Martian morning atmosphere during Northern spring from the Planetary Fourier Spectrometer (PFS) measurements

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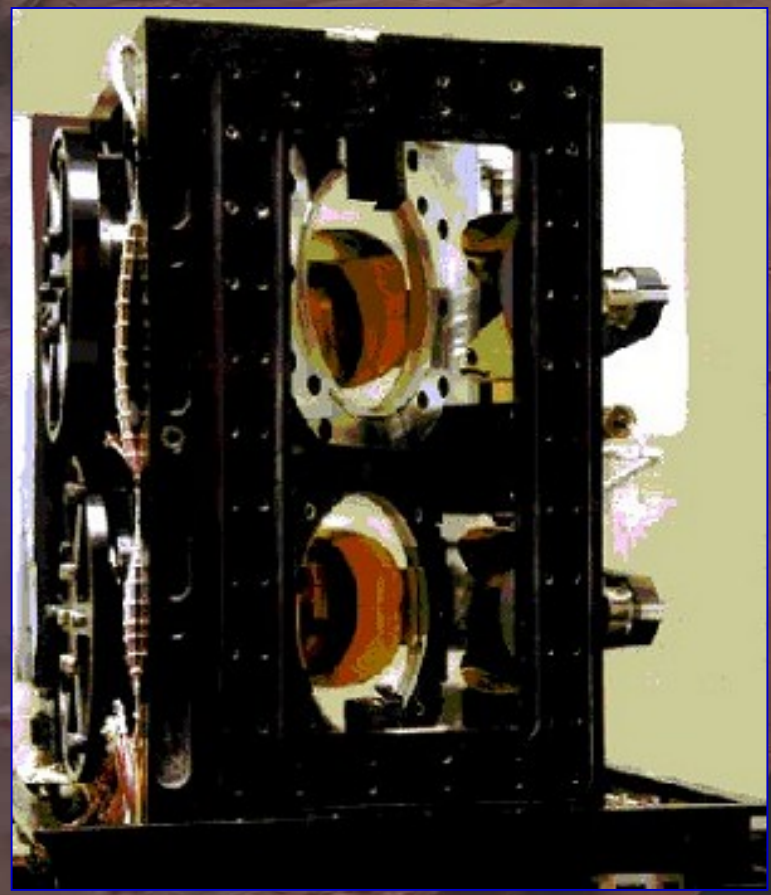
Summary

- Introduction
  - ✓ The PFS experiment
  - ✓ Physics of PFS data
- Rationale for morning observations
- The morning atmosphere in N spring
  - ✓ Dataset characteristics
  - ✓ PFS-derived T(z) fields
  - ✓ Aerosols contents
- Conclusions

The PFS experiment

- IR spectrometer, two main channels (LWC & SWC)
- Very wide range: [250-2000] cm^{-1} + [2000-8200] cm^{-1}
- High spectral resolution: 2.0 cm^{-1} (sampling: 1.0 cm^{-1})
- No imaging capability



Physics of PFS Data

Radiative transfer (RT) equation

$$I_\nu(\tau_{\nu,total},\mu,\phi) =$$

$$A.\quad \varepsilon_\nu B_\nu(T_{surf})\, e^{-\tau_{\nu,total}/\mu} +$$

$$B.\quad \frac{1}{\mu}\int_0^{\tau_{\nu,total}} (1-\varpi_{o,\nu}(\tau_\nu=\tau_\nu'))\, e^{-(\tau_{\nu,total}-\tau'_\nu)/\mu} B_\nu(T(\tau_\nu=\tau_\nu'))\, d\tau_\nu' +$$

$$C.\quad \frac{1}{4\pi\mu}\int_0^{\tau_{\nu,total}}\int_0^{2\pi}\int_0^{1} e^{-(\tau_{\nu,total}-\tau'_\nu)/\mu} e^{-\tau'_\nu/\mu'} \tilde{p}_\nu(\tau_\nu=\tau_\nu',\mu,\phi,\mu',\phi') I_\nu(\tau_\nu=0,\mu',\phi')\, d\mu'\, d\phi'\, d\tau_\nu' +$$

$$D.\quad \frac{1}{4\pi\mu}\int_0^{\tau_{\nu,total}}\int_0^{2\pi}\int_{-1}^{1} e^{-(\tau_{\nu,total}-\tau'_\nu)/\mu} \tilde{p}_\nu(\tau_\nu=\tau_\nu',\mu,\phi,\mu',\phi') I_\nu(\tau_\nu=\tau_\nu',\mu',\phi')\, d\mu'\, d\phi'\, d\tau_\nu' +$$

$$E.\quad \frac{F_{\nu,0}}{4\pi}\int_0^{\tau_{\nu,total}} \tilde{p}_\nu(\tau_\nu=\tau_\nu',\mu,\phi,\mu_0,\phi_0)\, e^{-(\tau_{\nu,total}-\tau'_\nu)/\mu} e^{-(\tau_{\nu,total}-\tau'_\nu)/\mu_0}\, d\tau_\nu'$$

Inversion may provide T(z) and aerosol loads!

Rationale for morning atmosphere observations

- The transition from dark to illuminated conditions may trigger a series of short-time scale transients:
  - ✓Air heating
  - ✓Sublimation of volatile species
  - ✓Local dynamics of the air masses

