Comparison of Atmospheric Observations and Predictions for the Atmospheric Entries of Spirit and Opportunity

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#2175 - Mars Atmosphere Posters

LPSC, Houston, Texas

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Introduction

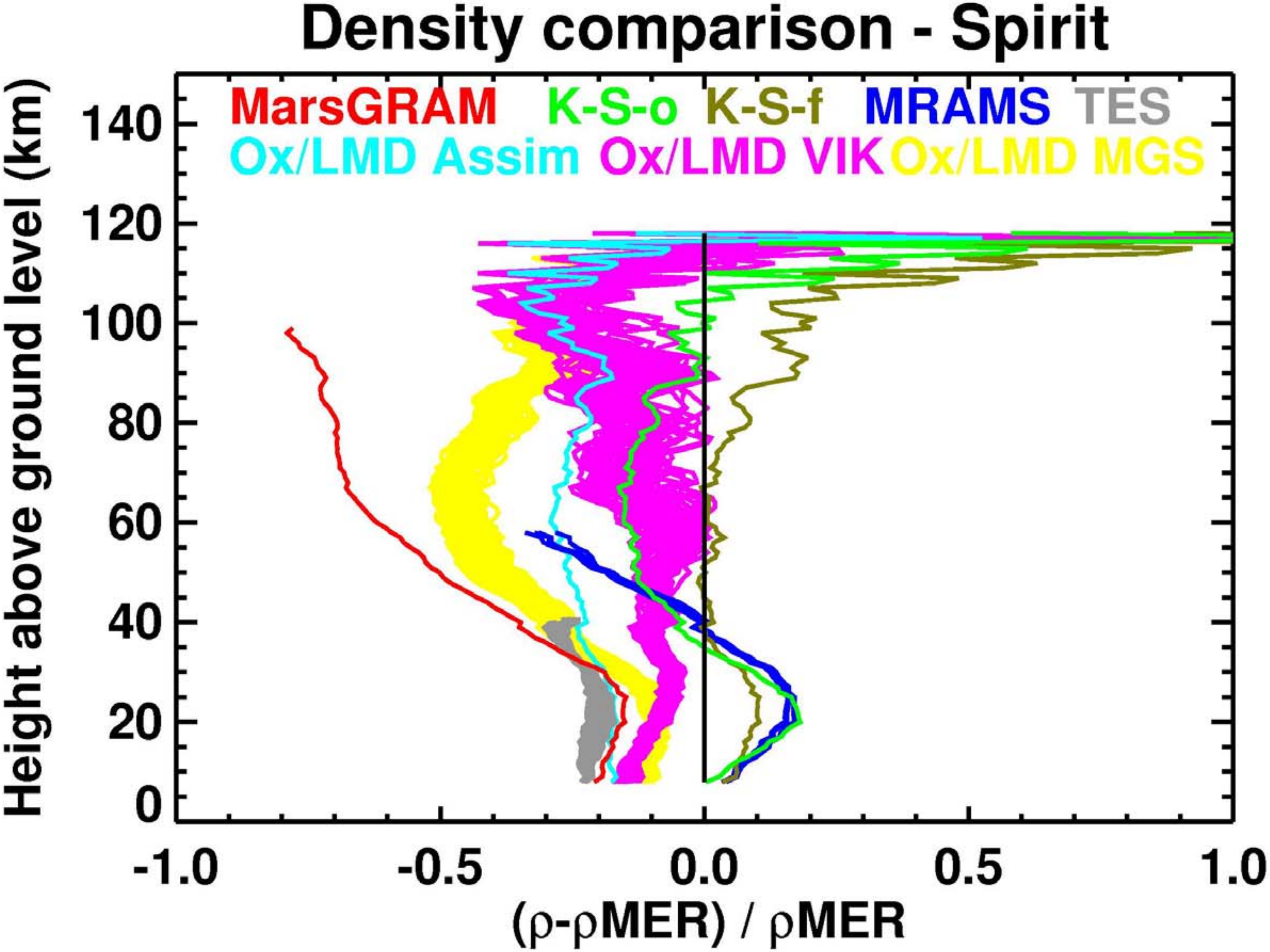
- Which model will make the most accurate atmospheric predictions for MSL Entry, Descent and Landing (EDL)?
- One way of testing available models is to evaluate their predictions for the EDL of Spirit and Opportunity.
- In addition to supporting the MSL project, this work should highlight some underlying strengths/weaknesses in the models.

