MGS Accelerometer-derived profiles of Upper Atmospheric Pressures and Temperatures: Similarities, Differences, and Winds

Withers, Bougher, and Keating

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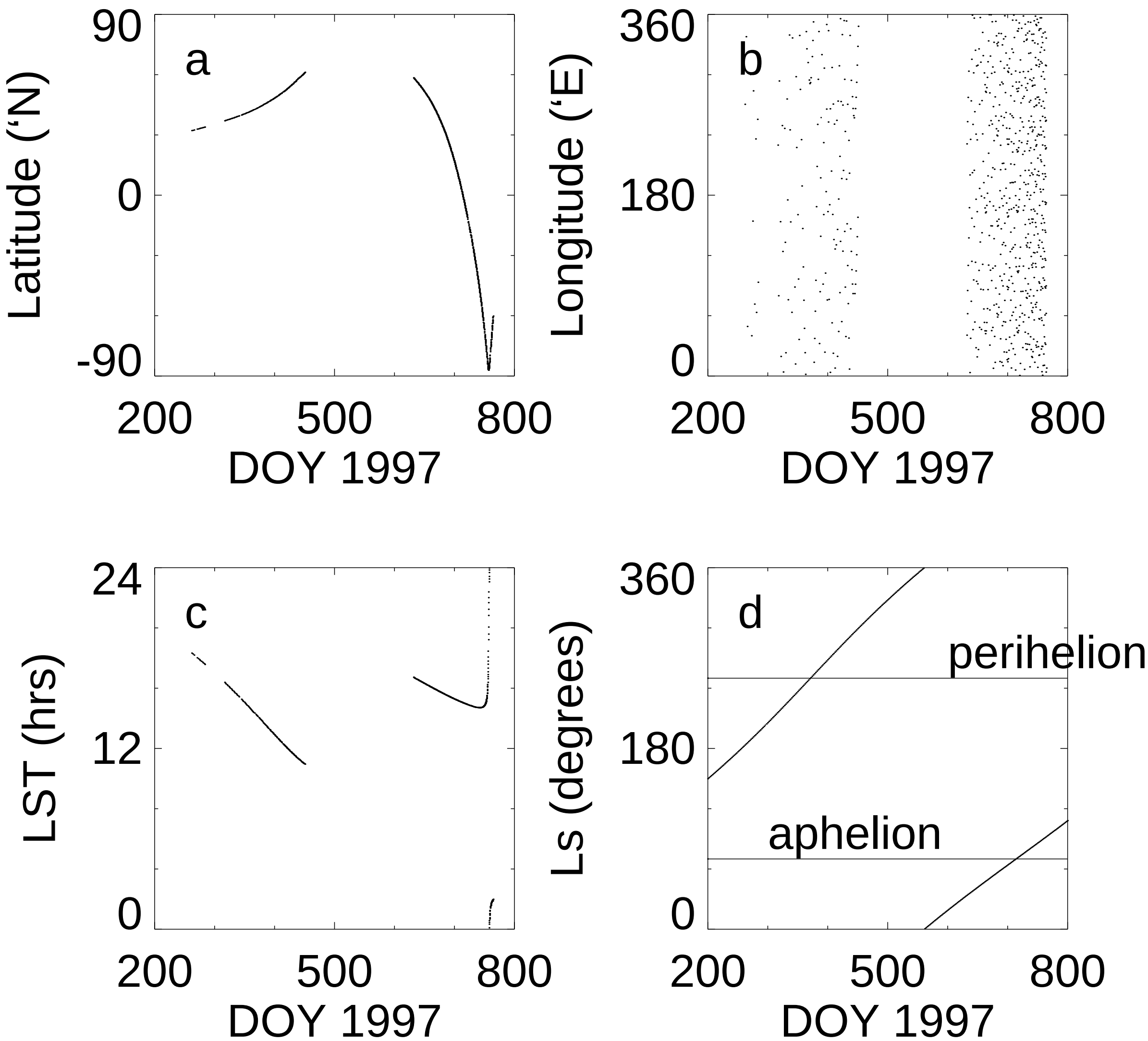
MGS Periapsis During Aerobraking



