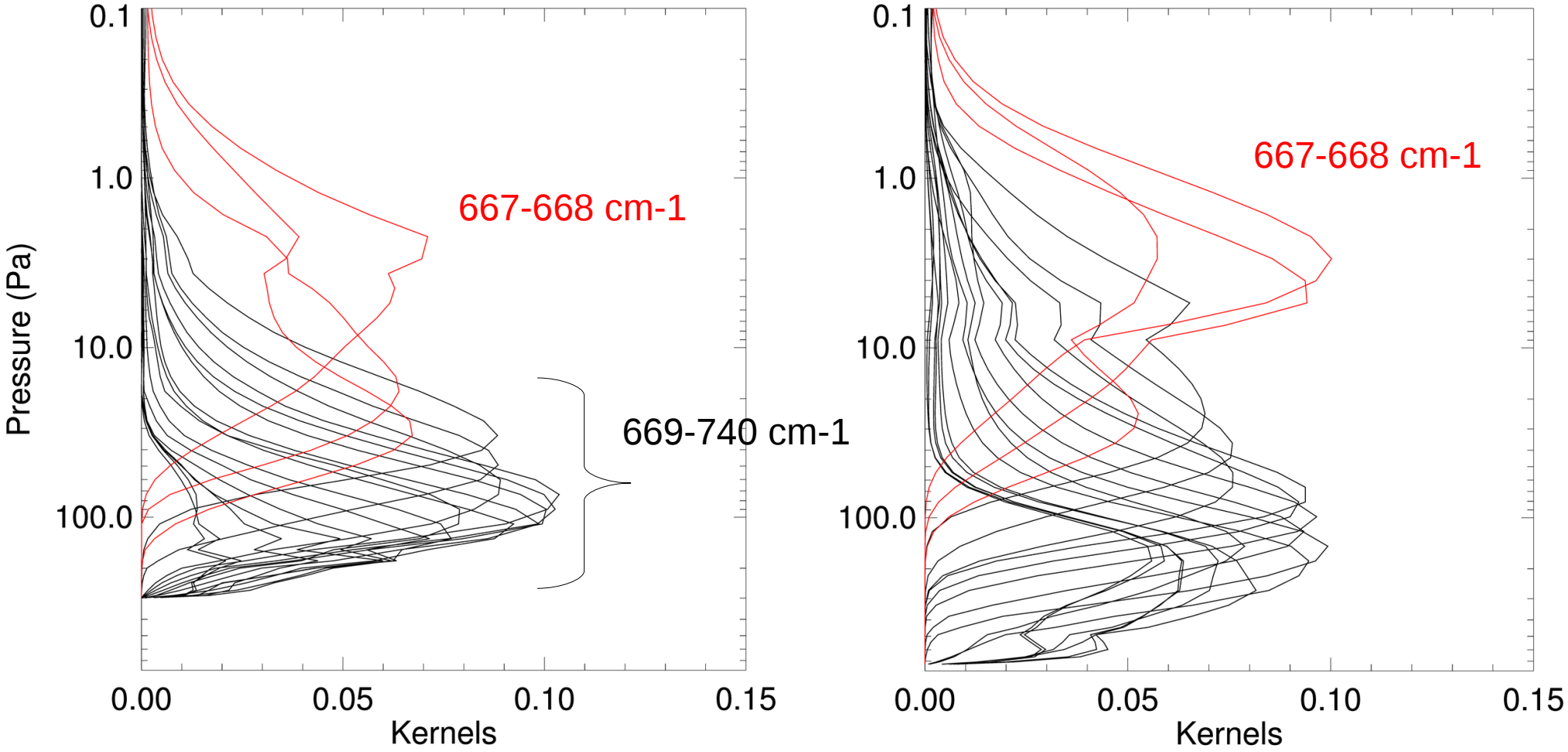


Synthetic retrievals for Ls=180°

- Retrieved cloud opacity can be wrong for two reasons :
  - Atmospheric temperature at cloud altitude close to surface temperature
  - Assumed cloud altitude is wrong (error will increase as the surface-atmosphere temperature contrast is lower)



Information content

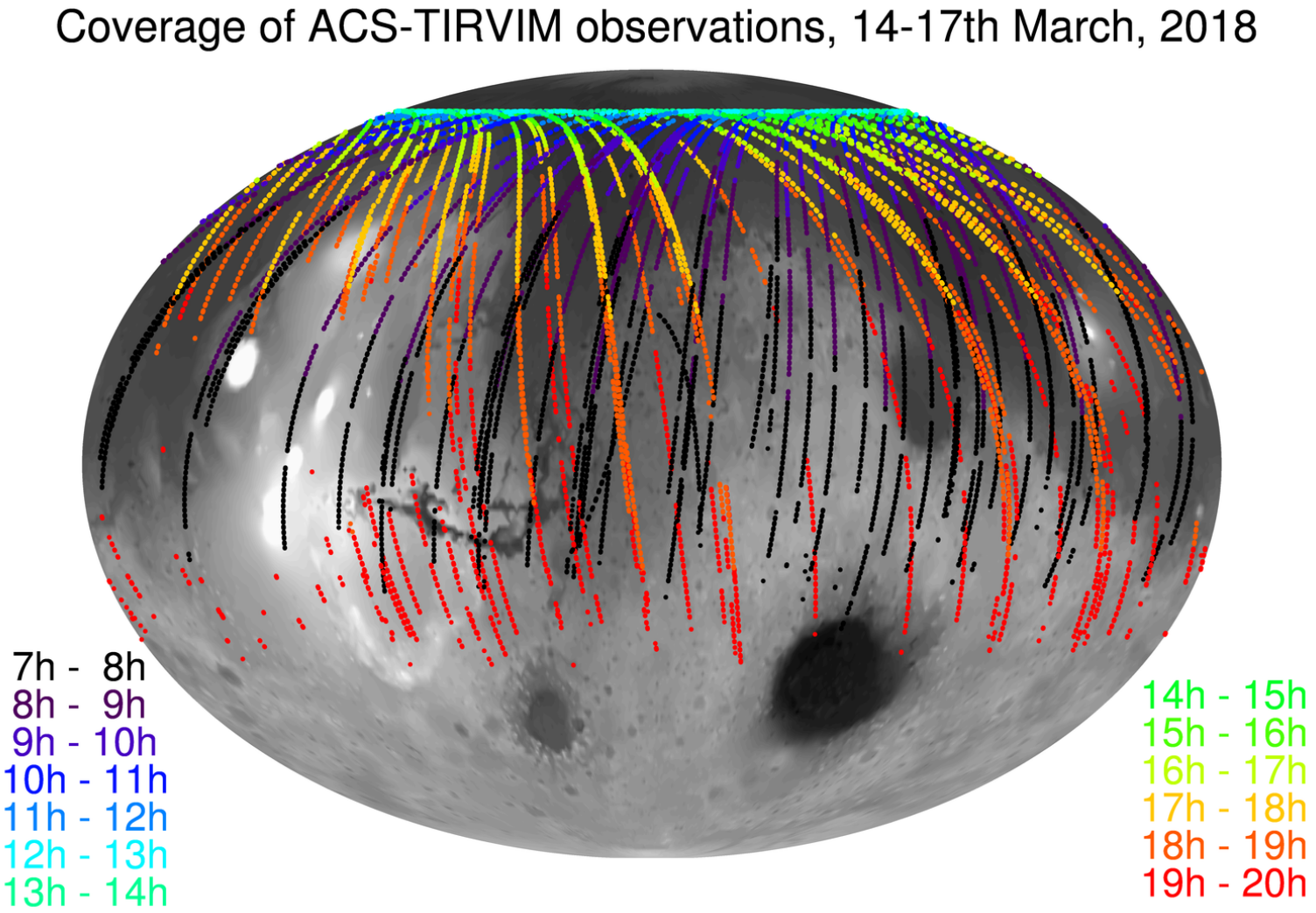


- Only the very core of the CO2 band is sensitive to the temperature at p~2 Pa.
- Broad Kernels (dI /dT) in the first kilometers and at high altitude
  - ➡ degeneracy of the slope of the retrieved temperature profile.