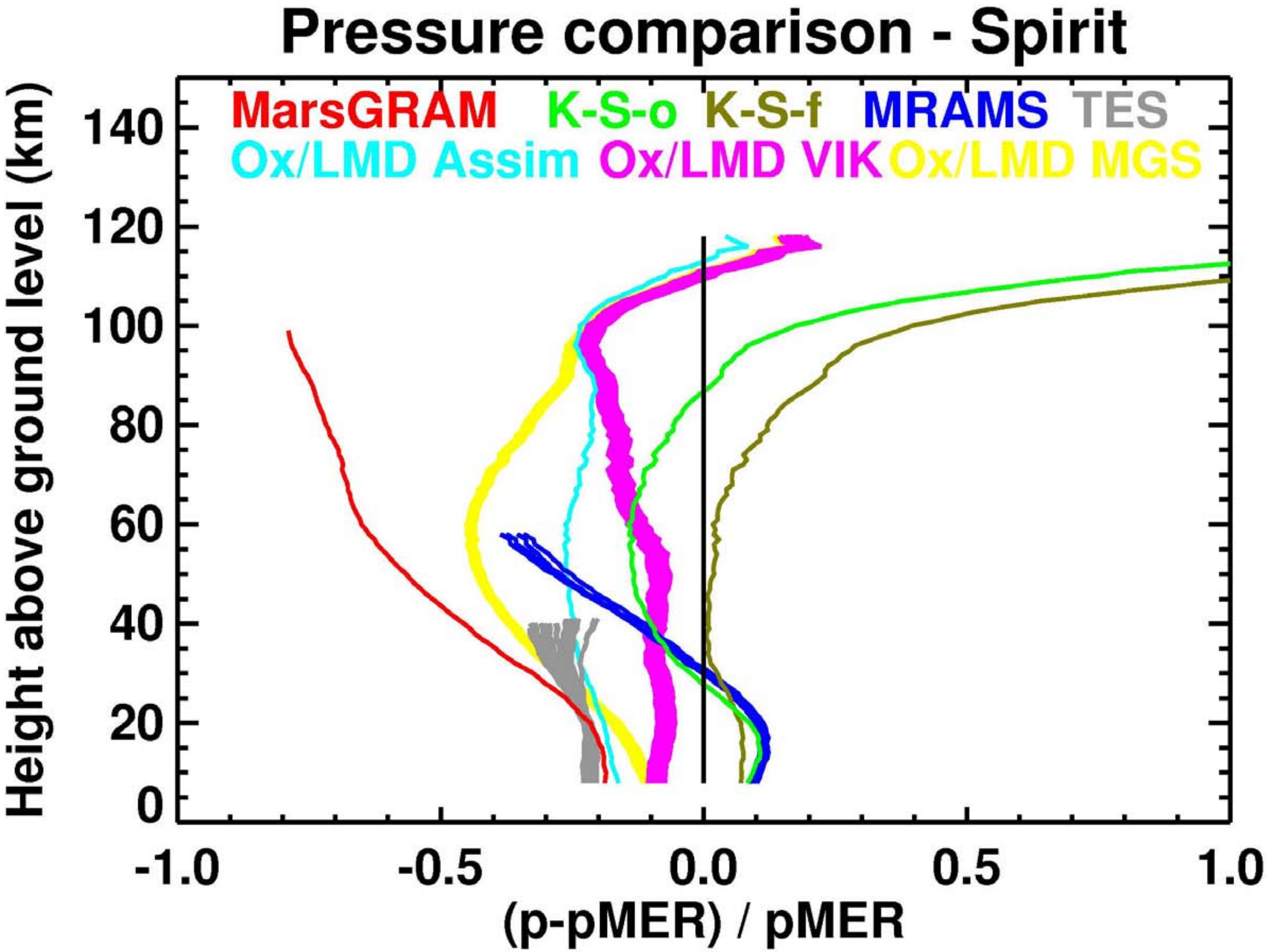
Available Data

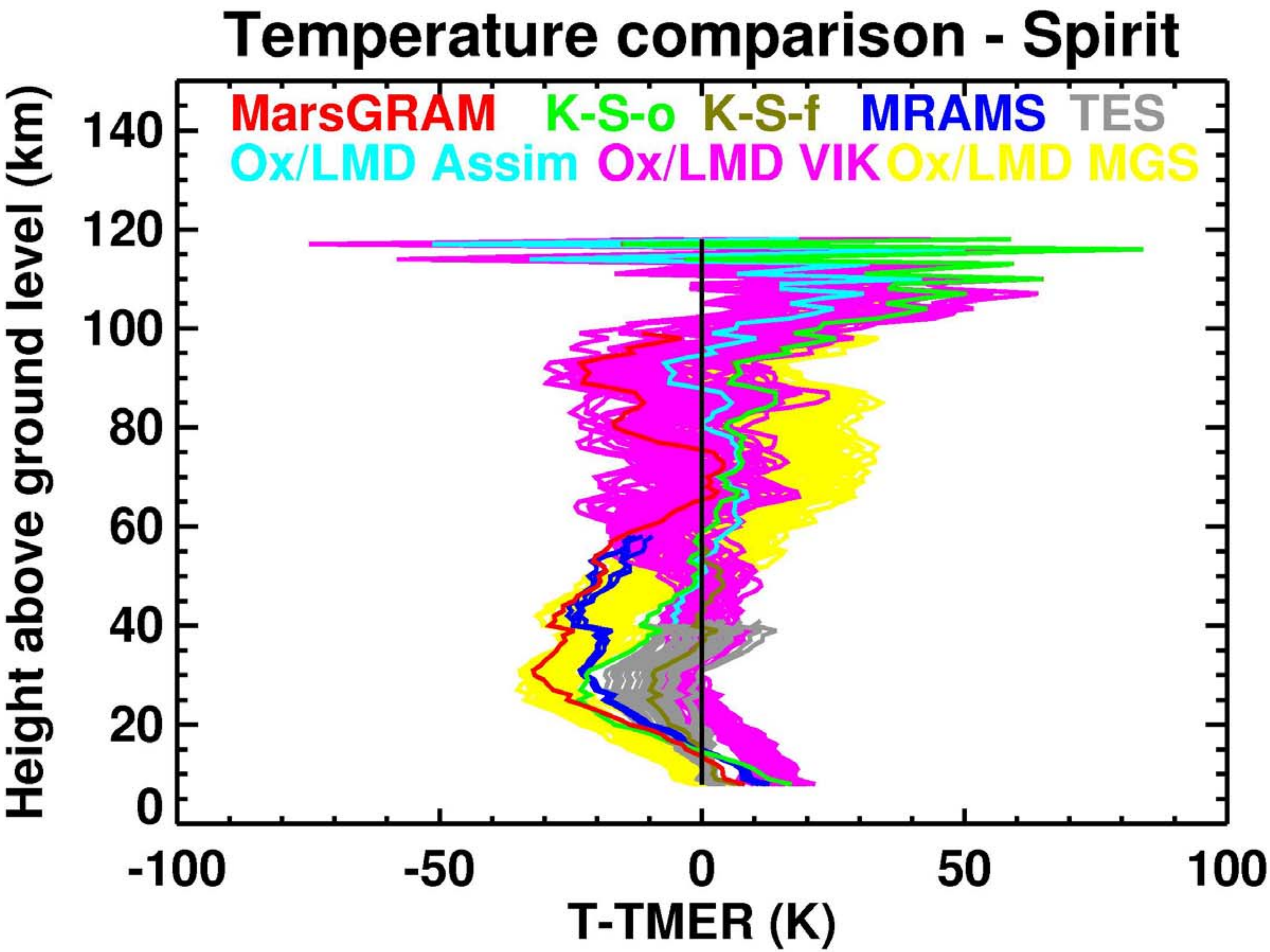
- Spirit and Opportunity entry profiles
  - Aerodynamic deceleration measured from ~100 km to parachute deployment at ~7 km
  - Density determined from deceleration
  - Pressure from density and hydrostatic equilibrium, upper boundary condition
  - Temperature from ideal gas law
- TES T(p) profiles (~20 profiles for each MER)
  - Measured IR radiances used to determine T(p) between surface and ~10 Pa (~40 km)
  - Select one TES profile per day as closest to EDL latitude, longitude and local solar time (LST)
  - TES latitude and LST very close to EDL conditions, longitude was up to 15^o away from EDL longitude
  - Use profiles from 10 days before EDL to 10 days after EDL
  - Density from ideal gas law
  - Altitude from hydrostatic equilibrium and <u>surface pressure</u> inferred from Viking lander data