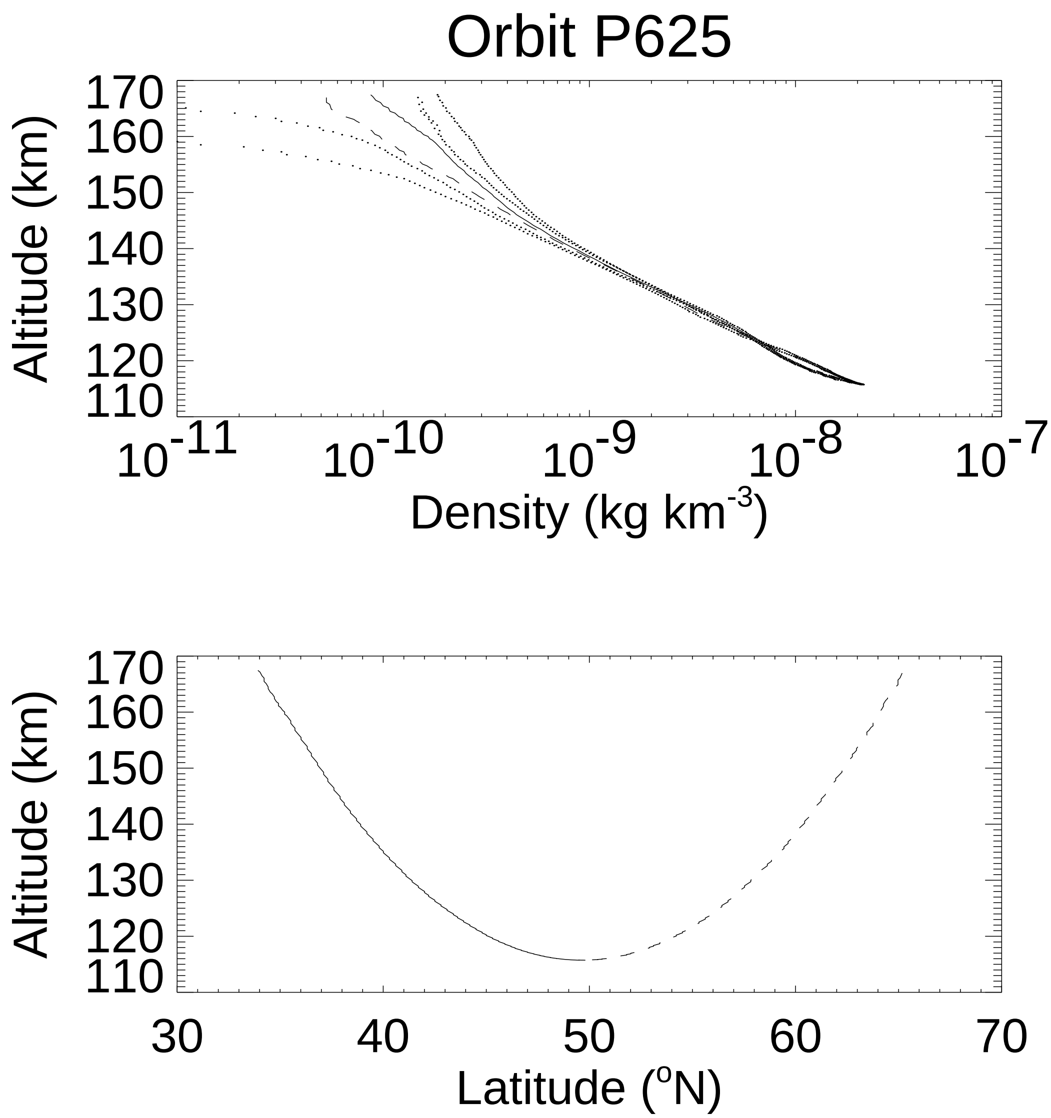
Only Phase 2 daytime data is used here

Introduction

The MGS accelerometer measured many density profiles in the martian upper atmosphere during aerobraking. Near-simultaneous measurements of an inbound and an outbound profile, separated by 10s of degrees of latitude, show that assuming hydrostatic equilibrium to obtain pressure profiles is an oversimplification.

We retain the next-largest term in the momentum equation, which relates to dynamical support of the atmosphere by a zonal wind, and obtain consistent inbound and outbound pressure profiles and an estimate of the upper atmospheric zonal wind speed.

