Atmospheric Profiles from Spirit and Opportunity

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• Acknowledgements: MER Atmospheric Advisory Team, David Kass, Mike Smith, many others
Data on PDS (Aug 2004) or Published

- SCLK / UTC time (4 Hz)
- Accelerations along spacecraft x,y,z axes (300 µg noise level, minimal post-flight calibration)
- J2000 attitude quaternions (caution…)
- Accelerations and angular rates for IMU axes, only partially complete (not currently useful)
- Not – entry states, but enough pieces are published in different places that they can be estimated
- Aerodynamics (graphical, not tabular)
- Not – IMU locations/orientations
Analysis Steps

• Entry state, $a(t)$, attitude, gravity give position and velocity profiles
• Drag equation, aerodynamics give density and angle of attack profiles
• Hydrostatic equilibrium, upper boundary condition, give pressure profiles
• Ideal gas law gives temperature profiles
• Monte Carlo uncertainty analysis
Spirit Results

Ps $\sim$ 7.3 mbar

1\(\sigma\) uncertainties in p/z in red crosses

No large waves in middle atmosphere

Unusual behaviour below $\sim$20 km, almost an inversion

1\(\sigma\) uncertainties in T/z in red crosses
Opportunity Results

Ps \approx 6.1 \text{ mbar}

1\sigma \text{ uncertainties in } p/z \text{ in red crosses}

Large wave in middle atmosphere, possible large inversion above 85 km

Unusual inversion below 10 km, similar to Pathfinder

1\sigma \text{ uncertainties in } T/z \text{ in red crosses}
Possibly too hot below 0.3 mbar

Shape consistent with some of the TES profiles

Thanks to Mike Smith for TES profiles

5-10 K too hot below 0.3 mbar

Shape consistent with all of the TES profiles except for lowest few km
Spirit’s profile is remarkably free of large waves.

Opportunity and Pathfinder are identical between 0.02 – 0.2 mbar.

Between 0.1 – 1 mbar, Spirit’s profile is the warmest.
Profiles are Important Because…

• Are MER profiles “too warm” like VL/MPF?
  – If Yes – systematic flaw in measurement technique, impact on Venus, Jupiter, Titan?
  – If No – error in VL/MPF datasets?

• Did mesoscale and other models work? Implications for future EDL

• Many other atmospheric measurements, global and local, before and after EDL

• First profiles soon after a large dust storm
My Next Steps

• My results not yet published because:
  – Aerodynamics only recently cleared ITAR restrictions
  – Chance of recalibration and re-release of data at any time, say one week after publication

• Publish results
• Archive/distribute results and software
• Collaborate with those who use models and/or other datasets
MER Entry

- Hypersonic, ballistic, direct entry to ~10 km, then parachute, retrorockets, airbags
- IMUs: Two Litton LN-200S (similar to LN-200 on AMRAAM missile) on each MER, 3 axis acc and 3 axis gyro
- No science team, so no “instrument paper”, no Science paper, minimal PDS archiving
- “Atmospheric Advisory Team” existed for operational support, but that work is secret
- Ask David Kass about data quality, archiving
- Engineers working on a parallel reconstruction with different goals
Data Flow

• Six measurements (3 acc, 3 angular rates) at various places within an IMU, IMU converts them to a common reference position and orientation within IMU
• MER converts each set of 3 acc and 3 angular rates to its CM and spacecraft axes
• MER converts angular rates + initial attitude into current attitude (quaternions)

• All positions/orientations must be known and correctly typed into software, transformation equations must be correct in software, initial attitude must be correct

• MER transmitted full set of J2000 quaternions and accelerations at spacecraft CM in spacecraft frame, but only partial set of raw data – so I hope processing was correct