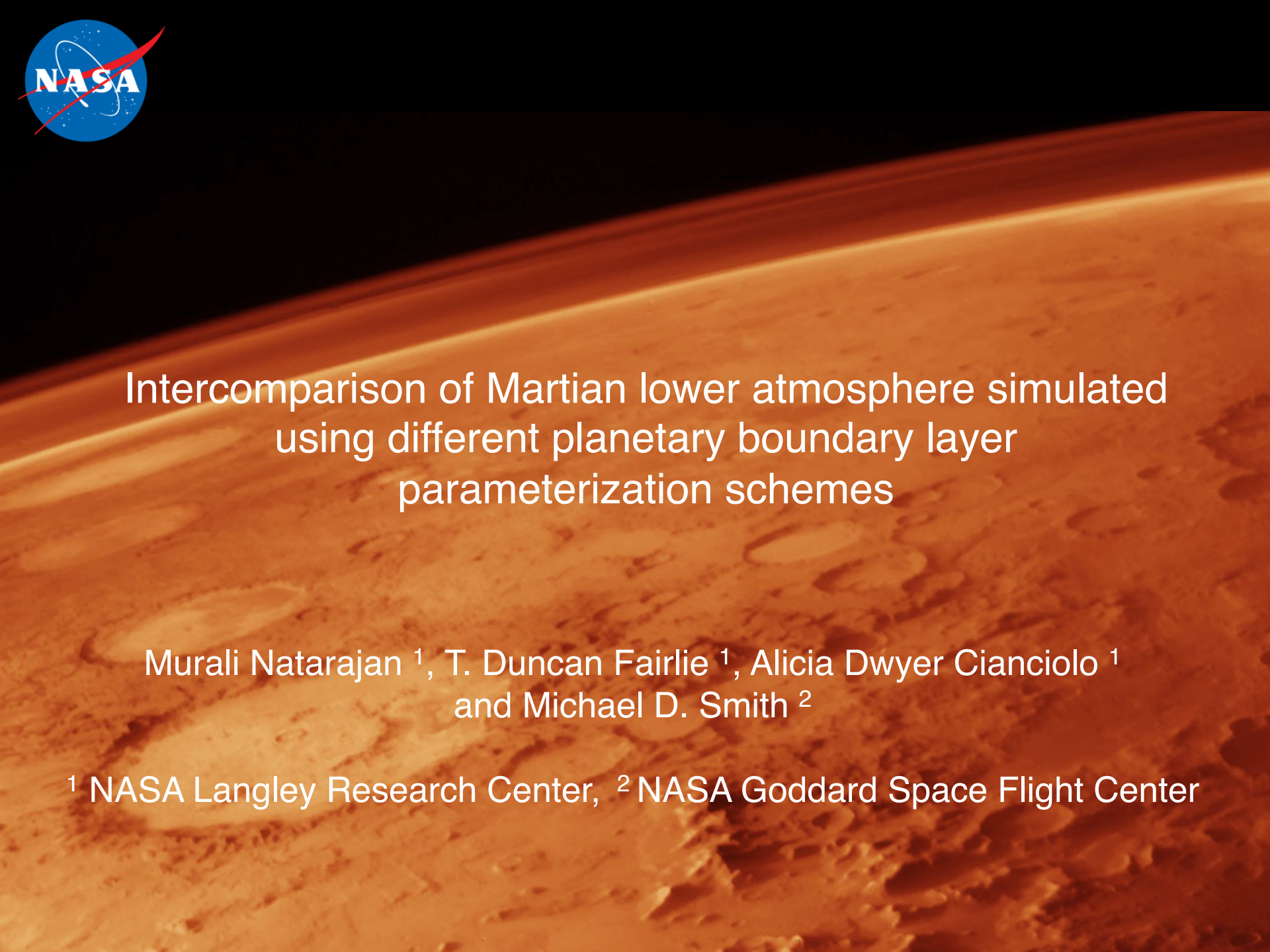


Intercomparison of Martian lower atmosphere simulated using different planetary boundary layer parameterization schemes

Murali Natarajan [1], T. Duncan Fairlie [1], Alicia Dwyer Cianciolo [1] and Michael D. Smith [2]

[1] NASA Langley Research Center, [2] NASA Goddard Space Flight Center

Introduction

- Planetary Boundary Layer processes influence temperature and horizontal momentum tendencies and impact phenomena like dust lifting and dust vertical mixing.
- GCMs and Mesoscale models use parameterizations to represent the effects of turbulence of different scales in the PBL.
- PBL schemes used in Earth system modeling can be applied to Mars.
- Evaluation of the performance of different schemes require near surface observations.