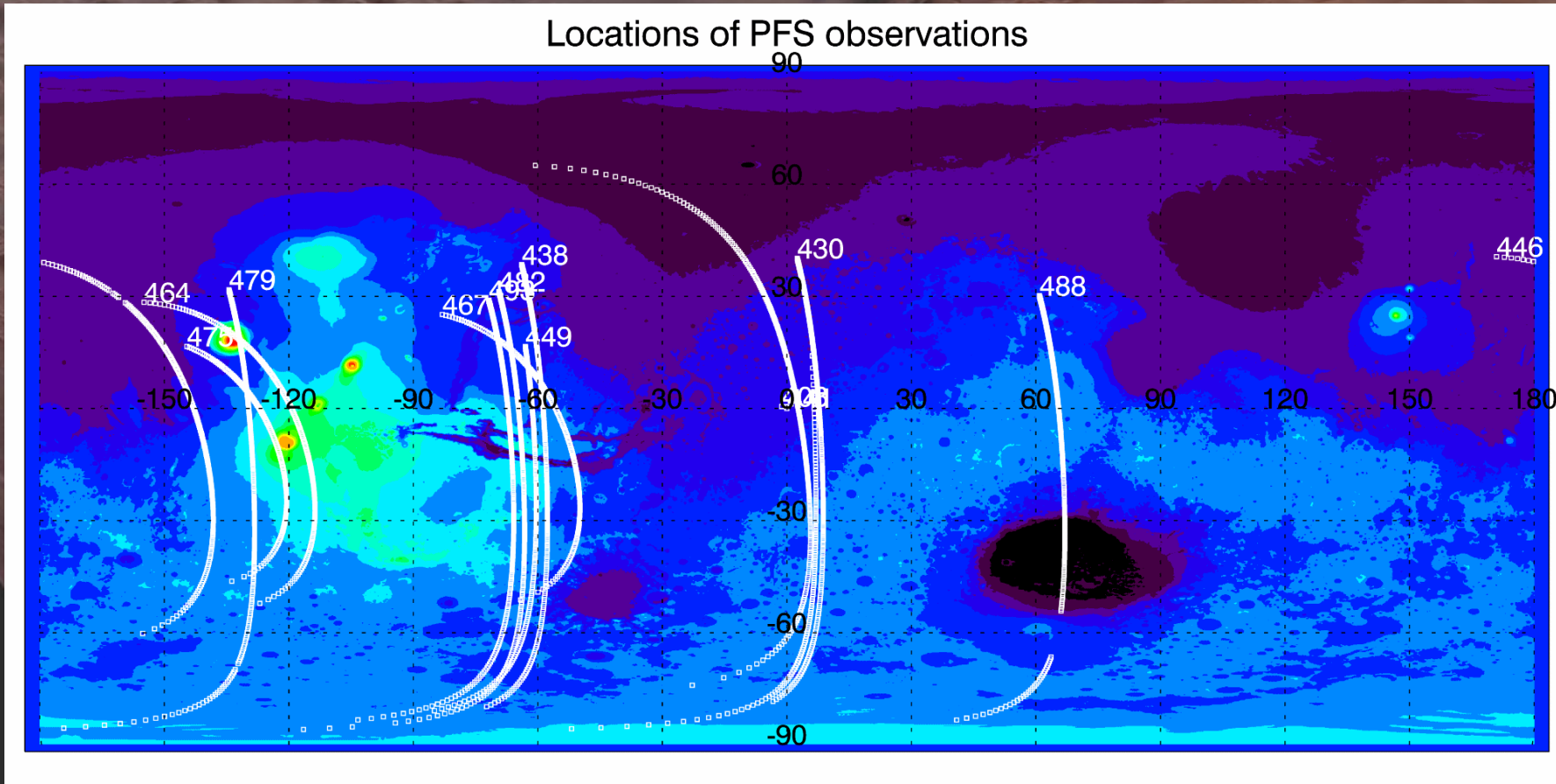
Observational possibilities

- MEX orbit is not Sun-synchronous
  - ✓Longitude of the ascending node wrt sub-solar longitude varies slowly along the mission
  - ✓Several local times can be explored by Nadir viewing instruments
  - ✓Complex local time – L_S – Longitude correlations in our dataset

Specific PFS possibilities

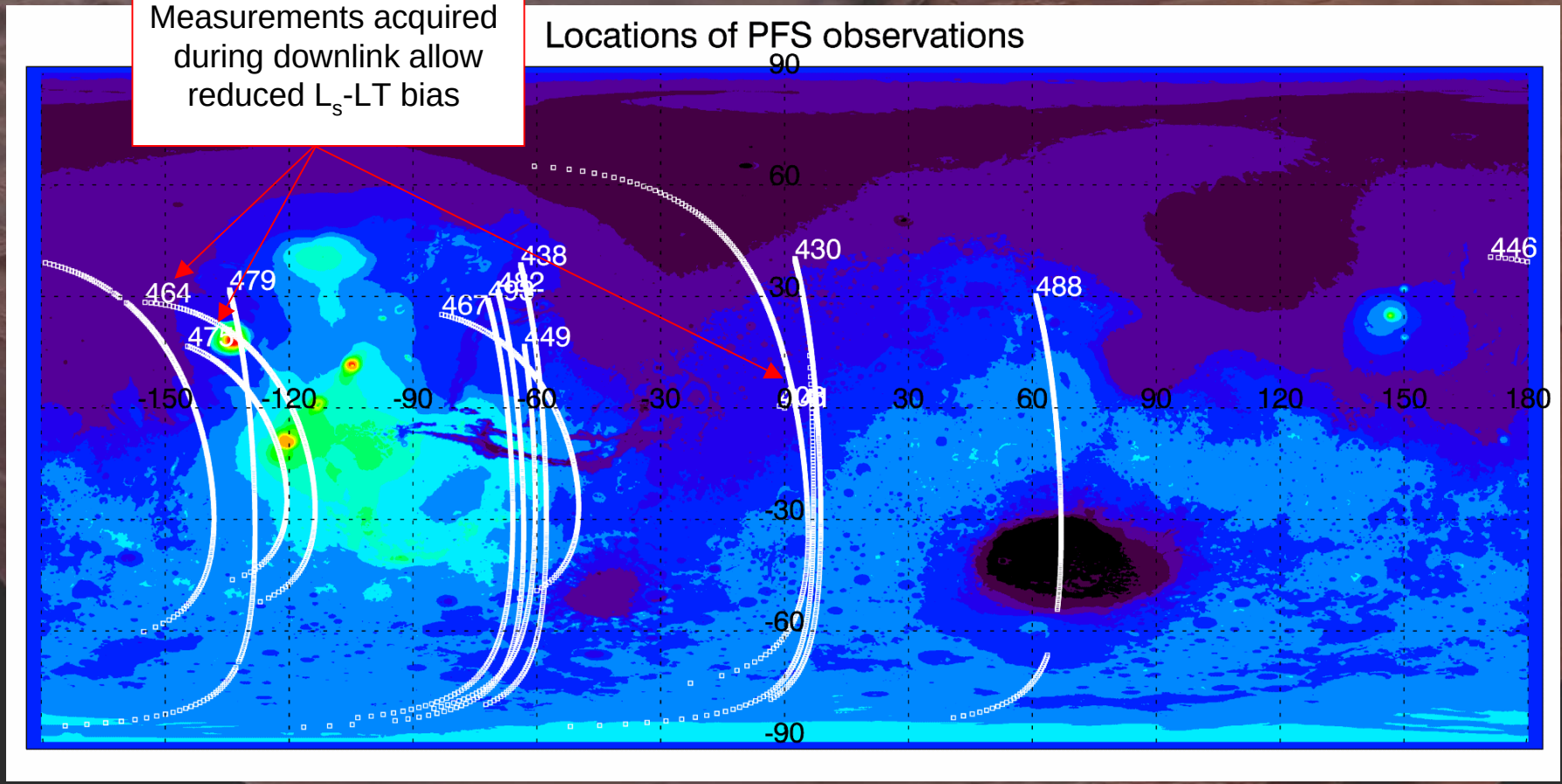
- Correlations in our dataset can be considerably reduced by:
  - ✓Usage of PFS autonomous scanner
  - ✓Observations during downlink sessions
- PFS can usefully integrate the huge dataset returned by MGS-TES (Sun-synchronous orbit) at different LTs