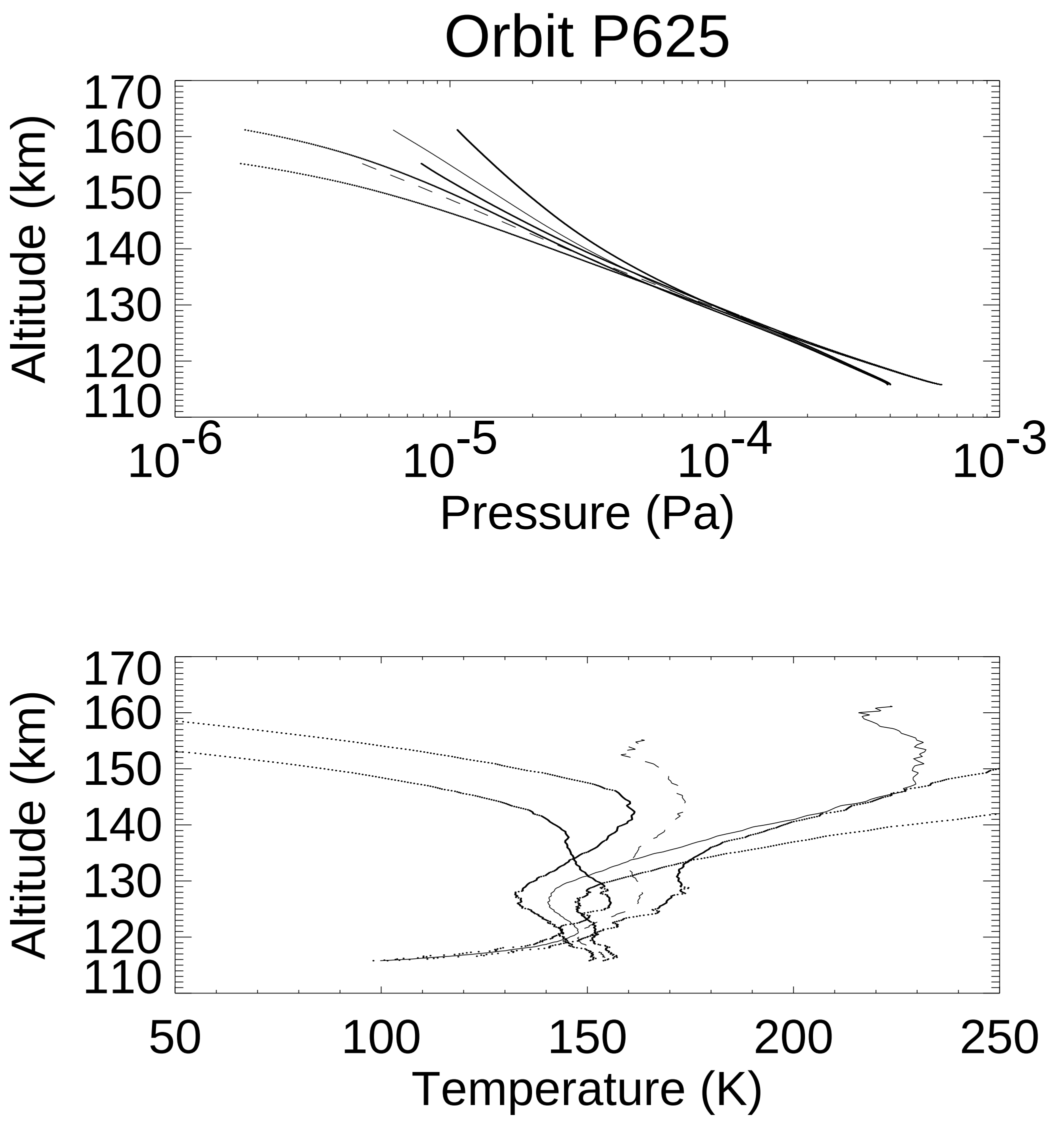
Typical Density Profile



Solid line: inbound

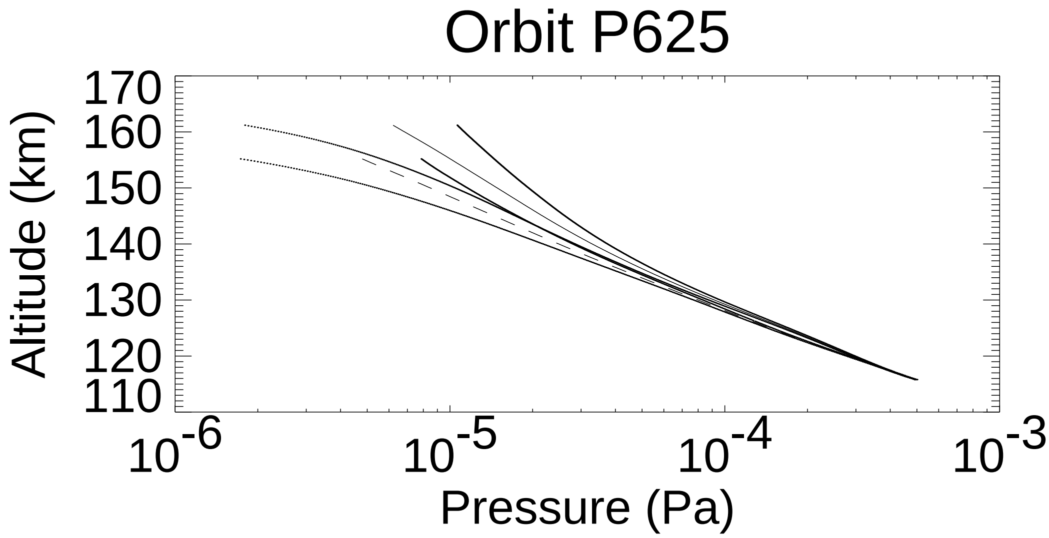
Dashed line: outbound

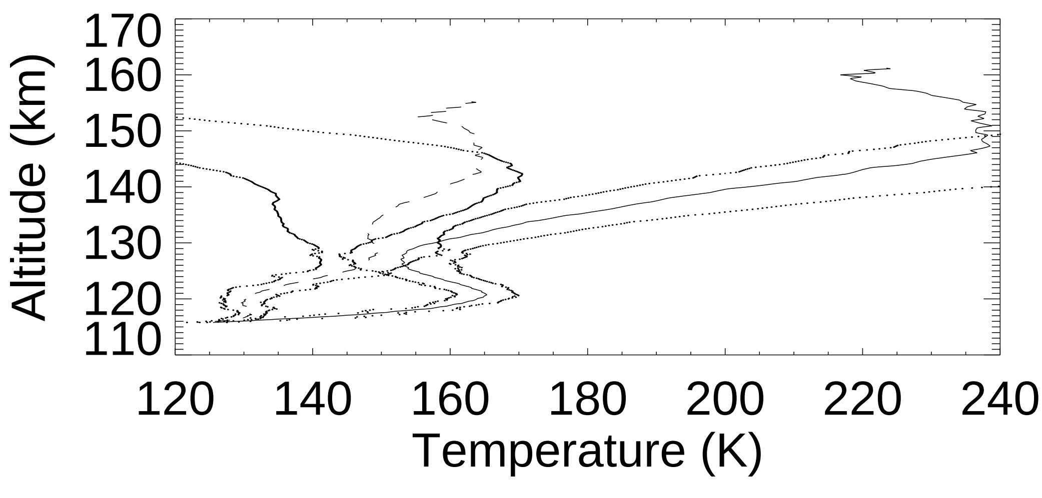
Pressure and Temperature profiles derived from hydrostatic equilibrium



