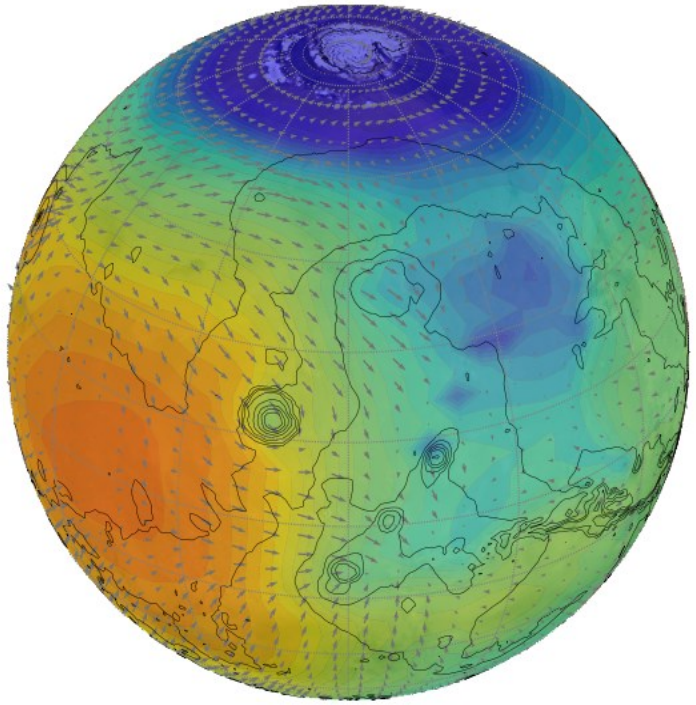
MCD Validation: where you should and should not trust the MCD



E. Millour, F. Forget and the MCD team

How accurate is the MCD ? Color code:

- **High Accuracy**
- **Acceptable Accuracy**
- **Possible problems**
- **Significant issues ; irrealistic values**

Pressure, Temperature, Density

- **Surface Pressure : excellent accuracy (<20 Pa)**
- **Surface temperature**
  - Typically < 10K
  - Possible errors due to local surface properties & slopes
  - In particular : near CO2 ice cap in spring
- **Atmospheric temperature and density below 70 km :**
  - Typically < 10K (larger error in clouds, local storms, polar night)
- **Atmospheric temperature above 70 km :** mean up to ~30K ;+ high variability **!**
- **Density above 70 km:**
  - mean < 30% (z<120 km) or 100% (z> 150 km)
  - Very High variability !! Travelling waves + gravity waves
- **Density above 250 - 300 km** (MCD extrapoles above top GCM layer)
  - Not well extrapolated in version 5.2 (assumes constant composition⇨ fix in MCD 5.3)
- - **Thermal and solar radiative fluxes**

Ice, aerosols and water

- **CO_2 ice cover**
  - Full GCM ~OK except end of S. Cap recession
  - Mars Climate database suffer from interpolation within 30° Ls step
- **Dust column opacity**
  - Dust prescribed daily scenario (available) driven by observations
  - Mars Climate database suffer from interpolation within 30° Ls step
- **Dust mass mixing ratio**
  - Error by a factor 2 to 3 in detached layers around 20-30 km.
  - Accurate Vertical extension
- **Dust effective radius**
- **Dust deposition rate**
- **[H2O] vapour**
  - **Column** accuracy < 20%
  - **Mixing ratio** : almost no observations to validate; supersaturation detected by SPICAM well predicted.
- **[H2O] ice**
  - **Column :** good agreement with TES ; suffer from Ls interpolation
  - **Mixing ratio :** difficult validation with MCS data: diurnal cycle not understood and discrepancy with TES...
  - **Effective radius:** Ok in GCM, but severely bugged in MCD.

Trace species and other characteristics

- **Long lived trace gas [CO2], [CO], [O], [O2], [N2], [Ar]**
  - **Accuracy Column & VMR below 120 km : high accuracy (2%)**
  - **VMR above 120 km:** Currently validated with MAVEN NGIMS data
  - **VMR above 250 km:** Not well extrapolated in version 5.2 (assumes constant composition⇨ fix in MCD 5.3)
- **Chemically active specie : [O3]**
- **[H], [H2]** above 100 km: discrepancy with MAVEN observations currently fixed.
- **[electrons]**
  - Between 60 km (1 Pa) and 200 km (5 10−6 Pa) : Good accuracy.
  - Below 60 km and above 200 km : unrealistic
- **Air specific heat capacity, viscosity and reduced gas constant r**
- **Convective PBL height, typical updraft and downdraft velocities in PBL**
- **Surface heat stress and surface sensible heat flux**

Validation of the MCD climatology

- Ongoing work
- Available measurements are the best way to evaluate and validate the MCD, e.g.:

  - **Surface temperatures**, **atmospheric temperatures** and **water vapour** can be compared to **TES** values.

  - **Atmospheric temperatures** and **water ice** can be compared to **MCS** values.

  - **Atmospheric temperatures** can also be compared to **MGS** and **Mars Express Radio Occultations**.

  - **Surface pressures** can be compared to **Viking Lander**, **Pathfinder**, **Phoenix** and **MSL** measurements.

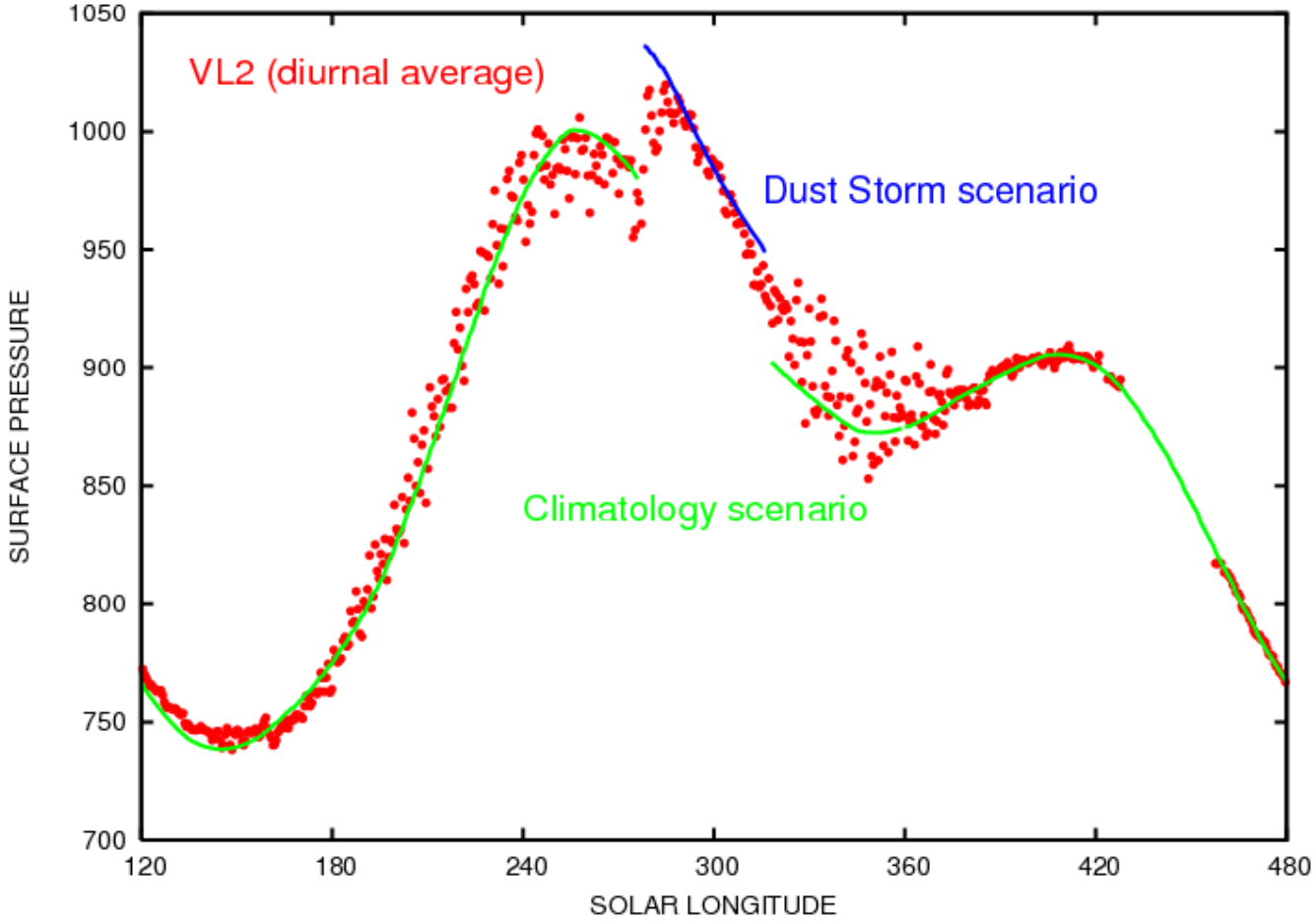
  - **…**

Surface Pressure

Viking Landers

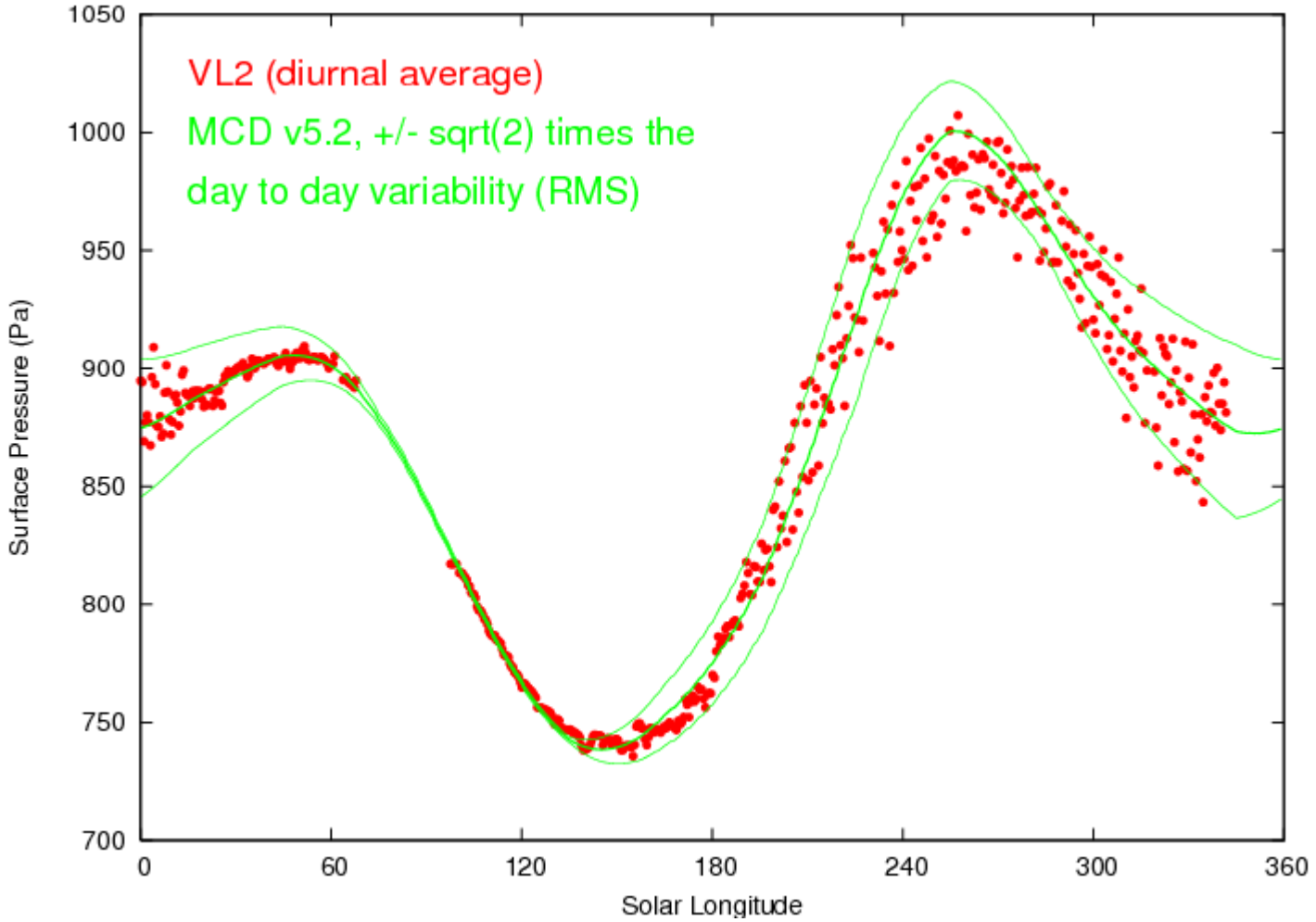
Mars Years 12-13

MCDv5.2 validation – VL2 pressure
Impact of dust scenario



- Change in global behavior due to dust storm is well captured by MCD scenarios.

MCDv5.2 validation – VL2 pressure day-to-day variability



- Seasonal evolution of the day-to-day variability is well captured by MCD.