Available Models

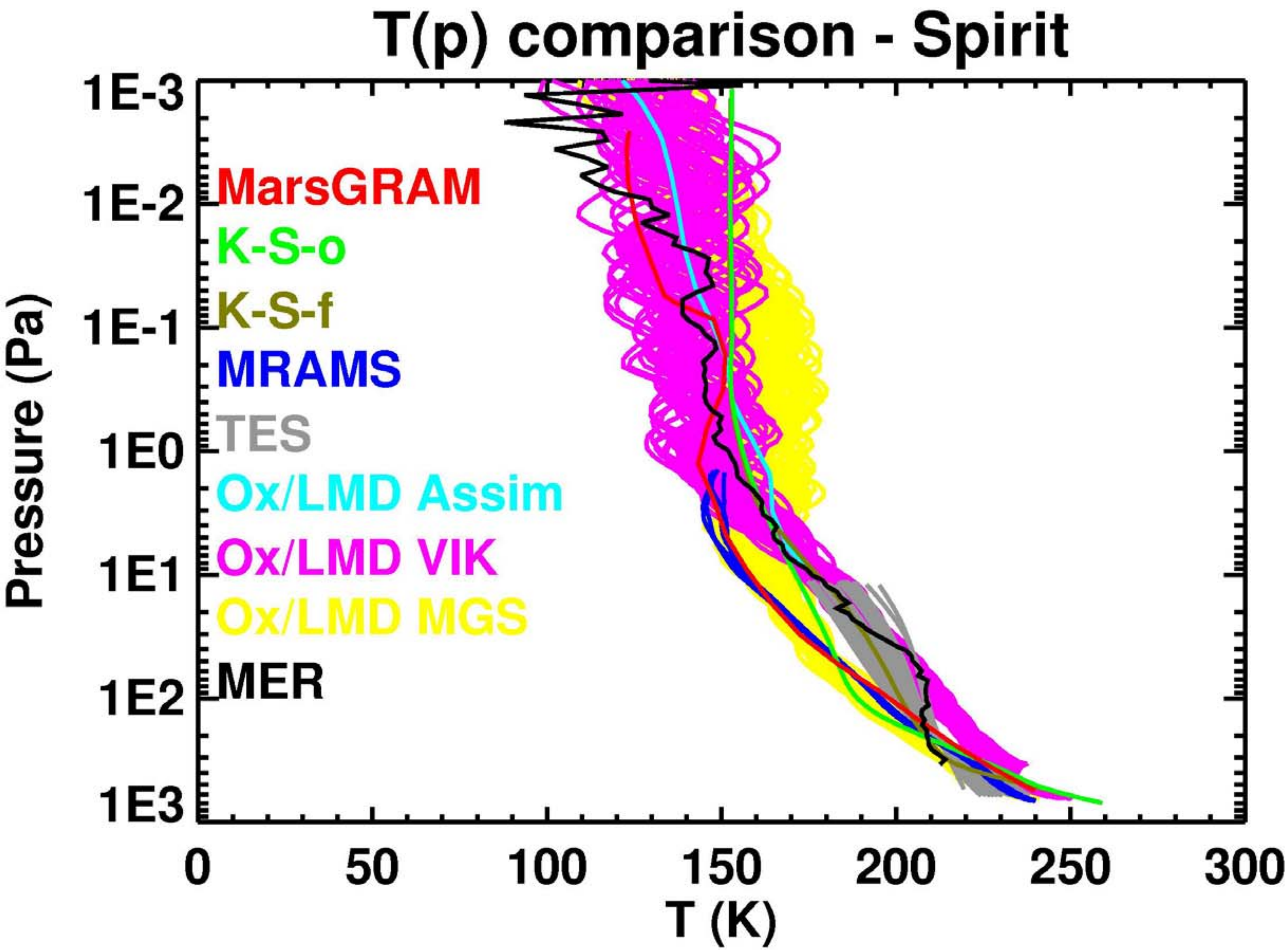
- MarsGRAM (1 profile for each MER)
  - Empirical model, commonly used by engineers for mission planning
- Kass-Schofield (2)
  - Empirical model based on TES T(p) data, developed specifically for MER EDL support
  - Two versions used here
    - Original. Used during most of the mission design process (1)
    - Final. Based on latest TES data, used for software adjustments a few weeks before EDL (1)
- MRAMS (4)
  - Mesoscale model used primarily to predict winds during EDL
- Oxford-LMD MGCM (151)
  - Established general circulation model
  - Three versions used here
    - “MGS dust”. Low dust amounts, cooler (50)
    - “Viking dust”. High dust amounts, warmer (50)
    - Assimilation. Model assimilates TES T(p) data for period before EDL (1)


Density comparison - Spirit
MarsGRAM
K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
Height above ground level (km)
0
20
40
60
80
100
120
140
-1.0
-0.5
0.0
0.5
1.0
(ρ-ρMER) / ρMER