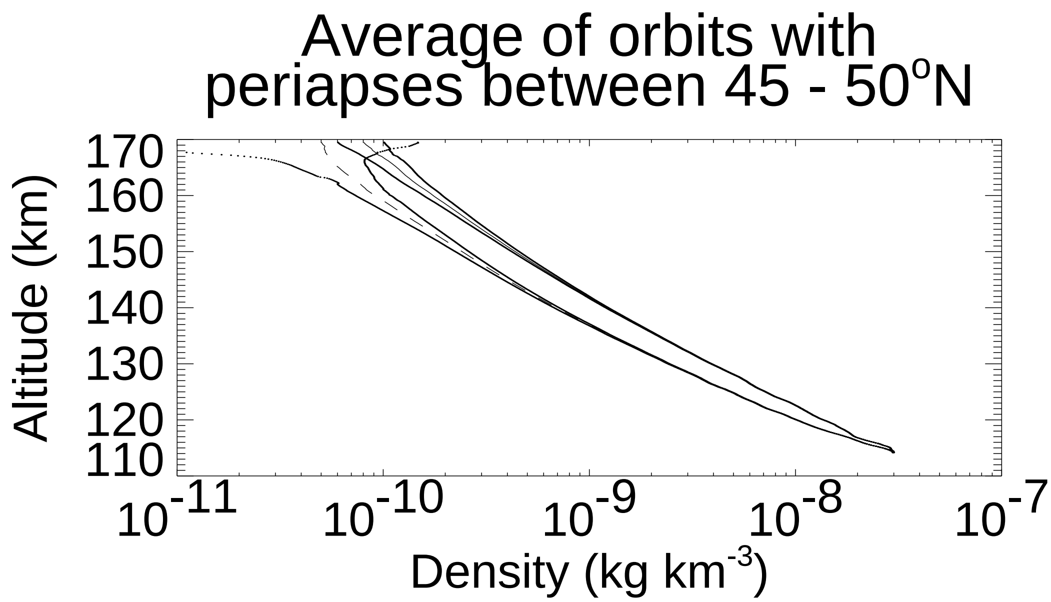
Note 30% discontinuities at periapsis

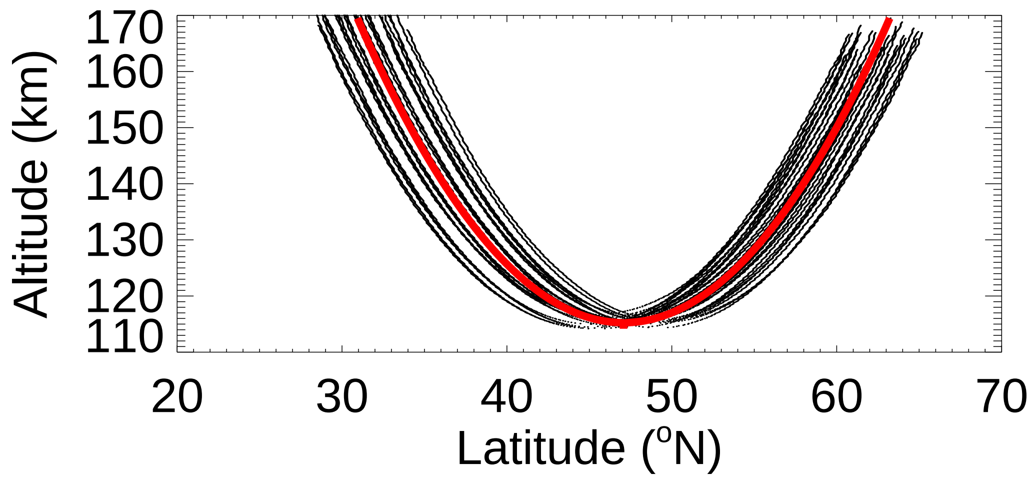
P, T profiles derived using a zonal wind





v_ϕ = -180ms^{-1} removes the discontinuity at periapsis

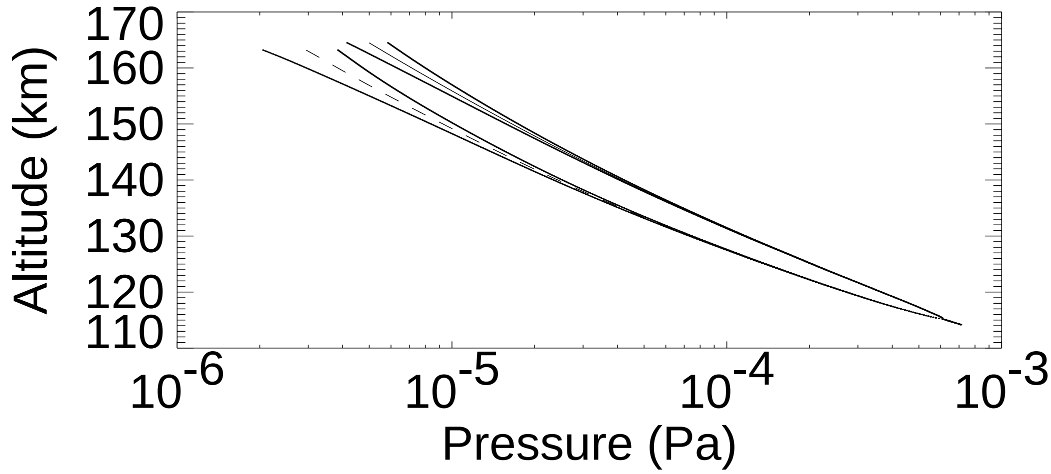


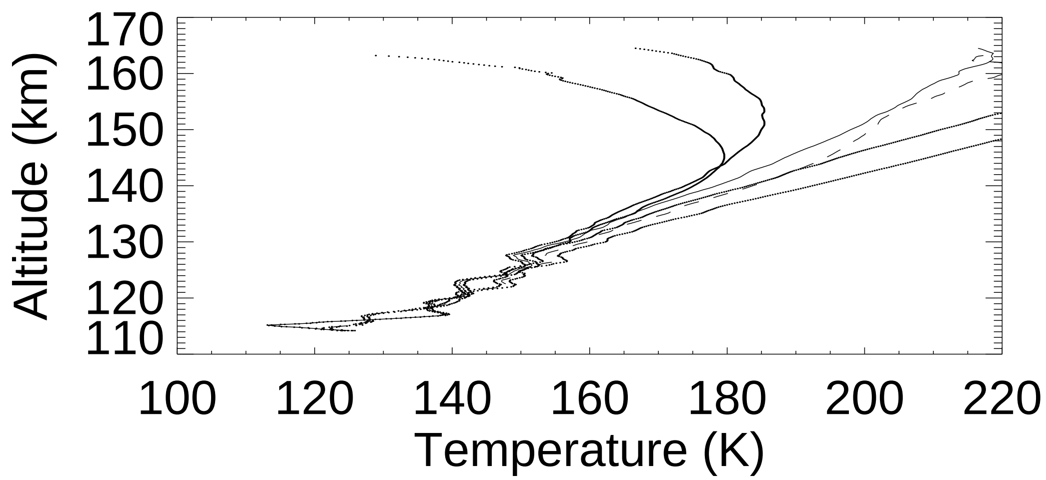


Decrease uncertainties and remove transient phenomena by averaging orbits

P, T profiles with $v_\phi = -60\ ms^{-1}$

Average of orbits with periapses between 45 - 50°N





$dT/dz = +0.2\ K\ km^{-1}$

Wave structure present

Momentum Equation

$$\frac{\partial \underline{v}}{\partial t} + (\underline{v}.\nabla)\underline{v} + 2\underline{\Omega} \times \underline{v} = \frac{-1}{\rho}\nabla p + \underline{g}_{eff}$$

$$\frac{Dv_\theta}{Dt} - 2\Omega \cos\theta v_\phi = \frac{-1}{\rho r}\frac{\partial p}{\partial \theta} + (g_{eff})_\theta$$

