

Upper atmospheric density profiles from the Mars Odyssey Accelerometer: Report on data processing, archiving plans, and scientific analysis

The Mars Odyssey Accelerometer dataset from aerobraking (2001-2002) has not yet been fully documented and delivered to the Planetary Data System. Some preliminary data products are available (densities and density scale heights at periapsis (about 100 km), 110 km, and 120 km altitude), but these are described by the PDS as being mostly undocumented and they have not been peer-reviewed. We have derived density profiles and other data products from measured accelerations. Data products are available online, are being prepared for delivery to the PDS, and are being used for scientific analysis. Zonal variations in density due to thermal tides will be quantified. Densities will be compared to predictions from a thermospheric general circulation model. Small-scale structure in density profiles will be characterized.

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Abstract 14.07

Saturday 2008.10.11 15:30-18:00

DPS Meeting 2008, Ithaca, New York

Today's need for data processing

Odyssey Accelerometer Archives (From PDS website)

About Accelerometer Data Products

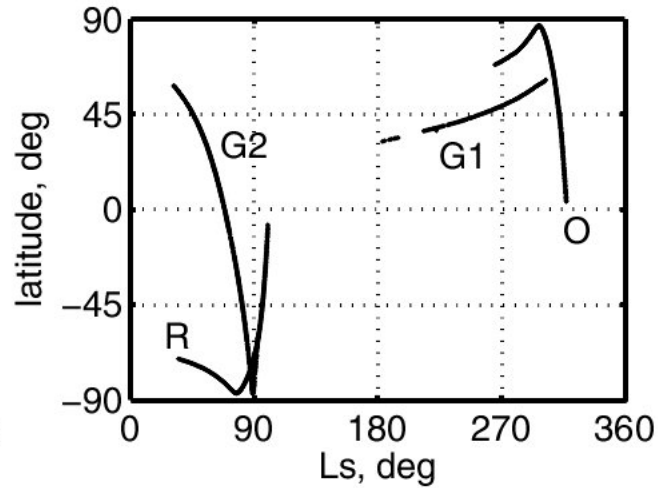
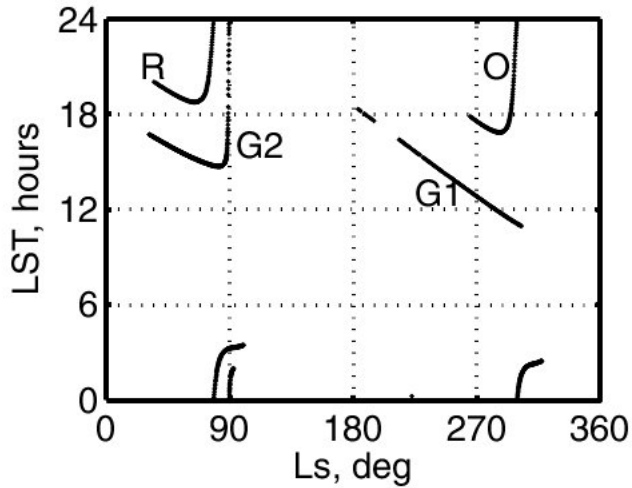
A [reduced Accelerometer data set](#) is being archived with PDS. At the present time, it is mostly undocumented and has not undergone a peer review. **Users should exercise due caution when using these data.** It is very likely that this will be the only Odyssey Accelerometer data set that is archived with PDS.

- Odyssey aerobraking ended in January 2002
- Accelerometer measurements of upper atmospheric densities have never been properly archived
- Our goal is to process and archive these data

Description of data processing

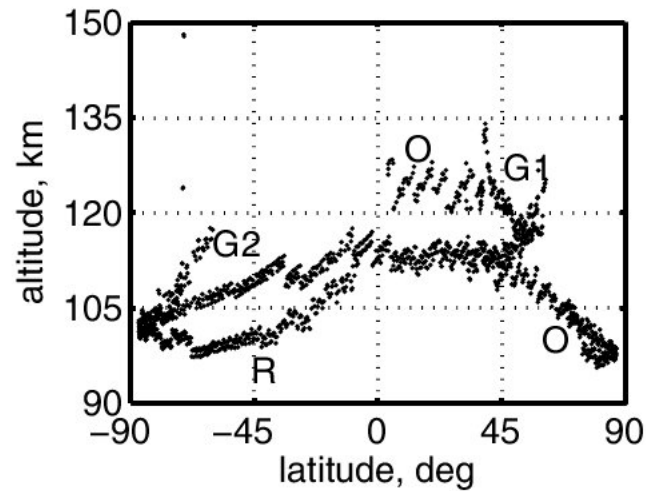
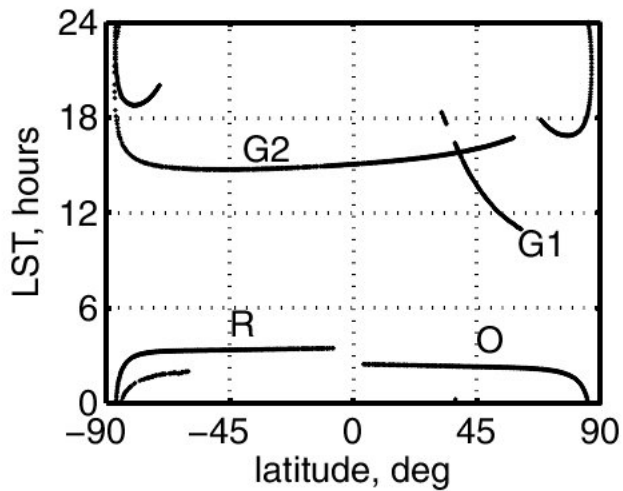
- Time series of measured accelerations delivered by operations team to PDS in non-compliant formats (poorly documented text files and MATLAB files)
- We acquired these files and extracted the data
- SPICE files used for position, velocity, orientation
- Instrument bias removed, effects of thrusters and angular accelerations not removed
- Density profiles found using drag equation and aerodynamic database
- Densities and density scale heights found at constant altitude levels