Observation characteristics

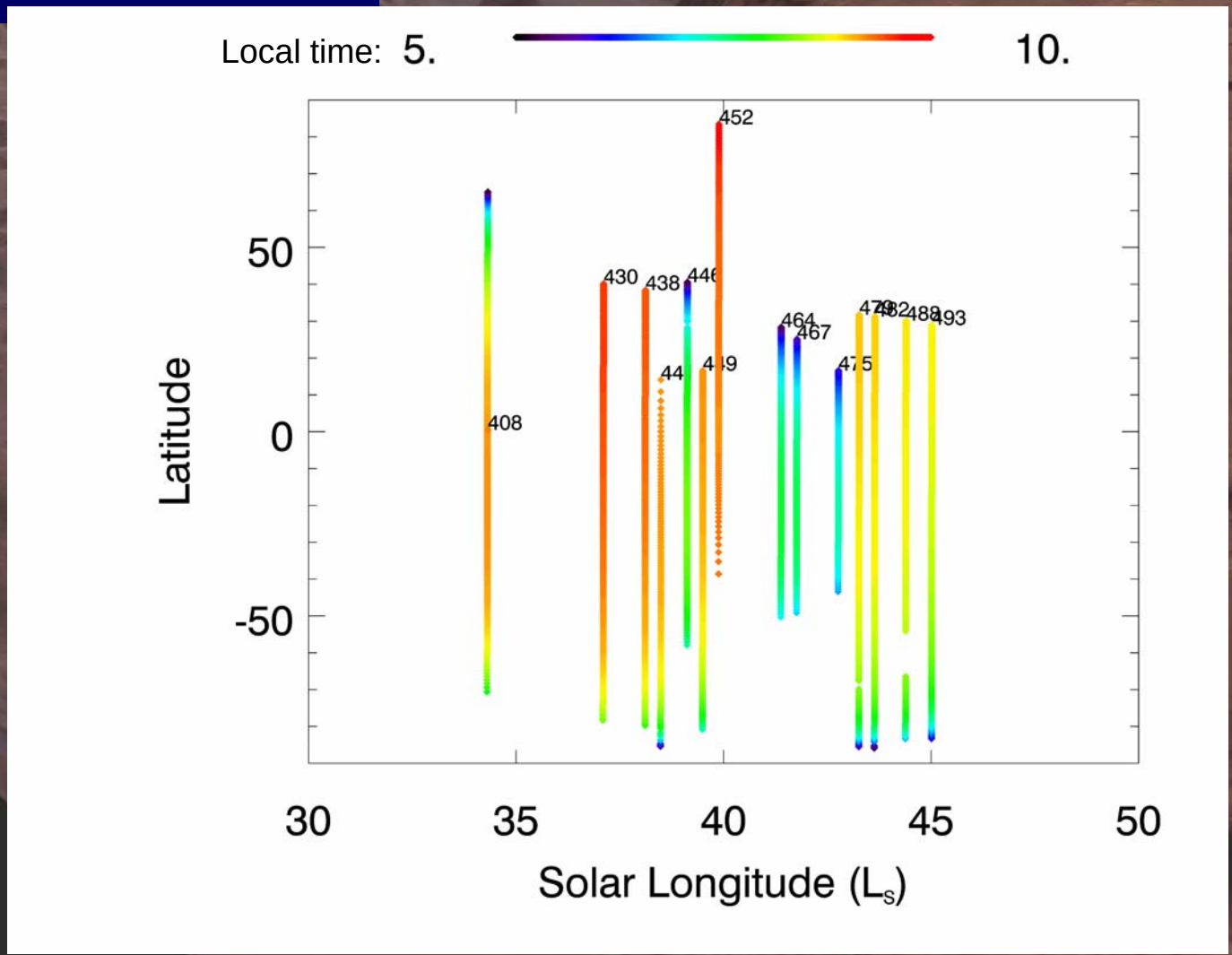


Observation characteristics

Measurements acquired during downlink allow reduced L_s-LT bias



Observation characteristics



T(z) fields

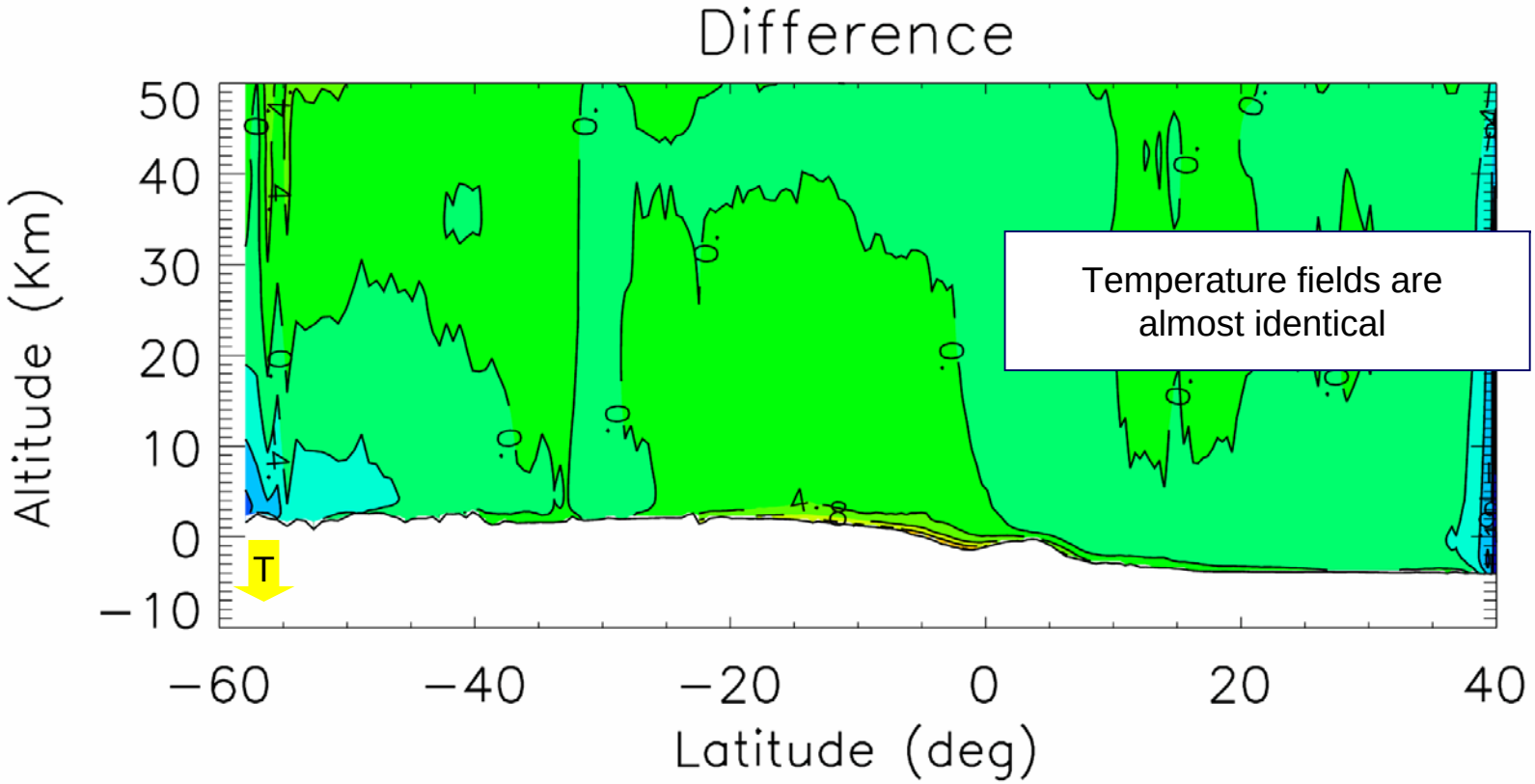
- Comparison with model expectation (EMCD 3.1) is the basic tool to catch unexpected phenomena.
- Issues:
  - ✓ Moderate spatial resolution ⇒ discrepancies near sharp topographic features (Vallis Marineris and Tharsis calderas)
  - ✓ Interpolation on season in the pre-computed distribution