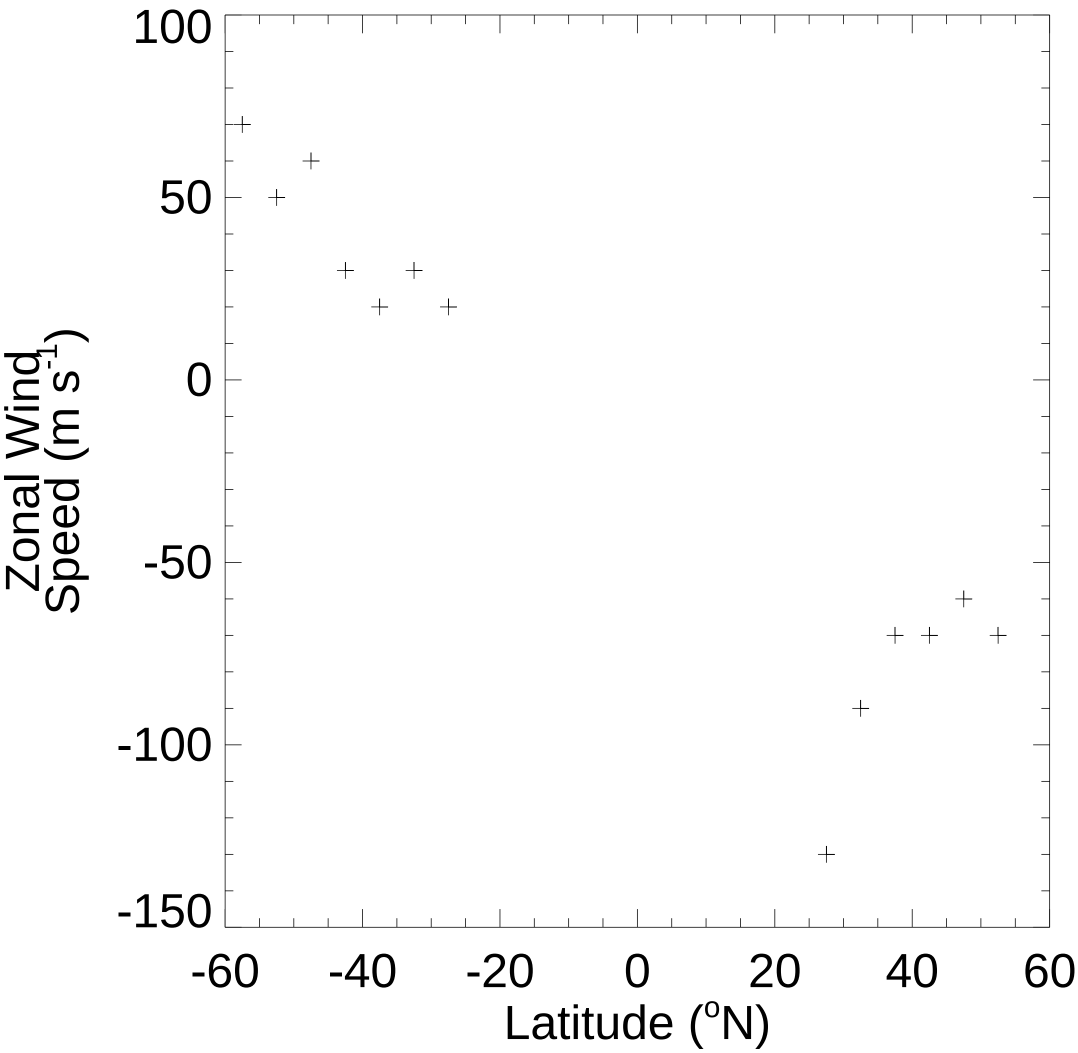
$$\frac{Dv_r}{Dt} - 2\Omega \sin\theta v_\phi = \frac{-1}{\rho}\frac{\partial p}{\partial r} + (g_{eff})_r$$

- Have neglected viscosity, MHD terms
- Can neglect Dt derivative for v_ϕ < few 100 ms^{-1}
- Simplest extension beyond hydrostatic is v_ϕ constant
- Correct v_ϕ is that which makes pressure profiles continuous at periapsis

Caveats to this approach

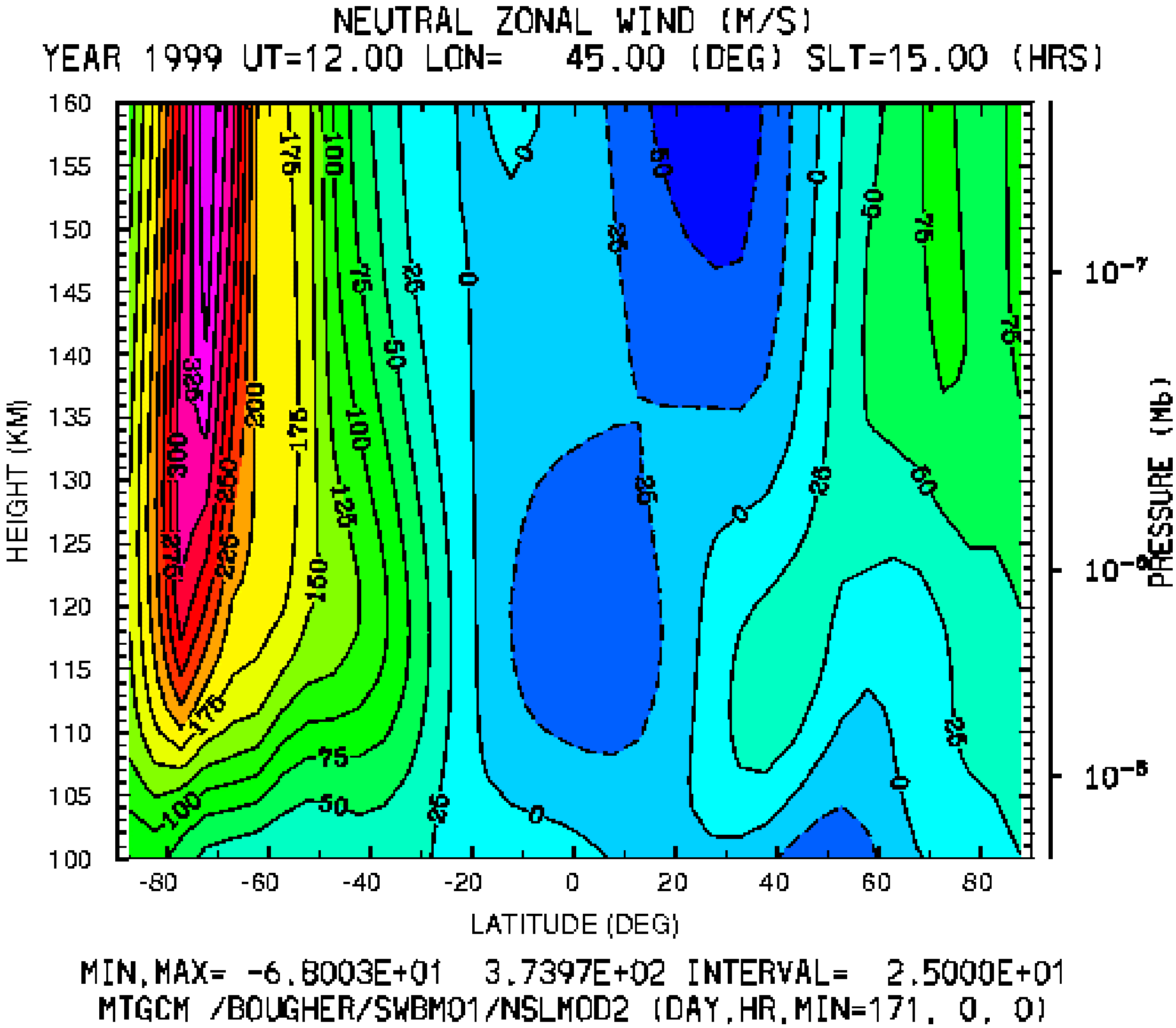
- Does not work where trajectory crosses equator or pole since sine or cosine terms misbehave. This can be discovered by careful study of the various terms in the detailed equations.
- Neglected terms are ~20% as large as smallest included term, so some caution is needed.
- Easy enough to average several $\rho(r)$ to find mean, less easy to average several $\rho(r,\theta)$ to find mean