Lessons learned

- Dust retrievals are not reliable if the surface-lower atmosphere temperature contrast is <12K
  - Information on dust will be missing in the morning and evening
- Ice retrievals are not reliable if the surface-cloud layer temperature contrast is <12K
- Ice and dust retrievals are sensitive to the assumed altitude.
- But temperature profile retrievals remain reliable !
  - Limitations : not sensitive to the first ~3 km ; vertical resolution ~1 scale height.

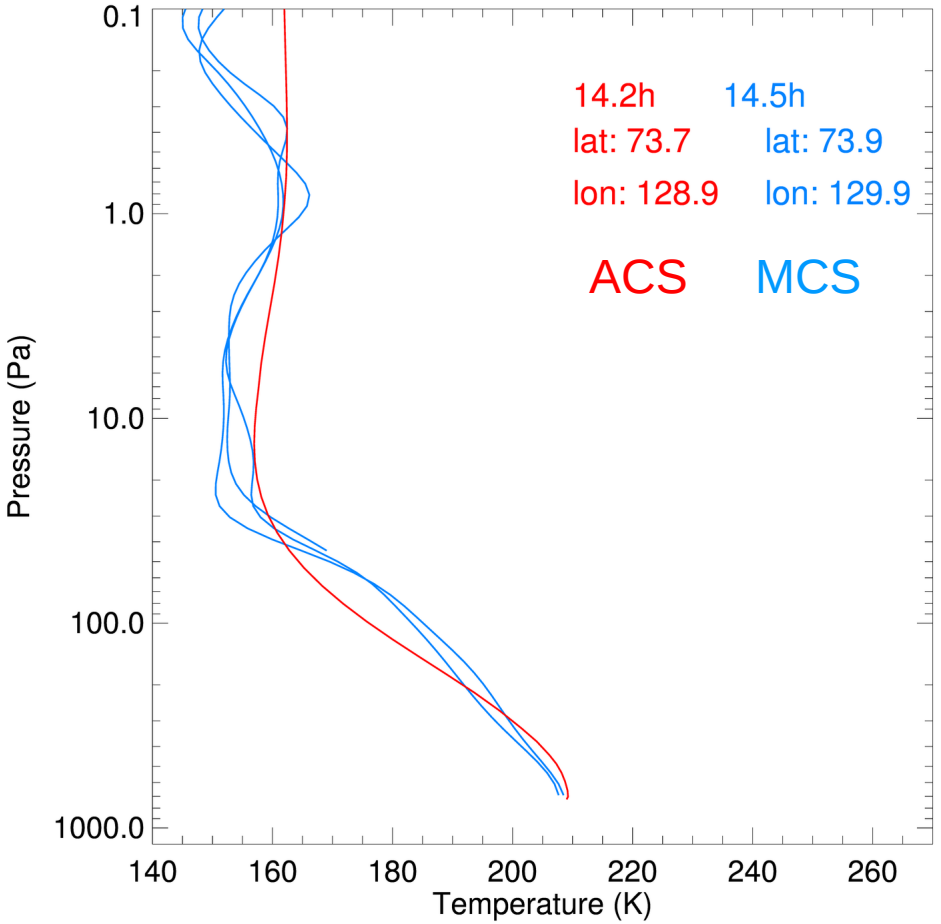
First days of TIRVIM observations (Ls=144)

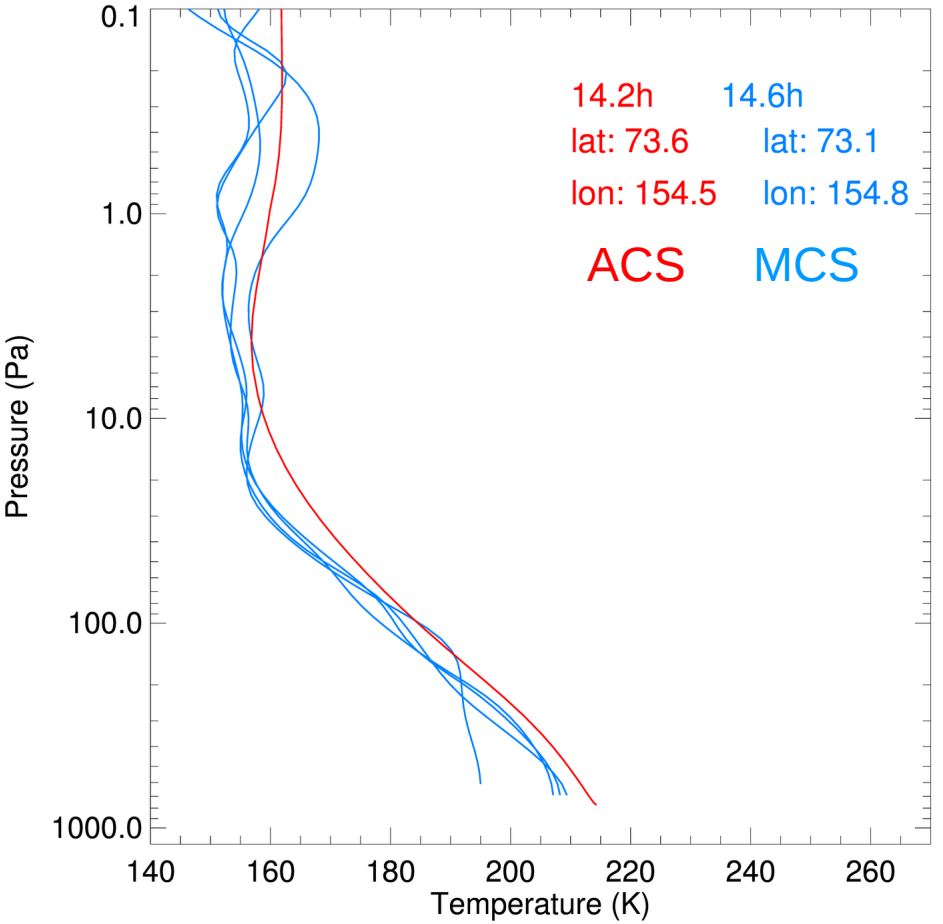


Nightime observations discarded at the moment (low signal-to-noise ratio).