Aerobraking coverage

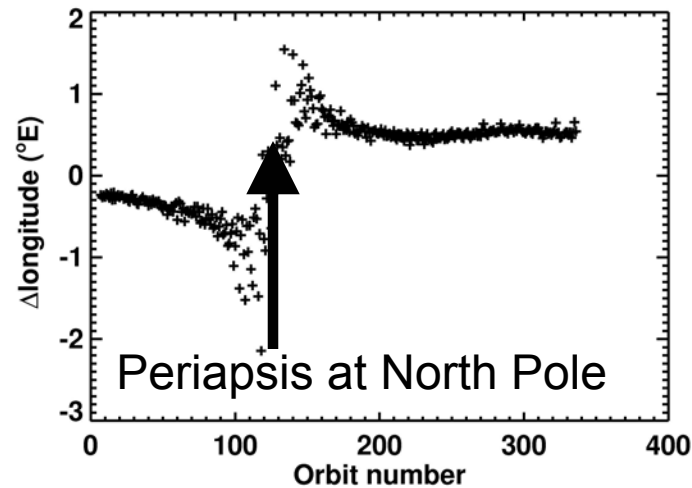
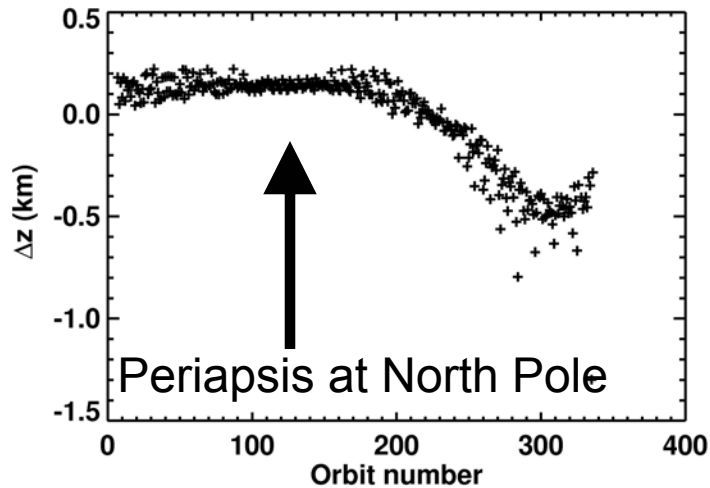
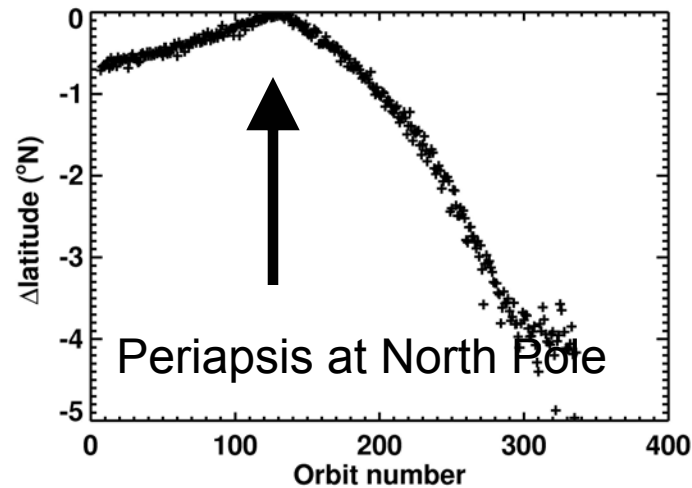
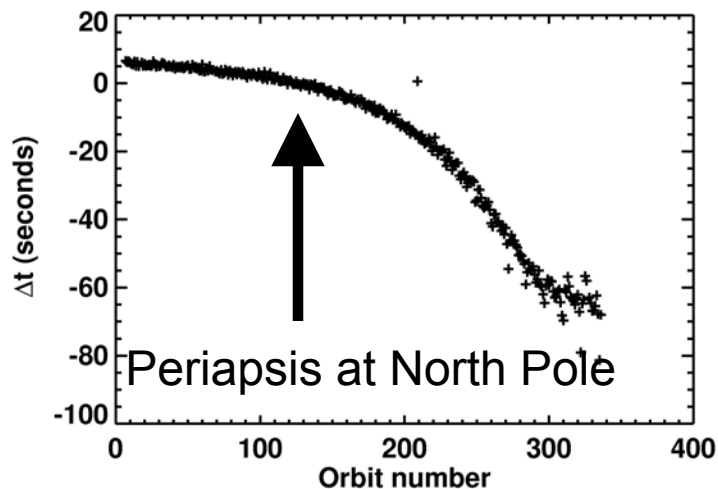


G1 = MGS Phase 1
G2 = MGS Phase 2
O = Odyssey
R = MRO

From Tolson et al.
(2007)