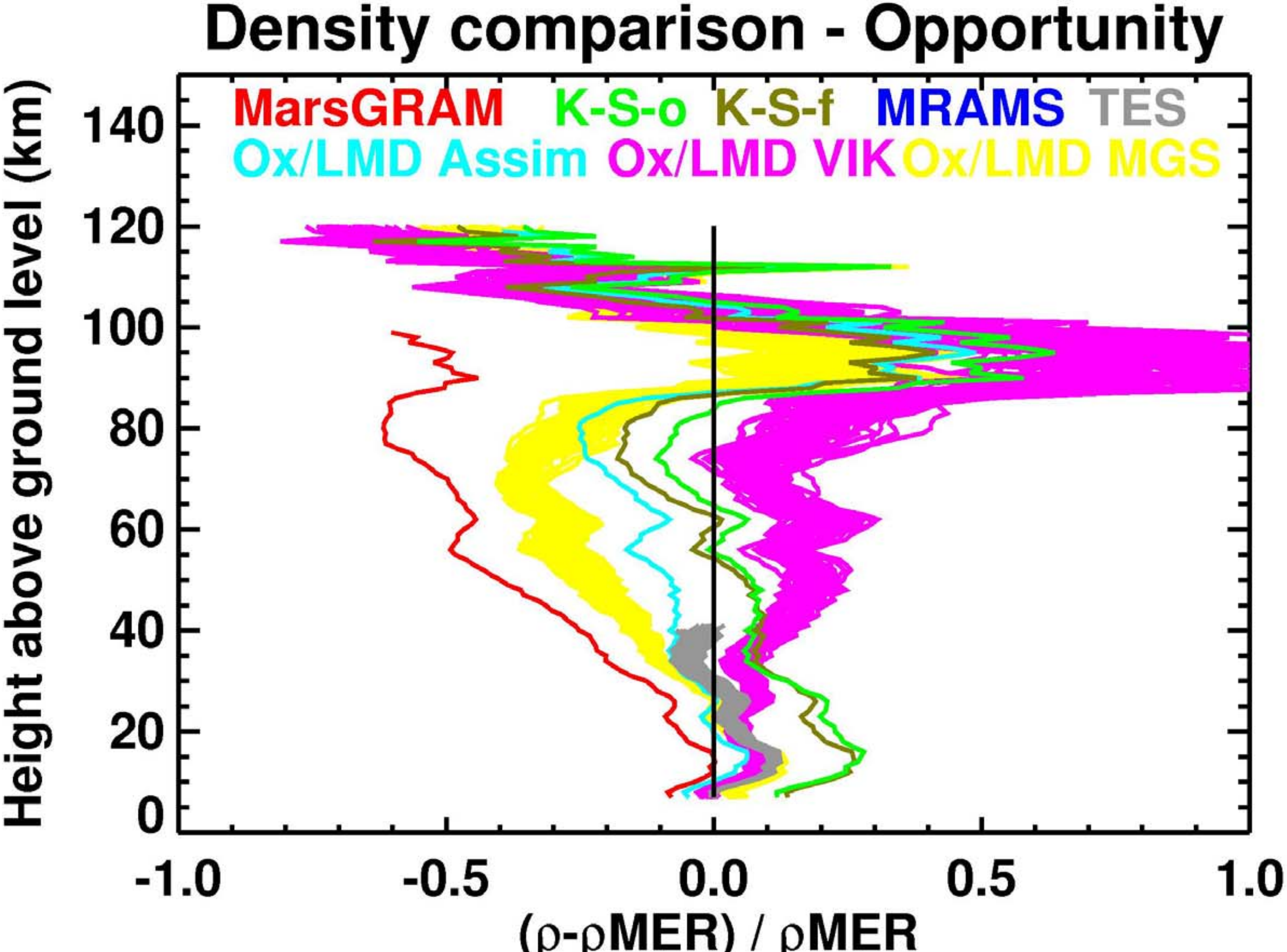

Pressure comparison - Spirit
MarsGRAM
K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
Height above ground level (km)
0
20
40
60
80
100
120
140
-1.0
-0.5
0.0
0.5
1.0
(p-pMER) / pMER



Temperature comparison - Spirit
MarsGRAM
K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
Height above ground level (km)
0
20
40
60
80
100
120
140
-100
-50
0
50
100
T-TMER (K)


T(p) comparison - Spirit
Pressure (Pa)
T (K)
1E-3
1E-2
1E-1
1E0
1E1
1E2
1E3
0
50
100
150
200
250
300
MarsGRAM
K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
MER

Spirit / 20 km	ρ (kg m^{-3})	P (Pa)	T (K)
MER	2.8E-3	113	209
MarsGRAM	2.4E-3	89	196
Kass-Schofield (original)	3.3E-3	123	193
Kass-Schofield (final)	3.1E-3	121	203
MRAMS (mean)	3.3E-3	125	199
TES (mean)	2.3E-3	88	202
MGCM (assimilation)	2.4E-3	92	203
MGCM (Viking dust)	2.6E-3	105	213
MGCM (MGS dust)	2.6E-3	94	190