PBL Schemes

- Medium Range Forecast Model (MRF)

  K diffusion scheme with a 'countergradient correction' term. This term incorporates the contribution of the large scale eddies to the total flux (Hong and Pan, 1996).

- Yonsei University (YSU)

  K diffusion scheme with 'Countergradient correction' term, like MRF. Includes explicit term for entrainment at PBL top proportional to the surface buoyancy flux. Updated as in WRF version 3.4.1.

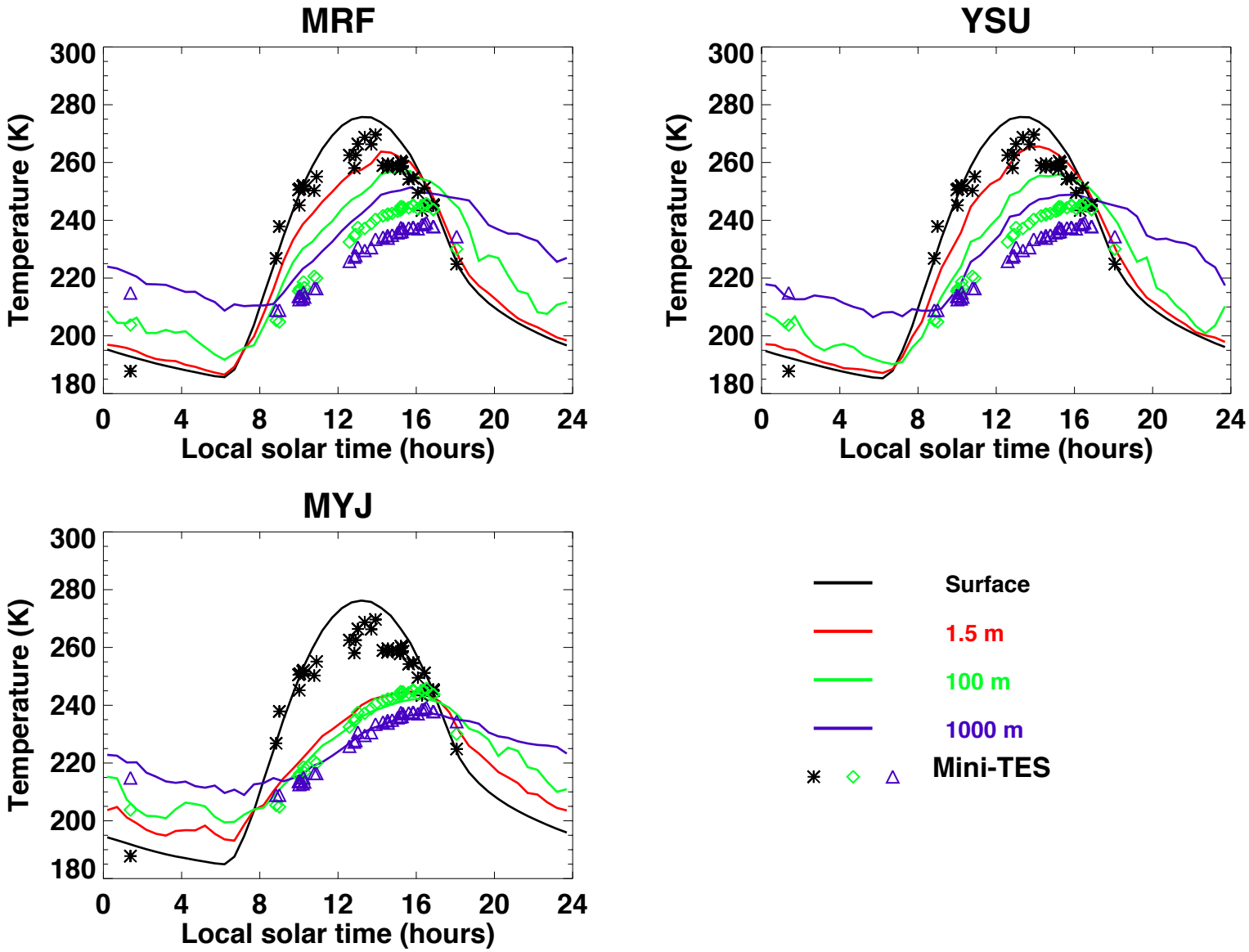
- Mellor-Yamada-Janjic (MYJ)

  Local Turbulent Kinetic Energy (TKE) closure scheme. K expressed as a function of TKE. Entrainment is part of PBL mixing.