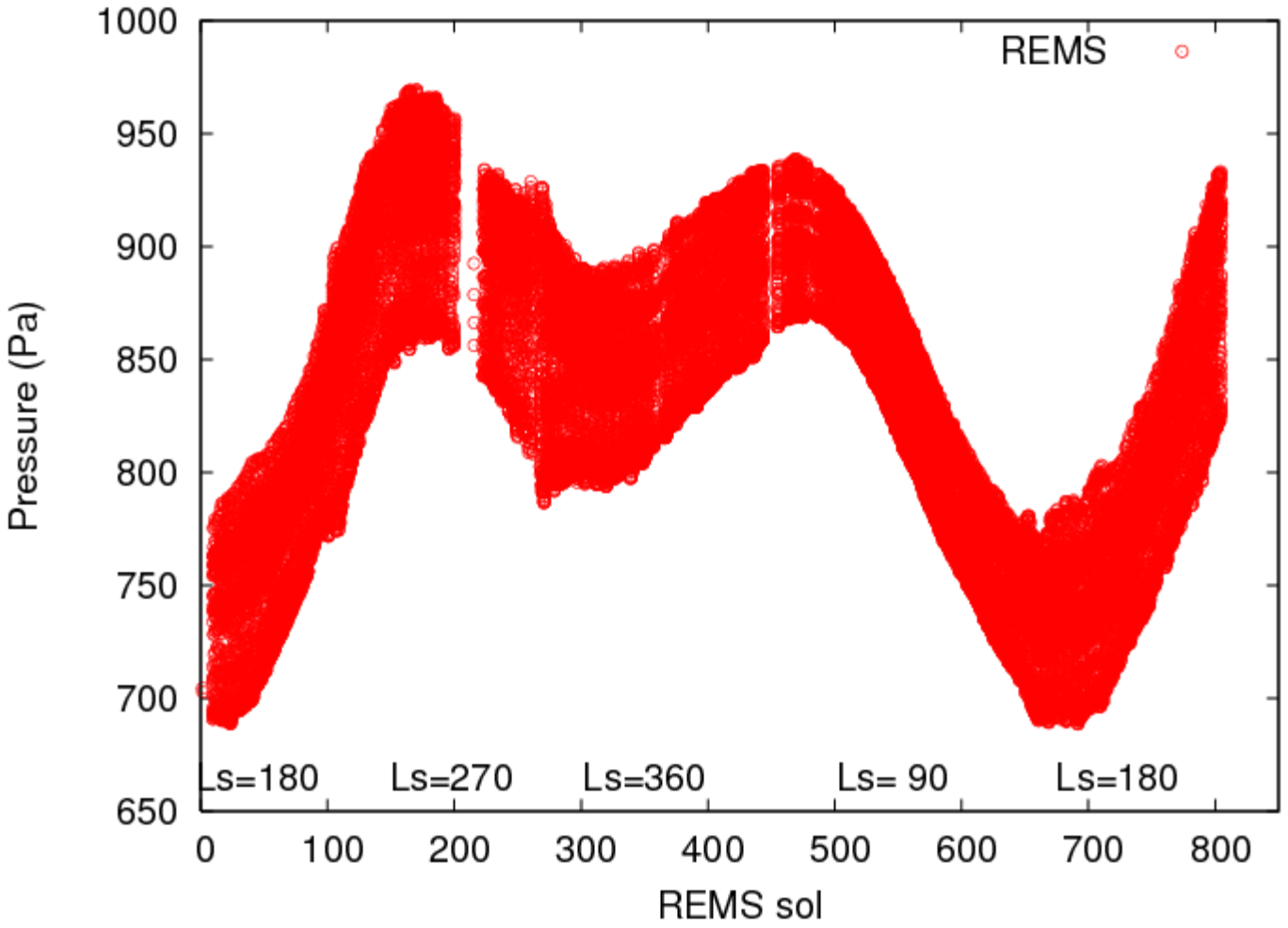
Surface Pressure

REMS onboard Curiosity

Mars Year 31-32

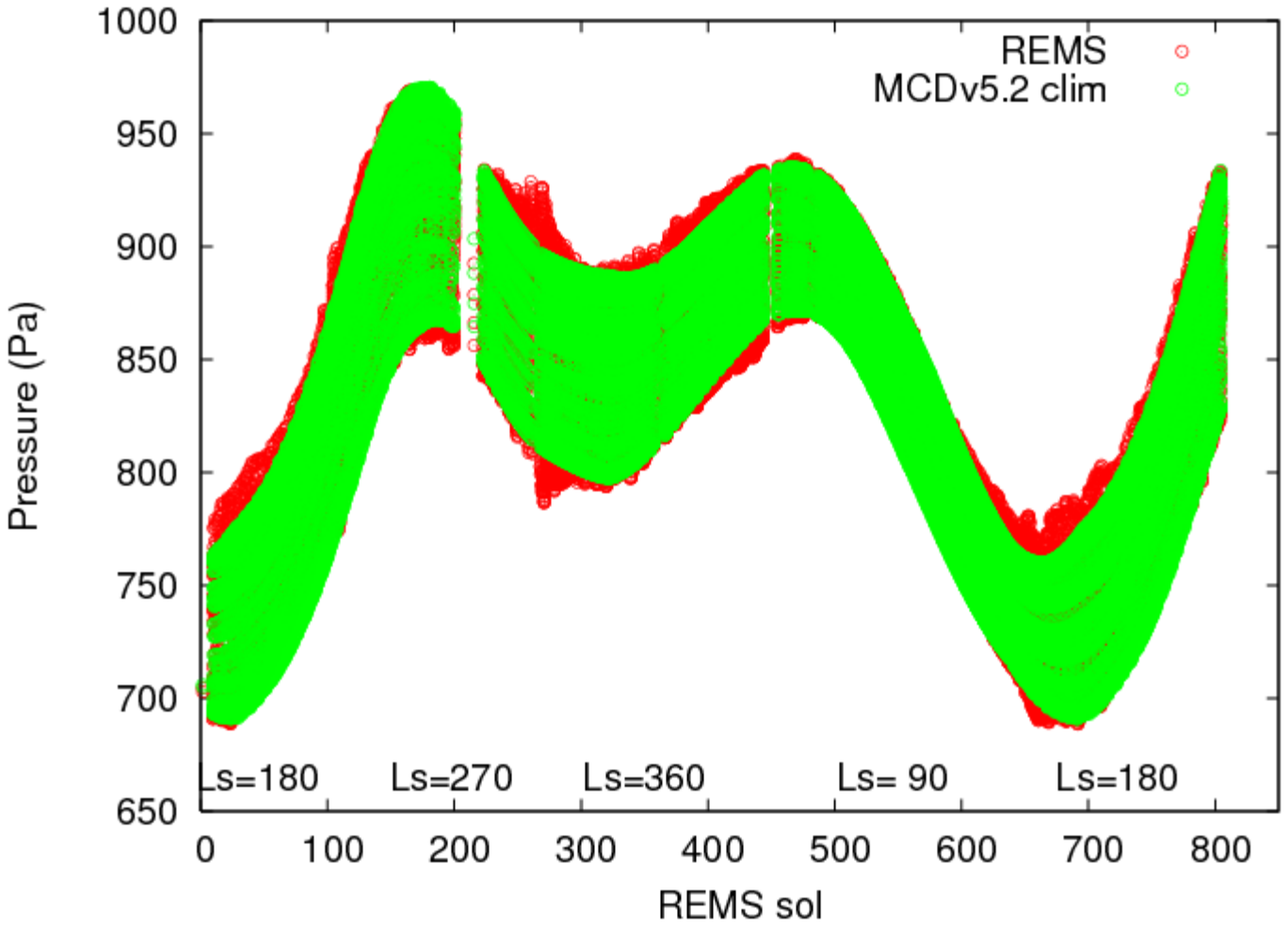
REMS pressure measurements

- Ongoing measurements for now over a Martian Year (MY31-32) and ongoing



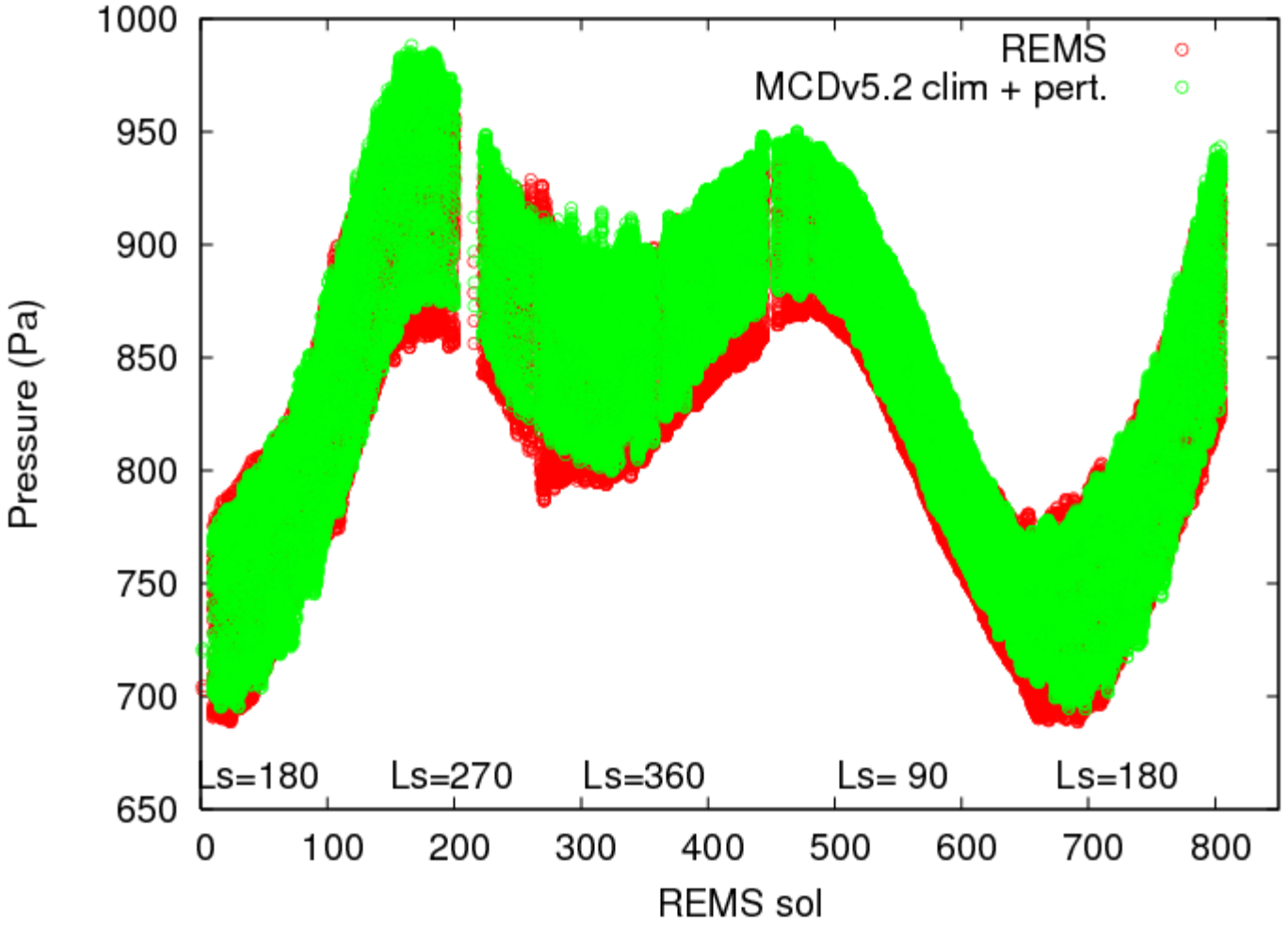
REMS pressure measurements

- Ongoing measurements for now over a Martian Year (MY31-32) and ongoing

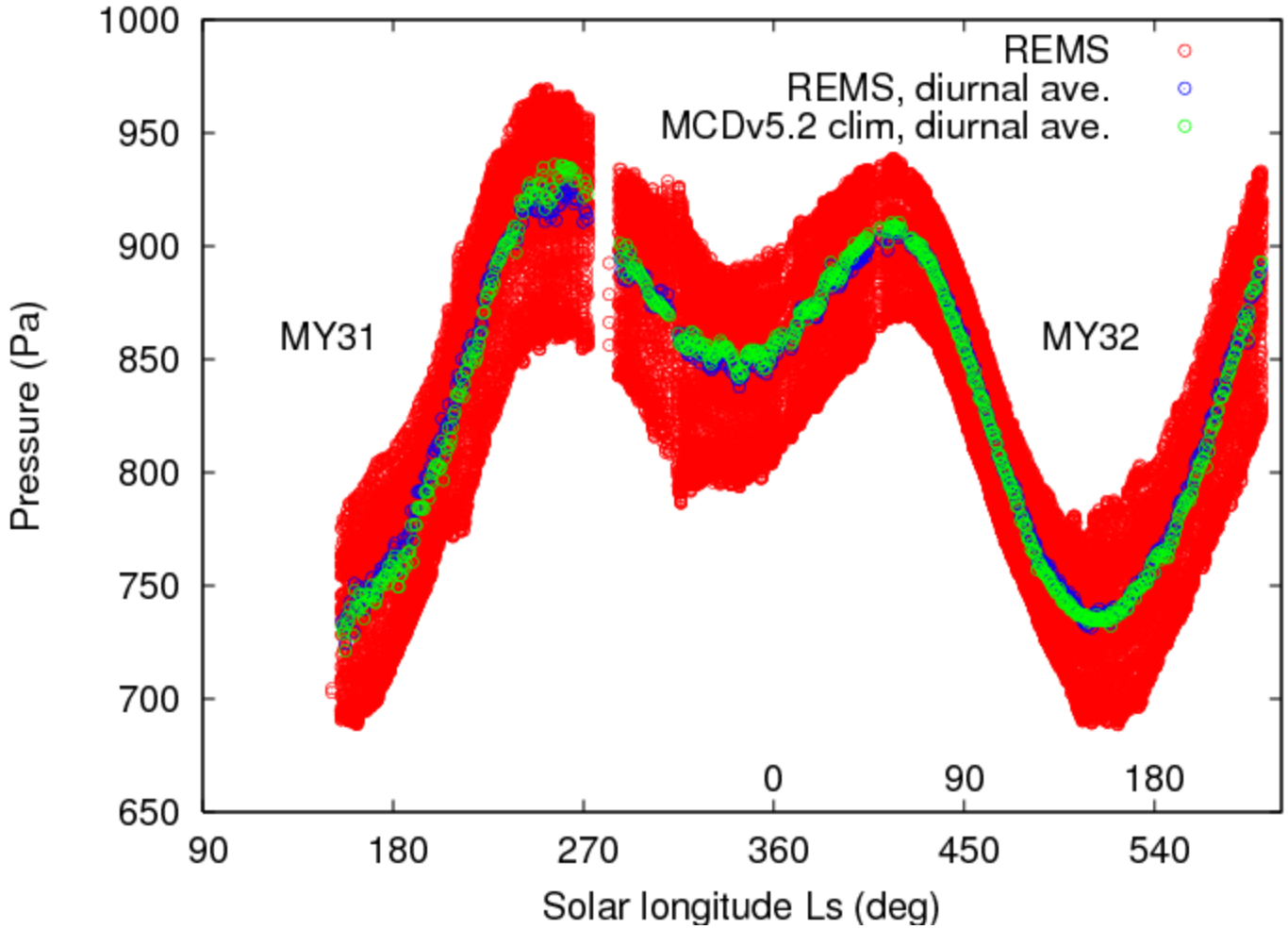


REMS pressure measurements

- Ongoing measurements for now over a Martian Year (MY31-32) and ongoing

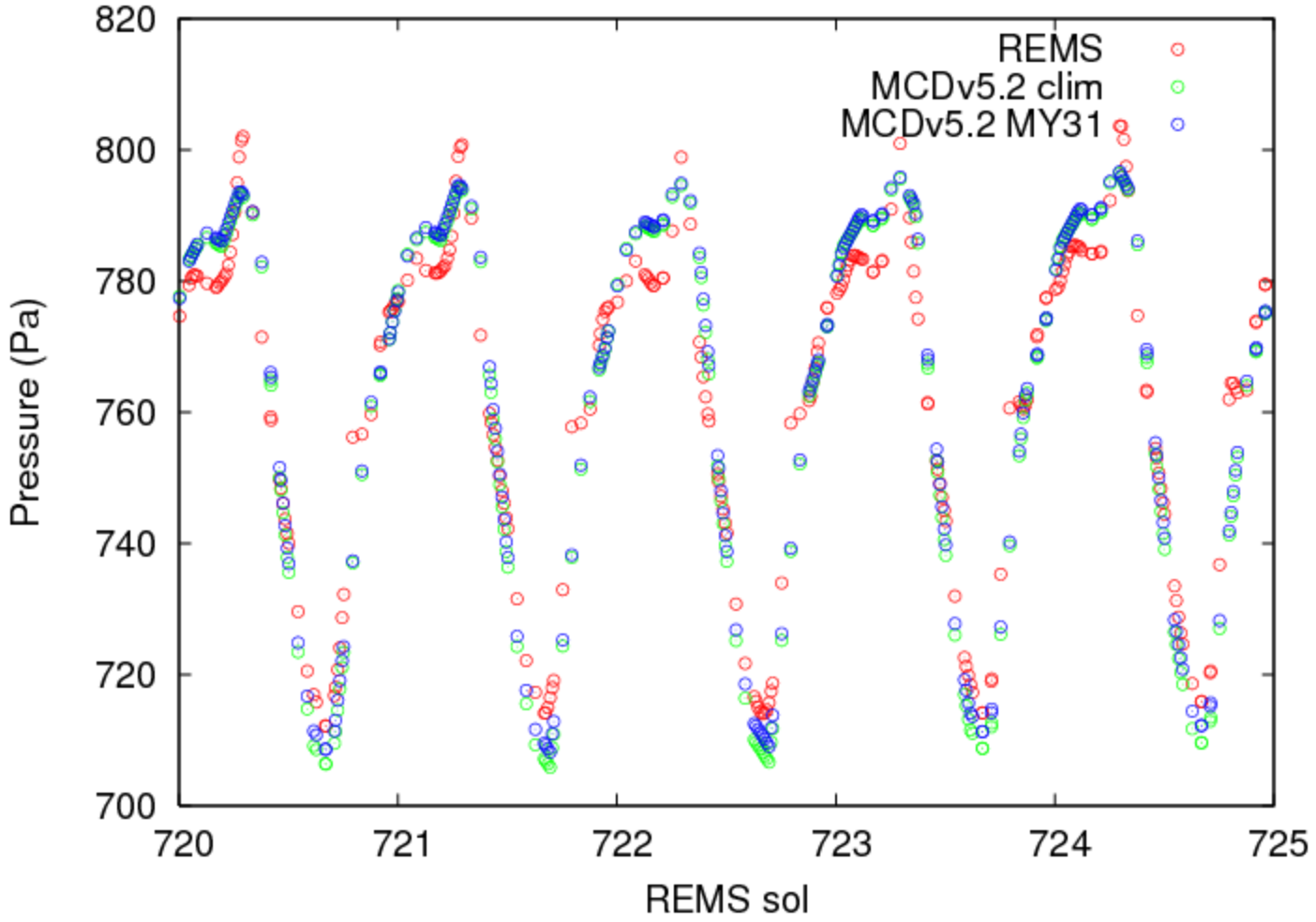


REMS pressure measurements



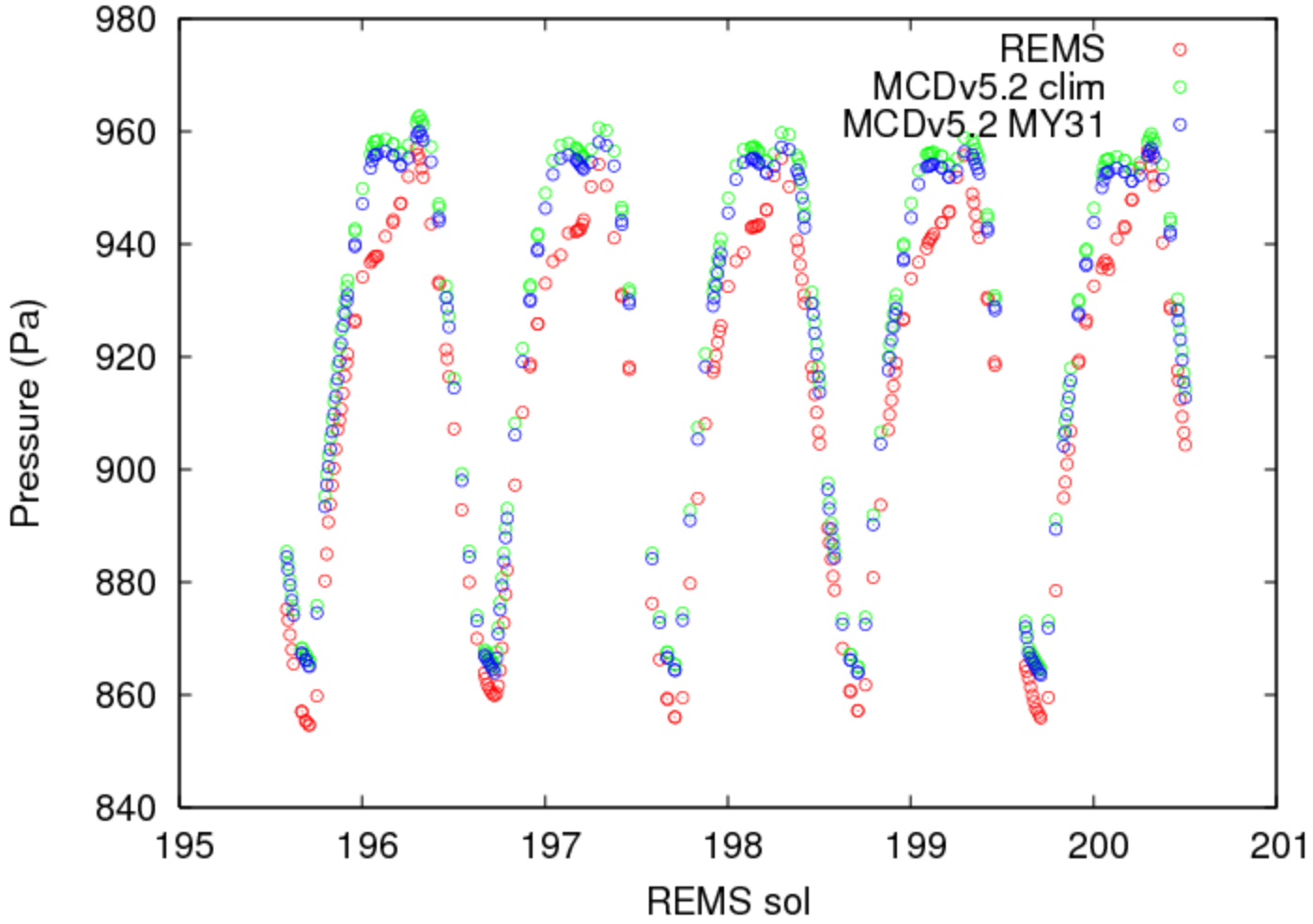
- Good representativeness of MCDv5.2 clim (and MY31, not shown) scenarios of the seasonal evolution of the Martian CO2 cycle

REMS pressure measurements



- Good representativeness of MCDv5.2 clim (and MY31) scenarios of the diurnal evolution of surface pressure (here for Ls 180).

REMS pressure measurements



- In some cases local mesoscale circulation, unresolved by the MCD, may induce variations (illustration for Ls=270).

Surface Temperature

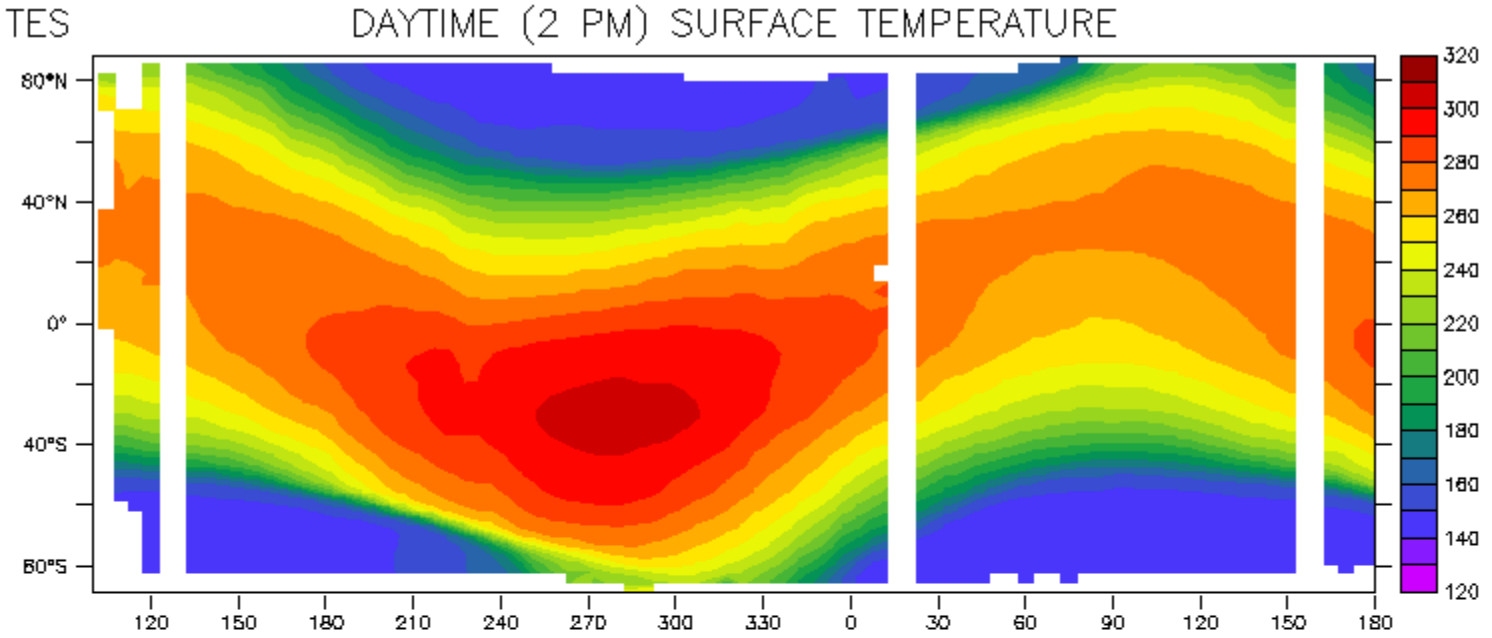
TES onboard MGS

Mars Years 24-27

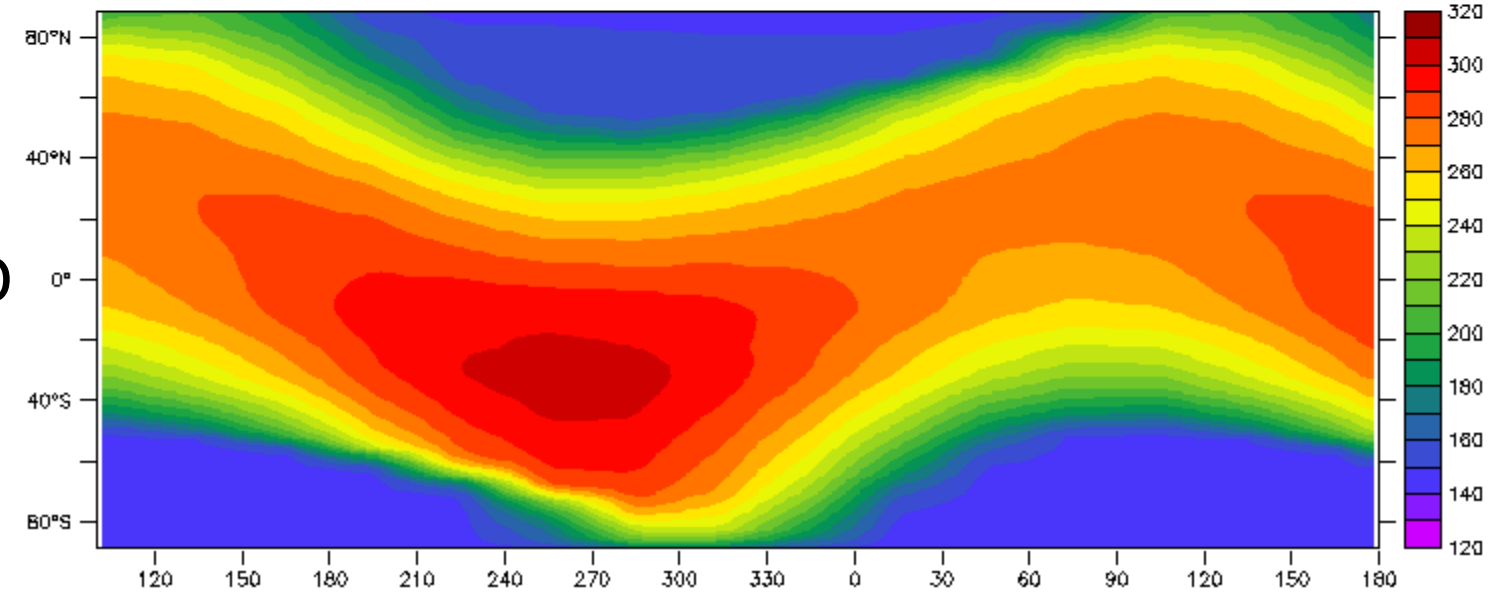
(2am-2pm measurements)