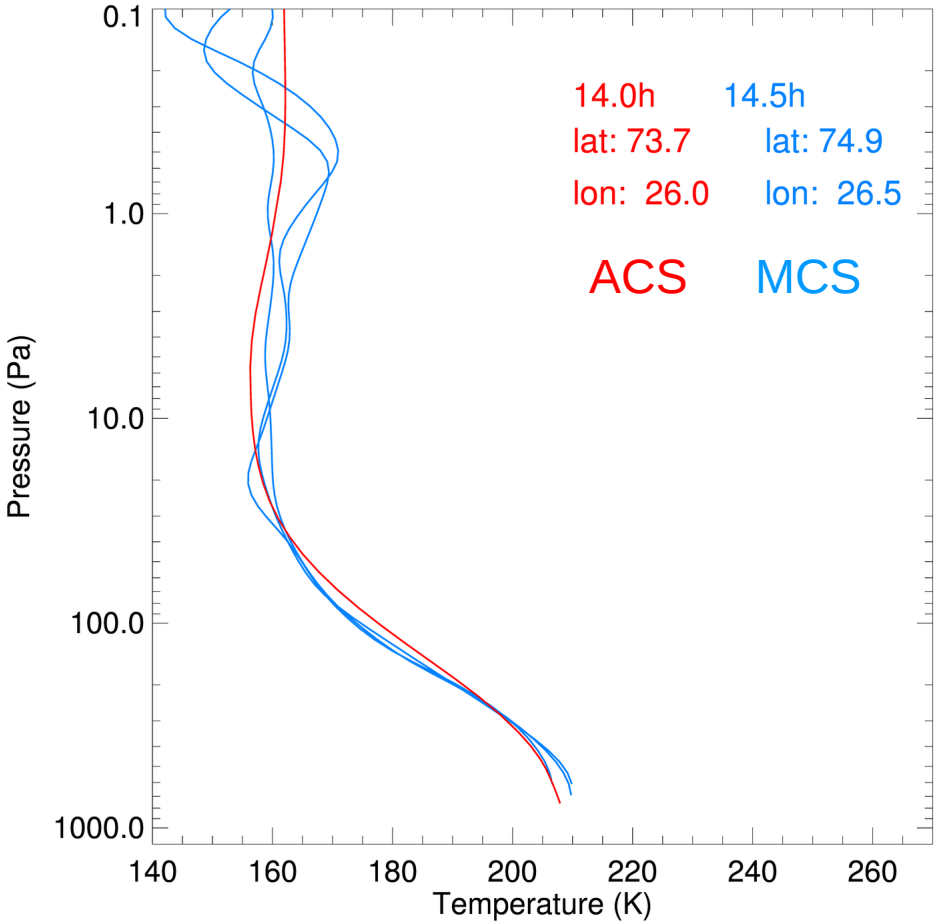
Comparisons with MCS : profiles

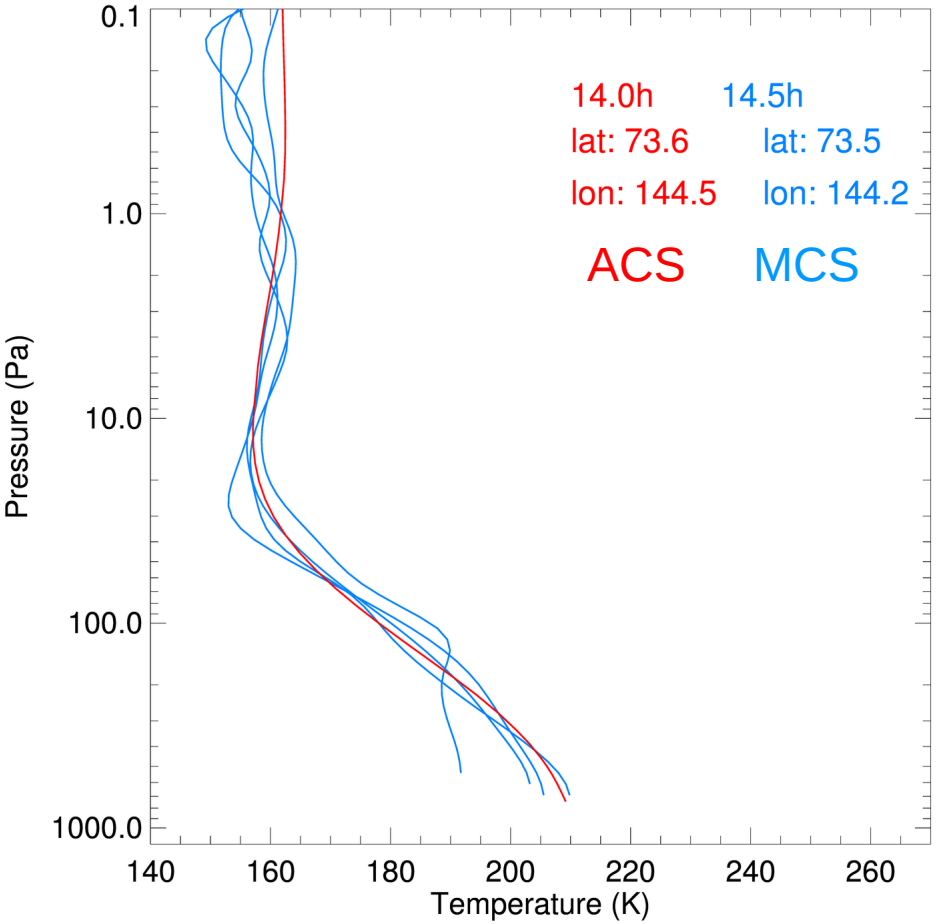
About 200 profiles co-located with MCS :
less than 5° away in longitude, 2.5° in latitude, 45min in local time.