Density comparison - Opportunity
MarsGRAM
K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
Height above ground level (km)
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20
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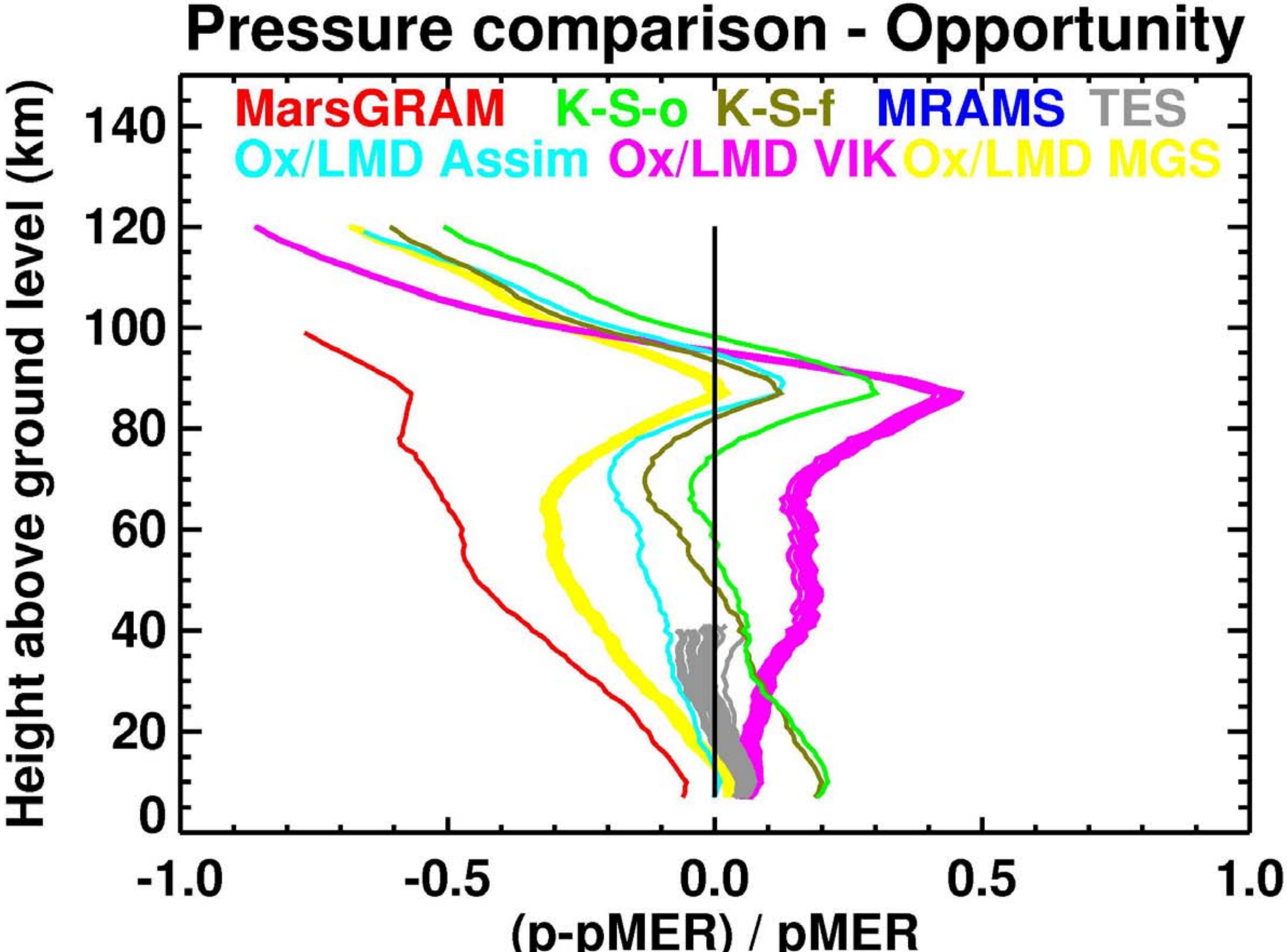
140
-1.0
-0.5
0.0
0.5
1.0
(ρ-ρMER) / ρMER