Zonal values of surface temperature

TES

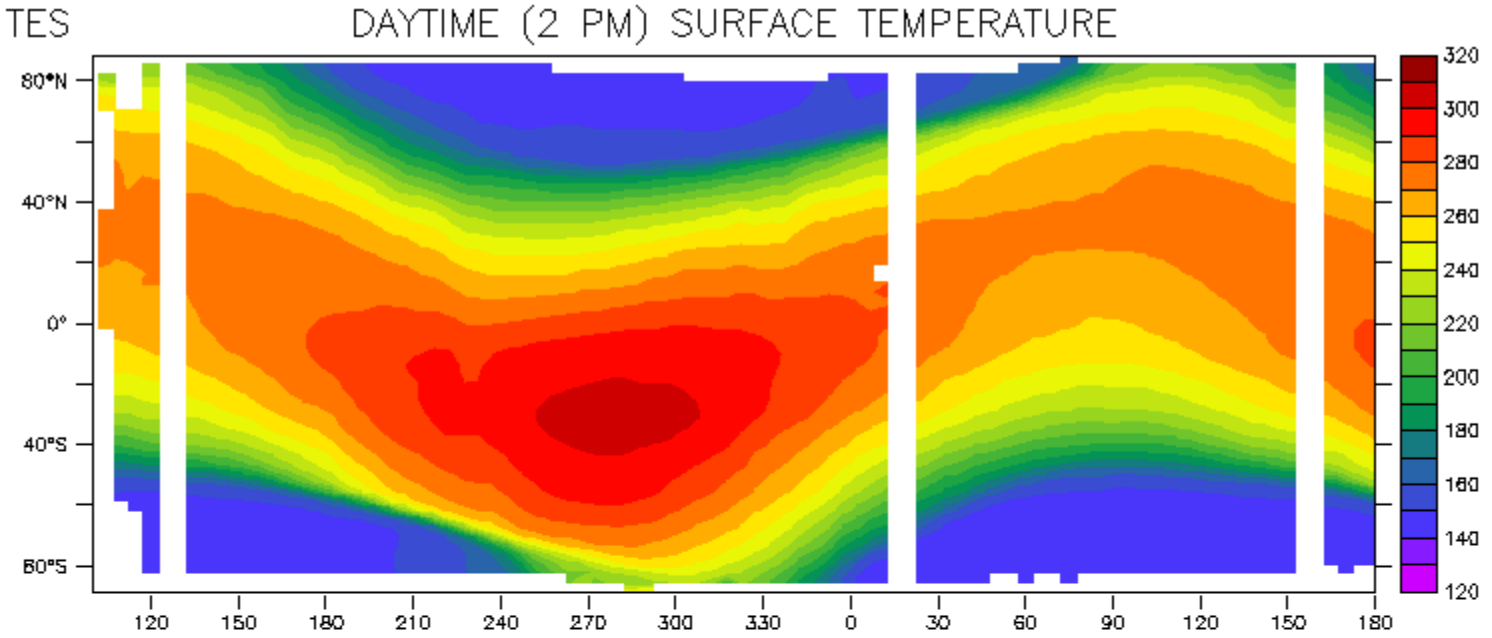


MCD clim

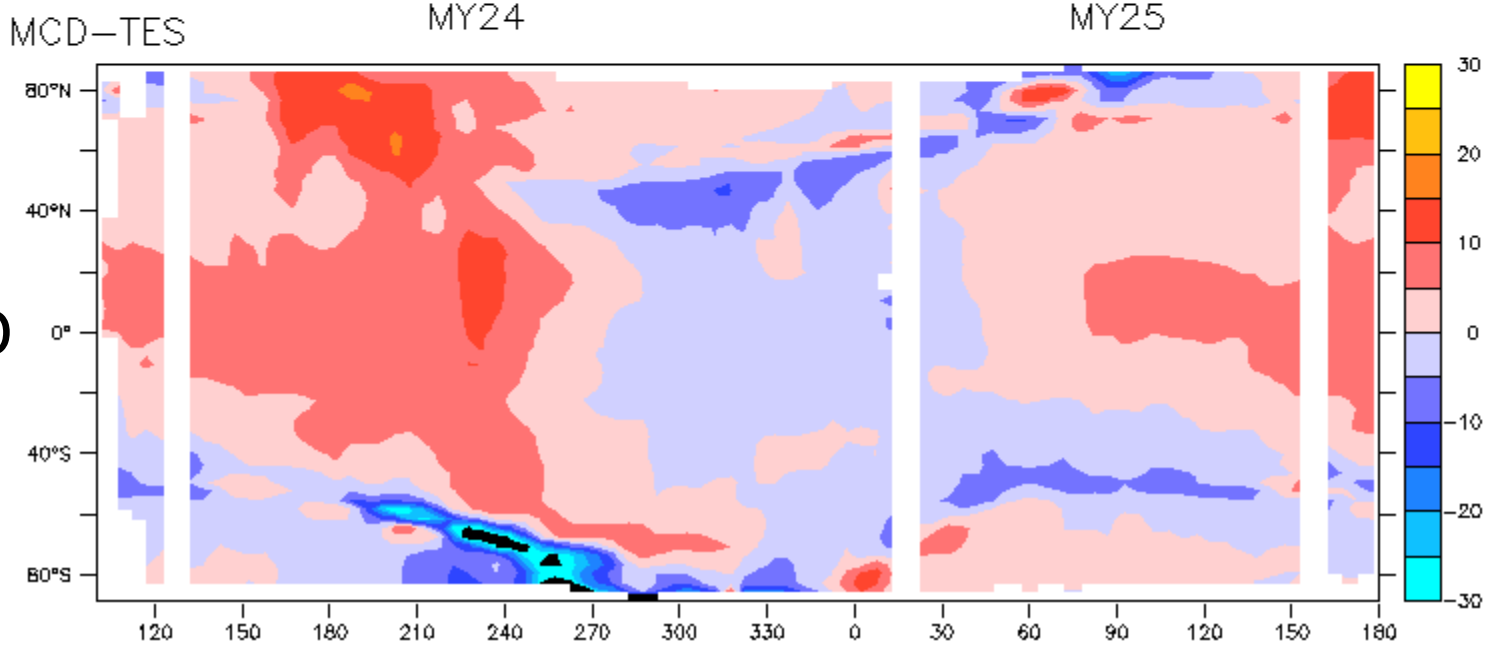


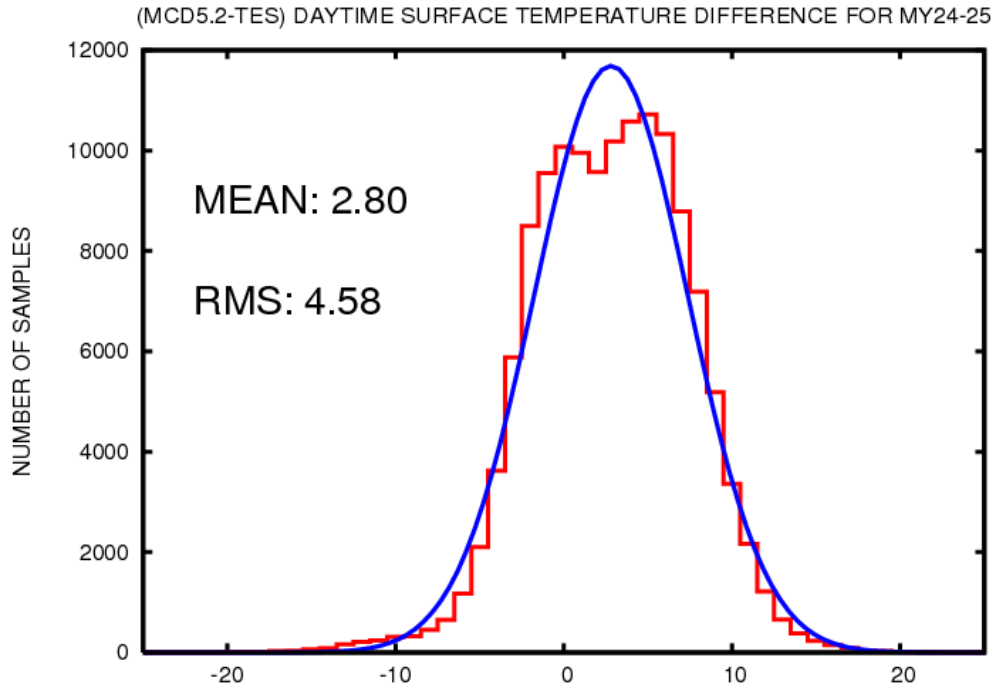
Zonal values of surface temperature

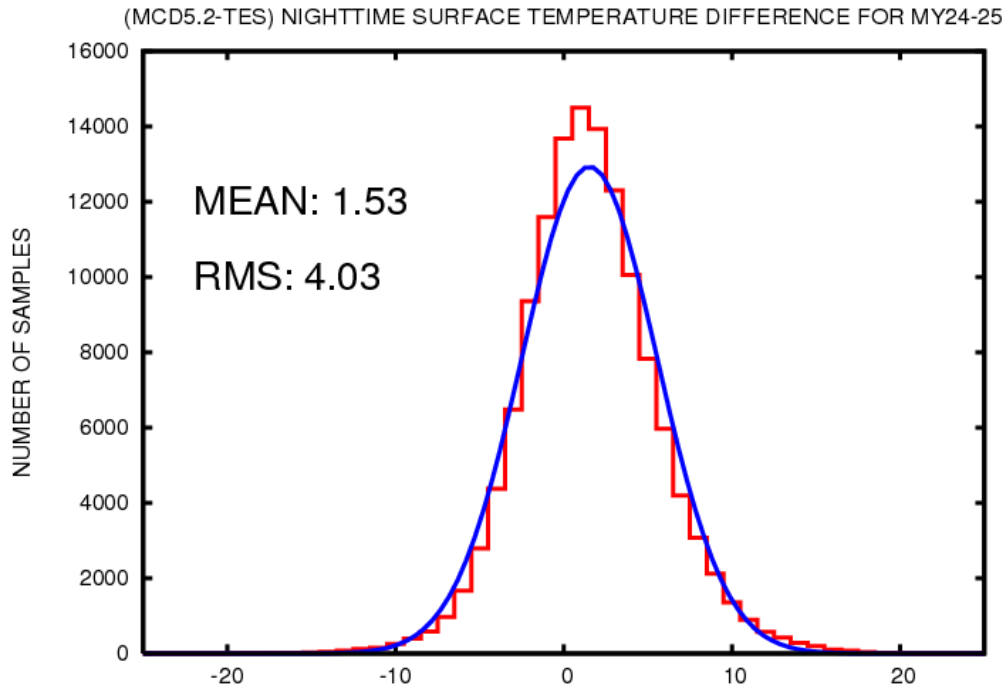
TES



MCD clim







Distributions of surface temperature difference between MCDv5.2 (clim scenario) and TES

- Statistics computed for:
  - MY24: 102.5 < Ls < 360
  - MY25: 0 < Ls < 180
  - -50 < latitude < 50
  - Bins of 1K

Note: MEAN and RMS values are computed from histograms; blue curves are normal distributions of same MEAN and RMS

Atmospheric Temperature

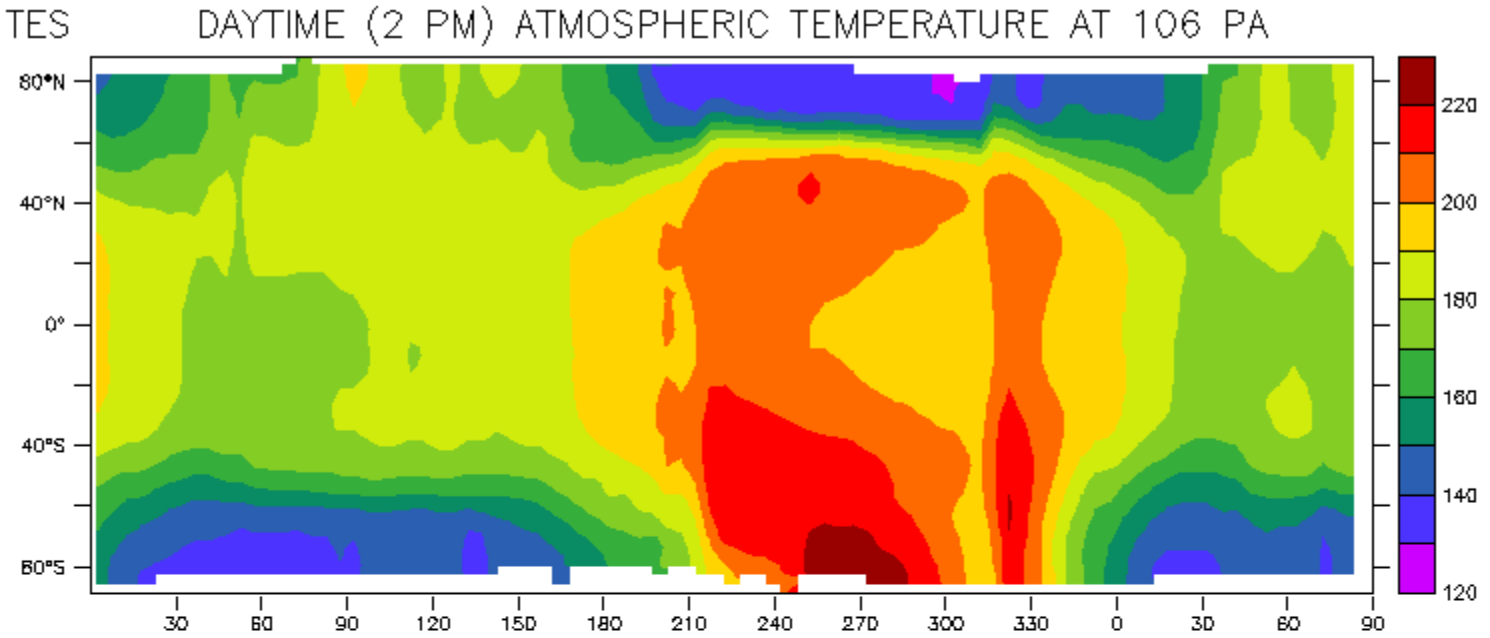
TES onboard MGS

Mars Years 24-27

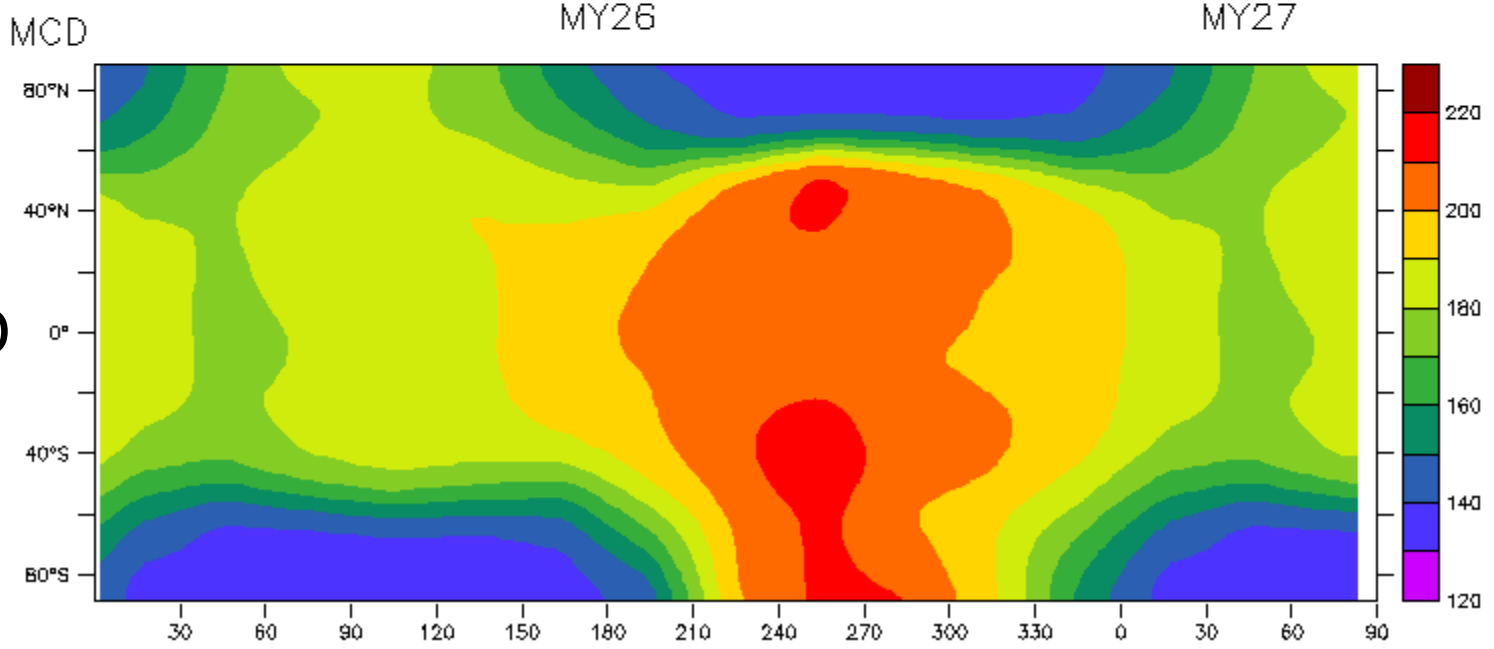
(2am-2pm measurements)

Zonal values of atmospheric temperature (106 Pa)