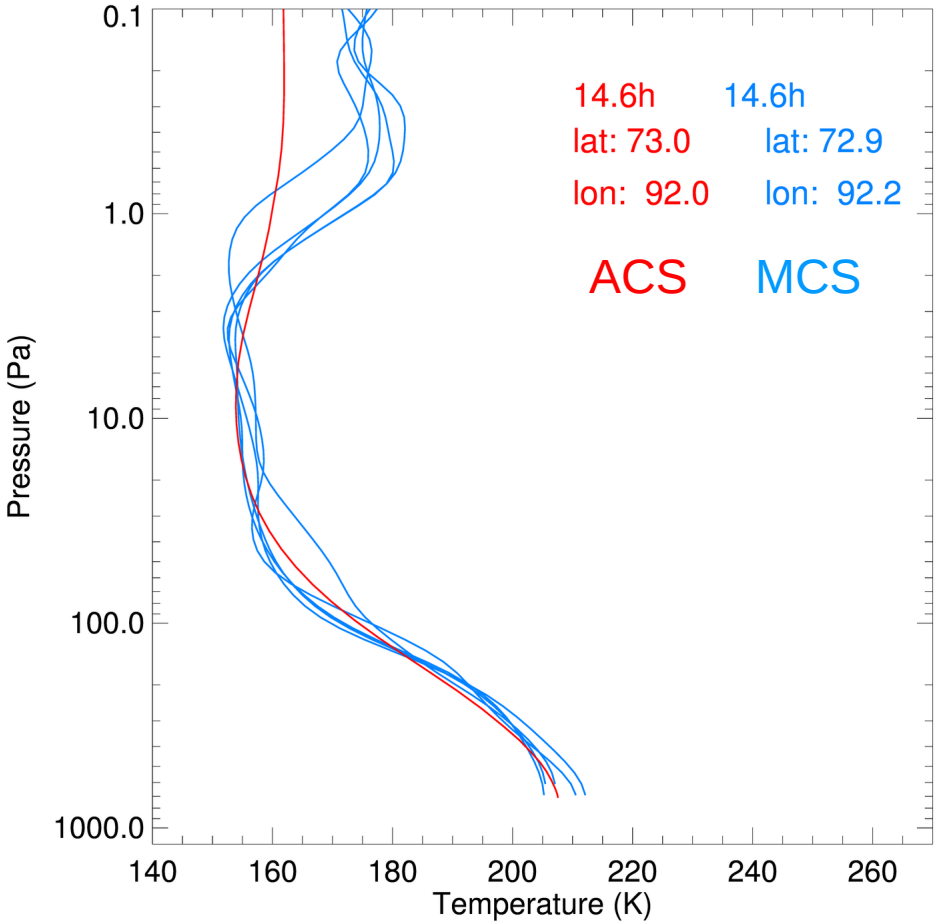


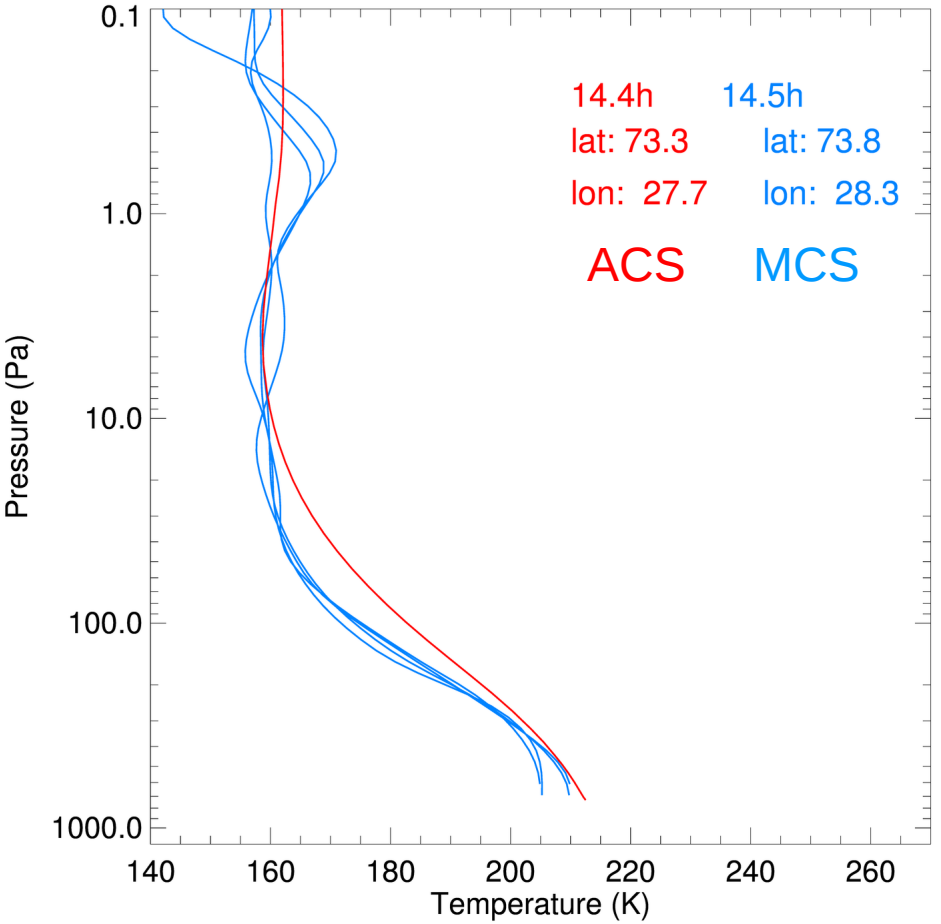
Comparisons with MCS : profiles



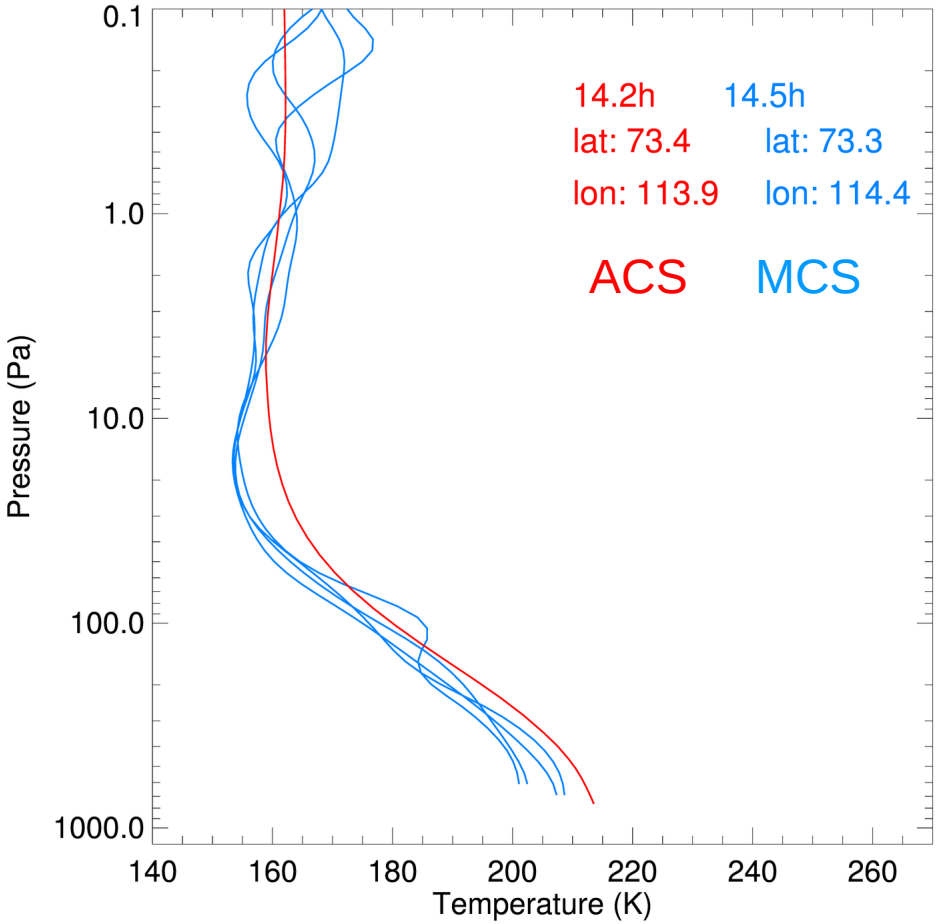


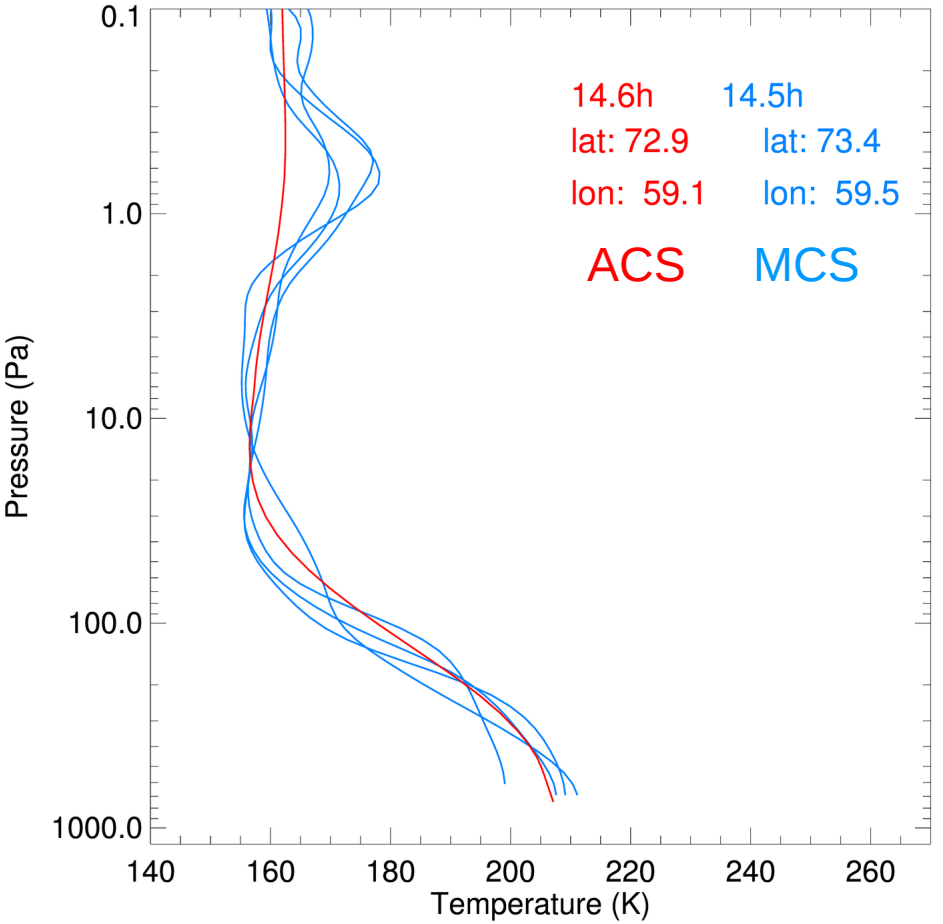