Best-fit zonal winds



Winds ~ 50 – 100 ms^{-1}, blow from east to west in northern hemisphere, vice versa in southern hemisphere

Simulated Winds



- Ls=90, F10.7=130, τ=0.3

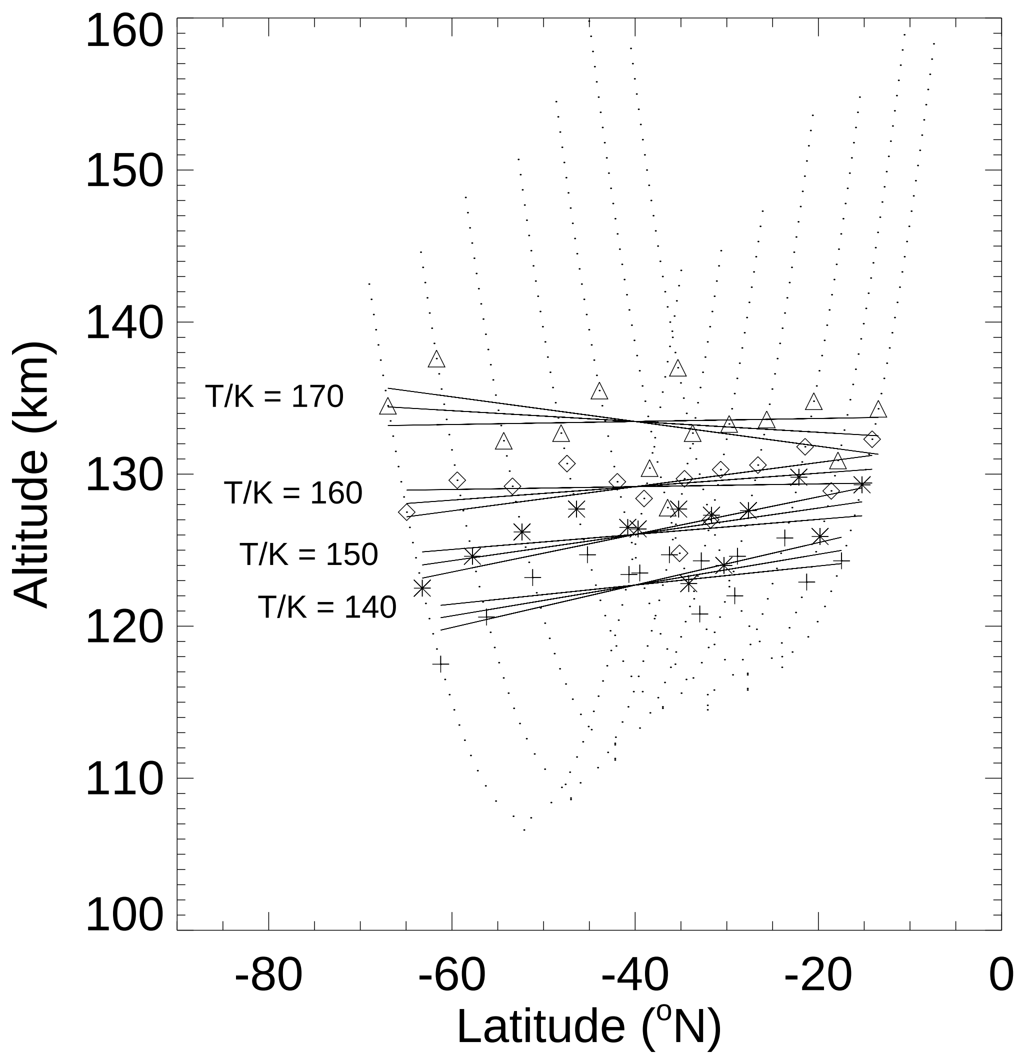
Wind Results

- Zonal winds are eastward in SH, westward in NH, speeds are greater in SH, latitudinal gradient is also greater in SH
- All of the above are seen in both the data and the model
- Wind speeds greater in NH data than in model
- Wind speeds increase towards South Pole faster in model than in data
- Overall, the data and the model are relatively consistent

Previous data on martian winds

- Viking lander entry measurements from 0 – 30 km
- Viking lander surface meteorology mast
- Observations of cloud motions and surface aeolian features
- Atmospheric sounding using orbiting IR spectrometers and thermal wind equation
- Nothing in the upper atmosphere at all