TES

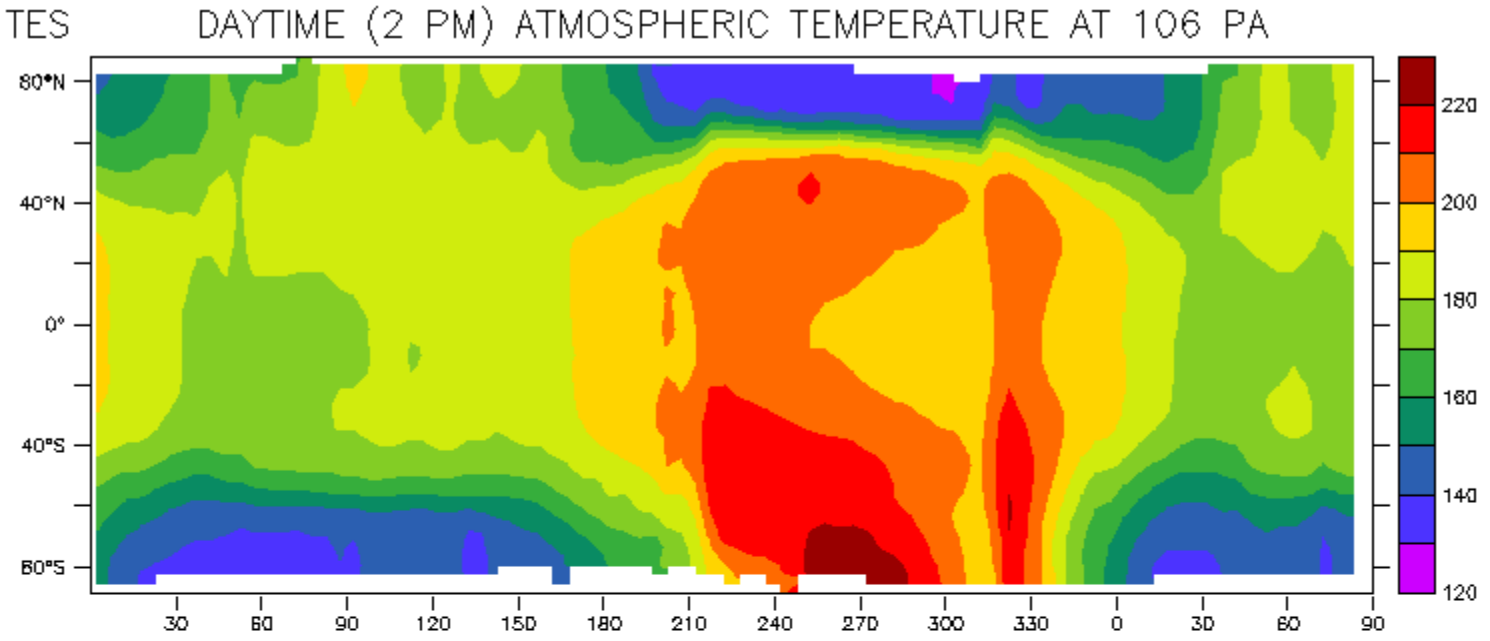


MCD clim

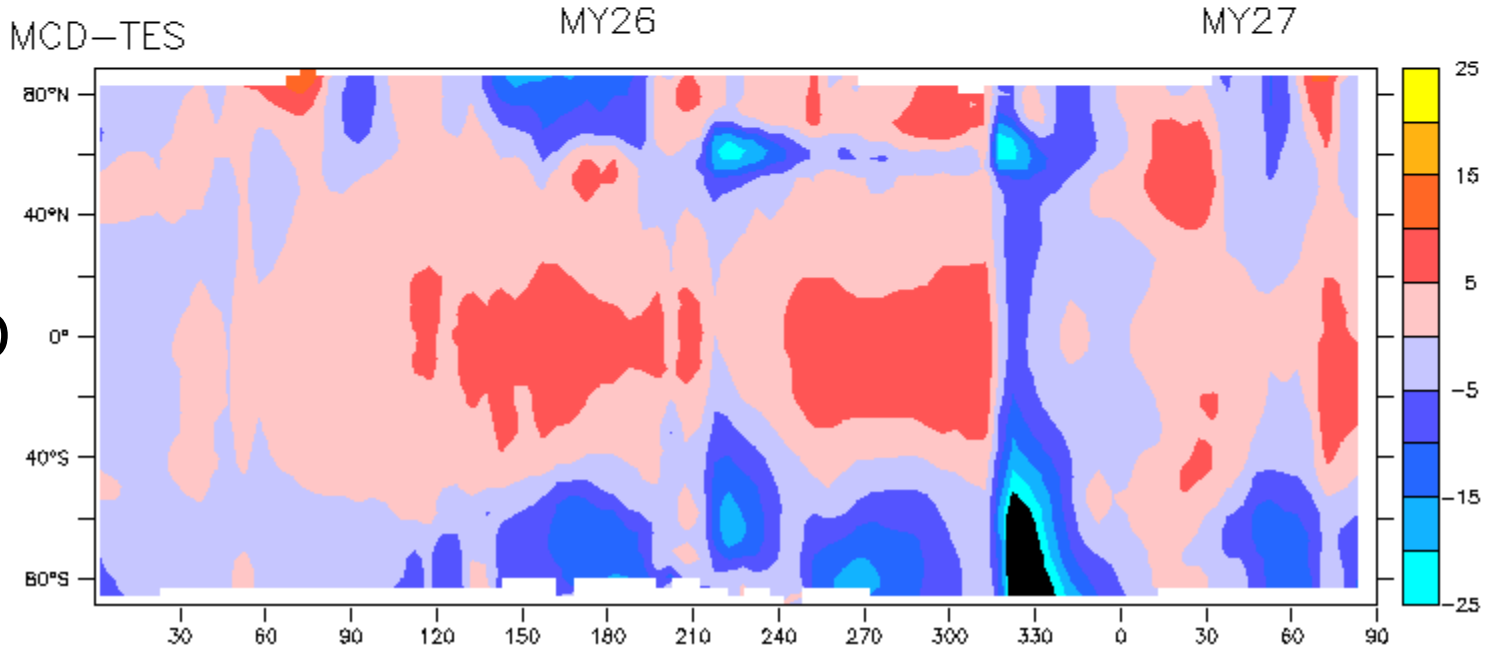


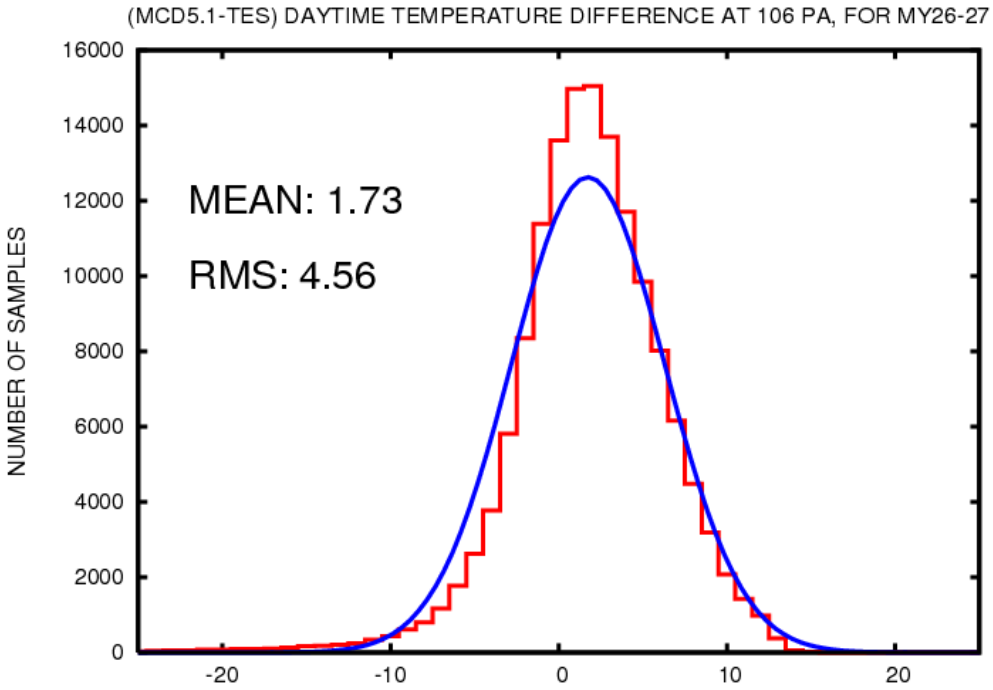
Zonal values of atmospheric temperature (106 Pa)

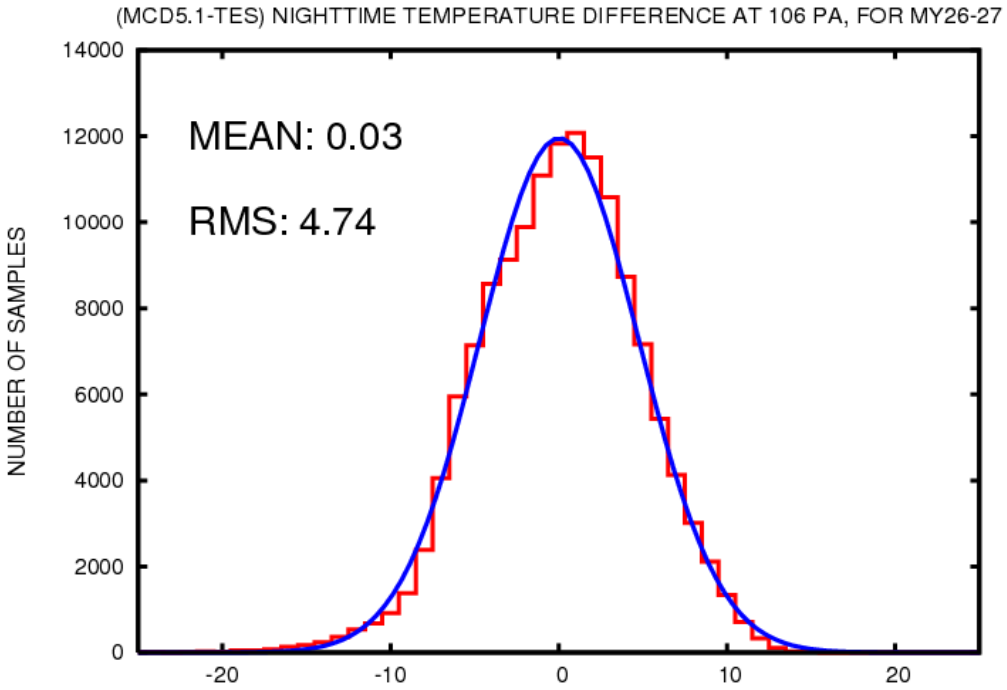
TES



MCD clim





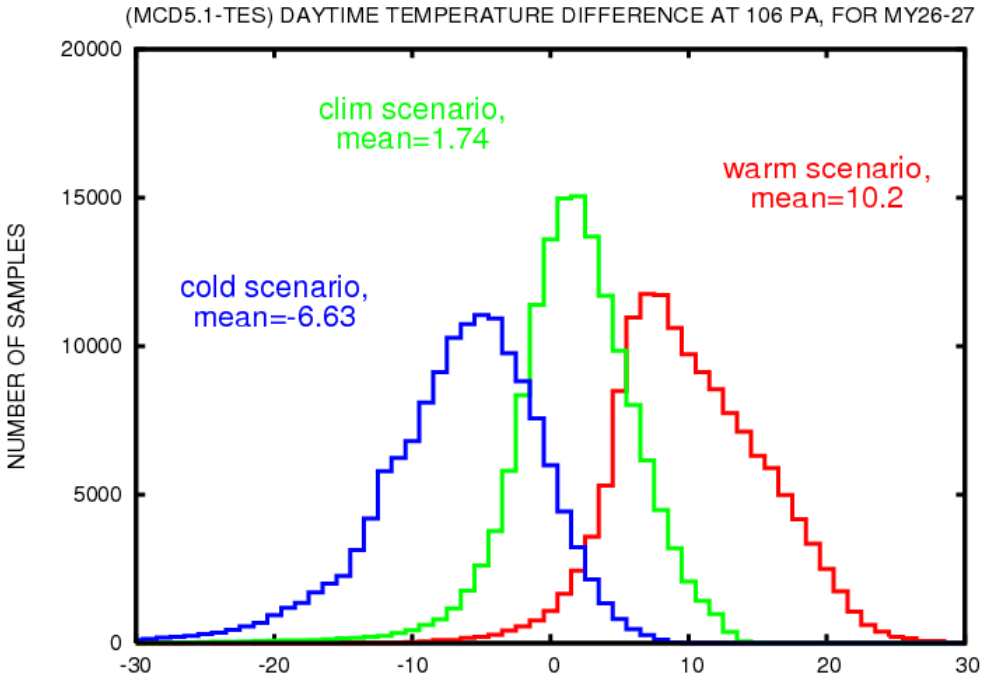


Distributions of atmospheric temperature difference, at 106 Pa, between MCDv5.2(high res.) and TES.

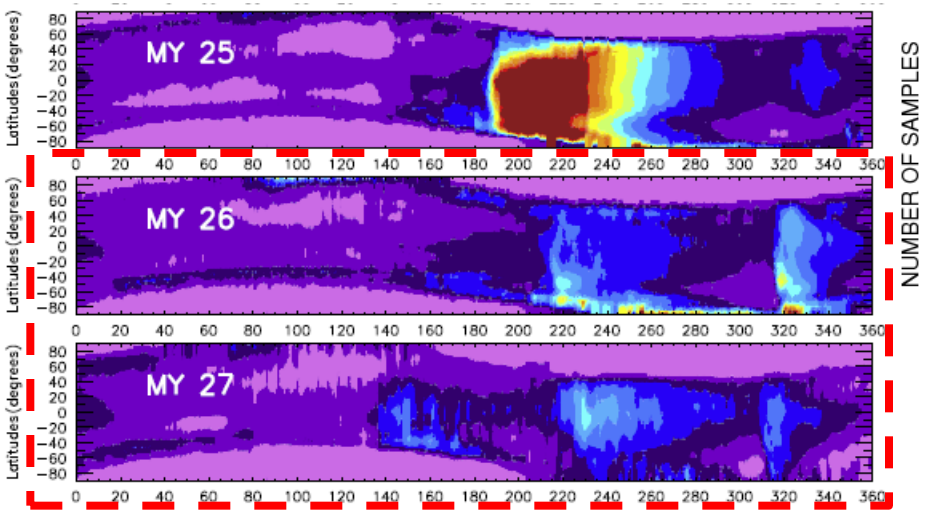
MCD a bit too warm at 2pm.

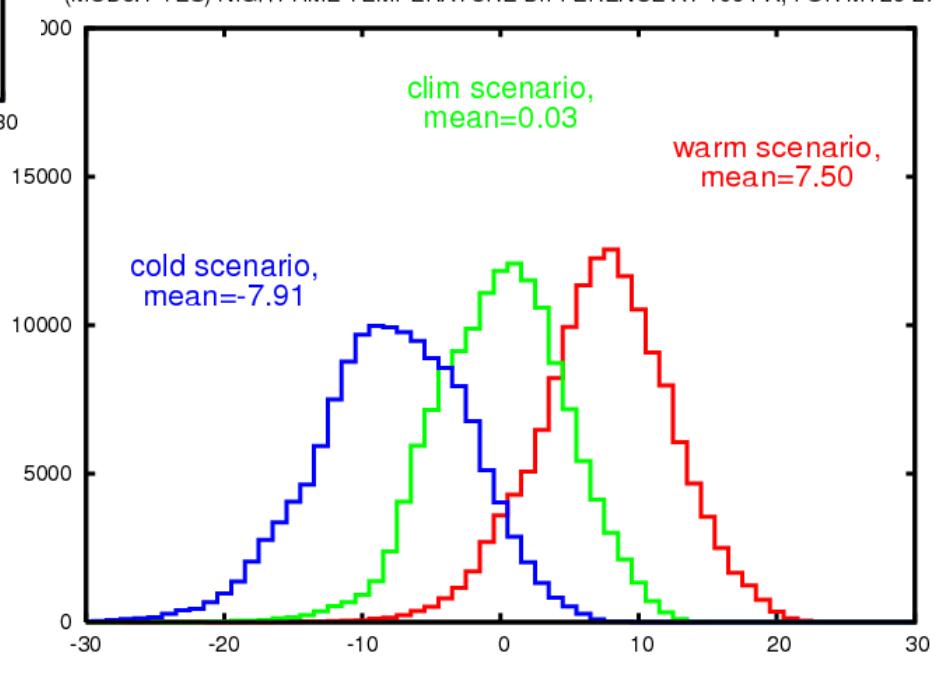
- Statistics computed for:
  - Pressure: 106 Pa
  - MY26: $0 < Ls < 360$
  - MY27: $0 < Ls < 85$
  - $-50 <$ latitude < 50
  - Bins of 1K

Bracketing TES with MCDv5.2 scenarios

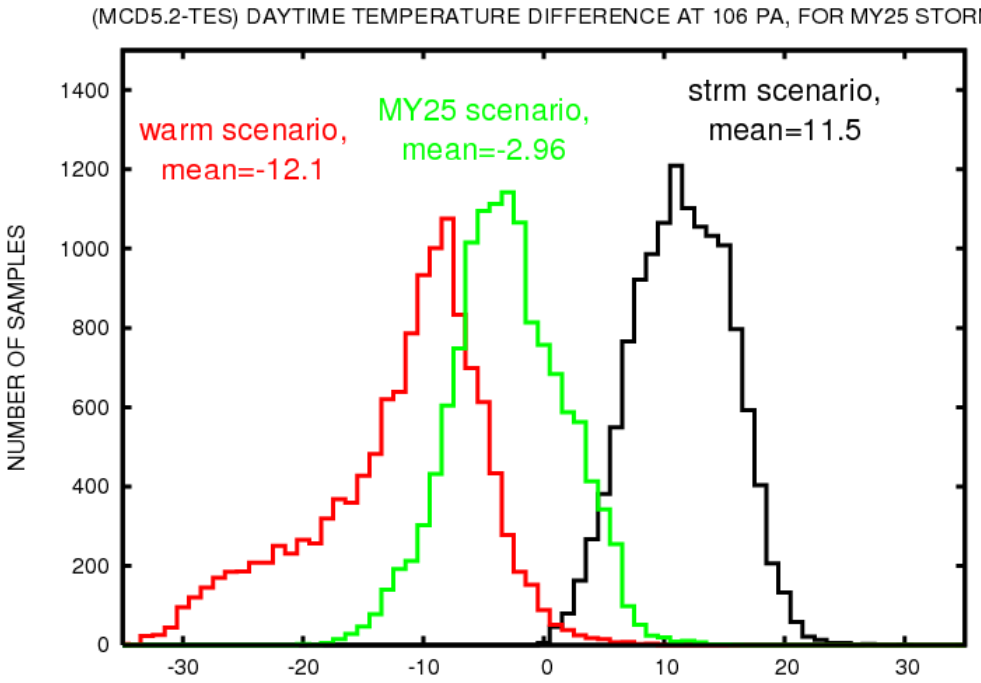


during regular martian years (e.g. MY26-27)