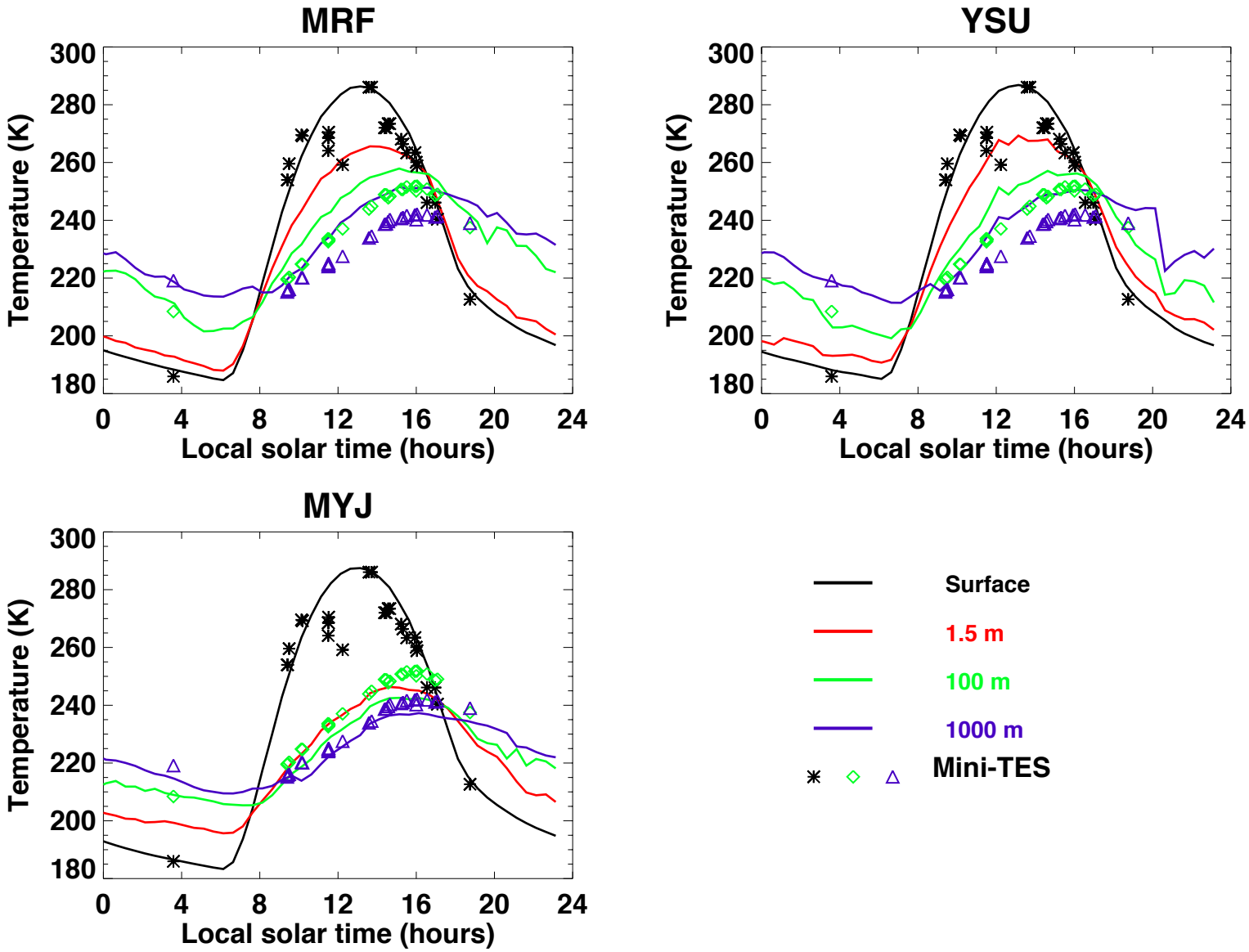
MarsWRF

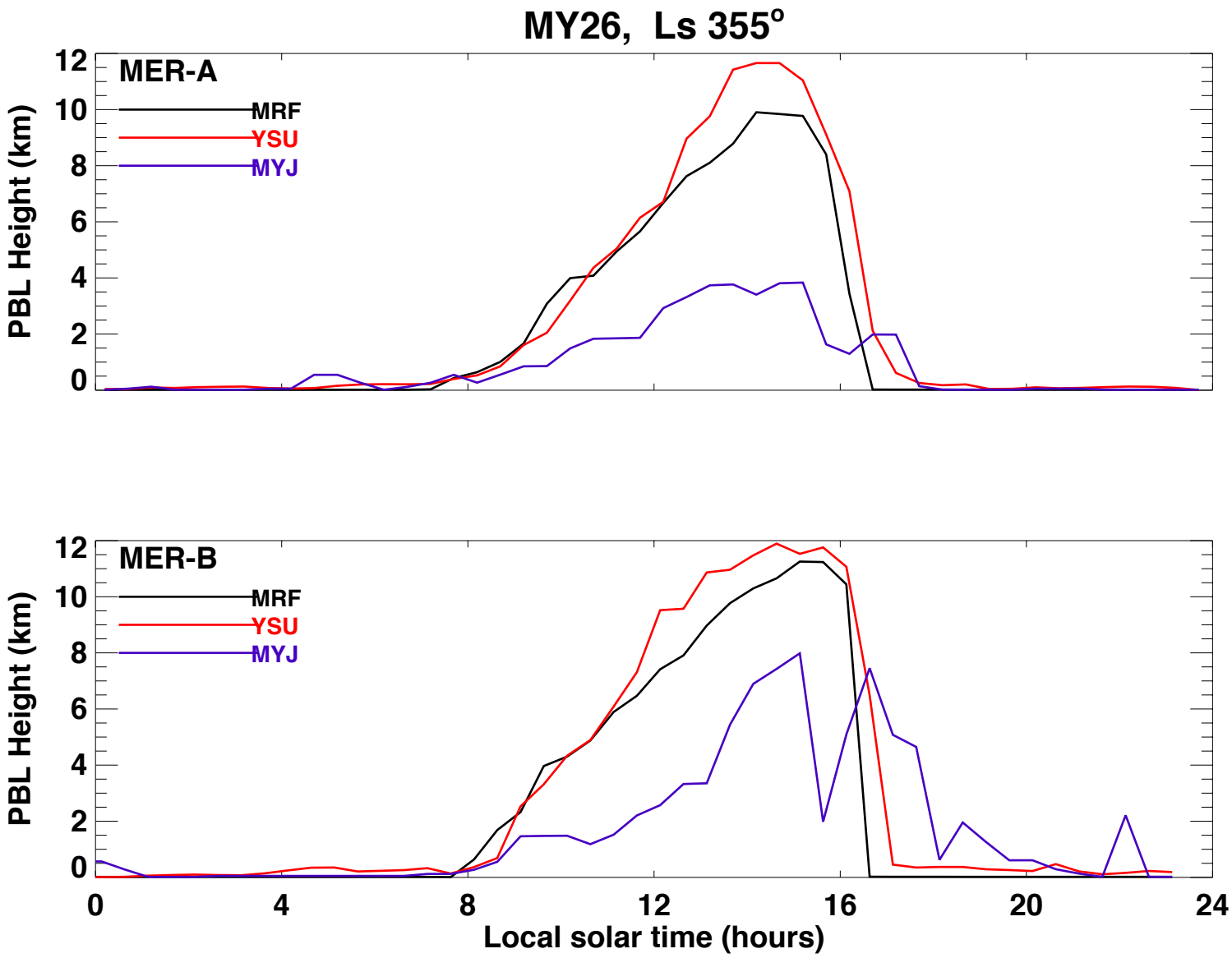
- PlanetWRF V3.3.1
- Compressible, non-Hydrostatic simulation on a finite difference grid
- “k-distribution” radiative transfer model (Mischna et al, JGR, 2012)
- Prescribed dust opacity for MY26 based on TES Nadir total IR opacity and TES-Limb data for vertical opacity profile
- Nested version of MarsWRF used for the mesoscale simulation. GCM with 5° x 5° resolution is the mother domain. 4 levels of nesting with highest resolution nest at 3.65 km x 3.65 km. Equal mass vertical grid with 40 intervals and 3 equal sub-intervals near the surface
- Mesoscale simulation for 3 sols at MER-A and MER-B locations at Ls around 355 in MY26
- Temperature data for this time period from Mini-TES used for comparisons