Pressure comparison - Opportunity
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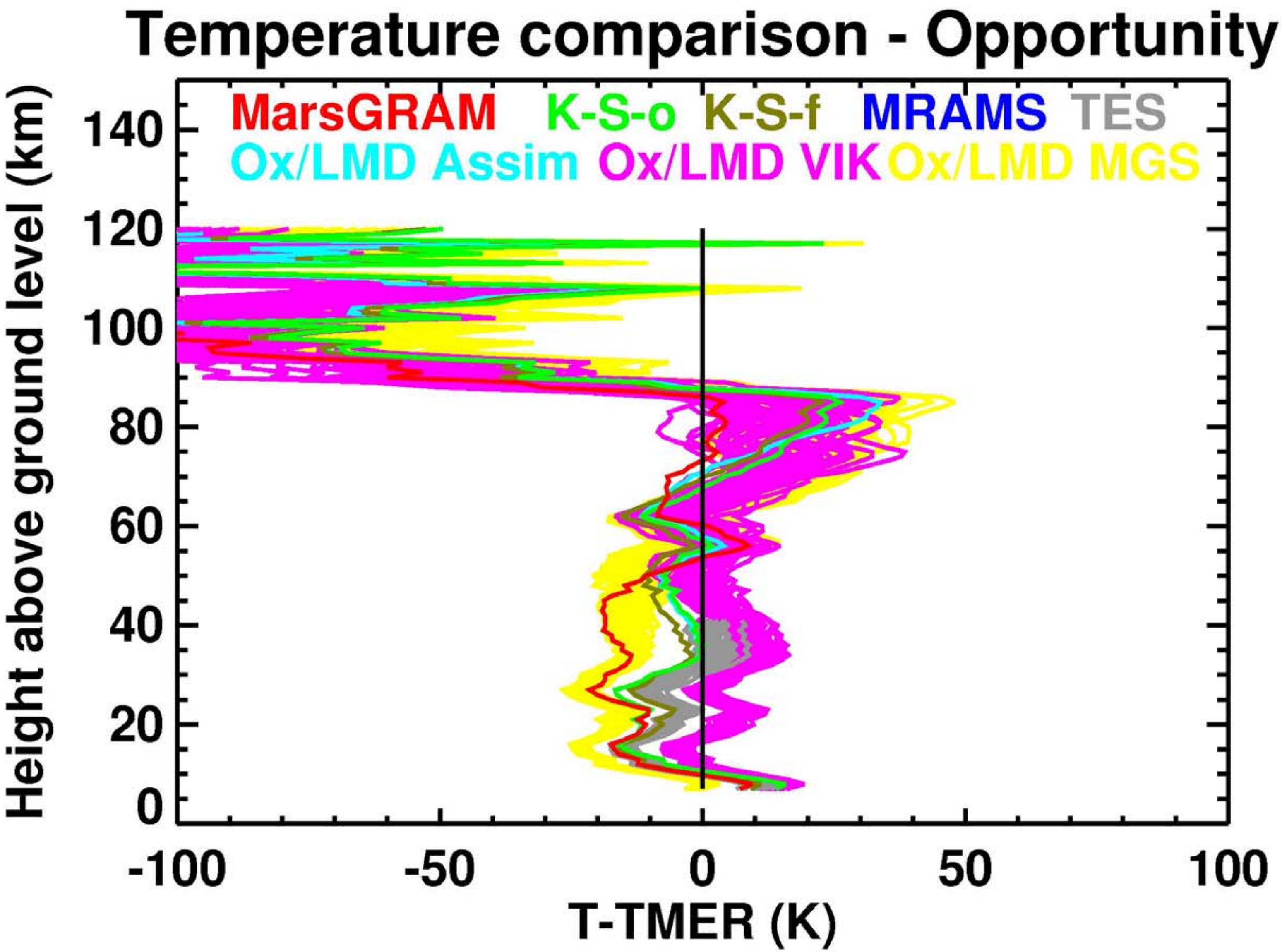
-0.5
0.0
0.5
1.0
(p-pMER) / pMER



