Errors in Viking Lander Atmospheric Profiles Discovered Using MOLA Topography

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Abstract’s Abstract: Each Viking lander measured a topographic profile during entry. Comparing to MOLA, we find a vertical error of 1 – 2 km in the Viking trajectory. This introduces a systematic error of 10-20% in the Viking densities and pressures at a given altitude.
Poster Layout

• 1\textsuperscript{st} column
  – \textit{Viking’s Radar Altimeter}

• 2\textsuperscript{nd} column
  – \textit{Topographic Profile from Viking Entry}

• 3\textsuperscript{rd} column
  – \textit{Comparison of Viking Profile to MOLA Data}

• 4\textsuperscript{th} column
  – \textit{Implications for Viking Atmospheric Profiles}

• 5\textsuperscript{th} column
  – \textit{Closing Remarks}
Viking Lander Schematic

- **Radar Altimeter** located on base of lander

Fig. 3. The Viking lander.

From Soffen (1977)
Viking Lander
Topographic Profiles

• During descent, a *radar altimeter* ranged from the lander to the surface below.
• The lander’s *trajectory is known* from the integration of acceleration data.
• Combine trajectory and surface ranging to obtain a *topographic profile along the ground track* of the lander.
• Altitude resolution for ranging ~ 100 m
• Sample interval ~ 0.2 s
• Maximum range ~ 130 km
VL1 Topographic Profile

• Actually a profile of radial distance above landing site, not topographic height above an equipotential surface.
• 5 km change in altitude over 500 km long portion of ground track
• 640 km distance, 16° N, -57°E
• 140 km distance, 21°N, -50°E
• Sloping down from Tharsis into Chryse Planitia

From Seiff (1993)
Hunting for the data

• We have only this figure for VL1 – where are the tabulated results for VL1 and anything for VL2?


• We cannot locate this reference, nor have we found any other mention of this dataset in the literature.

• **Where can we find out more about the Viking Lander topographic profiles?**
Quick Test on VL1 Profile

- VL1 profile has topography 6 km above landing site 600 km away, but MOLA 1 degree planetary radius dataset shows that there is no topography 6km above landing site closer than 1000 km away.
- Error in VL1 profile apparent in coarsest MOLA data.
- MOLA 1 degree planetary radius contour map, referenced to VL1 landing site, with landing site and ground track for VL1 profile shown.
Deriving Corresponding MOLA Profile

- Viking 1 landing site is 22.272 +/- 0.002 °N, 47.94 +/- 0.2 °W in *Viking-era areocentric coordinates* (Mayo et al, 1977).
- *Spacecraft trajectory* (altitude, latitude and west longitude pairs as a function of time) is archived with the PDS as dataset PSPA-00269 in same coordinate system.
- Subtract the west longitudes from east longitudes to convert them to east longitudes, then subtract an additional 0.2 degrees to convert into MGS-era east longitudes (Smith et al, 1998).
- Use MOLA 1/16 degree planetary radius dataset to obtain *MOLA values for planetary radius* relative to landing site as a function of latitude and longitude.
- *Convert latitude/longitude pairs into distance* from the VL1 landing site for comparison with the profile in Seiff’s figure.
Context Image

- **MOLA topography** with *landing site* and *ground track* for VL1 profile shown.
Comparison of MOLA and VL1 Topographic Profiles
Offset between Topographic Profiles

- No offset has been applied to the comparison figure; the offset is present in the data.
- Similar features can be seen in both profiles, so the VL1 radar altimeter was working well.
- VL1 profile is 2.3 km too high at 640 km distance – VL1 altitude is 130 km.
- VL1 profile is 0.8 km too high at 140 km distance – VL1 altitude is 30 km.
- The offset decreases, in an approximately linear fashion, as you approach the landing site.
- Based on the similarity of the profiles, errors in latitude and longitude are tenths of a degree at most.
Global Context and Location

In *Chryse Planitia*, amongst outflow channels and near the hemispheric dichotomy

**VL1 Landing Site**
VL1 Atmospheric Profiles

• Measurements of accelerations during descent, together with an initial spacecraft position and velocity, are integrated to give the spacecraft’s trajectory down to the surface.

• Accumulation of errors is controlled by using radar ranging data as additional constraints.

• Acceleration data also yield profiles of atmospheric density, $\rho$, pressure, $p$, and temperature, $T$, along spacecraft’s trajectory.

• These profiles are used to plan future atmospheric entries and are an important component of the Mars Reference Atmosphere.
Errors in VL1 Atmospheric Profiles

• The radar altimeter data used to generate the VL1 topographic profile is referenced to the spacecraft’s trajectory.

• The offset between MOLA and VL1 topography shows that the altitude of the spacecraft trajectory is systematically in error by 1 – 2 km.

• A published $\rho$, $p$, or $T$ measurement at a given altitude is actually relevant at an altitude 1 – 2 km away. Hence the accepted profiles of $\rho$, $p$, and $T$ as a function of altitude are incorrect.

• Using a scale height of 10 km, published densities and pressures at a given altitude are systematically in error by 10 – 20%, but published temperatures are not significantly affected.
How to Correct the Atmospheric Profiles

• *Simple approach* – Calculate error in VL1 altitude scale as a function of altitude by matching up VL1 and MOLA topographic profiles, then shift $\rho$, $p$, and $T$ measurements from the incorrect altitude scale to the correct altitude scale.

• *Better approach* – Rederive VL1 entry trajectory using *additional constraint of MOLA topography* together with radar altimeter data, then rederive atmospheric profiles using new trajectory.
Viking Density and Pressure Profiles

- From Seiff and Kirk (1977a)
References

• Mayo et al, 1977, JGR, v82, pp4297-4303
• Seiff and Kirk, 1977a, JGR, v82, pp4364-4378
• Seiff and Kirk, 1977b, Viking Lander Altimeter Update, in Minutes of the second meeting of the Viking Mars Physical Properties Working Group, assembled by JW Meredith, pp26-30, JPL – *Have you seen this?*
• Seiff, 1993, JGR, v98, pp7461-7474
• Soffen, 1977, JGR, v82, pp3959-3970
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Viking Lander
Entry Sequence

From Soffen (1977)