SH Temperatures

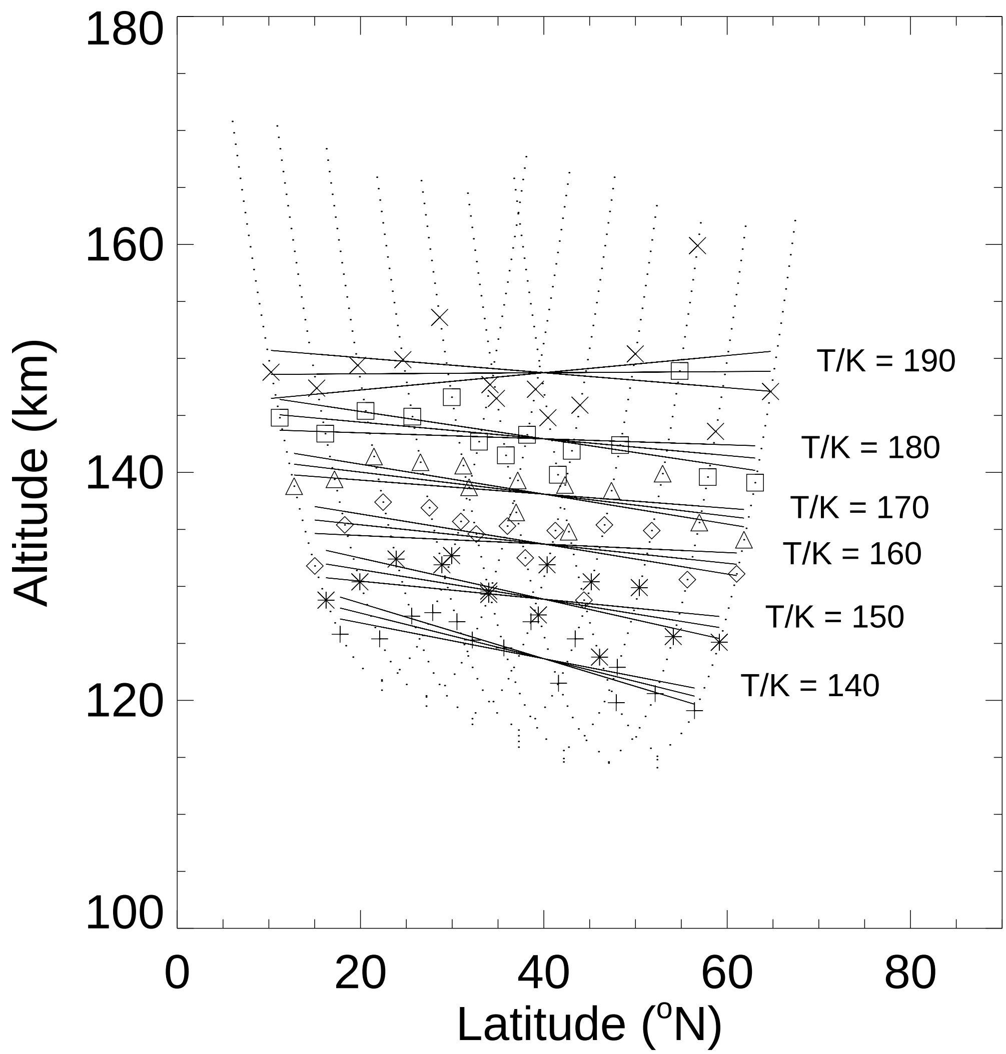


Dotted parabolae are average trajectories for each 5 degree latitude bin

Symbols locate specific isotherm in smoothed temperature profile

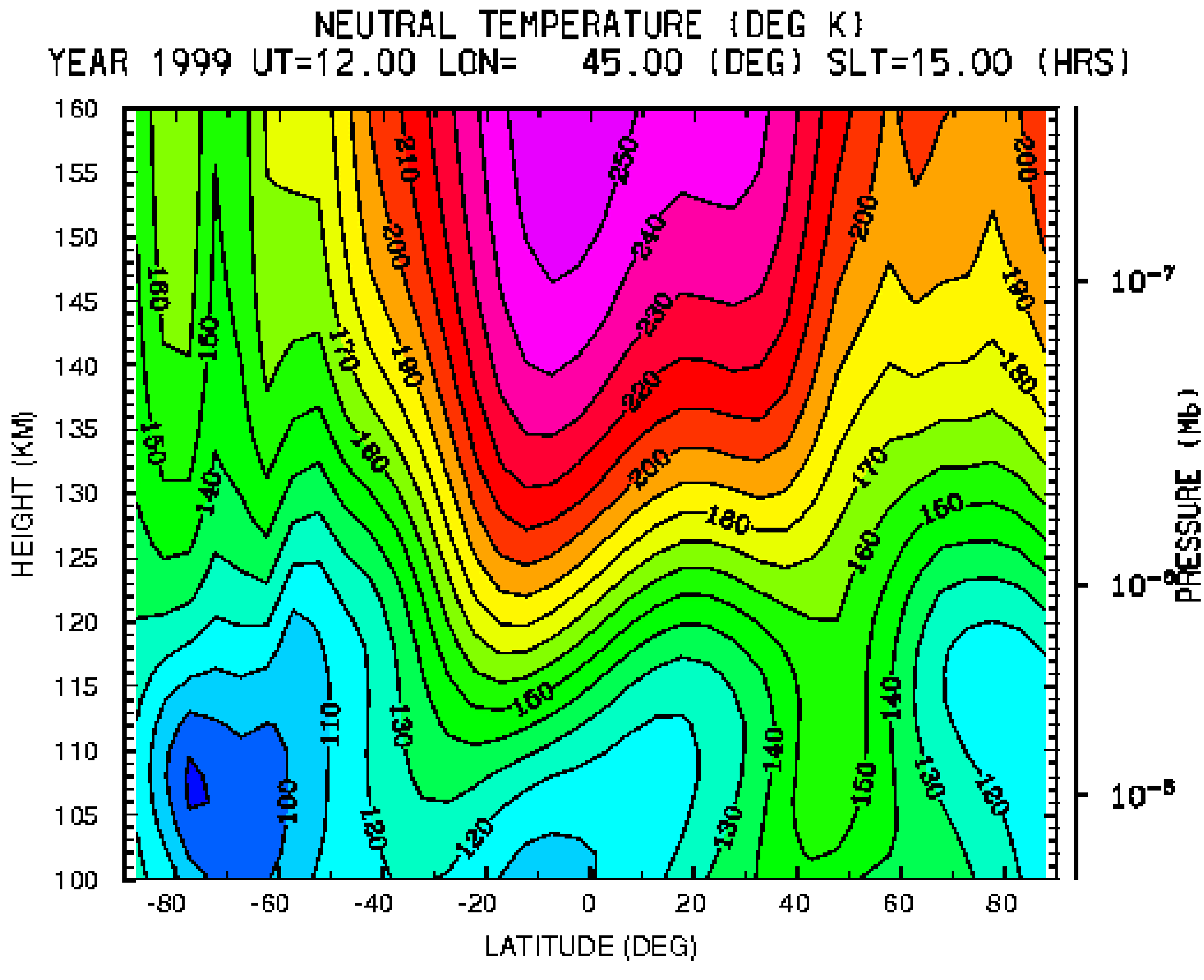
Solid lines are fits to isotherms with uncertainties