T(z) fields

- Orbit are classified in three LT bins according the observational conditions near the equator

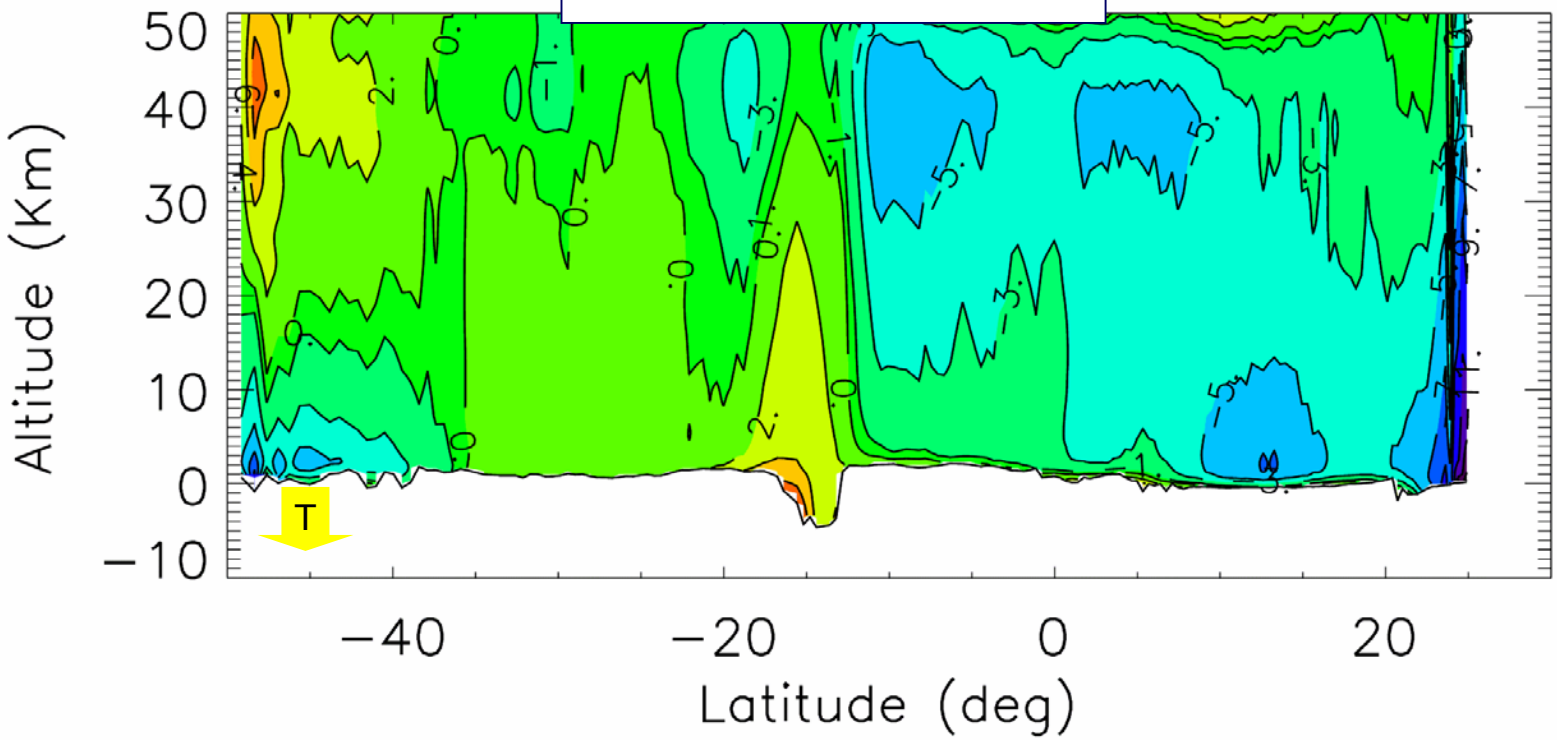
	LT	Sun Elev.
Early	6.30-8	<25°
Middle	8-9	<45°
Late	9-10	<65°

Orbit 446 (L_s 39.1)



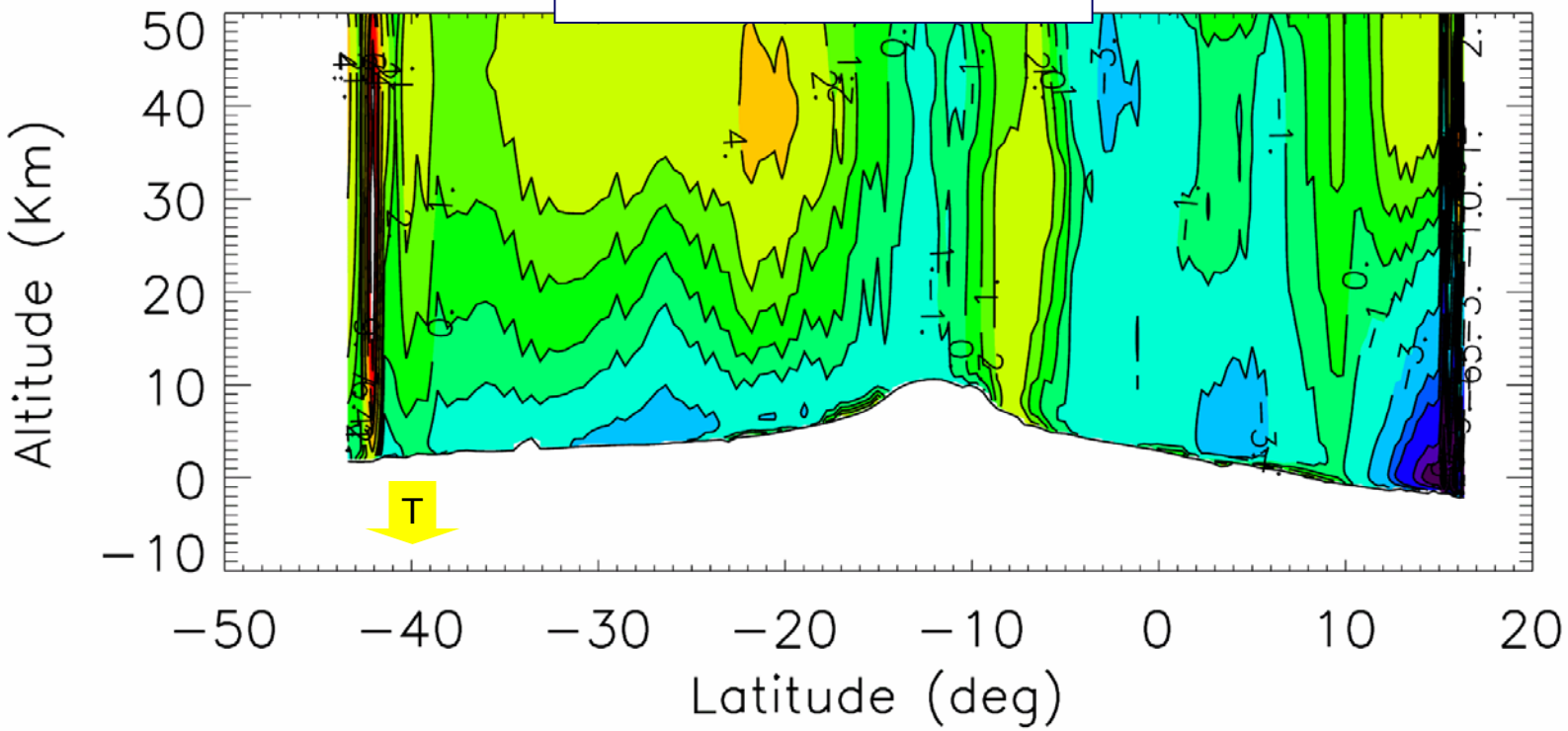
Orbit 467 (L_s 41.7)