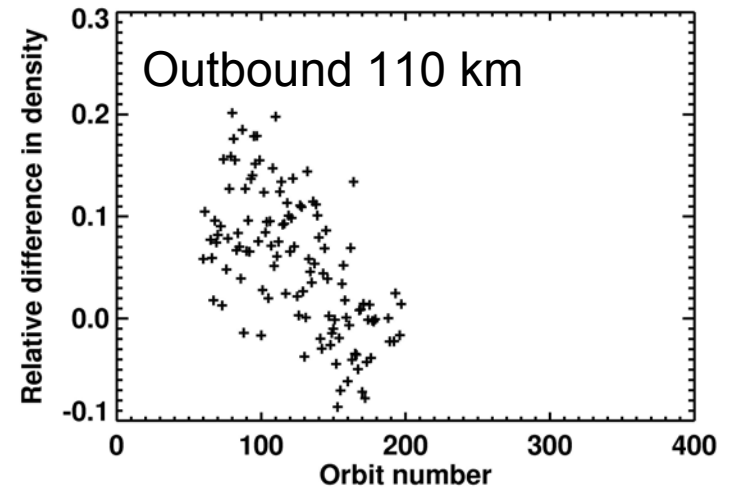
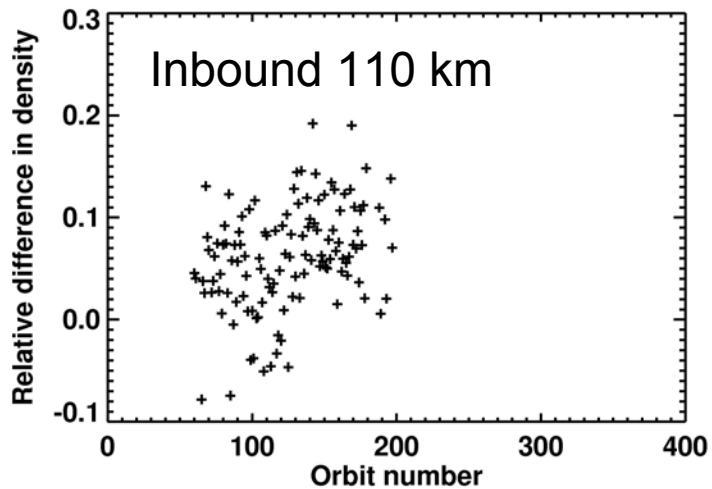
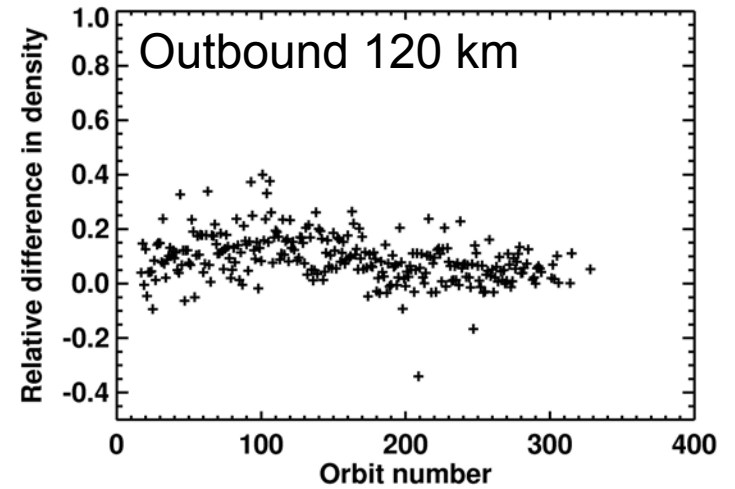
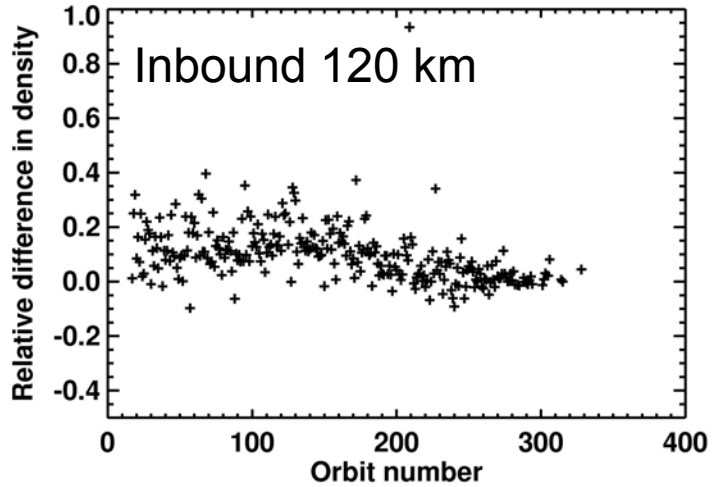
Comparison of derived ODY periapsis position to operations team's result



Interpretation of position offsets

- Differences in periapsis position are large, but controlled by periapsis latitude
- Most plausible explanation is use of different areoids to define “periapsis”
- Expect differences in “110 km” and “120 km” as well
- Subsequent density difference will be $\sim 5\%$

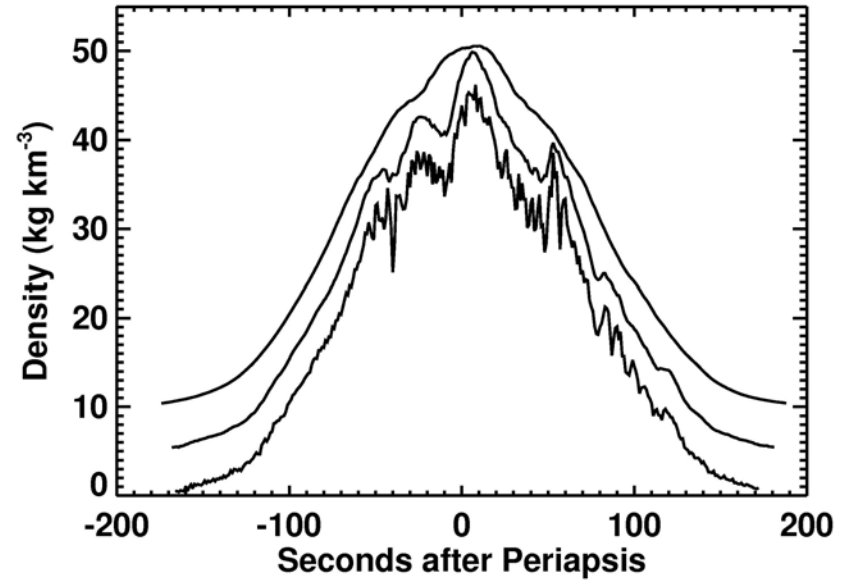
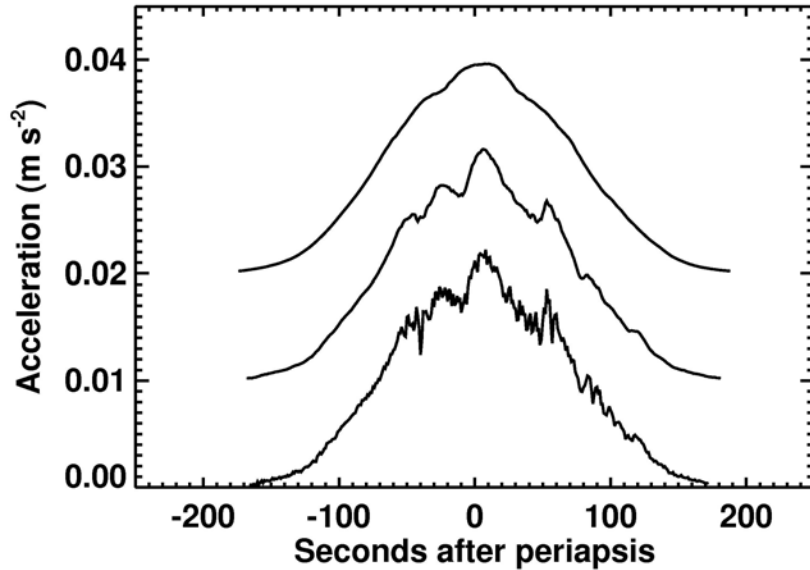
Density comparisons