Temperature comparison - Opportunity
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K-S-o
K-S-f
MRAMS
TES
Ox/LMD Assim
Ox/LMD VIK
Ox/LMD MGS
Height above ground level (km)
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100
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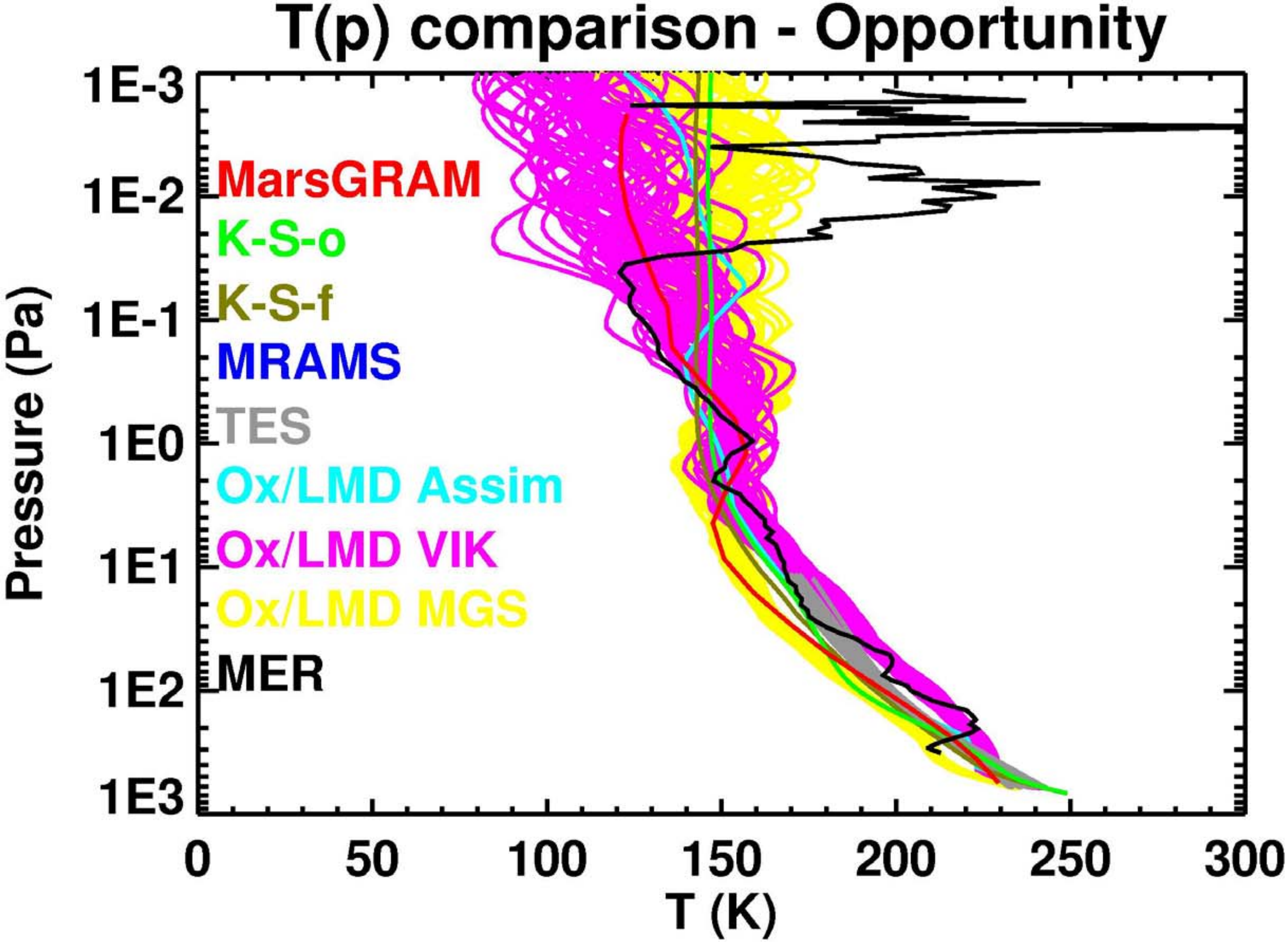
60
40
20
0
-100
-50
0
50
100
T-TMER (K)


T(p) comparison - Opportunity
Pressure (Pa)
1E-3
1E-2
1E-1
1E0
1E1
1E2
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T (K)
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Opportunity / 20 km	ρ (kg m^{-3})	P (Pa)	T (K)
MER	2.6E-3	100	204
MarsGRAM	2.4E-3	88	193
Kass-Schofield (original)	3.1E-3	116	193
Kass-Schofield (final)	3.0E-3	114	197
MRAMS (mean)			
TES (mean)	2.7E-3	101	198
MGCM (assimilation)	2.6E-3	97	198
MGCM (Viking dust)	2.7E-3	107	210
MGCM (MGS dust)	2.6E-3	95	189

Caveats and Needed Improvements

- Uncertainties
  - MER measurement uncertainties
  - TES measurement uncertainties and surface pressure boundary condition
  - Estimates of uncertainties/variabilities in model predictions
- Common altitude scale
  - Are all altitudes referenced to the same level?
- Common mean molecular masses
  - Are all models, MER data analysis and TES data analysis using the same mean molecular mass?

Future Work

- Address caveats
- Make more quantitative comparisons
- Determine useful ways to summarize results for dissemination to MSL EDL team
- Investigate effects of these different r(z) profiles on atmospheric entry of a Mars lander
- What are physical reasons for differences?
- What are the scientific implications of these differences?

Conclusions

- Different models used to support EDL predicted r(z) profiles for MER that differed by 20%
- Such differences have operational impacts
- Engineers planning MSL EDL should be prepared for different atmospheric models to make density predictions that differ by 20%