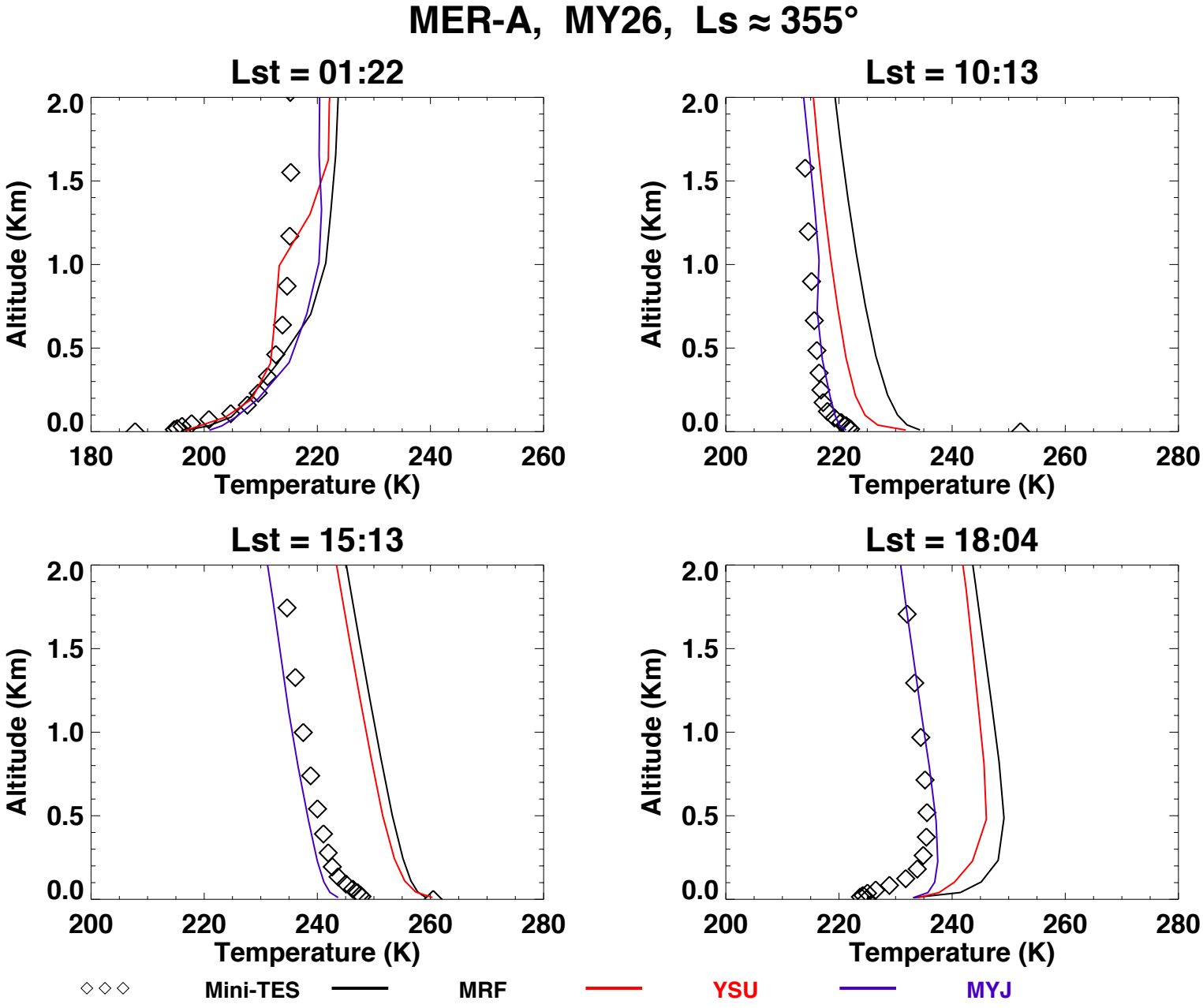
MER-A, MY26, Ls ≈ 355°

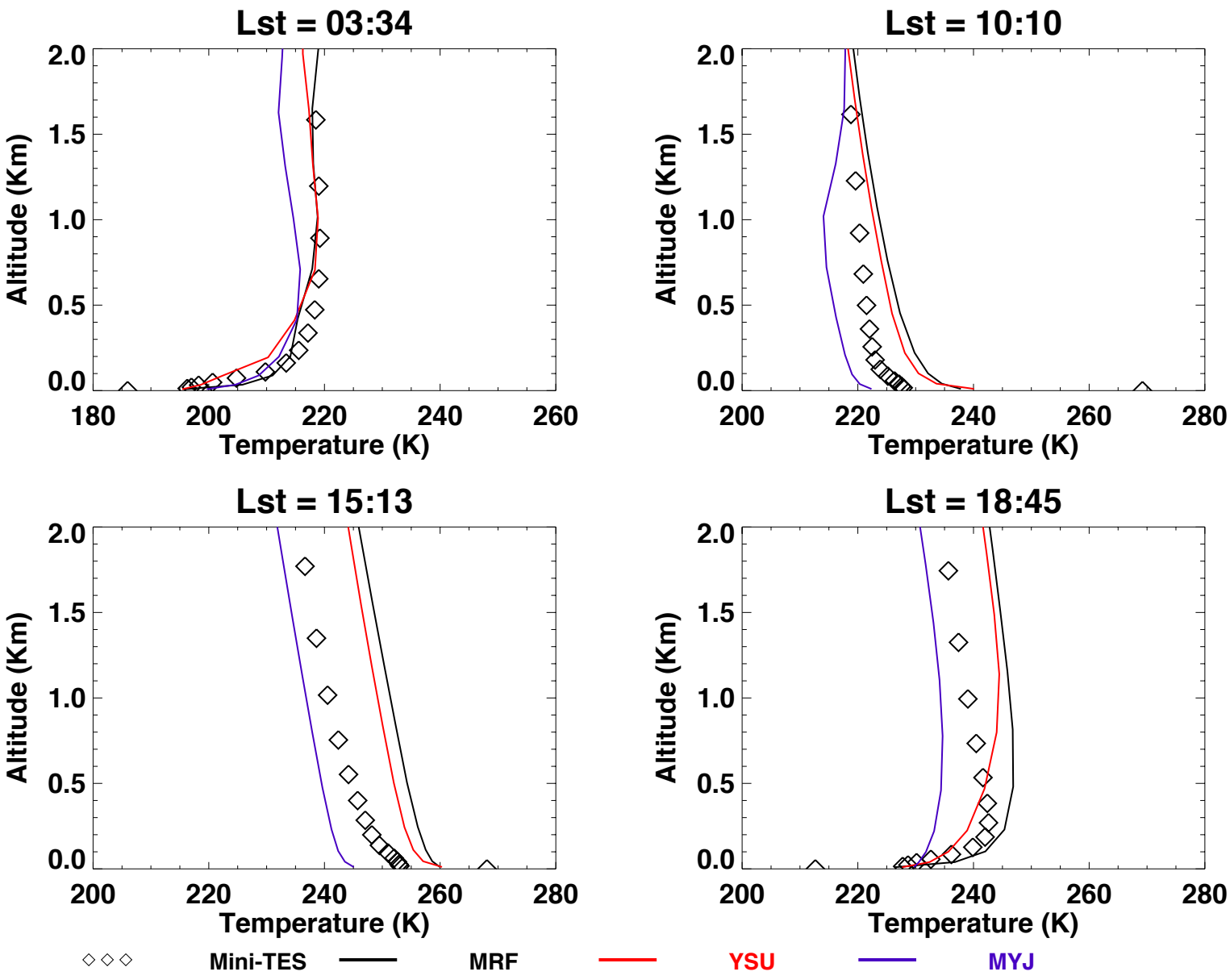


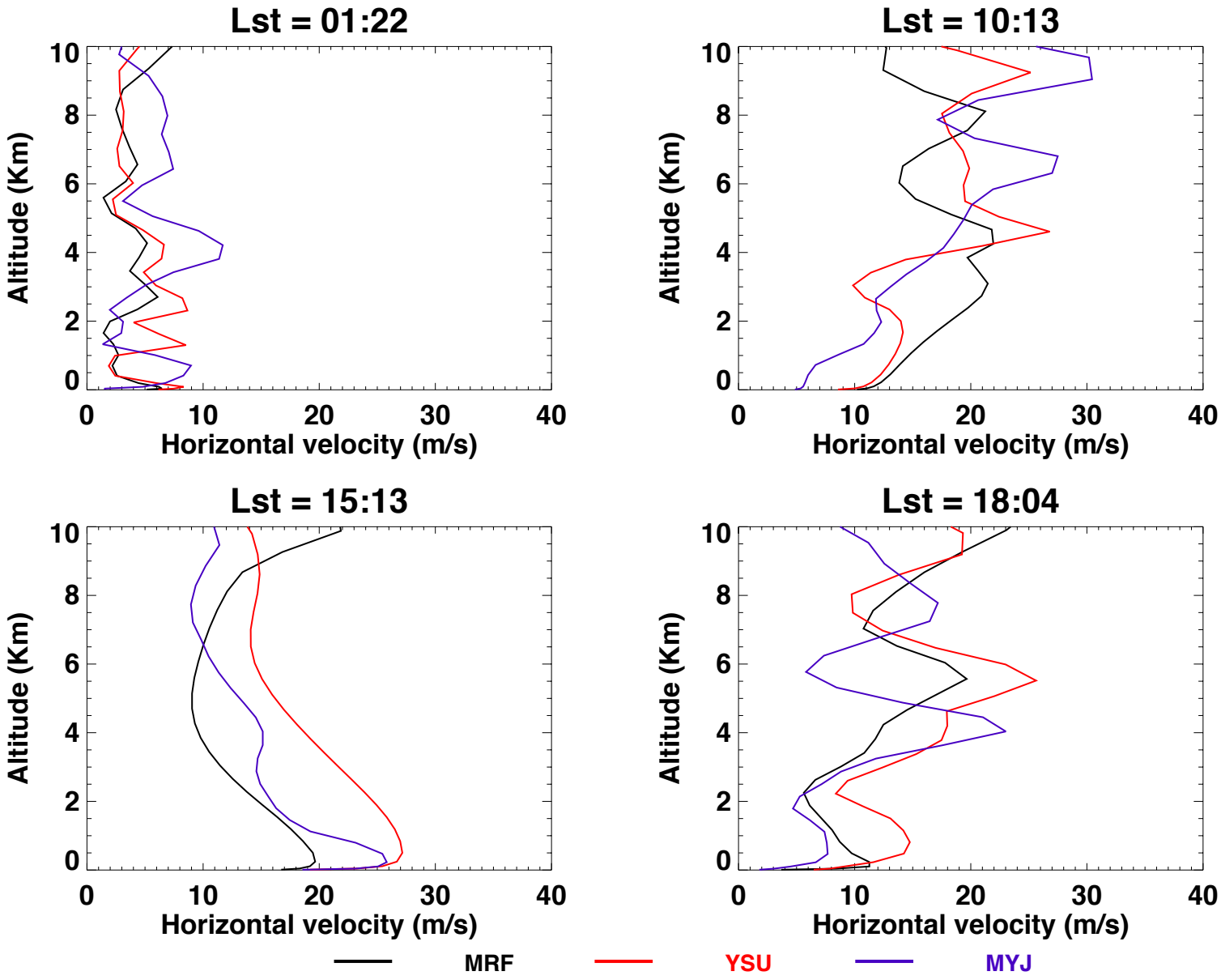
MER-B, MY26, Ls ≈ 355°

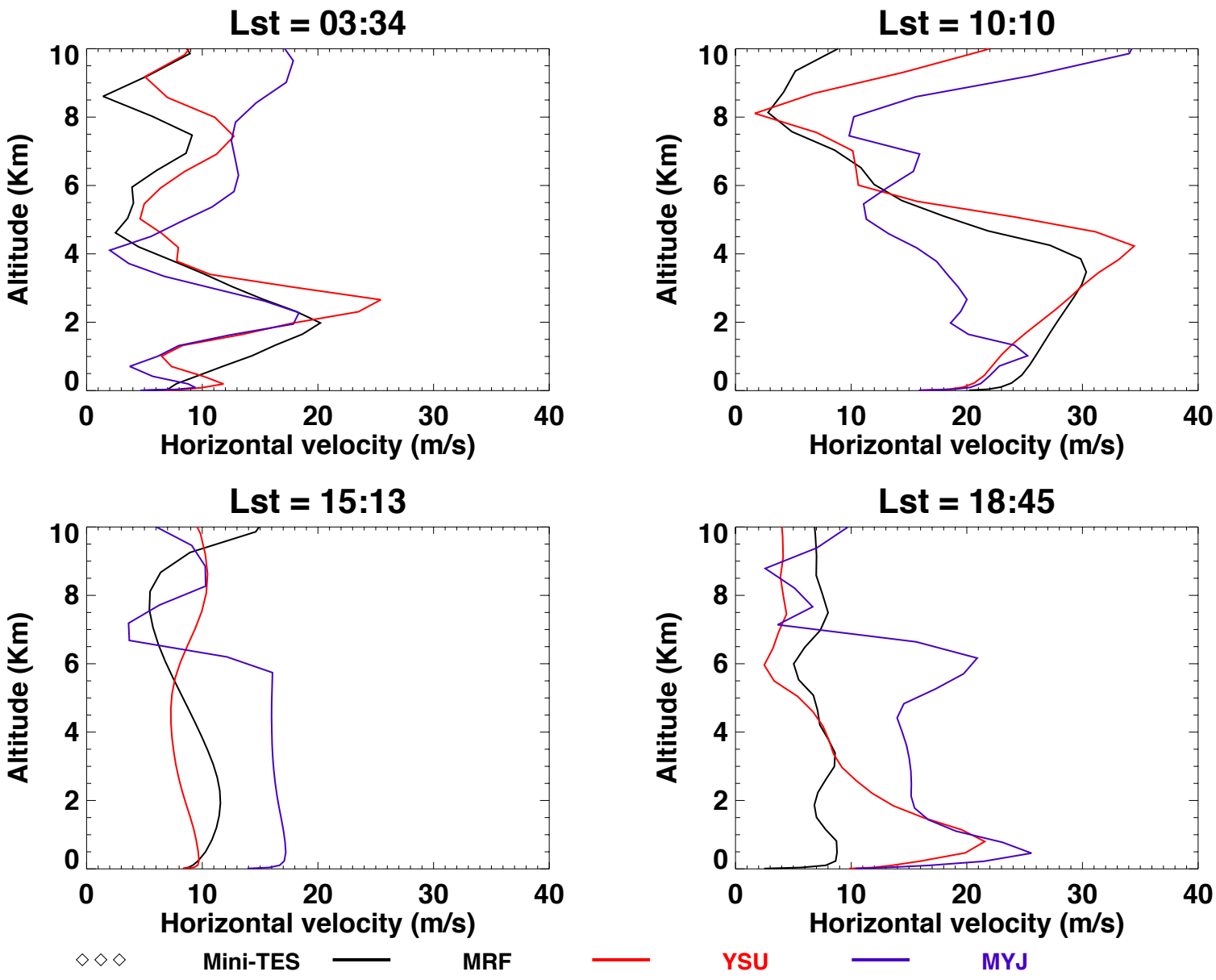



MY26, Ls 355°
MER-A
MRF
YSU
MYJ
PBL Height (km)
0
2
4
6
8
10
12
MER-B
MRF
YSU
MYJ
PBL Height (km)
0
2
4
6
8
10
12
0
4
8
12
16
20
24
Local solar time (hours)


MER-A, MY26, Ls ≈ 355°
Lst = 01:22
Lst = 10:13
Lst = 15:13
Lst = 18:04
Altitude (Km)