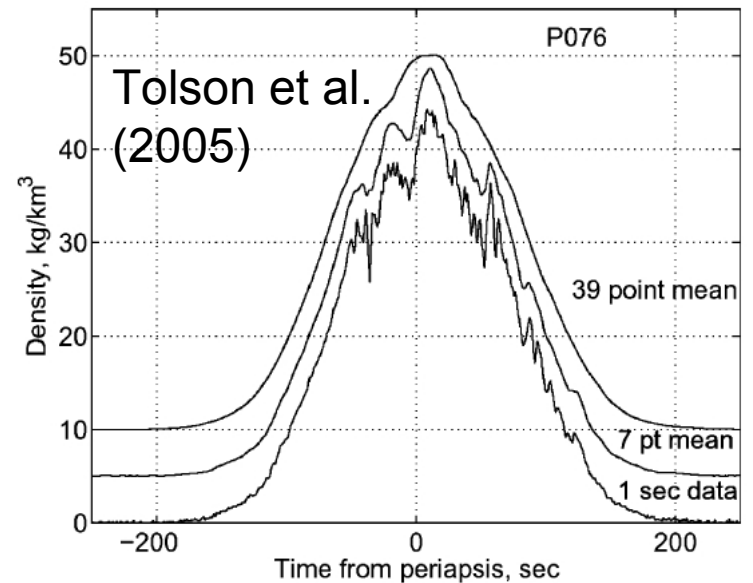
Interpretation of density comparison

- Mean difference is 6% at 110 km, 10% at 120 km
- Standard deviation of difference is 6% at 110 km, 10% at 120 km
- Formal uncertainties in operations team's results are 5% at 110 km and 120 km.
- Formal uncertainties in our results are ~1% at 110 km and ~3% at 120 km. These are too small as they assume that some systematic uncertainties (mass and aerodynamics) are Gaussian.
- Expected differences are about 10% (5% from areoid differences, 5% from other causes). This is consistent with typical differences, but some differences at 120 km are much greater.

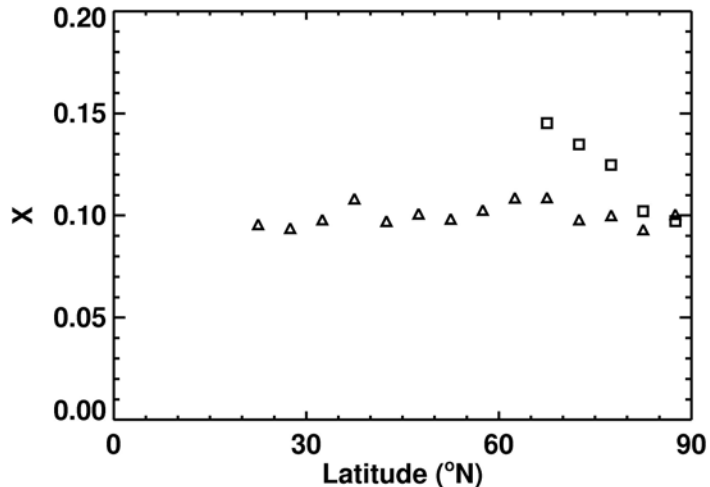
Orbit P076



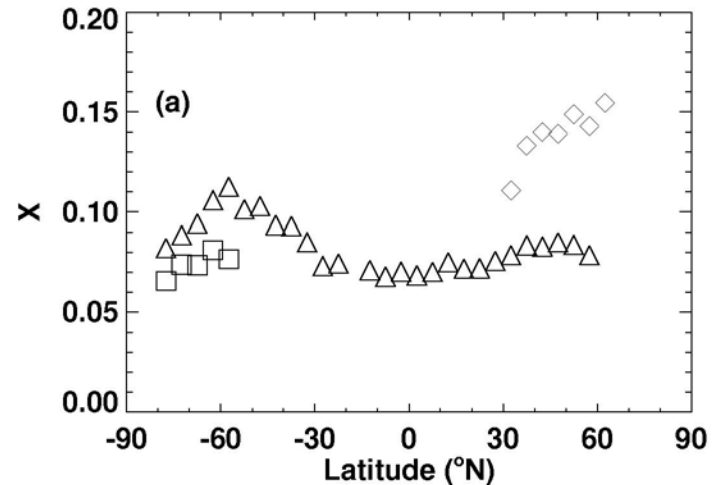
- Raw data have 1 sample per second.
- Signal-to-noise increased by using 7 point and 39 point averages.
- Time series of densities agree well with operations team's results



Small-scale density structure (due to gravity waves?)