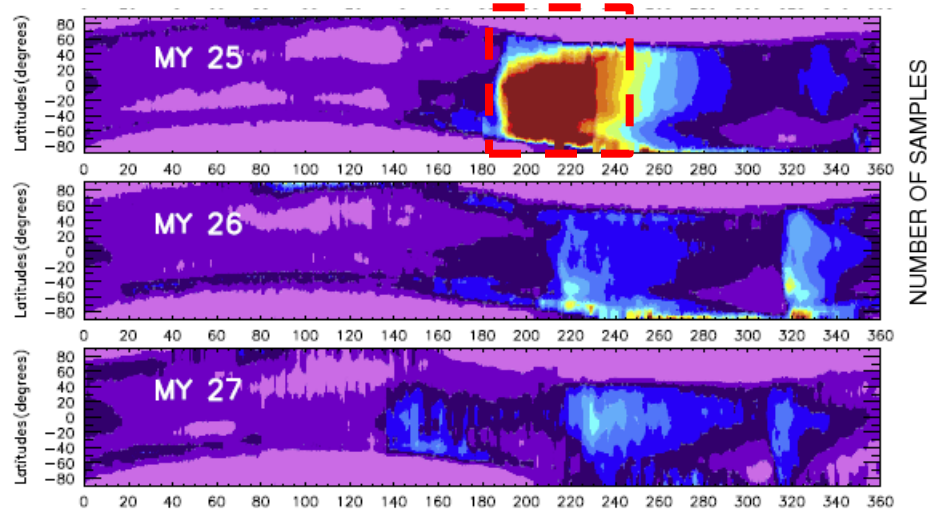


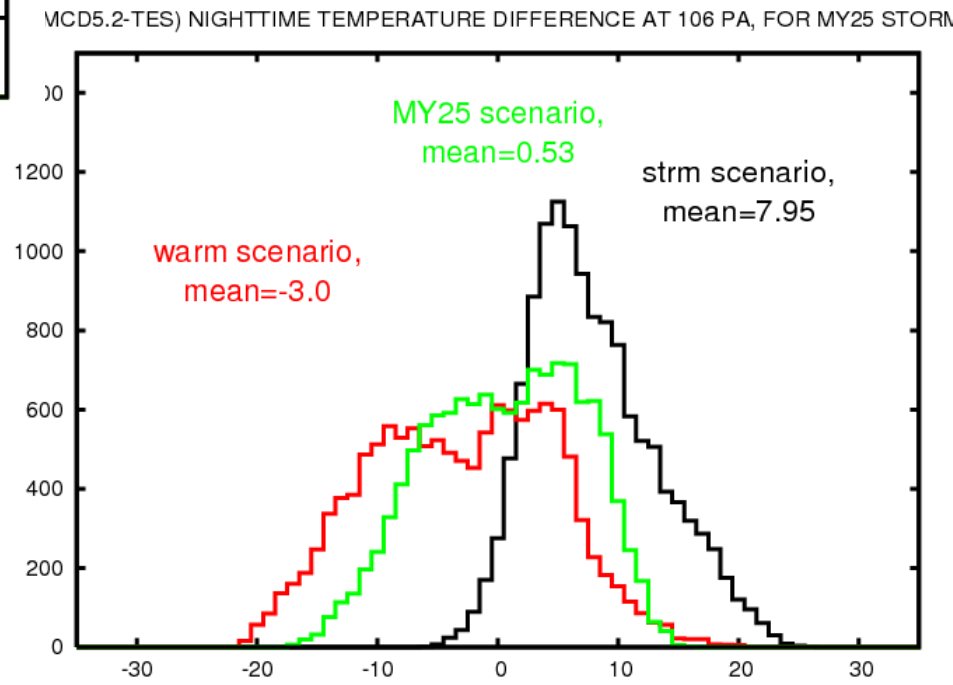


Bracketing TES with MCDv5.2 scenarios



during global Planet encircling storm (MY25)





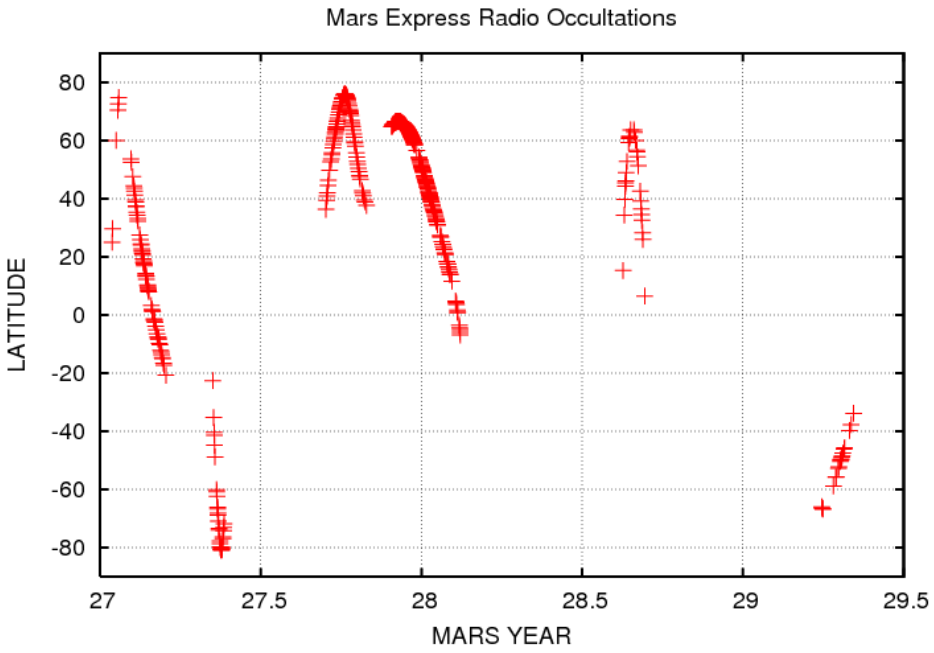
Atmospheric Temperature

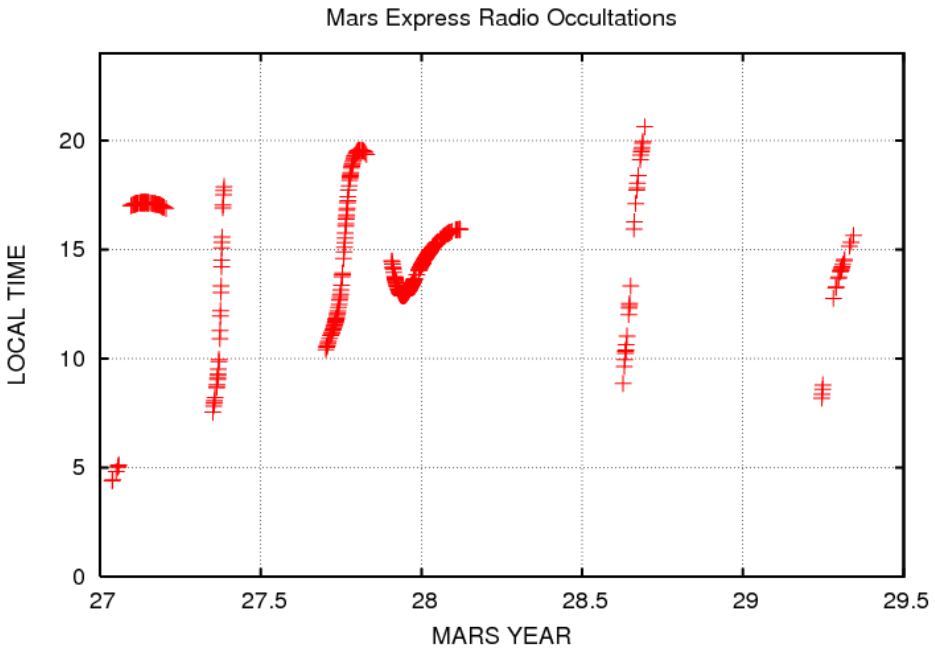
Mars Express Radio Occultations

Mars Years 27-29

Mars Express Radio Occultation data

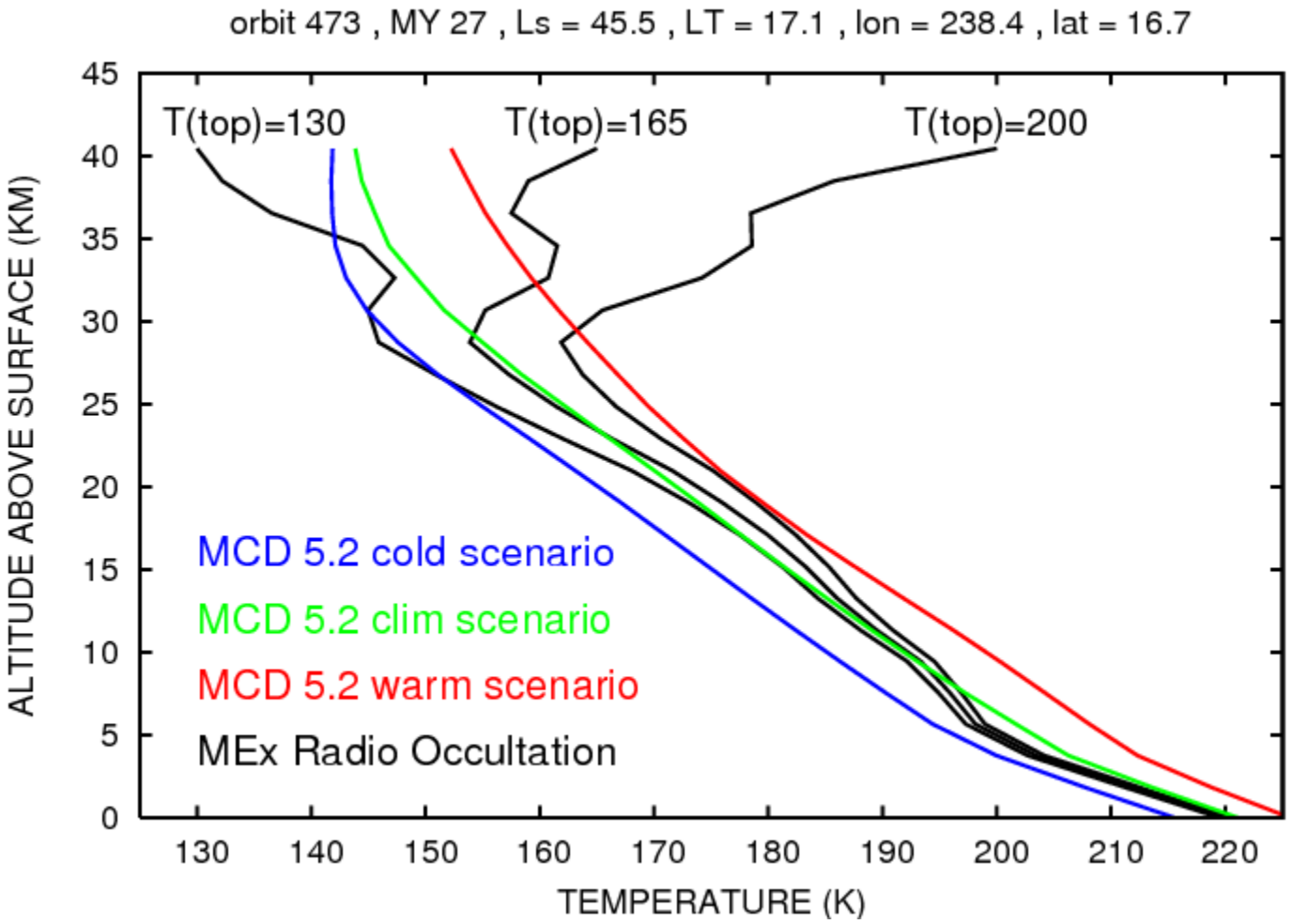
- Radio Occultation profiles available, over years 2004-2008, ie MY27-MY29 (**208 profiles**; kindly provided by S. Tellman).
- Span a good range of local times and latitudes.

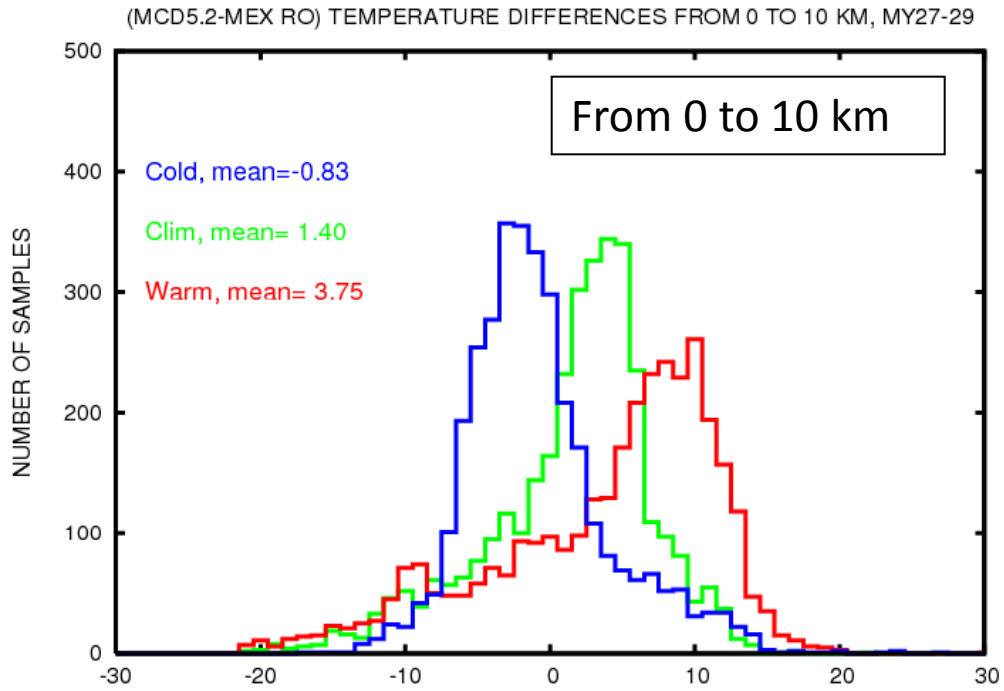


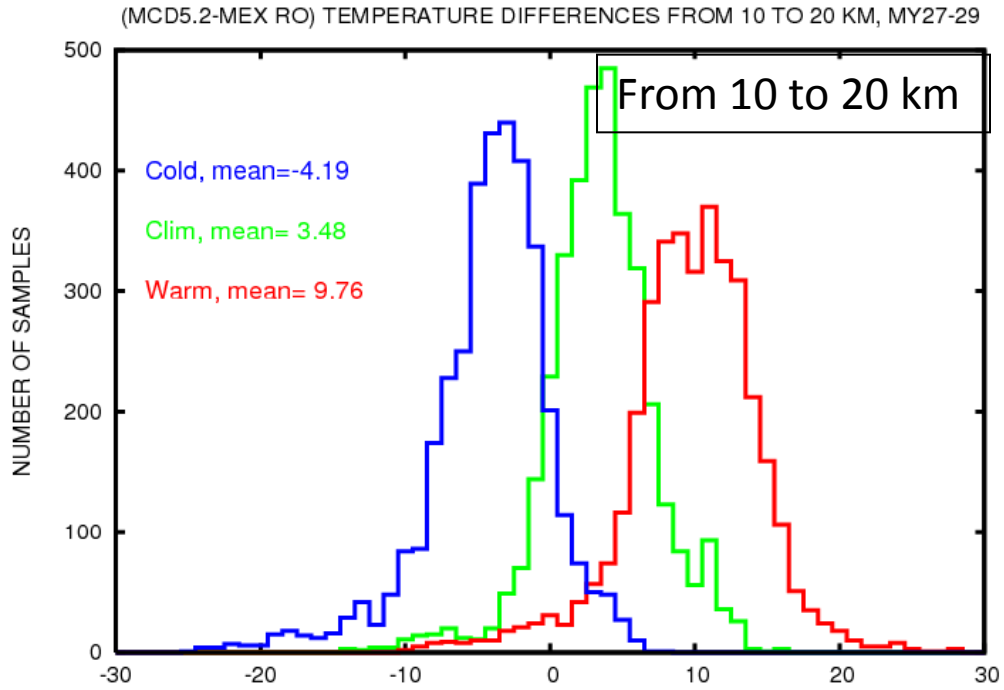


Mars Express Radio Occultation data

- Radio Occultation retrievals require an a priori upper atmosphere temperature T(top).

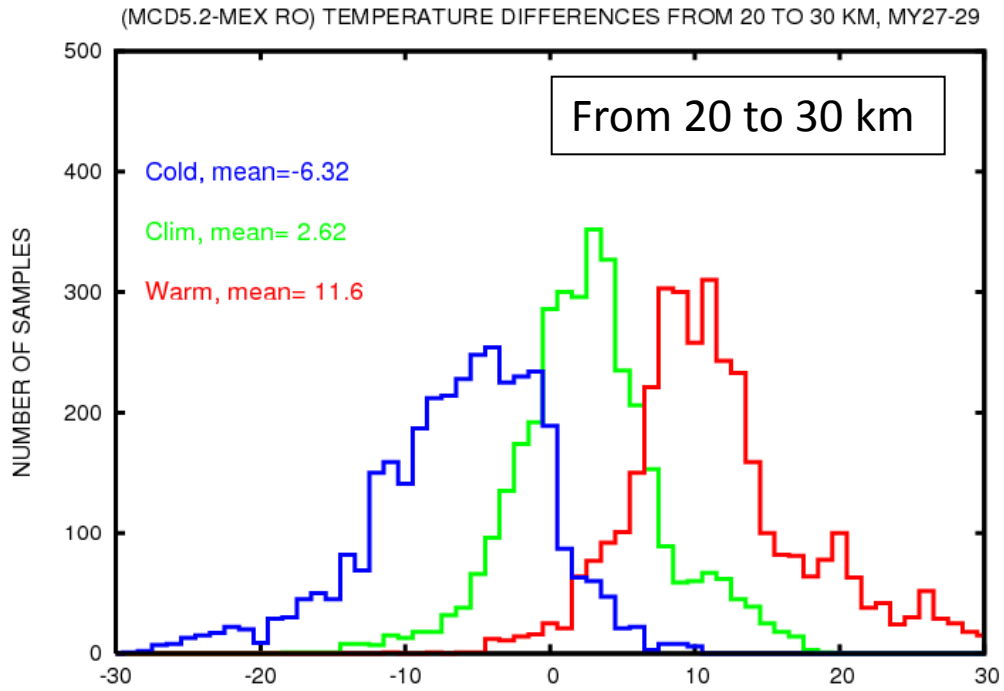


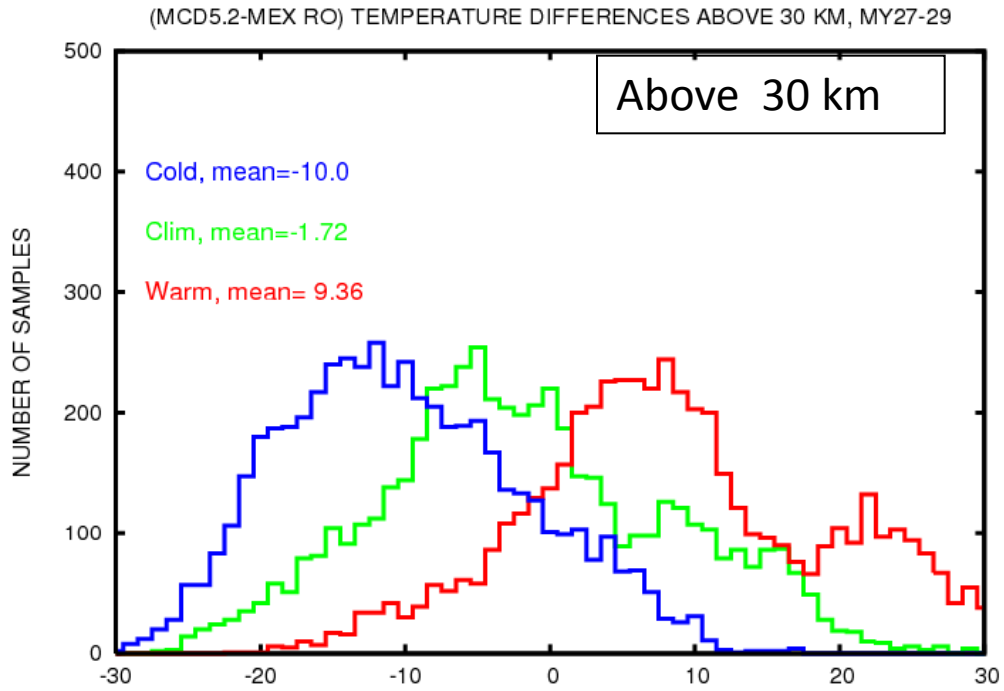




Distributions of atmospheric temperature differences between MCDv5.2 cold/clim/warm scenarios and Mars Express Radio Occultations

- Statistics computed for:
  - MY27-MY29, 208 profiles
  - Bins of 1K
  - Altitude bands of 10 km





Distributions of atmospheric temperature differences between MCDv5.2 cold/clim/warm scenarios and Mars Express Radio Occultations

- Statistics computed for:
  - MY27-MY29, 208 profiles
  - Bins of 1K
  - Altitude bands of 10 km