NH Temperatures



Markings as for SH plot

Simulated Temperatures

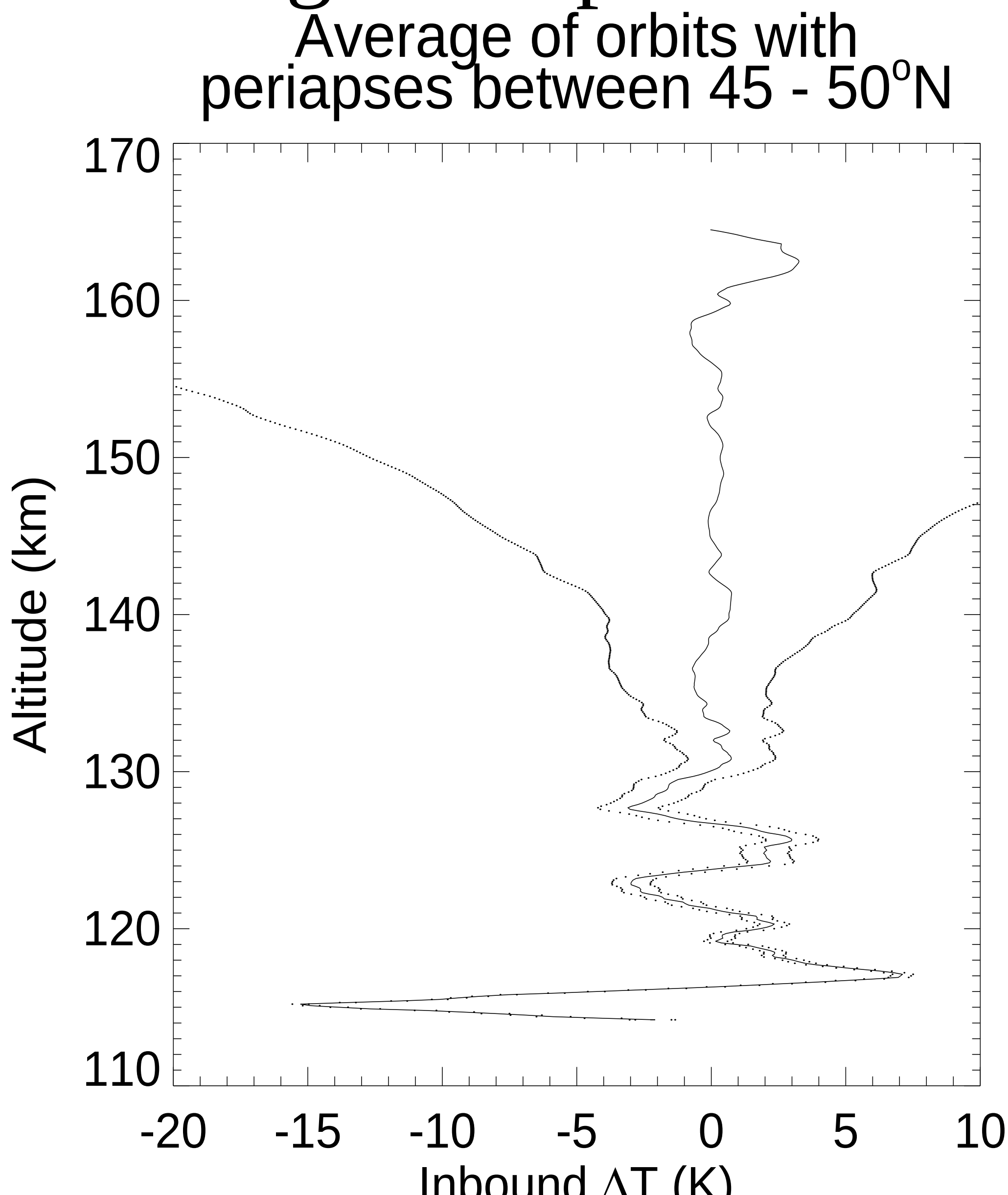


- Ls=90, F10.7=130, τ=0.3

Temperature Results

- SH data are ~ 10K warmer than NH, model has NH ~ 10K warmer than SH
- $dT/dz \sim +2\text{-}3\ K\ km^{-1}$ in both the data and the model
- Temperatures decrease from equator to pole in data, but increase in model
- …but magnitudes of the temperatures agree between the data and the model
- Overall, the data and the model are not very consistent

Difference between inbound T profile and smoothed background profile



Vertical wavelength of oscillations ~ 5 – 10 km

Temperature Oscillations

- Temperature profiles in other latitude bands also have vertical oscillations with a wavelength ~ 5 – 10 km
- Traditional explanation for such oscillations in the only other high (vertical) resolution temperature profiles (entry probes) is thermal tides
- However, dominant tidal modes have wavelengths ~ 20 (diurnal) or ~ 100 km (semidiurnal), significantly different from those observed here

Future Work

- How much do the various assumptions affect the results, ie how robust are the results?
- If v_ϕ is allowed to vary with altitude, how does it vary with altitude?
- Can variations on this technique be extended into equatorial and polar regions?
- Mars Odyssey dataset