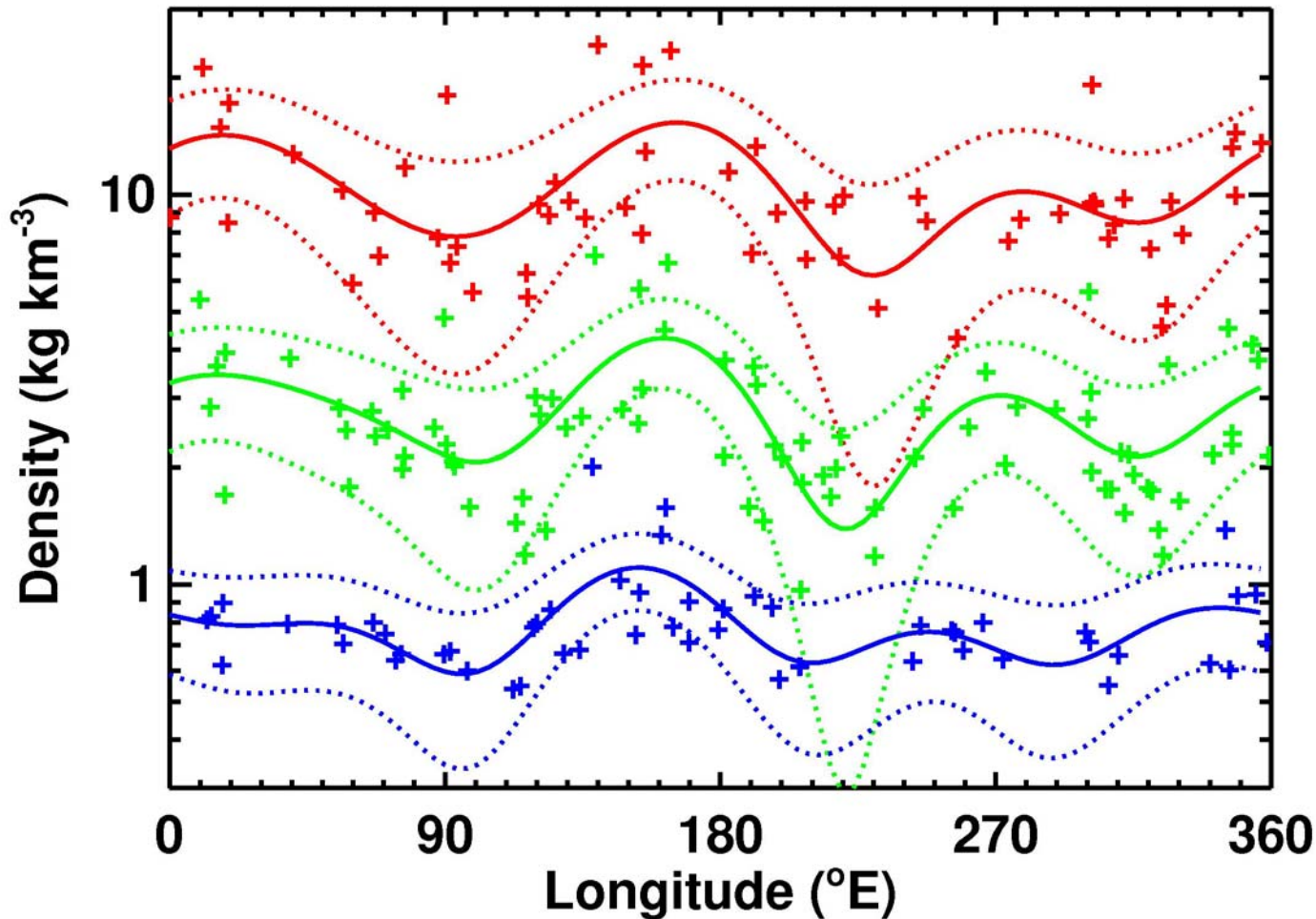


$$Y = 2 \frac{(\rho_7 - \rho_{39})}{(\rho_7 + \rho_{39})}$$
$$X = \sqrt{Y^2}$$



- Left – Odyssey results. Squares are dayside profiles and triangles are nightside profiles.
- Right – MGS results. Diamonds are Phase 1, squares are Phase 2/nightside and triangles are Phase 2/dayside
- Large values of X at 60 degrees S/N
- Little variability in X in tropics and mid-latitudes

Tides at 60-70N, dayside



Red = 120 km
Green = 130 km
Blue = 140 km

Tidal phases stay constant as z changes

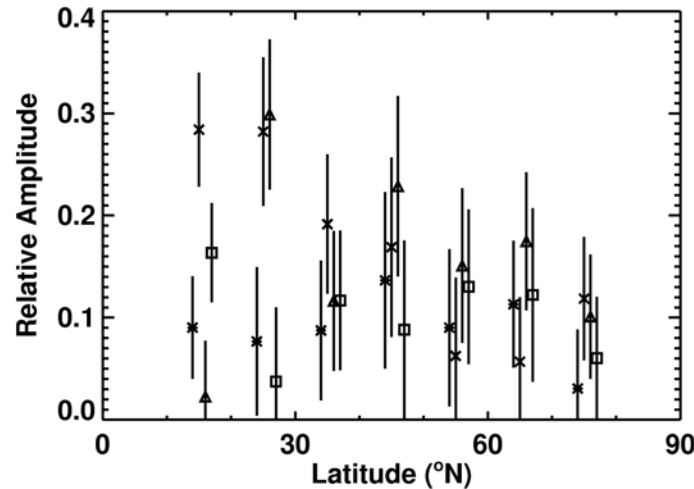
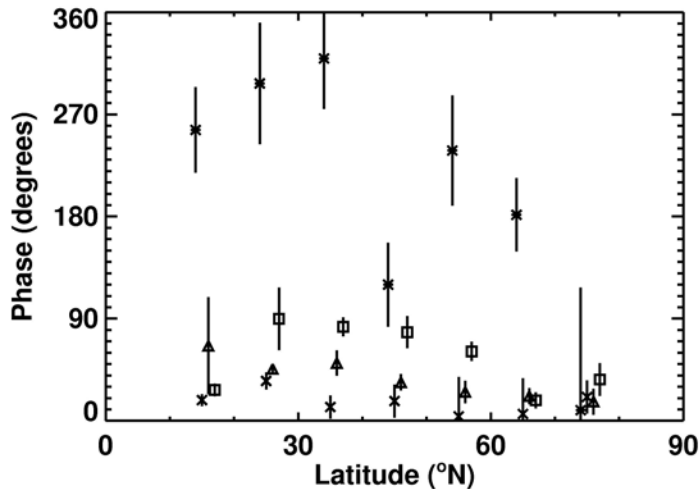
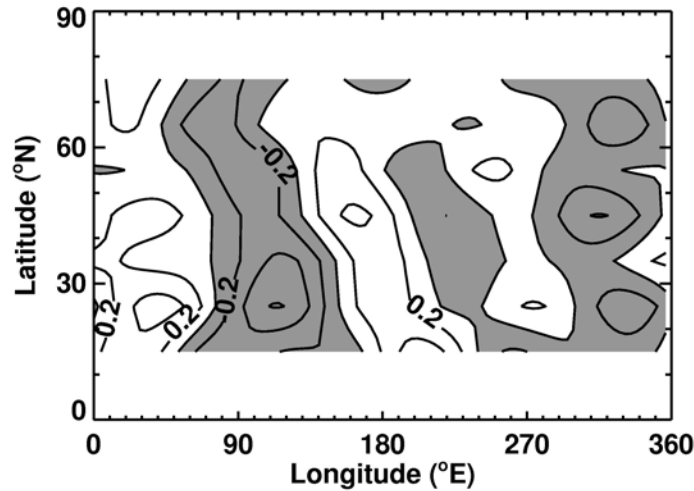
Tidal amplitudes decrease as z increases