Atmospheric Temperature

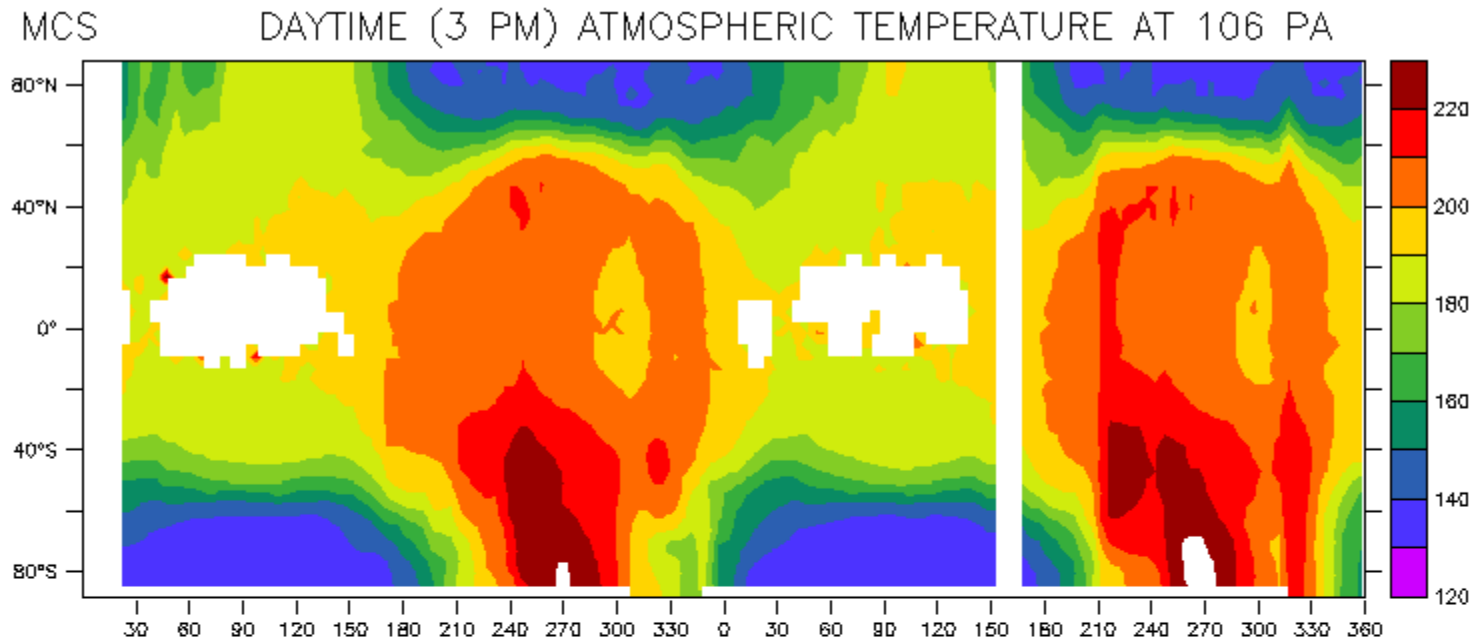
MCS onboard MRO

Mars Years 28-31

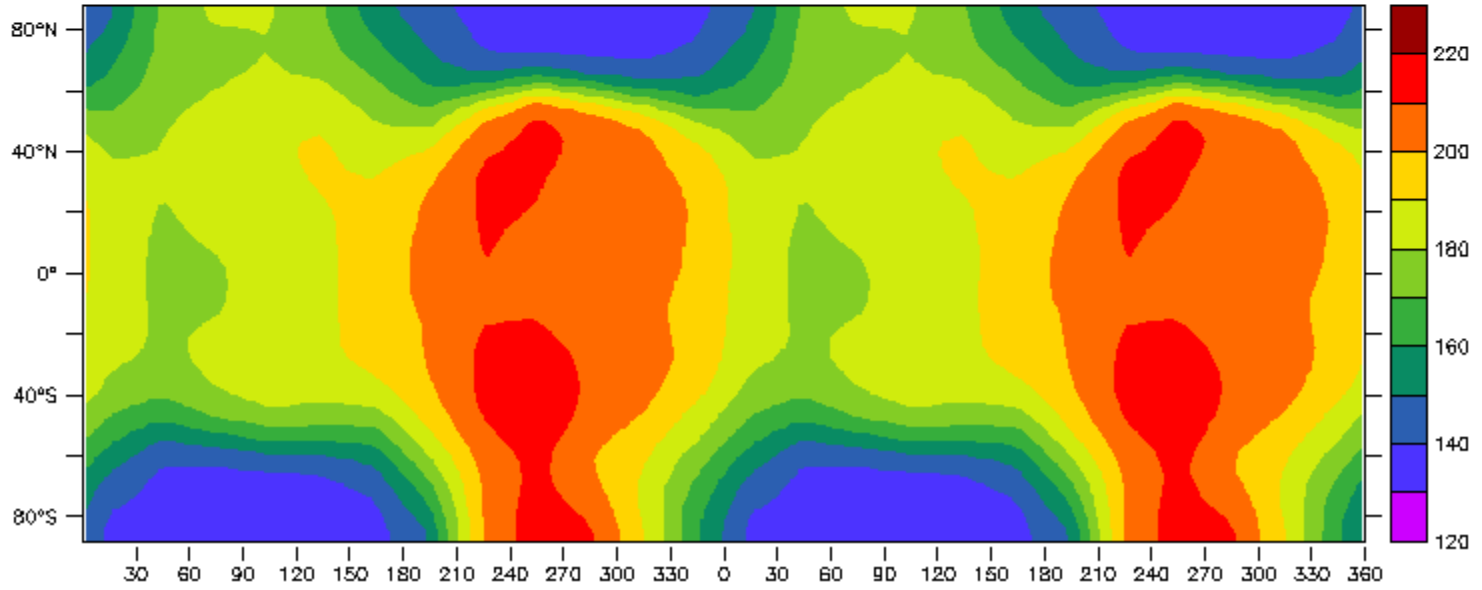
(3am-3pm measurements)

Zonal values of atmospheric temperature (106 Pa)

MCS

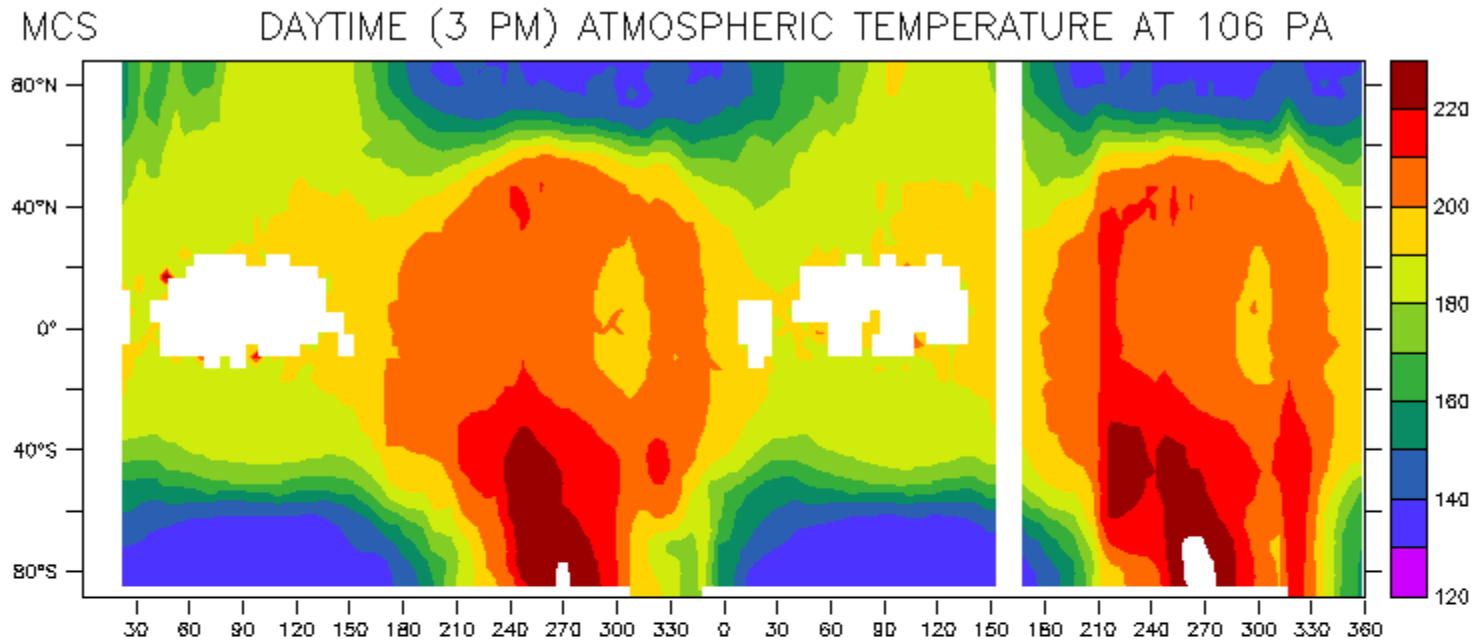


MCD clim

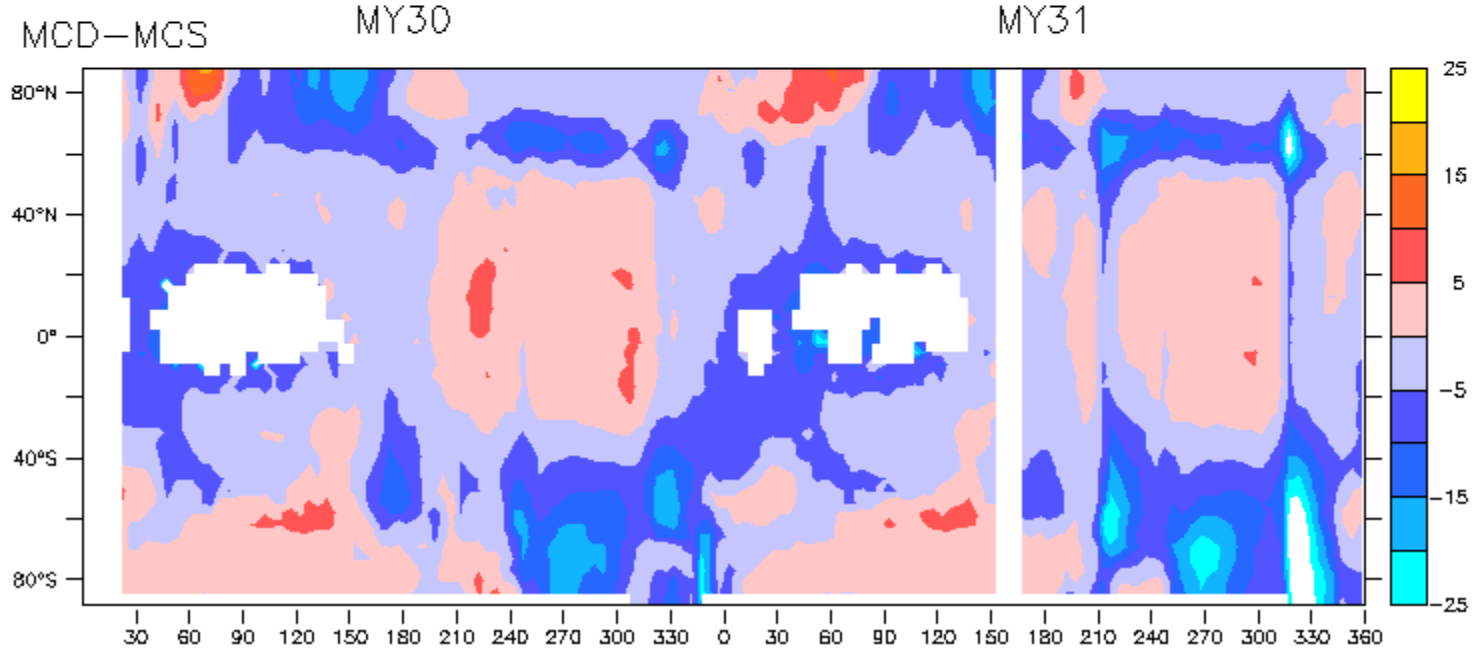


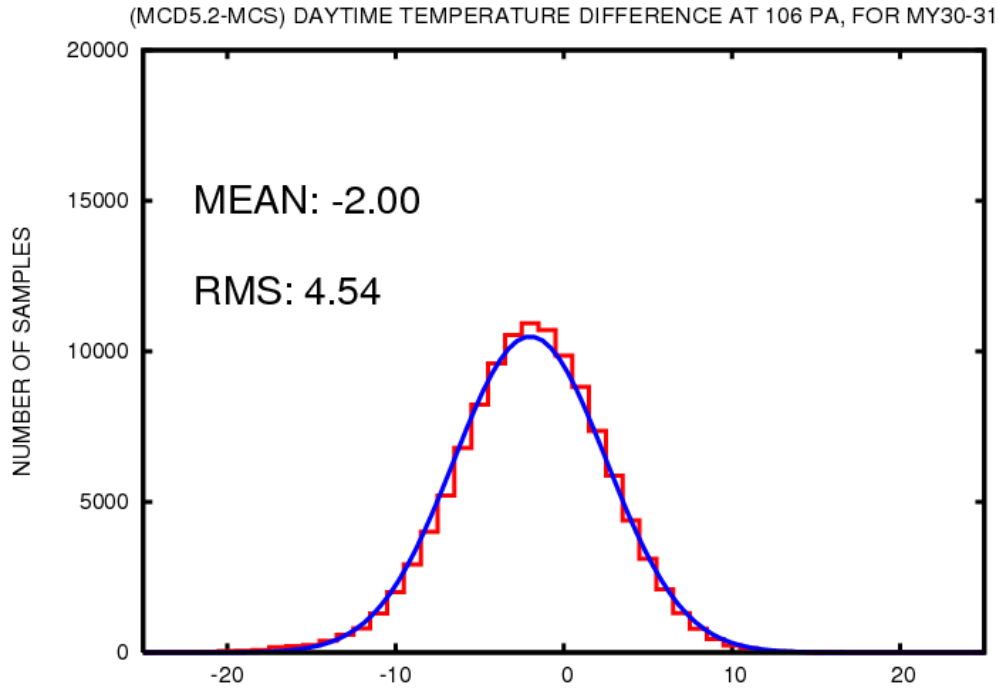
Zonal values of atmospheric temperature (106 Pa)

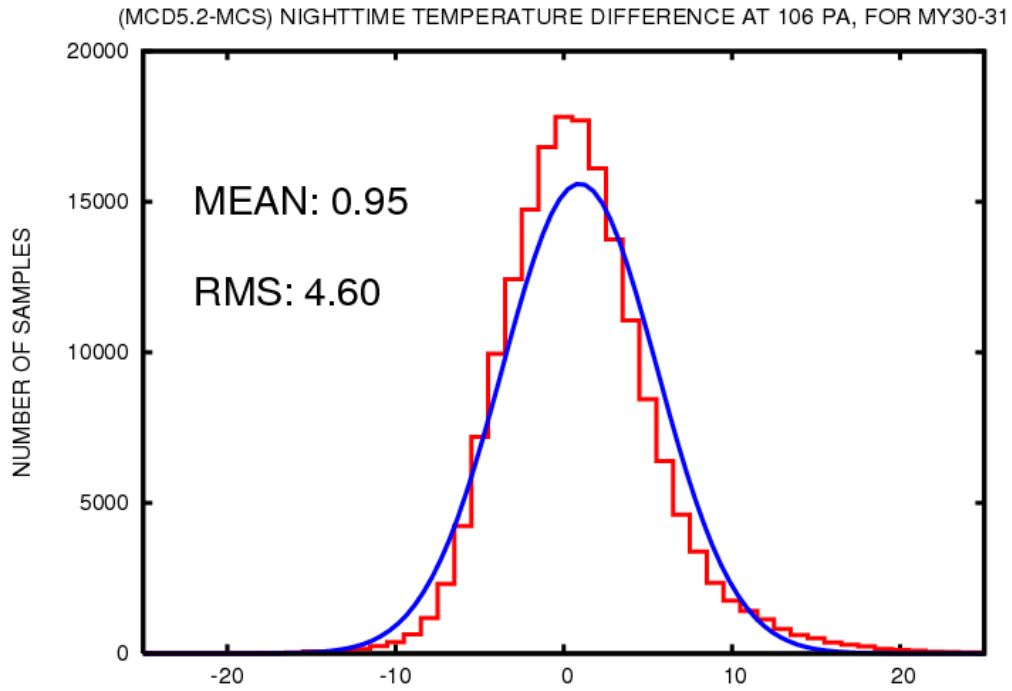
MCS



MCD clim







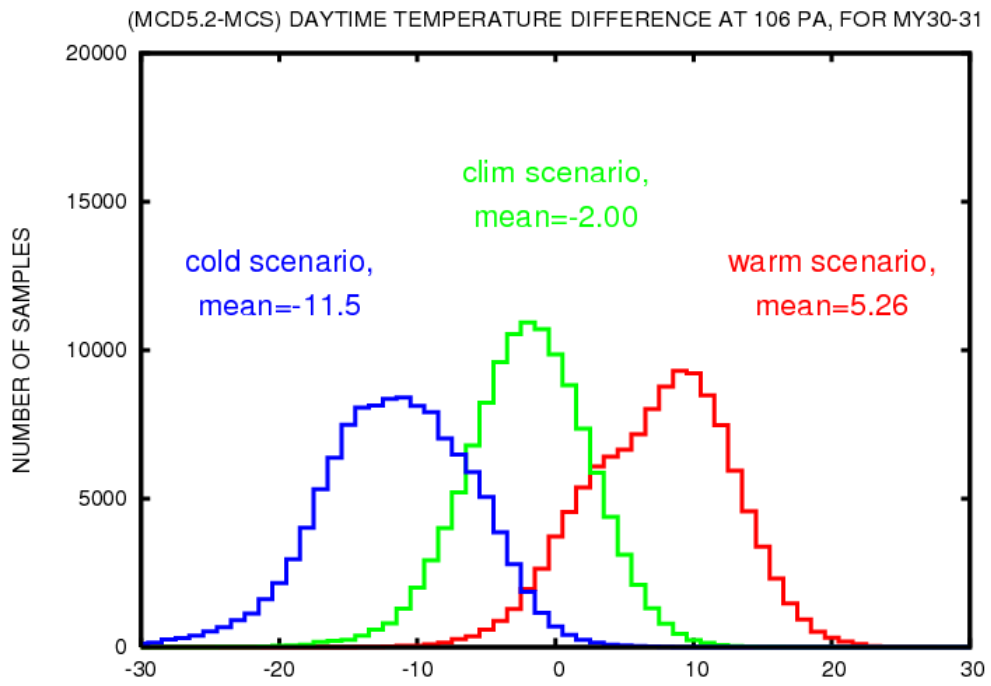
Distributions of atmospheric temperature difference, at 106 Pa, between MCDv5.2 and MCS.

MCD a bit too cold at 3pm.

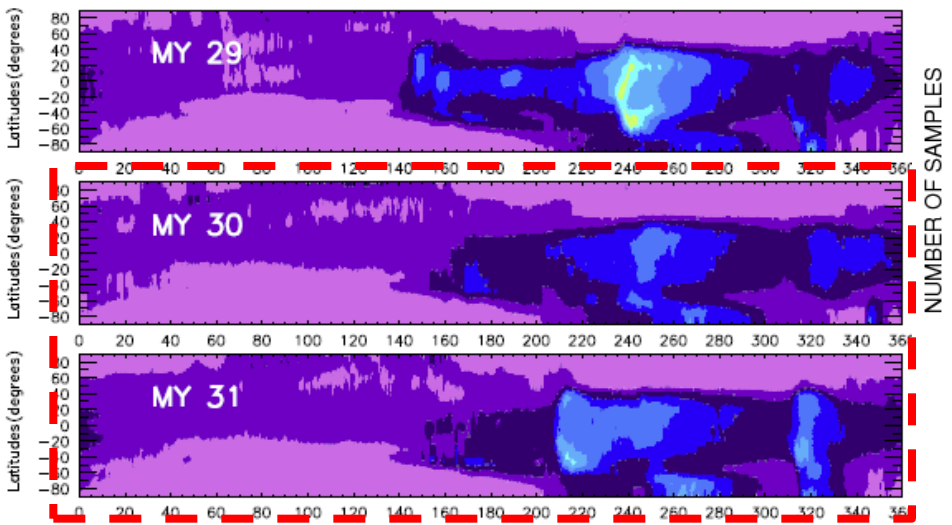
(whereas it was found to be a bit too warm at 2pm wrt TES!)