Comparisons with MCS : profiles



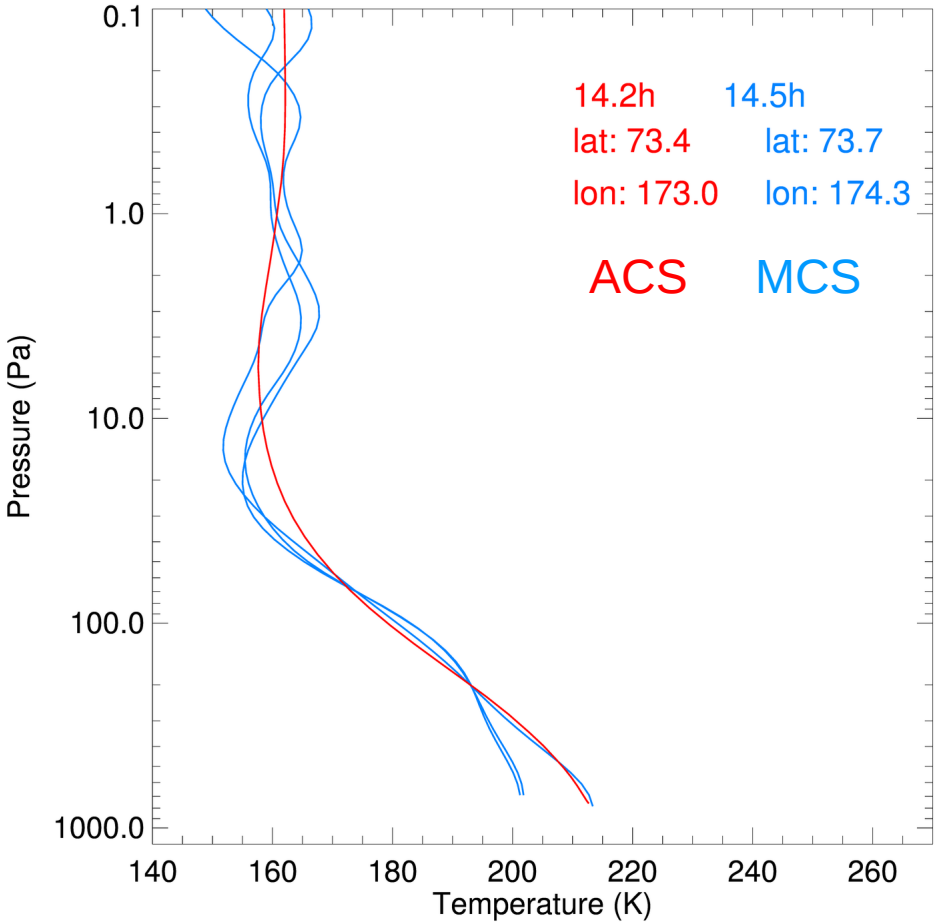


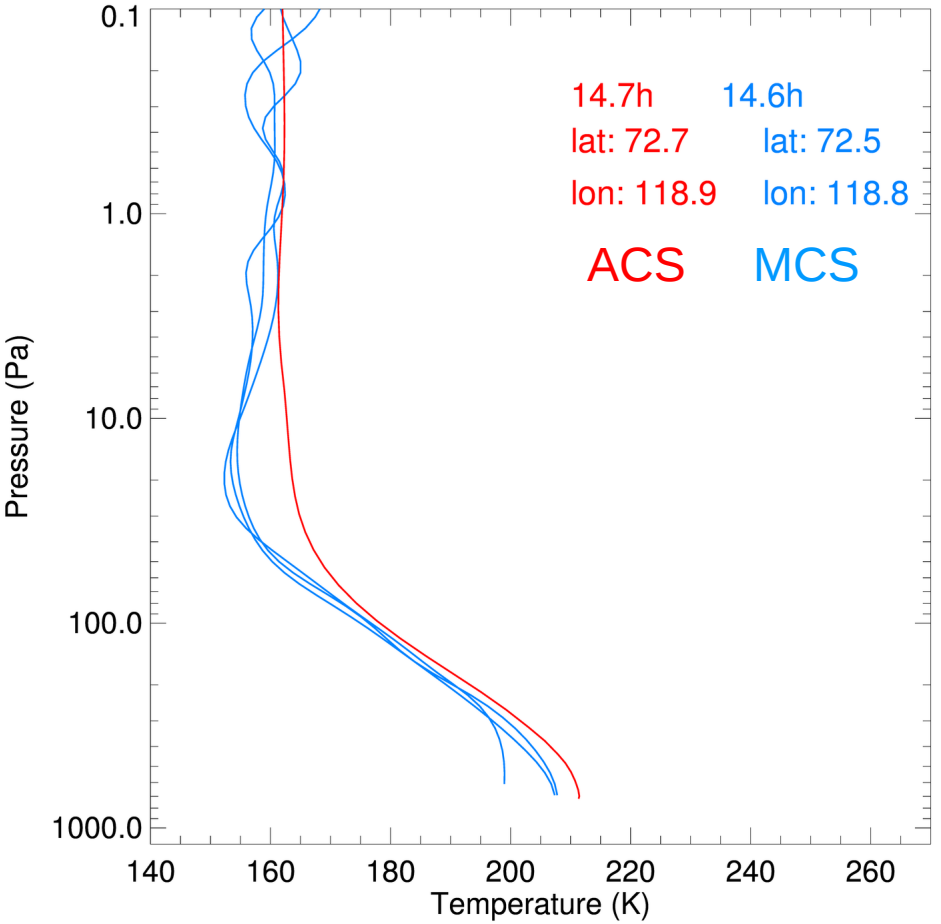
Comparisons with MCS : profiles



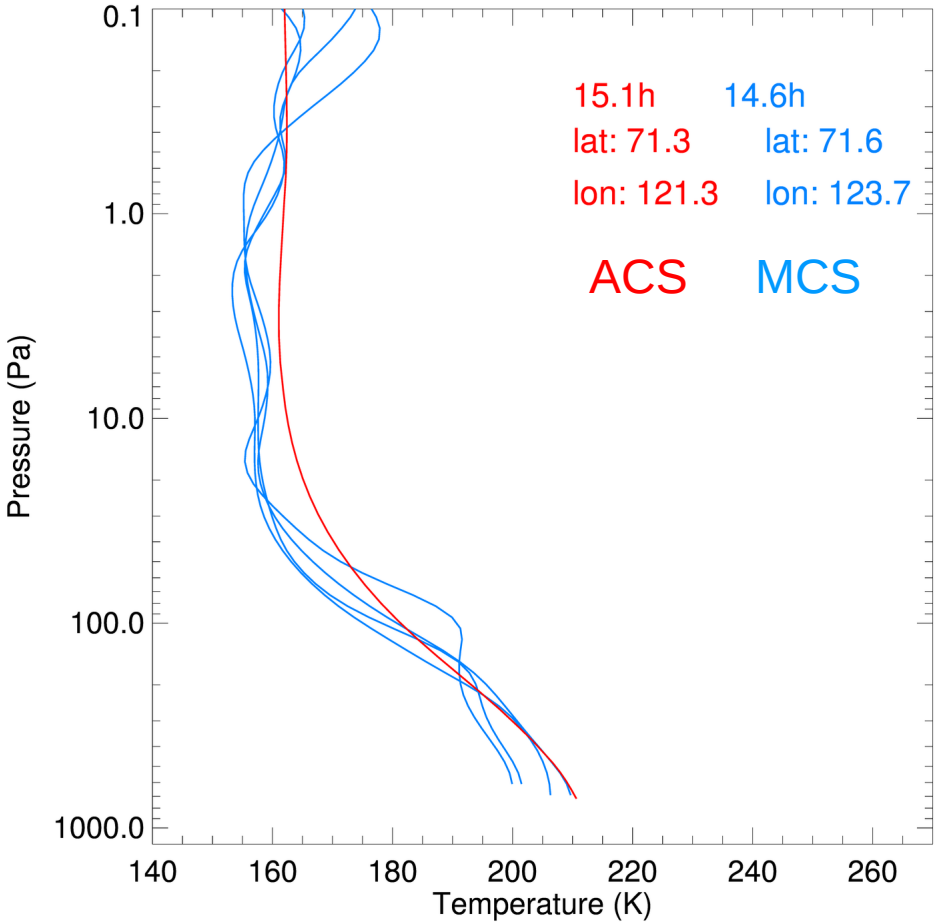


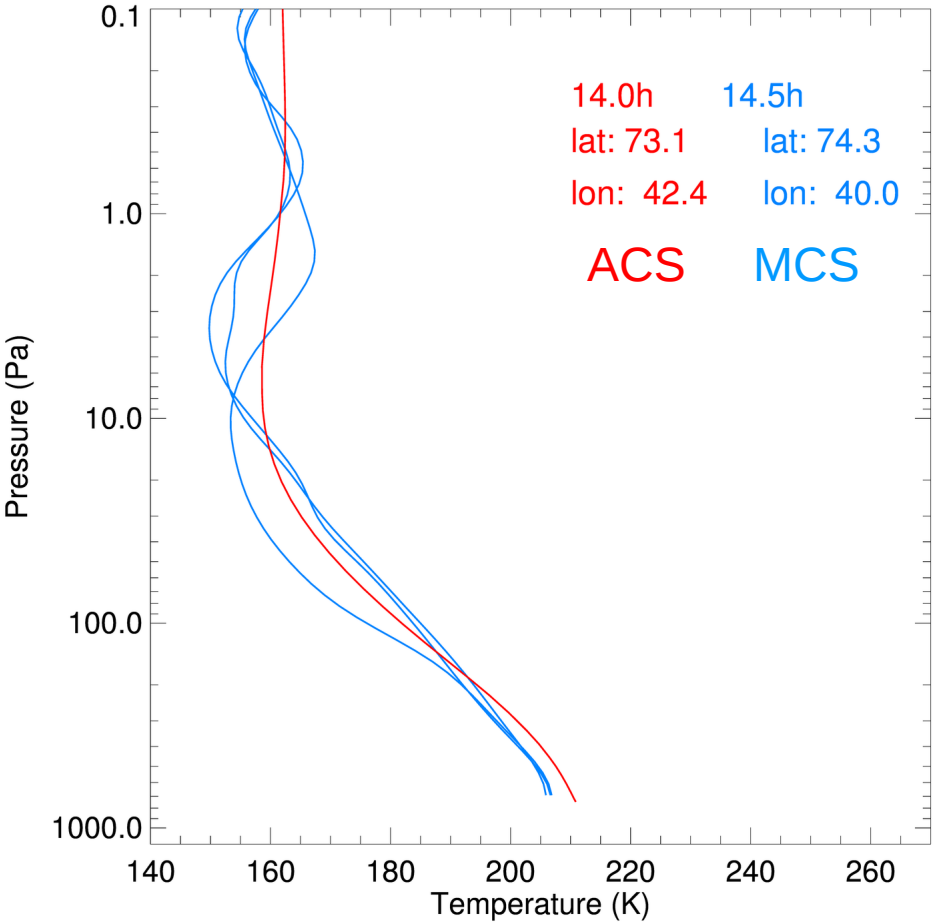