Zonal mean density decreases as z increases

Meridional structure of tides

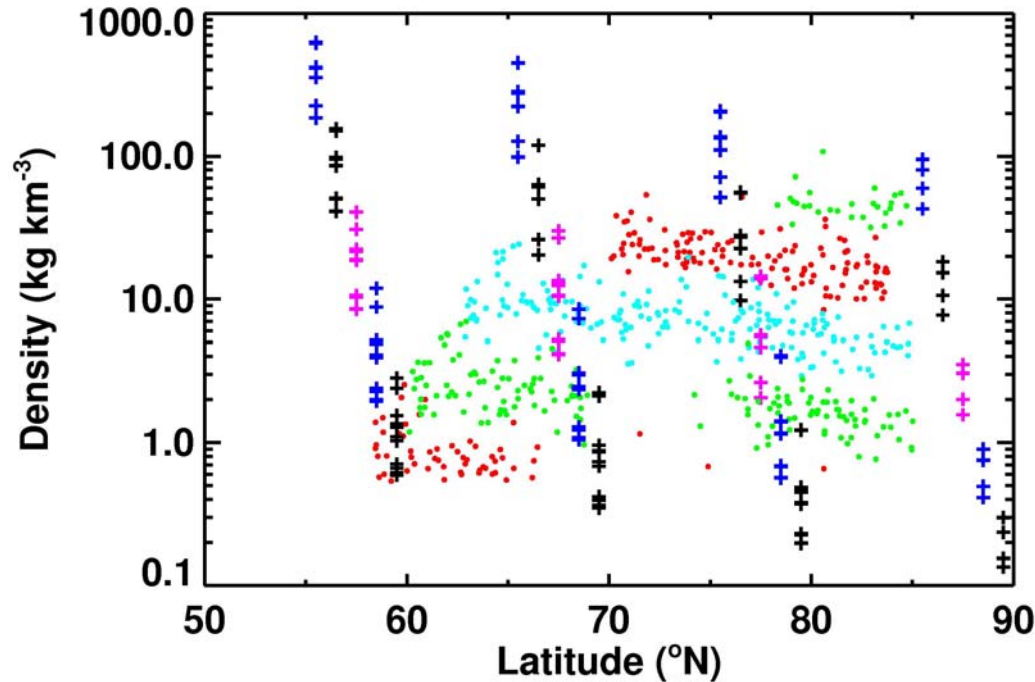
Upper left - Inbound densities at 120 km (nightside)
Normalized fitted densities with contour intervals of 0.2 (dimensionless) and negative regions (low densities) shaded

Lower left - Phases from corresponding wave-4 fits.
Wave-1 = asterisks, wave-2 = crosses, wave-3 = triangles, wave-4 = squares.
Maximum value of wave-n phase is $360/n$



Lower right -
Amplitudes.

Comparison to MTGCM – Dayside densities



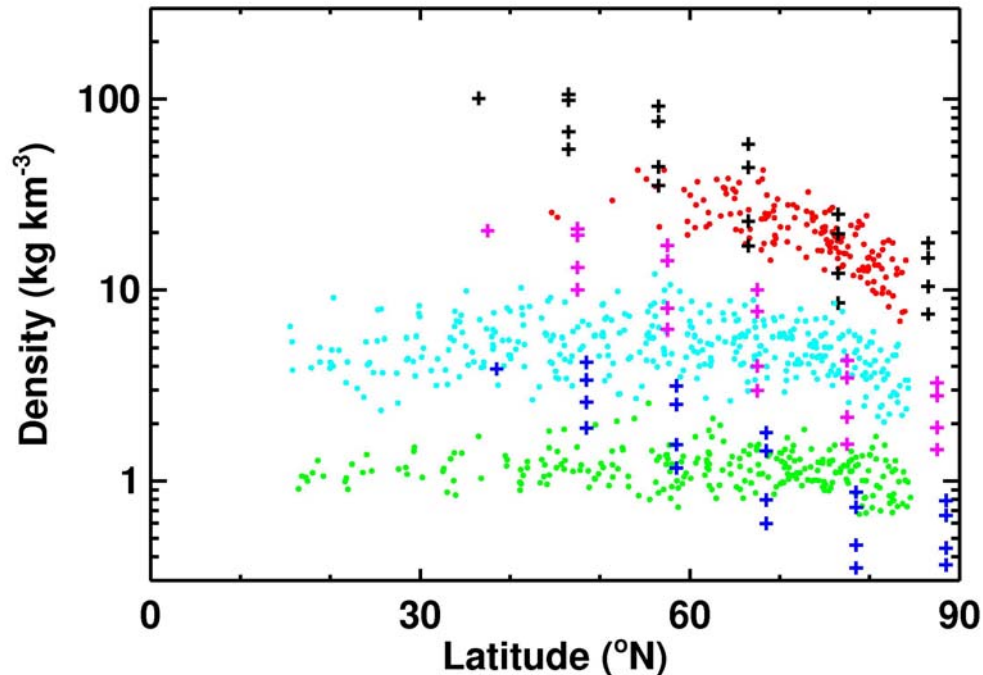
MTGCM simulations cover
16, 17, 18 hrs LST,
 $\tau = 0.3, 1.0, 3.0,$
 $L_s = 256, 277, 297$ degrees

Hence range in simulated
atmospheric conditions

Dayside MTGCM (crosses) and ODY (small filled circles) densities. All MTGCM results at $X7.5$ degrees latitude, but some are shifted in latitude for clarity.
MTGCM – Dark blue = 100 km and 130 km, black = 110 km and 140 km, pink = 120 km
ODY – Green = 100 km and 130 km, red = 110 km and 140 km, light blue = 120 km

Observed and simulated densities are very consistent.