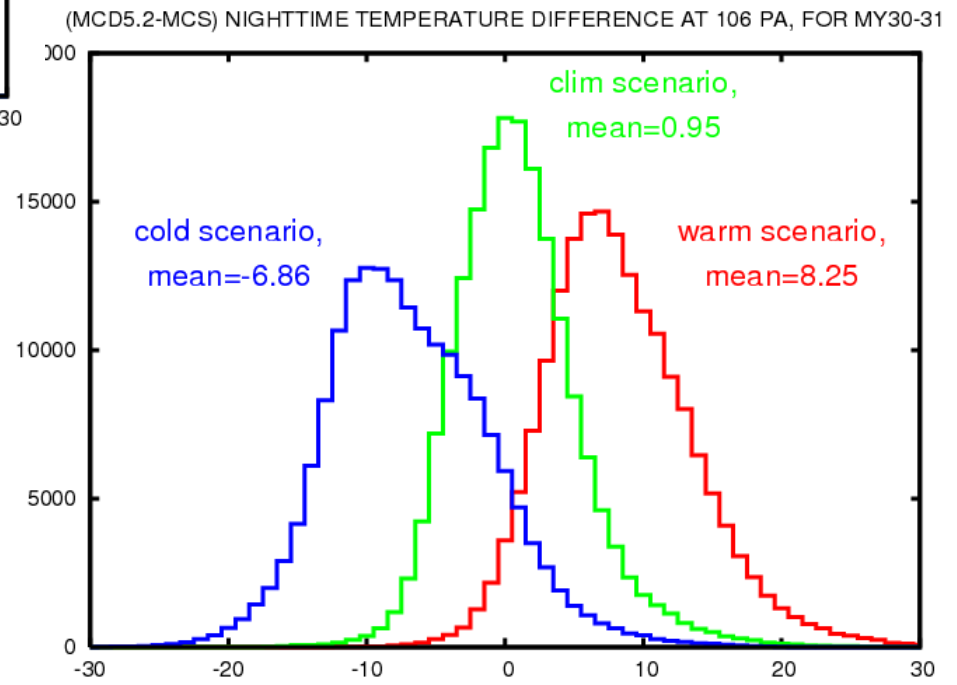
- Statistics computed for:
  - Pressure: 106 Pa
  - MY30: 0 < Ls < 360
  - MY31: 0 < Ls < 360
  - -50 < latitude < 50
  - Bins of 1K

Bracketing MCS with MCDv5.2 scenarios



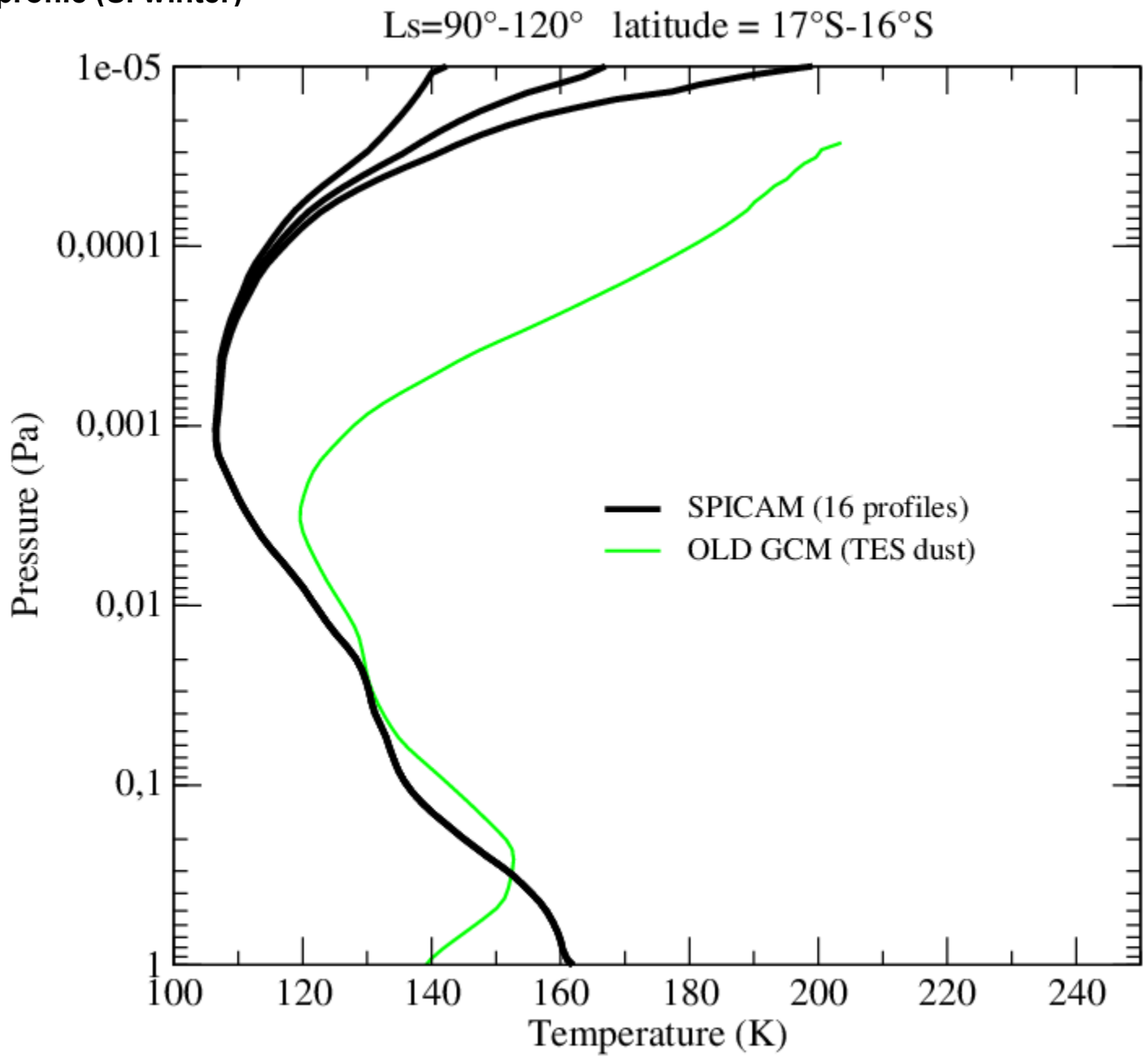
during regular martian years (e.g. MY30-31)





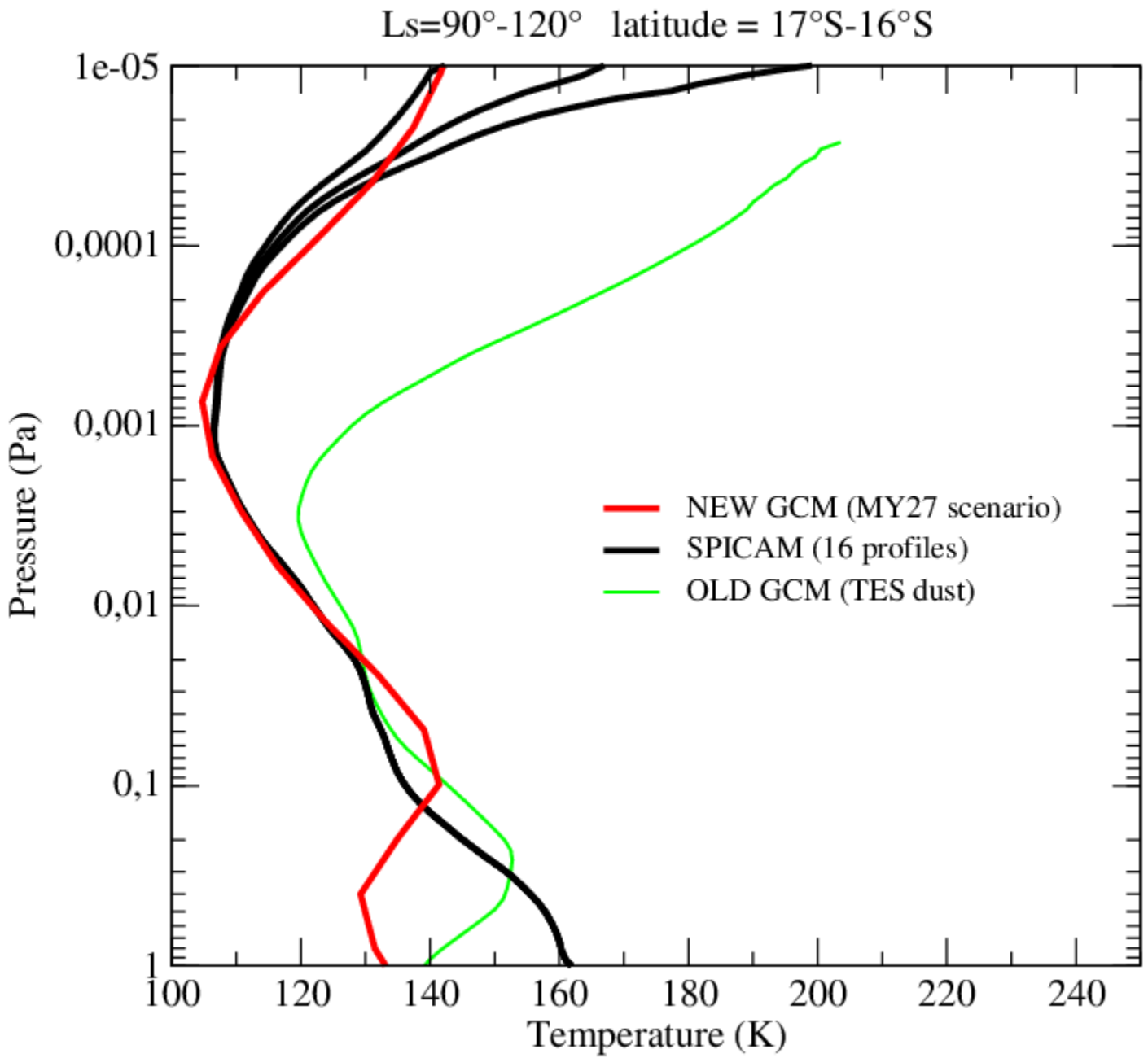
UPPER ATMOSPHERE: Spicam observations and MCD 4.3 vs MCD 5

Mean profile (S. winter)



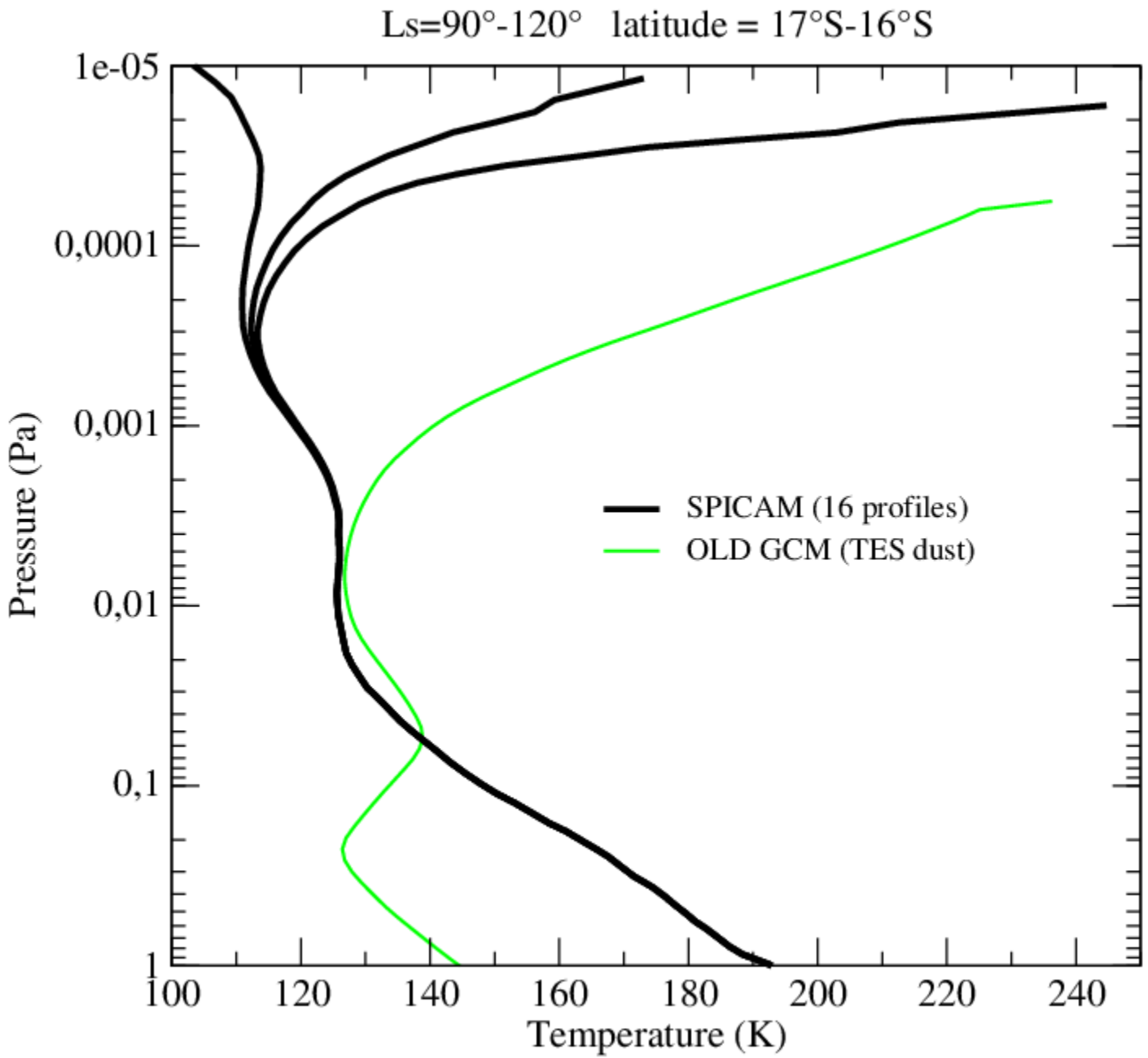
UPPER ATMOSPHERE: Spicam observations and MCD 4.3 vs MCD 5

Mean profile (S. winter)



UPPER ATMOSPHERE: Spicam observations and MCD 4.3 vs MCD 5

Mean profile (N. winter)



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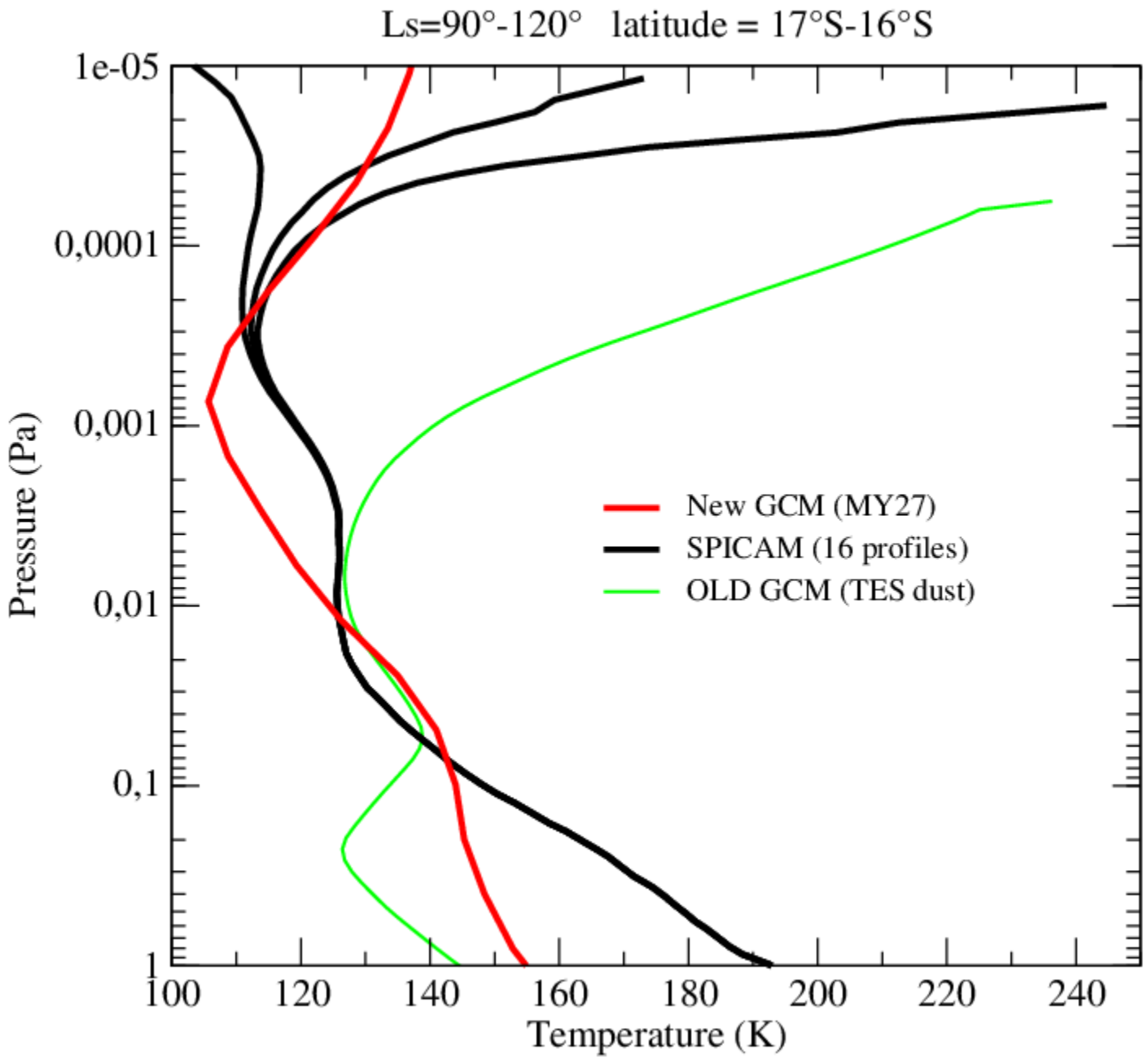
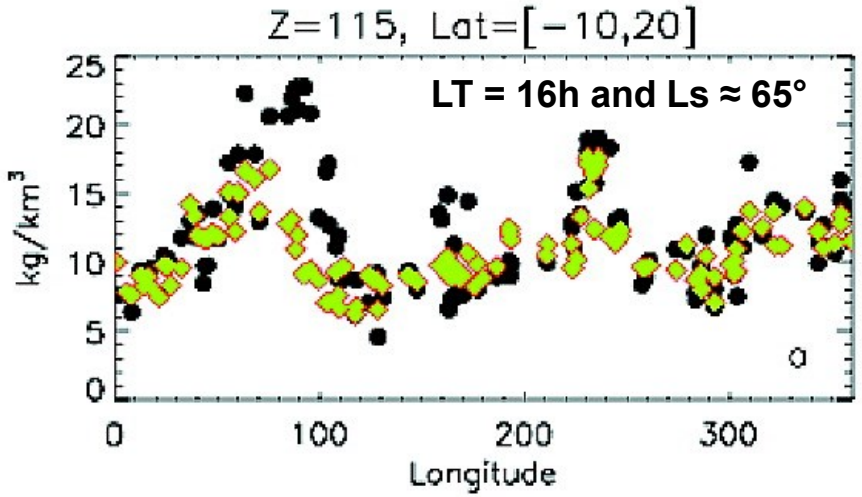
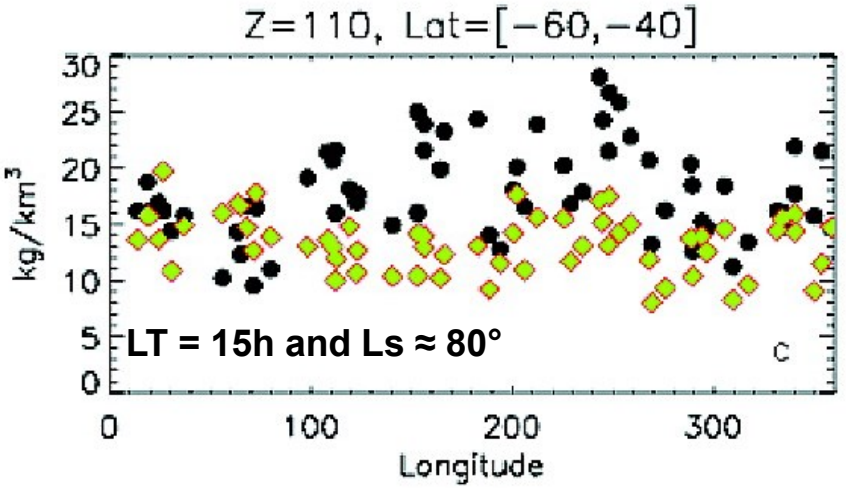
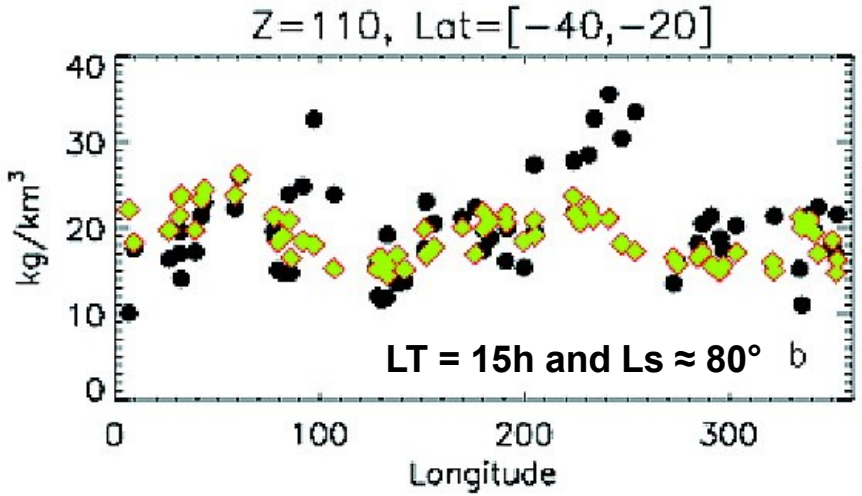
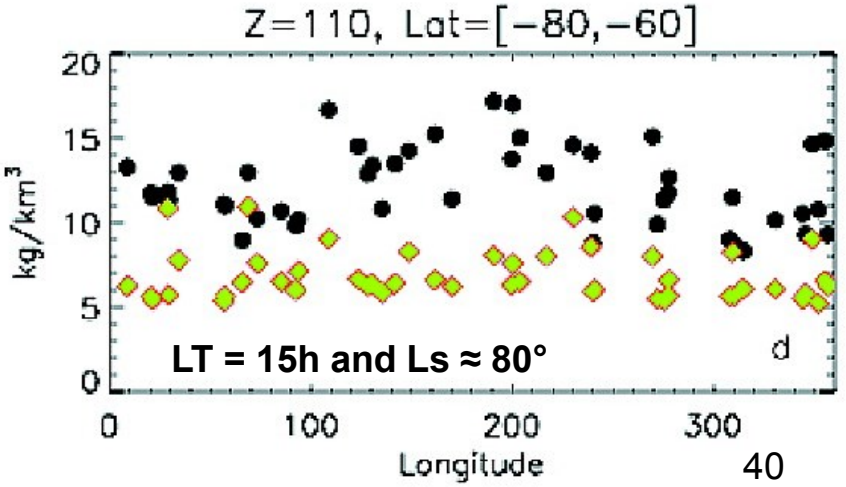