Comparisons with MCS : profiles



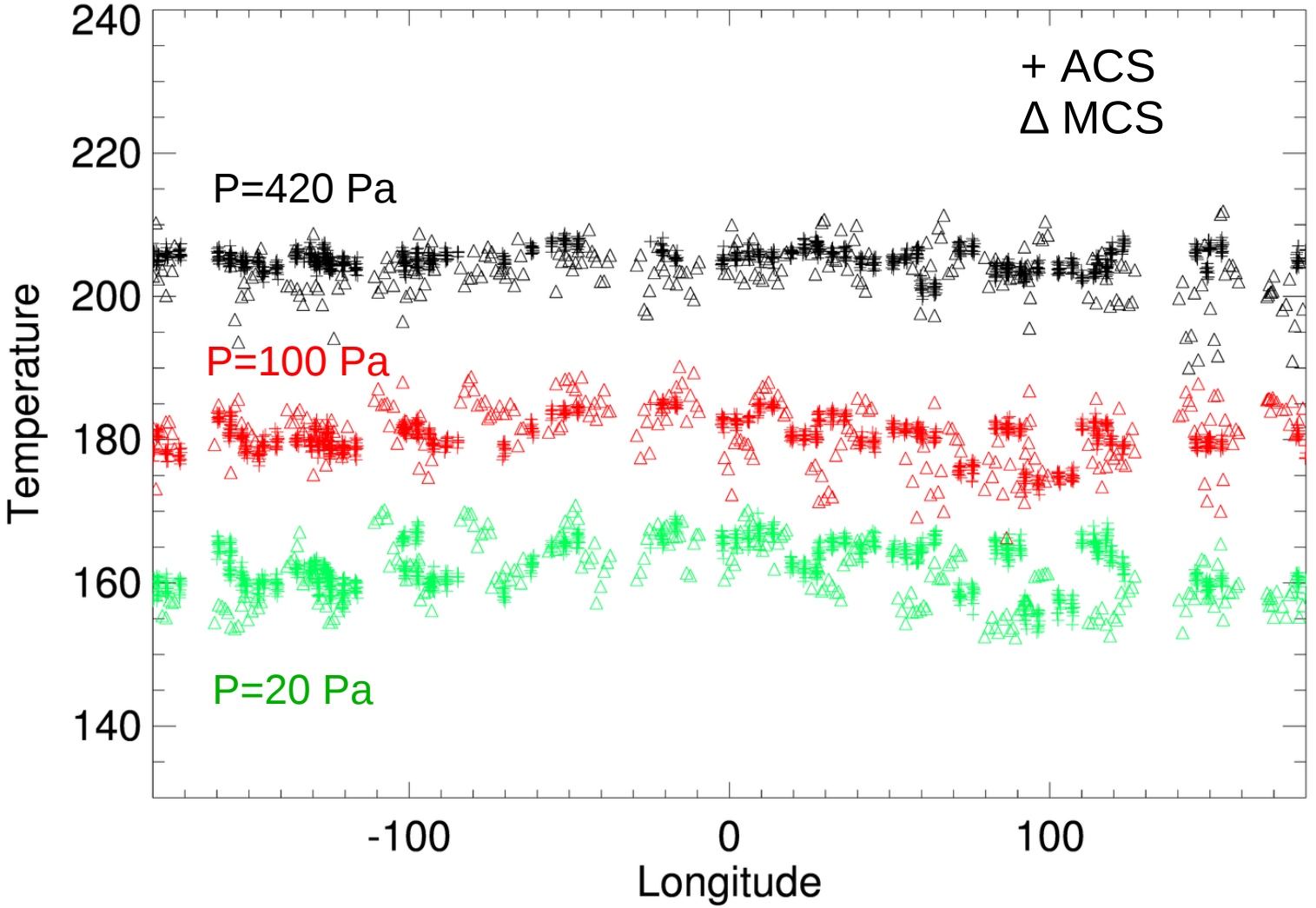


Comparisons with MCS : profiles



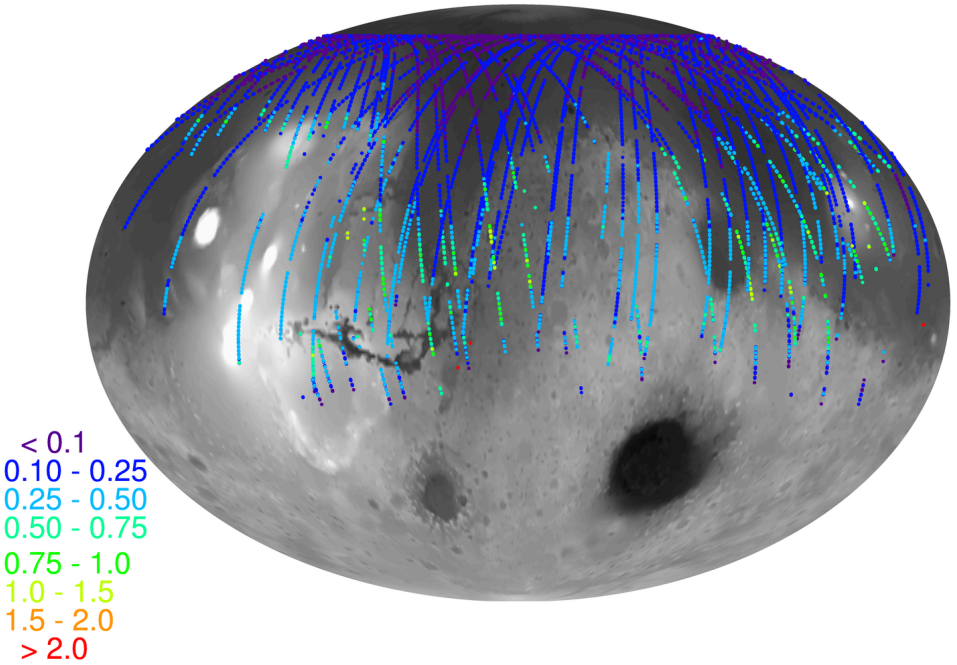


Comparisons with MCS : all cases