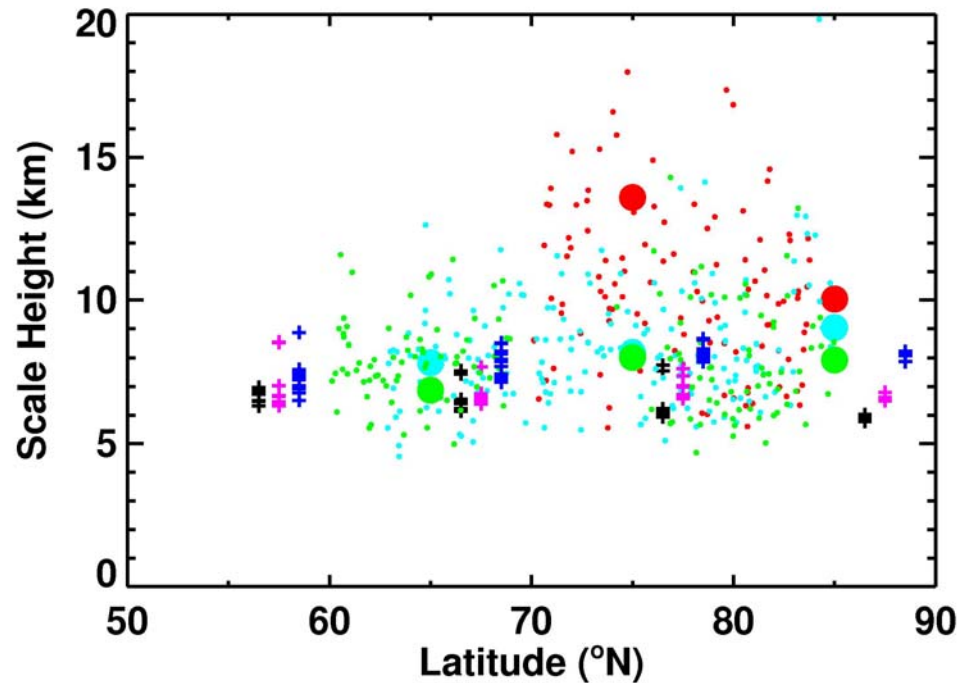
Comparison to MTGCM – Nightside densities



Same colours as previous slide, but for 110 km, 120 km, 130 km only
Simulations at tau = 0.3, 1.0 only

Observed polar densities consistent with tau=1.0 simulations.
Observed mid-latitude densities smaller than simulated densities
Observations have strong meridional density gradient, simulations do not

Comparison to MTGCM – Dayside density scale heights

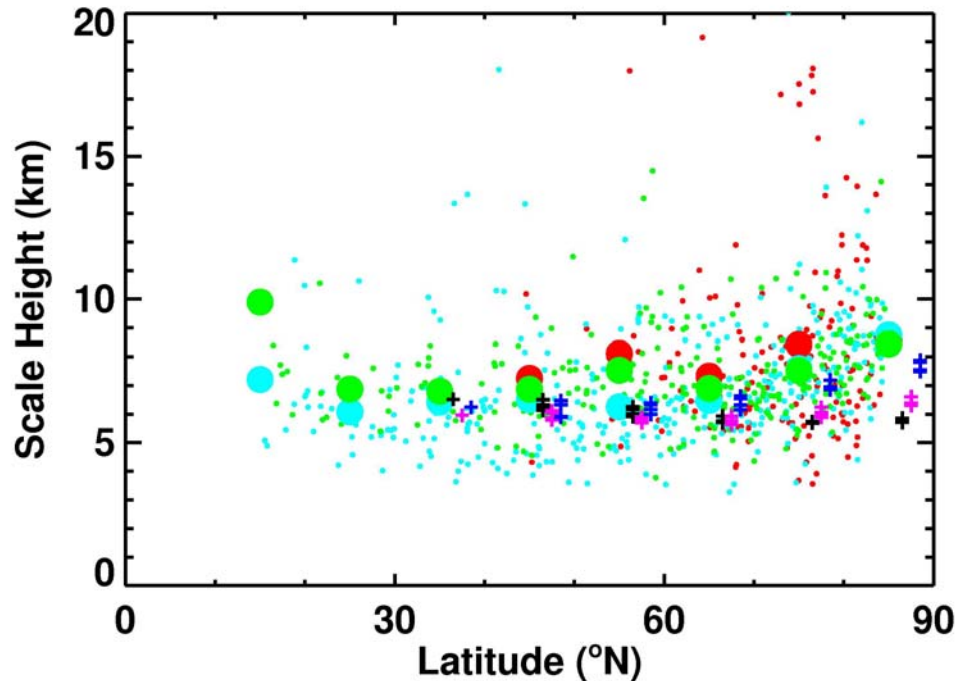


MTGCM (crosses) and ODY (small filled circles) scale heights. Large filled circles are averages of all observed scale heights in ten degree latitude window. 110, 120, 130 km. Colours as on previous slide.

Equatorward of 80N, observations and simulations agree.

Poleward of 80N, observations have scale height decreasing as altitude increases, but simulations have opposite trend. Observed scale heights greater than simulations.