Upper atmosphere: MGS aerobraking density observations compared to MCD

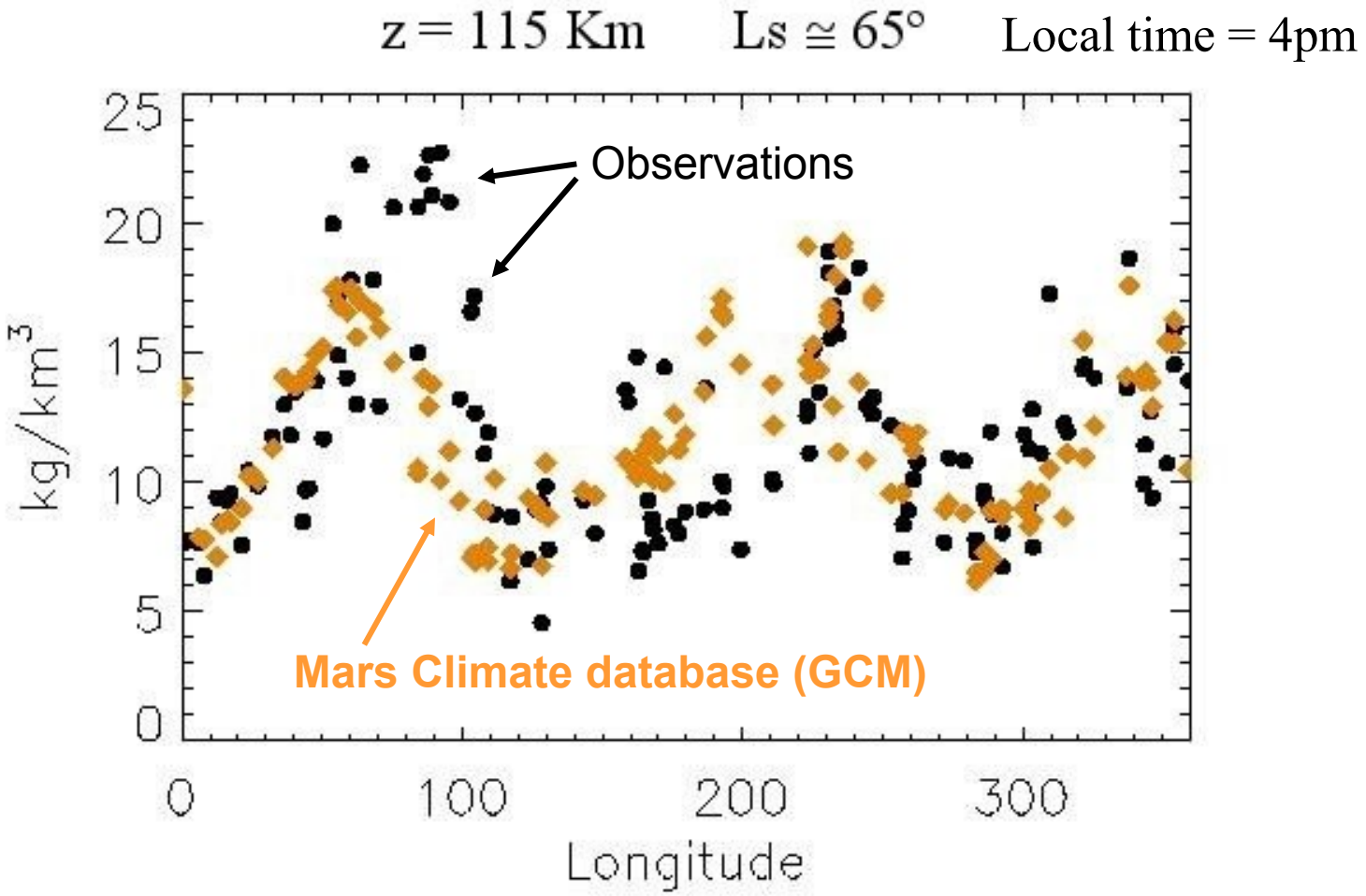








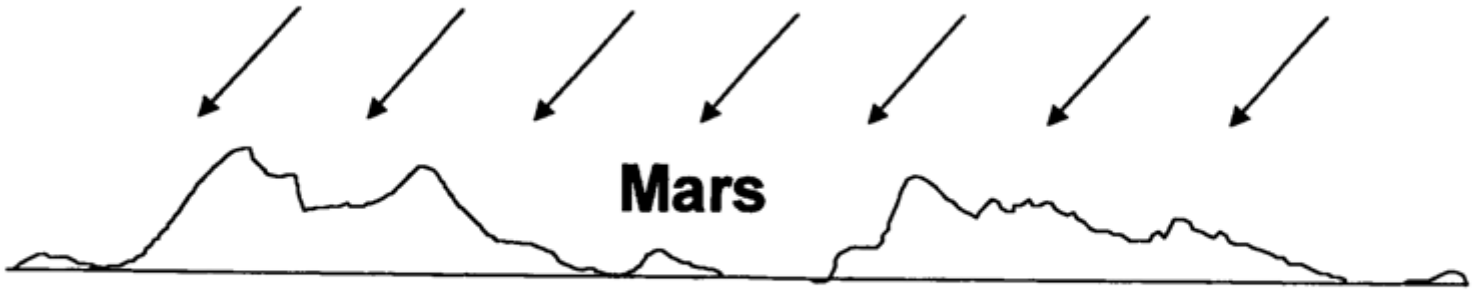
Detailed analysis of MGS aerobraking measurements with the MCD



- Migrating tides : Wave directly forced by the sun $\Rightarrow$ propagate westward

- On Mars, the solar forcing interact with the topography and create "Non migrating tides" $\Rightarrow$ they can propagate eastward !

Westward migrating solar radiation interacting with s = 2 topography



$$\cos(\Omega t + \lambda)\cos 2\lambda \;\longrightarrow\; \cos(\Omega t + 3\lambda) + \cos(\Omega t - \lambda)$$

solar radiation

topography

westward propagating s=3

eastward propagating s=1

Similarly,

$$\cos(2\Omega t + 2\lambda)\cos 2\lambda \;\longrightarrow\; \cos(2\Omega t + 4\lambda) + \cos(2\Omega t)$$

westward propagating s=4

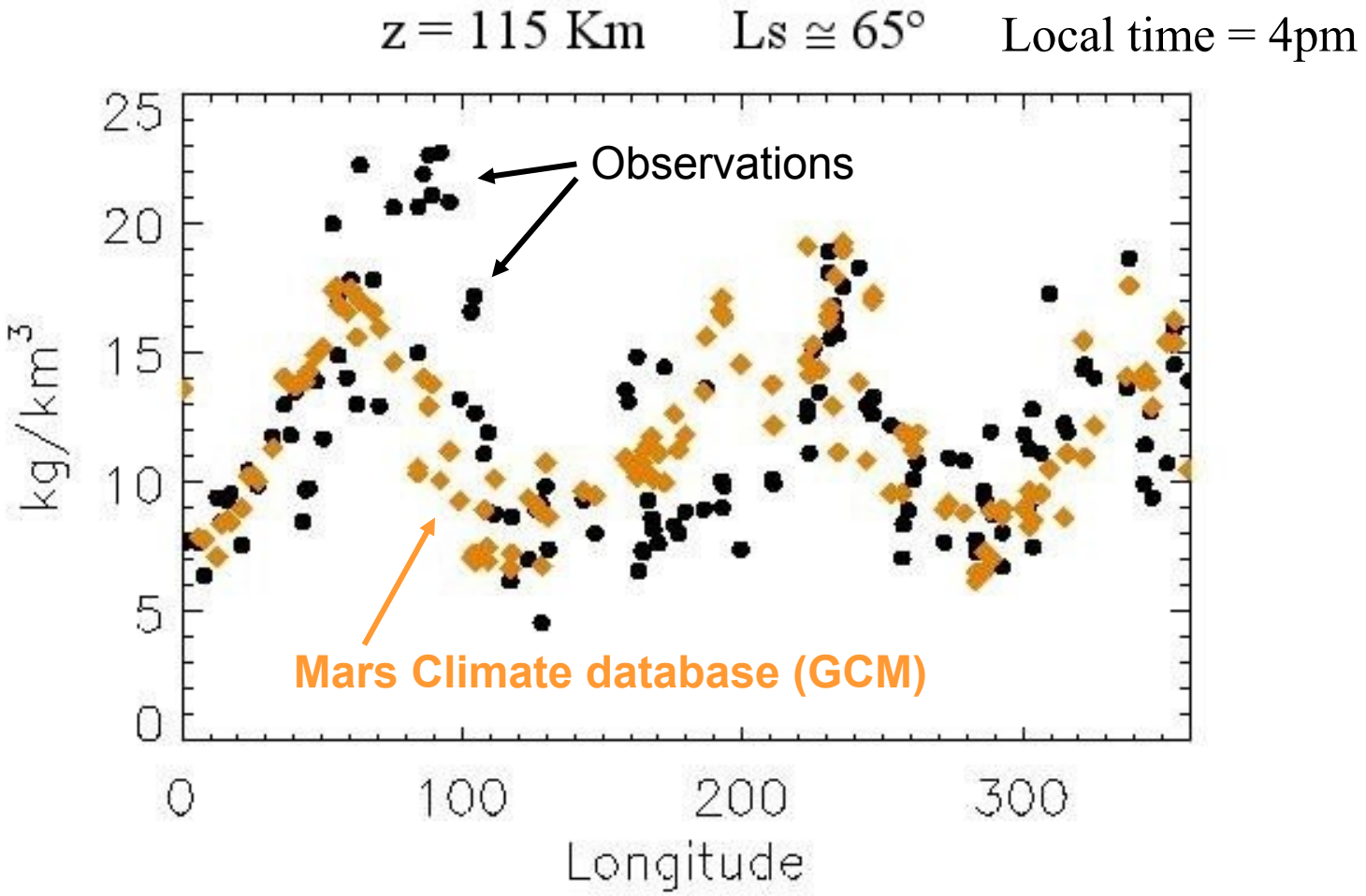
standing s=0

solar radiation

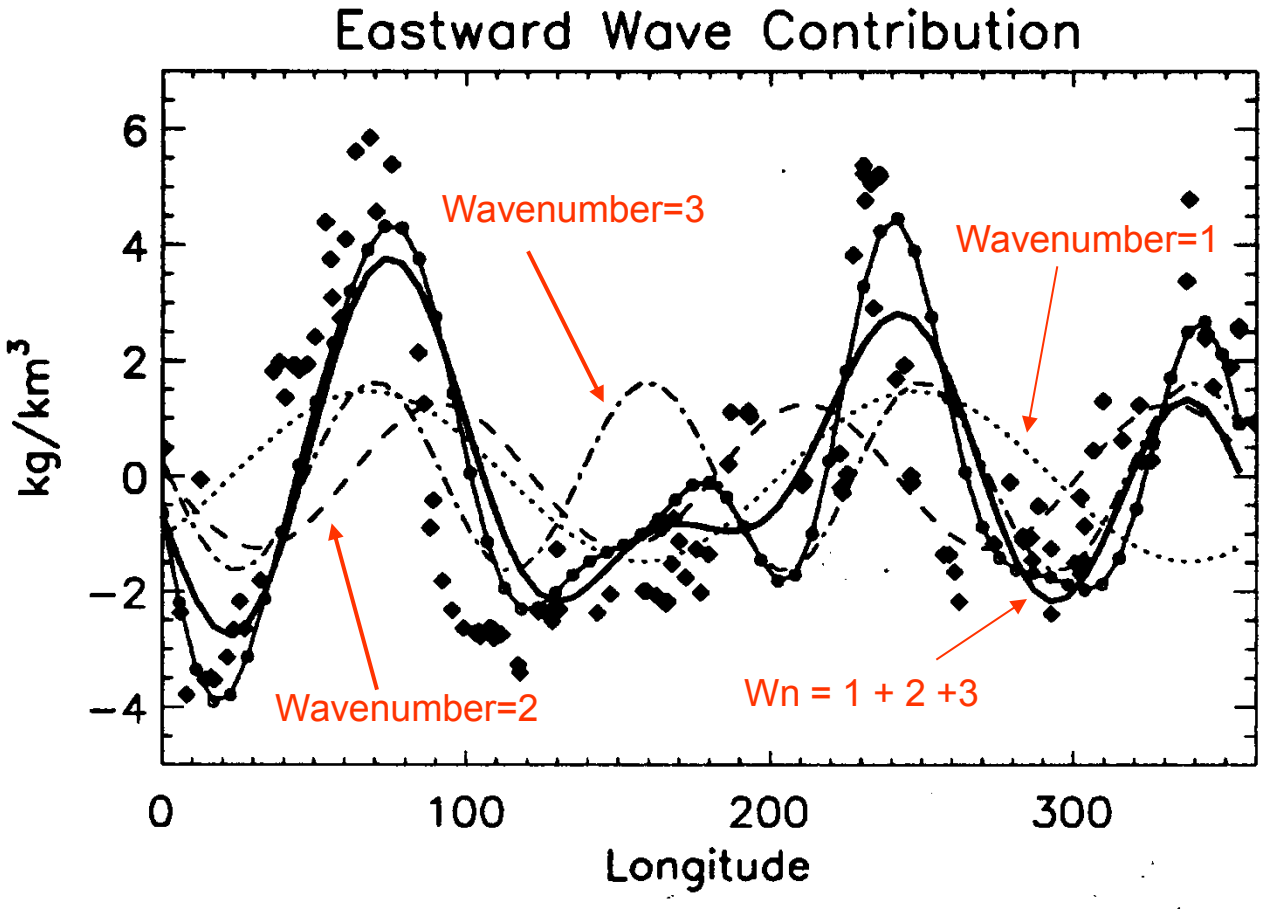
topography

Forbes et al. 2002

Detailed analysis of MGS aerobraking measurements with the MCD



MGS aerobraking in-situ density simulation: Analysis of the waves involved



How accurate is the MCD ? Color code:

- **High Accuracy**
- **Acceptable Accuracy**
- **Possible problems**
- **Significant issues ; irrealistic values**

Pressure, Temperature, Density

- **Surface Pressure : excellent accuracy (<20 Pa)**
- **Surface temperature**
  - Typically < 10K
  - Possible errors due to local surface properties & slopes
  - In particular : near CO2 ice cap in spring
- **Atmospheric temperature and density below 70 km :**
  - Typically < 10K (larger error in clouds, local storms, polar night)
- **Atmospheric temperature above 70 km :** mean up to ~30K ;+ high variability **!**
- **Density above 70 km:**
  - mean < 30% (z<120 km) or 100% (z> 150 km)
  - Very High variability !! Travelling waves + gravity waves
- **Density above 250 - 300 km** (MCD extrapoles above top GCM layer)
  - Not well extrapolated in version 5.2 (assumes constant composition⇨ fix in MCD 5.3)
- - **Thermal and solar radiative fluxes**

Ice, aerosols and water

- **CO_2 ice cover**
  - Full GCM ~OK except end of S. Cap recession
  - Mars Climate database suffer from interpolation within 30° Ls step
- **Dust column opacity**
  - Dust prescribed daily scenario (available) driven by observations
  - Mars Climate database suffer from interpolation within 30° Ls step
- **Dust mass mixing ratio**
  - Error by a factor 2 to 3 in detached layers around 20-30 km.
  - Accurate Vertical extension
- **Dust effective radius**
- **Dust deposition rate**
- **[H2O] vapour**
  - **Column** accuracy < 20%
  - **Mixing ratio** : almost no observations to validate; supersaturation detected by SPICAM well predicted.
- **[H2O] ice**
  - **Column :** good agreement with TES ; suffer from Ls interpolation
  - **Mixing ratio :** difficult validation with MCS data: diurnal cycle not understood and discrepancy with TES...
  - **Effective radius:** Ok in GCM, but severely bugged in MCD.

Trace species and other characteristics

- **Long lived trace gas [CO2], [CO], [O], [O2], [N2], [Ar]**
  - **Accuracy Column & VMR below 120 km : high accuracy (2%)**
  - **VMR above 120 km:** Currently validated with MAVEN NGIMS data
  - **VMR above 250 km:** Not well extrapolated in version 5.2 (assumes constant composition⇨ fix in MCD 5.3)
- **Chemically active specie : [O3]**
- **[H], [H2]** above 100 km: discrepancy with MAVEN observations currently fixed.
- **[electrons]**
  - Between 60 km (1 Pa) and 200 km (5 10−6 Pa) : Good accuracy.
  - Below 60 km and above 200 km : unrealistic
- **Air specific heat capacity, viscosity and reduced gas constant r**
- **Convective PBL height, typical updraft and downdraft velocities in PBL**
- **Surface heat stress and surface sensible heat flux**