Air tends to be colder
Northward of ~10N



Orbit 475 (L_s 42.7)

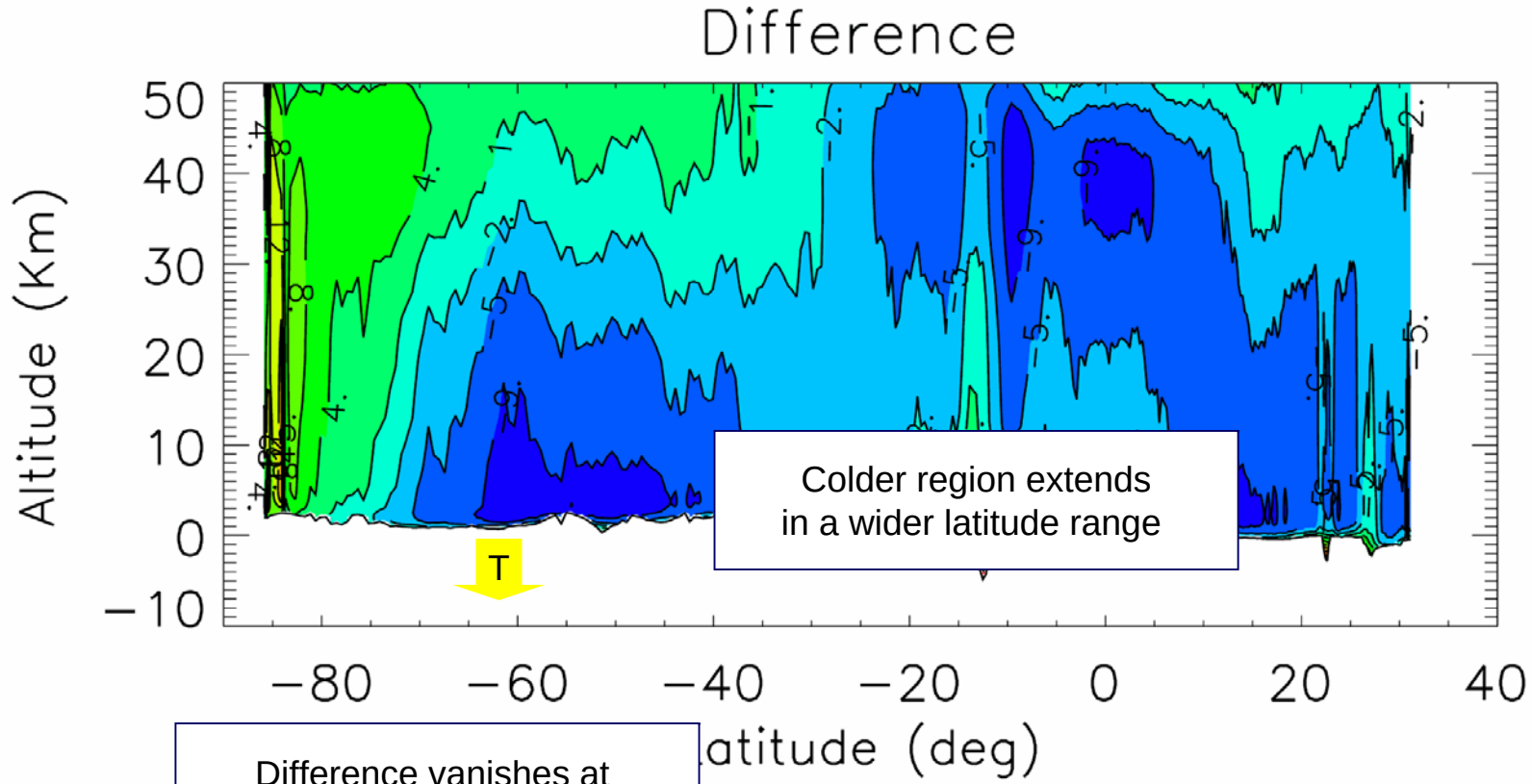
Air tends to be colder
Northward of ~10N



