“Should we believe Atmospheric Temperatures…”
or
Unusual atmospheric temperatures from Mars Pathfinder

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Unusual Temperature Inversion prior to Parachute Deployment

Figure from John Wilson
Is it a real T inversion?

• Modellers (eg Colaprete et al.) have suggested that feature is due to radiative cooling from a water ice cloud
• Hinson and Wilson discuss T inversions in their RS data. Both their inversions (only seen over Tharsis) and modelled inversions are narrower in vertical extent than the MPF inversion and have a more asymmetric vertical profile

Colaprete et al., 2000
Desired Temperature Profile

- $T/K = 216 - z/km$  
  30 K increase desired
Implications for Density and $P$

- $T = \frac{m_{\text{mean}}}{k_B} \times \rho / \rho$
- Need continual changes in density
Changes to Aerodynamic Coefficients

• $\rho = -2m/C_A \times a_z/v_R^2$
• Can cloud particles alter drag coefficients?
• $\rho_{atm} = 10^{-7}$ g/cc
• $\rho_{cloud} = 10^{-12}$ g/cc
Aerodynamic Database
(Gnoffo et al., 1996)

- Ma = 9.4, \( C_a = 1.64 \), \( z = 22.1 \) km
- Ma = 6.6, \( C_a = 1.60 \), \( z = 19.4 \) km
- Ma = 2.0, \( C_a = 1.34 \), \( z = 9.9 \) km

- How does \( C_a \) vary between 19.4 and 9.9 km? Linearly with Ma? Hard to interpolate.
- What are uncertainties in \( C_a \)?
- Is the Ma = 2.0 result reliable?
What if $C_A = 1.50$, not 1.34?
Effects of Winds

- $\rho = -2m/C_A \times a_z/v_R^2$
- $15\ m\ s^{-1}$ likely
Angular Accelerations (1)

• \( \rho = -2m/C_A \times a_z/v_R^2 \)
• Need \(~0.5 – 1.0\) m s\(^{-2}\) decrease in all axial accelerations below 20 km (cf actual values of 30 m s\(^{-2}\) at 18 km and 8 m s\(^{-2}\) at 9 km)
• Changes to normal accelerations can’t really affect results sufficiently
• Too big for simple instrumental error
• Az measured “on” z-axis 50 mm from CofM where “on z-axis” means <15 mm from axis
Angular Accelerations (2)

- Have not looked at full rigid body equations, but measured accelerations will contain additional terms like $\Omega^2r$ or $d\Omega/dt\ r$
- Pre-entry roll rate $\Rightarrow \Omega=0.06 \text{ rad} \, s^{-1}$
- Angle of attack periodicity $\Rightarrow \Omega=4.5 - 2.5 \text{ rad} \, s^{-1}$
- $\Omega^2r$, $r = 50 \text{ mm}$, gives $1.0 - 0.3 \text{ m} \, s^{-2}$

- Potentially very interesting, but needs careful study. MER acc/gyro data will be useful for better understanding motions of entry vehicle
Refined Hydrostatic Equilibrium

• \[ \Delta p = \rho \left( g_r \Delta r + g_\theta r \Delta \theta + g_\phi r \sin \theta \Delta \phi \right) \]
• Contributions to \( g_r \) and \( g_\theta \) from planetary rotation and oblateness, \( g_\phi = 0 \)
• Effects small for steep entry or E-W entry
• Effects large for shallow entry or N-S entry
• Pathfinder T, p changed by <1%
• Atmospheric dynamics also affect above equation, but effects are 10x smaller.
Unresolved Paradox

• (1) $T(z)$ from ACC is in error by 30 K
• (2) $T(z)$ from RS, TES, and models is in error by 30 K
• Which is it? This is an important question
• My best guess: $\Omega^2r$ and $C_A$ errors at low Ma

• Does this have any impact on Huygens? Maybe
• Possible help from Galileo/PV (direct p, T sensors after chute deploy) and MER (acc/gyros give full dynamical history)
• I worry about $C_A$ interpolation at low Ma when it changes rapidly and how this affects derived angle of attack, atmospheric structure – what is appropriate error analysis?