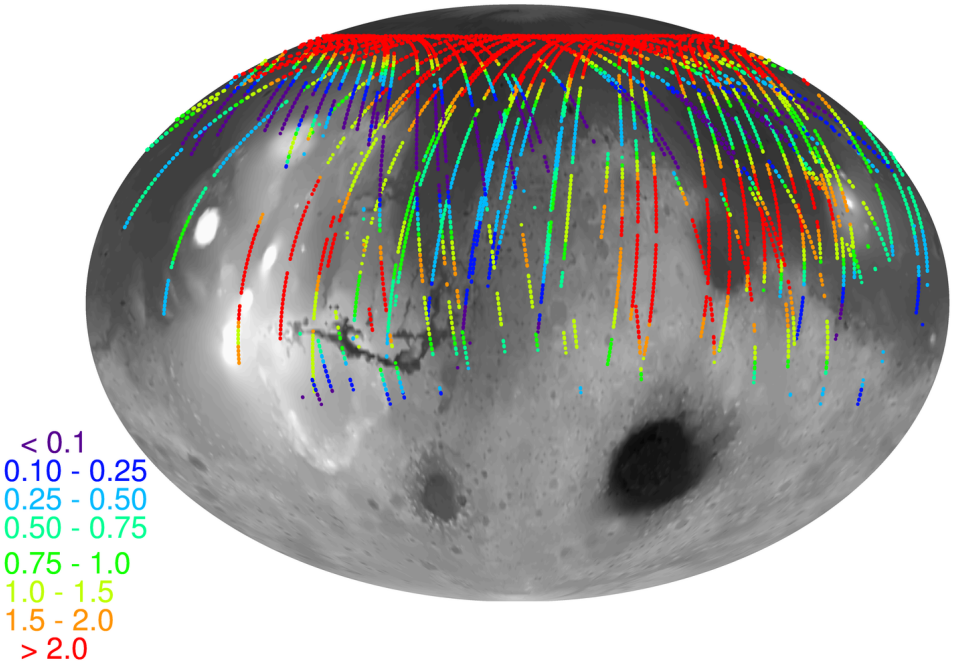


Cloud opacity at Ls=144°

Retrieved from TIRVIM



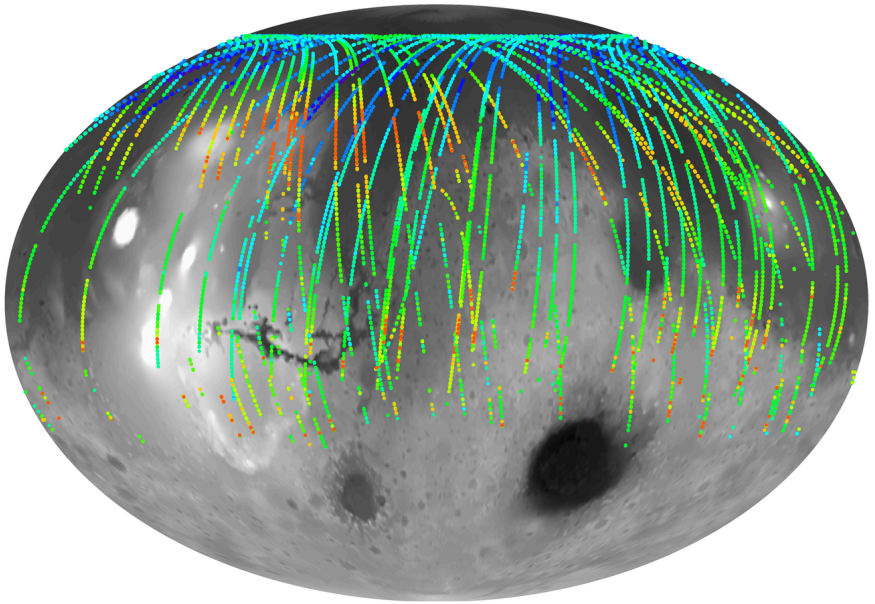
MCD « climatology » scenario



Much less clouds than the « climatology » scenario at high latitudes.