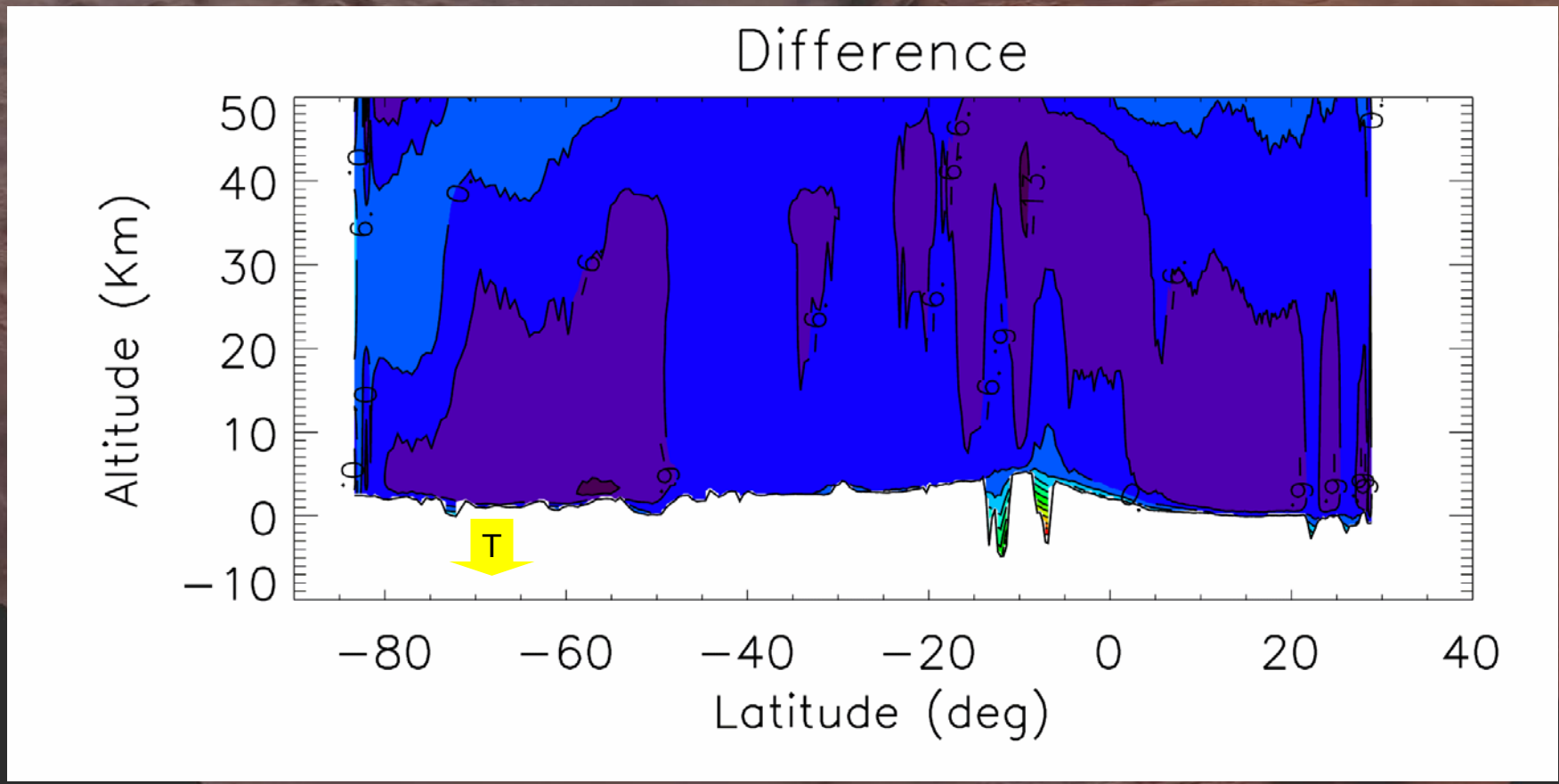
Early morning T(z) fields

- In general sense, excellent agreement between PFS data and model expectations is observed
  - ✓ Colder air temperatures at middle latitudes
  - ✓ Very similar or warmer close at southern latitudes
- Possible interpretation
  - ✓ Enhanced global circulation
  - ✓ An effect of model interpolation on season

Orbit 482 (L_s 43.6)



Orbit 493 (L_s 45.0)



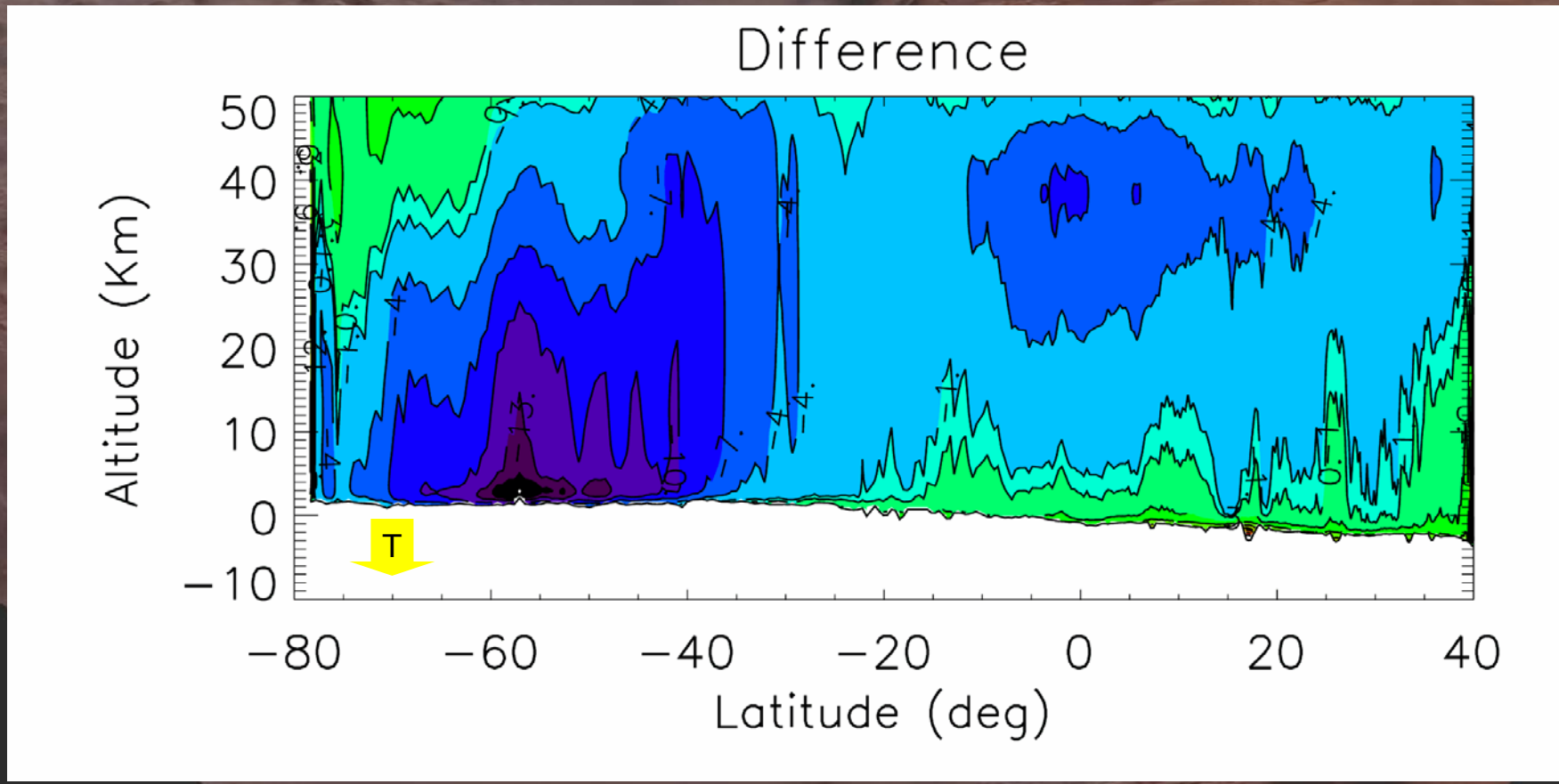
Middle morning T(z) fields

- Deviations between observed and measured temperature fields are stronger and latitudinally more extended than in the previous case
- Differences tend to vanish in the not illuminated regions