Temperature (K)
0.0
0.5
1.0
1.5
2.0
180
200
220
240
260
280
Mini-TES
MRF
YSU
MYJ


MER-B, MY26, Ls ≈ 355°
Lst = 03:34
Lst = 10:10
Lst = 15:13
Lst = 18:45
Altitude (Km)
Temperature (K)
2.0
1.5
1.0
0.5
0.0
180
200
220
240
260
280
Mini-TES
MRF
YSU
MYJ


MER-A, MY26, Ls ≈ 355°
Lst = 01:22
Lst = 10:13
Lst = 15:13
Lst = 18:04
Altitude (Km)
Horizontal velocity (m/s)
0
2
4
6
8
10
0
10
20
30
40
MRF
YSU
MYJ


MER-B, MY26, Ls ≈ 355°
Lst = 03:34
Lst = 10:10
Lst = 15:13
Lst = 18:45
Altitude (Km)
Horizontal velocity (m/s)
0
2
4
6
8
10
0
10
20
30
40
Mini-TES
MRF
YSU
MYJ

Summary

- MarsWRF mesoscale simulations are used to compare the effect of different PBL parameterization schemes.
- Model temperature profiles agree in shape with data from Mini-TES instrument onboard MER-A and MER-B but there are some differences in the magnitude.
- Non-local PBL schemes (MRF and YSU) yield nearly 10° K higher temperatures compared to Mini-TES data while MYJ scheme results are in good agreement with data during daytime at MER-A. For MER-B, all 3 schemes agree with the data within 5° K except during afternoon.
- The development of the convective boundary layer during the day is well reproduced by all schemes, but the maximum height of PBL in the MYJ case is much lower.
- The vertical profiles of horizontal wind are in good agreement overall, but there are no observations to evaluate the results.