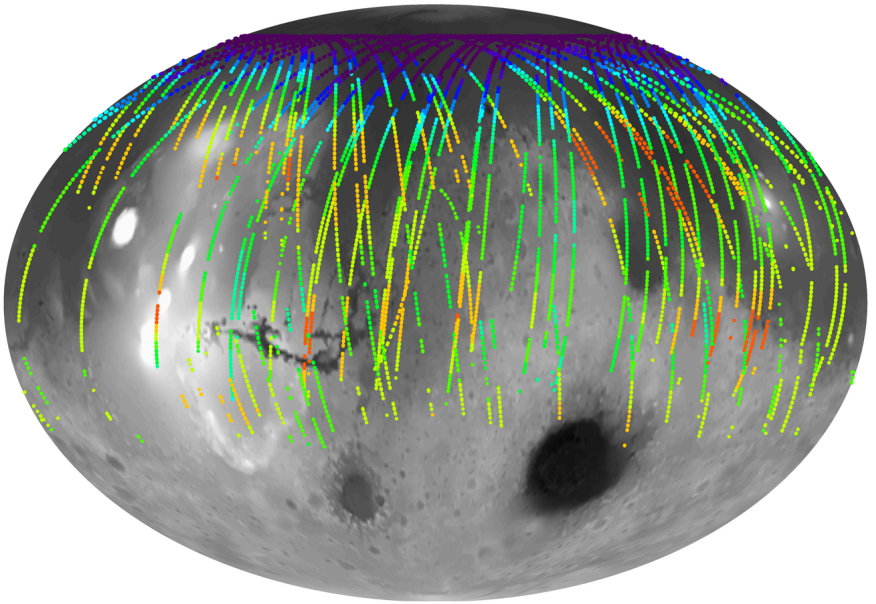
Temperature at 1 hPa

Retrieved from TIRVIM



174K 178K 182K 186K 190K 194K

MCD « climatology » scenario

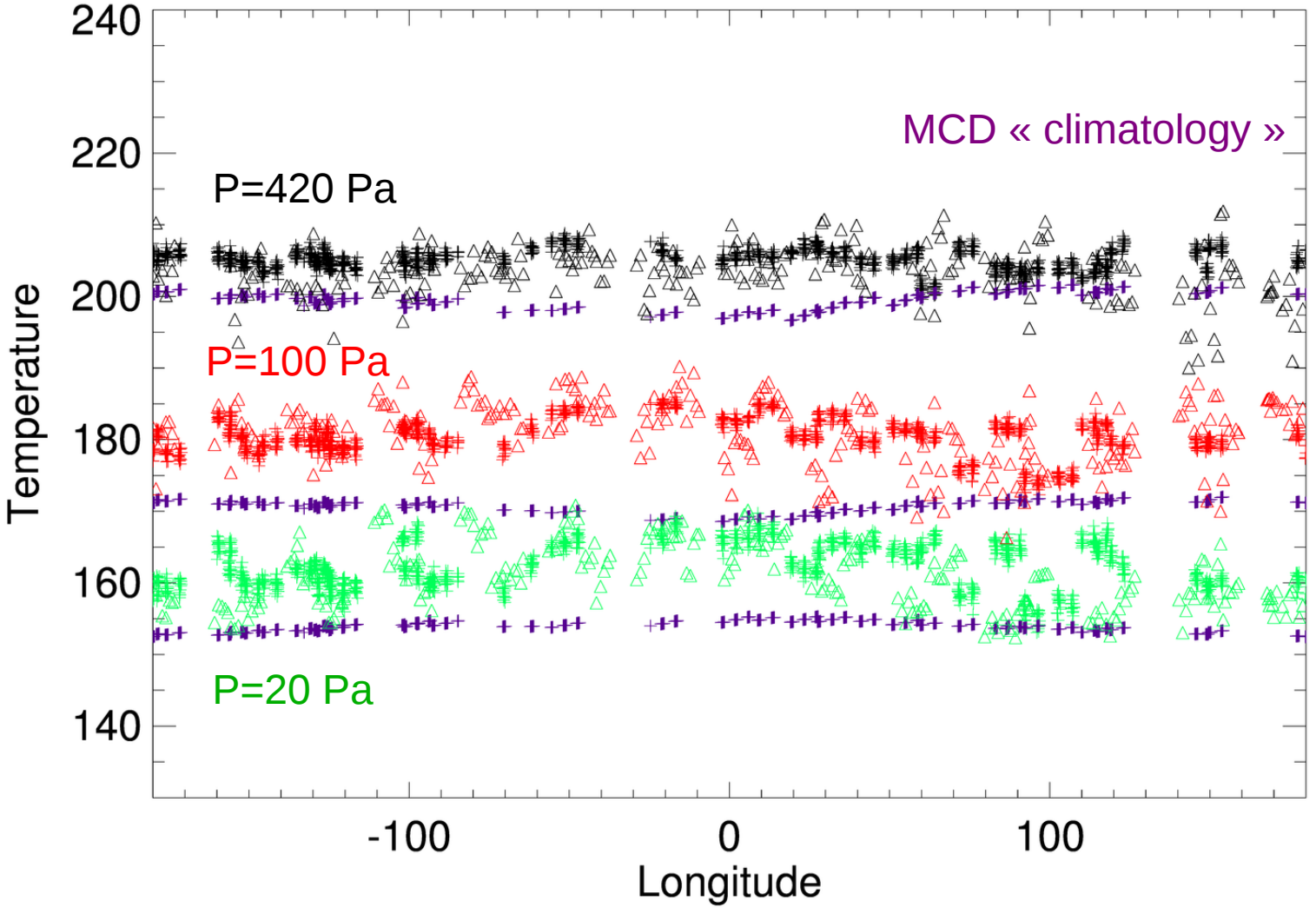


174K 178K 182K 186K 190K 194K

Much less clouds than the « climatology » scenario at high latitudes :
⟶ consistent with warmer (+8K) retrieved temperatures.

Summary

- Retrievals of temperature profile are very satisfactory ; **excellent comparison with MCS** – will be continued with more data.
- Dust retrieval challenging, in particular near 8am and 6pm.
- Ice retrieval : sensitive to the altitude of the cloud layer.
- Degeneracy (several local Chi2 minimum) between aerosol opacity and surface temperature in some situations.
  - Would help to better constrain the near-surface temperature.
- First 4 days analysed but much more TIRVIM data now available
- Stay tuned !


MCD « climatology »
P=420 Pa
P=100 Pa
P=20 Pa
Temperature
240
220
200
180
160
140
-100
0
100
Longitude