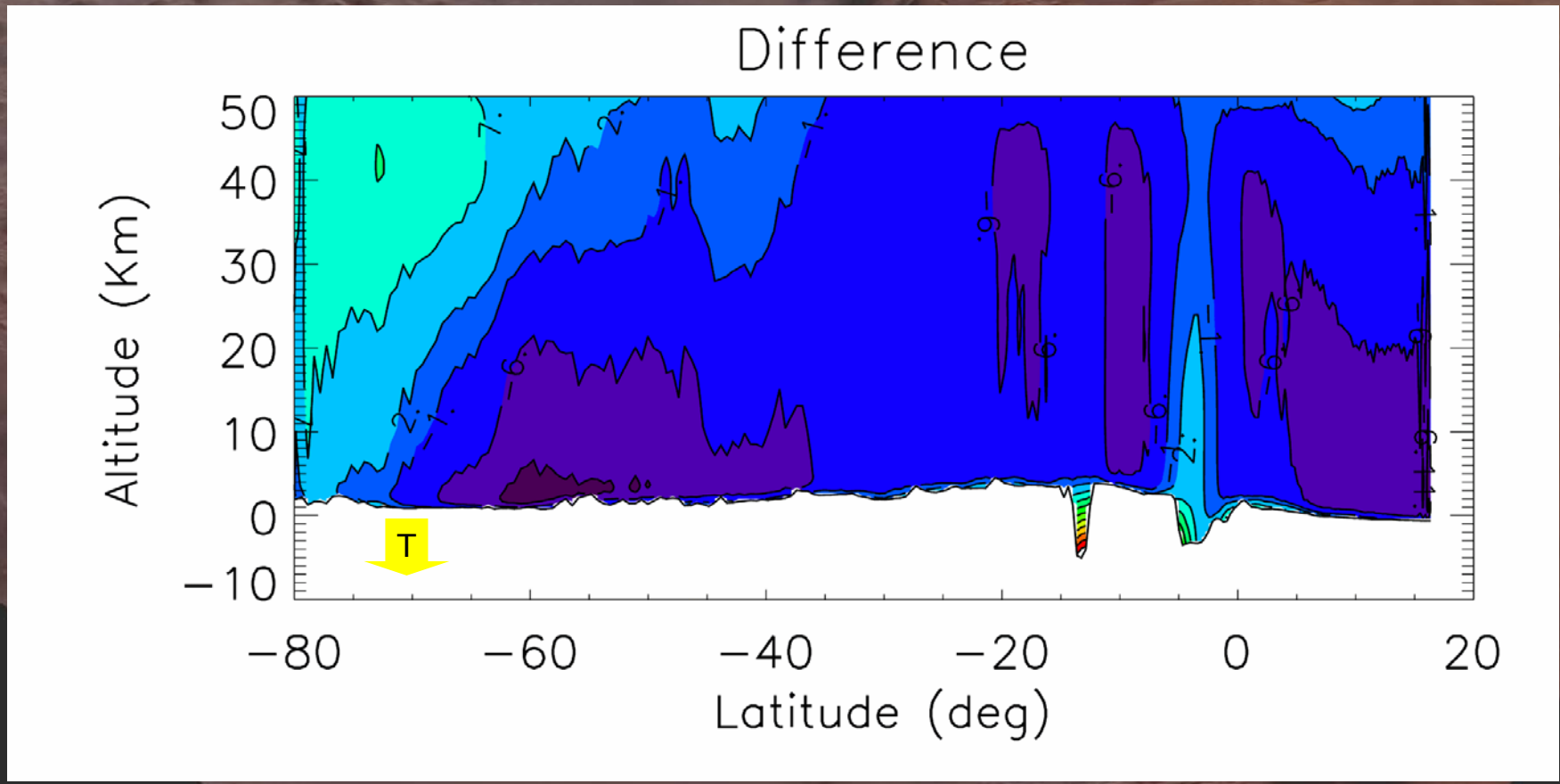
Possible interpretation:

- Latter point suggest a possible role by a short time scale phenomenon: the atmosphere has an higher time response to solar heating, possibly due to:
  - ✗ differences in dust loading
  - ✓ differences in aerosol optical properties
  - ✓ sublimation processes
- Dynamical effects?

Orbit 430 (L_s 37.1)



Orbit 449 (L_s 39.5)