Comparison to MTGCM – Nightside density scale heights

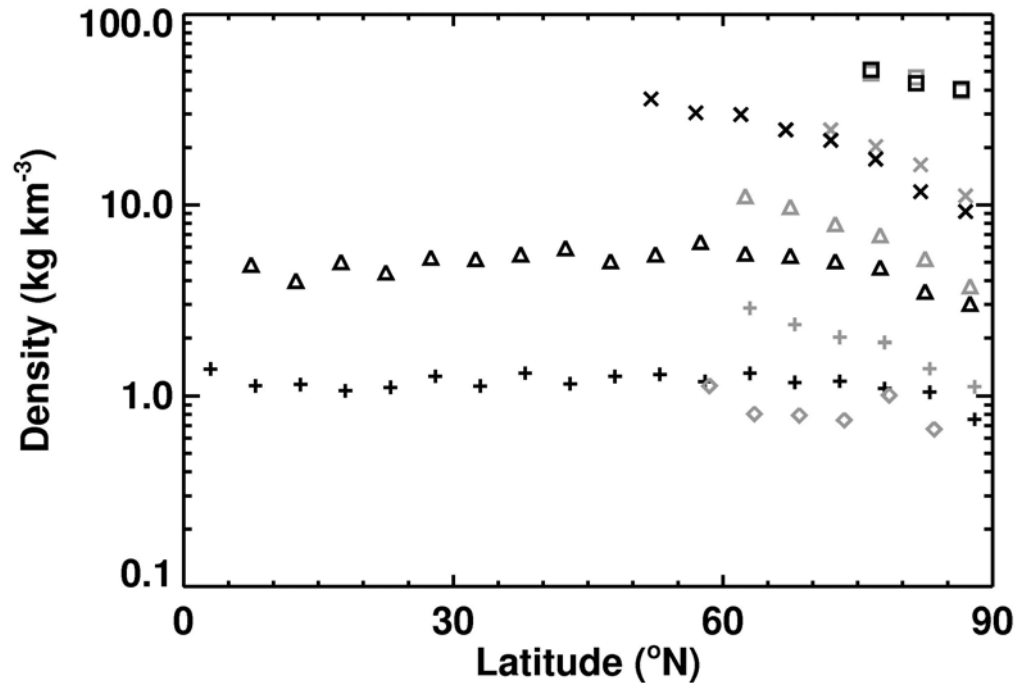


MTGCM (crosses) and ODY (small filled circles) scale heights. Large filled circles are averages of all observed scale heights in ten degree latitude window. 110, 120, 130 km. Colours as on previous slide.

Equatorward of 70N, observations and simulations agree.

Poleward of 70N, observed scale heights greater than simulations.

Mean observed densities

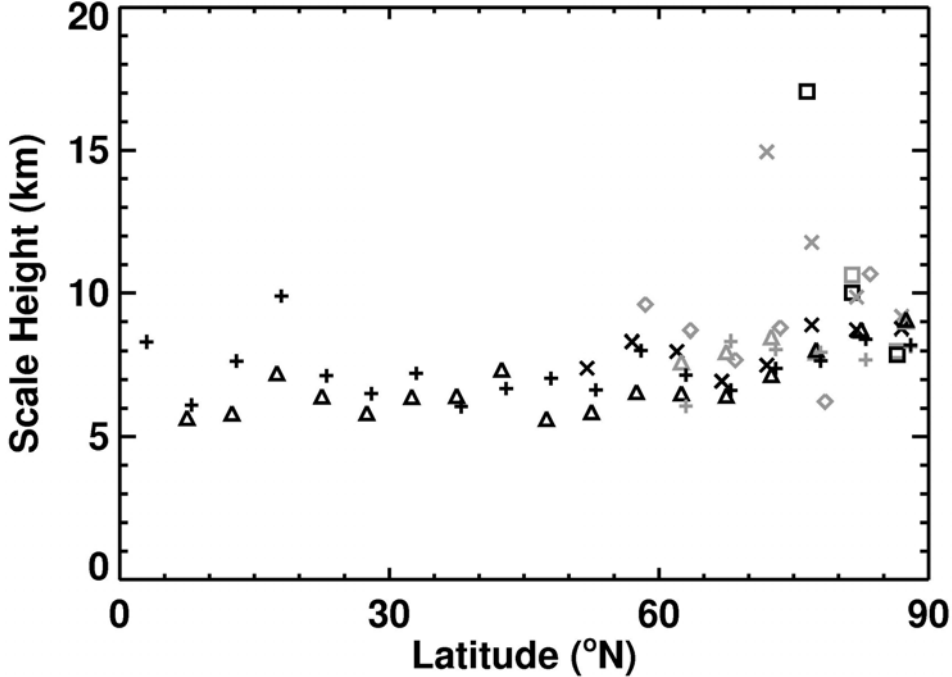


Mean dayside (grey) and nightside (black) densities from five degree intervals.
Squares = 100 km, X = 110 km, Triangles = 120 km, + = 130 km, Diamonds = 140 km

Differences between dayside and nightside densities increase as altitude increases and as latitude moves from pole to equator.

Data taken around northern polar night, so it is reasonable that polar densities are similar on dayside and nightside.

Mean observed scale heights

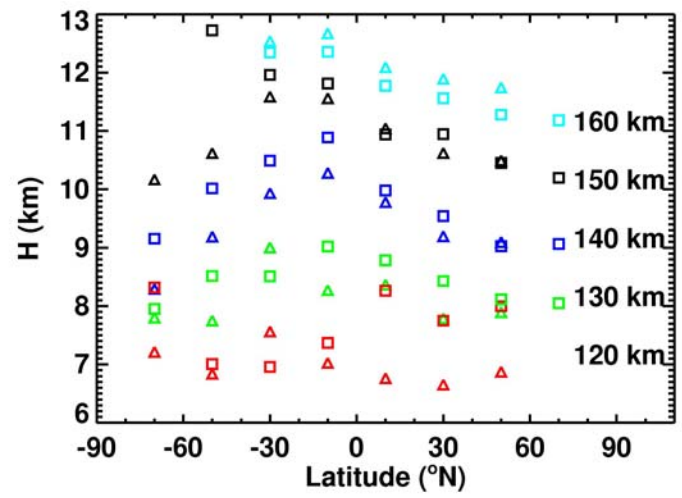


Mean dayside (grey) and nightside (black) scale heights from five degree intervals.

Squares = 100 km, X = 110 km, Triangles = 120 km, + = 130 km, Diamonds = 140 km

Scale heights greater near pole than in tropics and mid-latitudes.

Scale heights greater on dayside than nightside



MGS dayside Phase 2 scale heights.

Meridional trends in dayside scale heights are very different in MGS and ODY.

Archiving status

- Data products have been formatted in compliance with PDS rules
- Documentation has been written and formatted in compliance with PDS rules
- Data products and documentation delivered to Atmospheres Node of PDS earlier this year, awaiting review

Conclusions

- Density profiles and constant altitude densities and scale heights have been derived from ODY accelerometer data
- Results have been compared to operations team's results
- Scientific analysis of data products is underway
- Data and documentation at PDS awaiting review