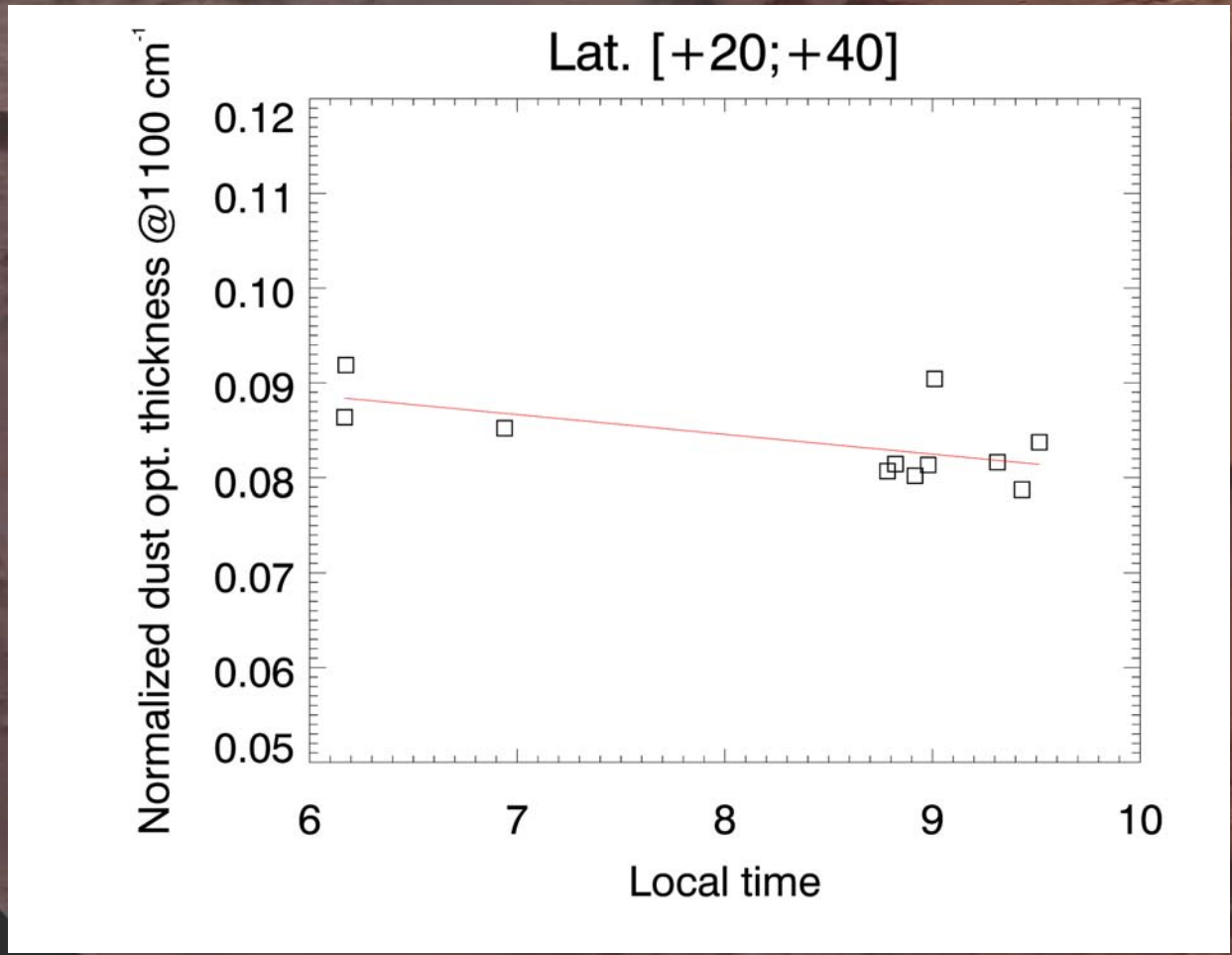
“Late” morning T(z) fields

- Trends in the are very similar to the ones observed in the previous local time bin
- Atmosphere tends to remain colder than model expectations

T(z) fields: synopsis

- Main features in expected T(z) fields are confirmed by PFS observations
- Discrepancies show different systematic patterns at different local times $\Rightarrow$ phenomena at different time scales

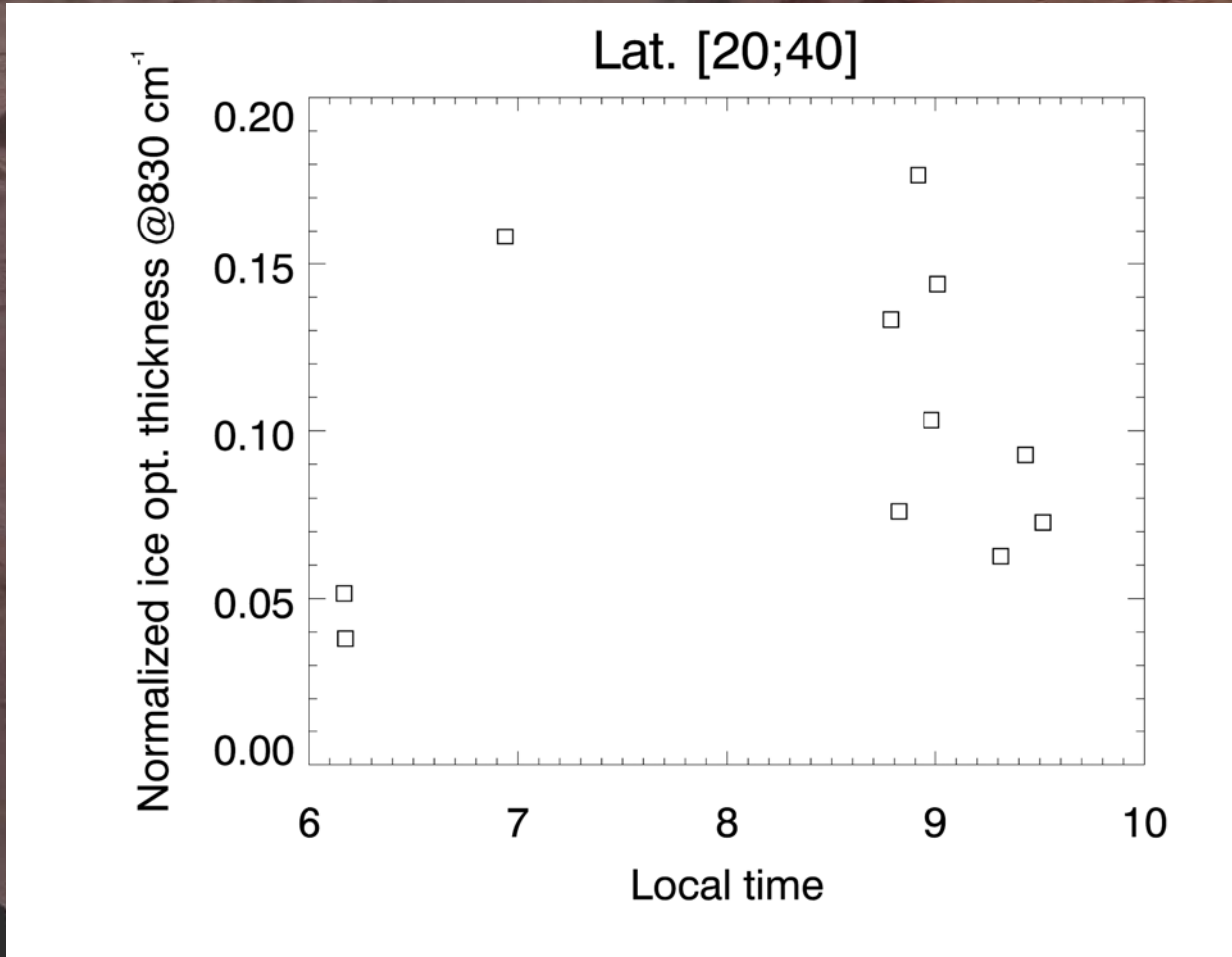
Dust content vs. local time



Dust content vs. local time

- Dust loads at 9LT are basically identical to the values assumed by EMCD in MGS dust scenario
- Despite retrievals errors, data point toward a decrease in dust content with local time
- Possible interpretations:
  - ✓ Discrepancies between dust and gas scale heights
  - ✓ Water ice coating on dust grains
  - ✓ Peculiar dynamic (which one?)
- This behavior confirms the previous study by Formisano et al., (2001) based on IRIS data

Ice content vs. local time



Ice content vs. local time

- PFS data suggest an increase in the early hours followed by a rapid fall around 9.30 PM
- Possible interpretation:
  - ✓ Sun heating triggers the release of water from a surface source or directly dust grains (more effective thermal IR absorbers)
  - ✓ In later hours, warmer air leads to ice sublimation
  - ✓ Later phenomenon is less effective at lower latitudes

Conclusions

- Observations still lack qualitative modeling!

  But..

- Morning observations highlight phenomena in the Martian atmosphere not fully encompassed by EMCD 3.1
- Discrepancies are of moderate magnitude
- Condensation processes may possibly play an important role

Future work

- Quantitative simulation of condensation processes is mandatory
  - ✓ Assessment of role in short-time atmospheric energy balance
  - ✓ Important constraints from PFS-derived water vapor content
- Extensive comparison with EMCD 4.0
- Statistic is expected to be improved by further PFS observations acquired in the same period

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Background image: ESA/HRSC team

Observational possibilities