VARIABILITY OF THE THERMOSPHERIC TEMPERATURE AND WIND STRUCTURE OF MARS: MAVEN NGIMS MEASUREMENTS AND CORRESPONDING GLOBAL MODEL SIMULATIONS

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Introduction.

The Mars upper atmosphere, encompassing the thermosphere, ionosphere, and lower portion of the exosphere (~100 to 500 km), constitutes the reservoir that regulates present day escape processes from the planet. However, without knowledge of the physics, chemistry and dynamics operating in this reservoir region and driving its significant variations (e.g., solar cycle, solar rotational, seasonal, diurnal, etc), it is not possible to reliably extrapolate current results over evolutionary history. The characterization of this thermosphere-ionosphere-exosphere reservoir is therefore one of the major science objectives of the MAVEN mission.

MAVEN Measurements:

The primary MAVEN instrument for sampling neutral thermospheric structure is the NGIMS (Neutral Gas and Ion Mass Spectrometer) instrument. It measures the neutral composition of the major gas species (e.g. He, N, O, CO, N_2, O_2, NO, Ar and CO_2) and their major isotopes, with a vertical resolution of ~5 km for targeted species and a target accuracy of <25% for most of these species (Mahaffy et al. 2015a,b). Thermospheric temperatures are derived from neutral density vertical structure (Bougher et al., 2015a; 2016). Most recently, a new technique was developed, tested and routinely implemented to extract both zonal and meridional winds from these same in-situ orbit passes below ~250 km (Benna et al. 2016). The technique involves commanding Articulated Payload Platform (APP) nods of ± 6° around the j and k axes at a rate of 1° per sec. This provides measurements of cross-winds of up to 350 m/s with a resolution of ±30 m/s, plus measurements of along the track winds with a resolution of ± 100 m/s. Full flow direction determination (wind direction and magnitude) is made every ~40 sec. Several wind measurement campaigns have been conducted since March 2016, spanning Ls ~ 130 to 230 (near aphelion to near perihelion seasons) and approaching solar moderate to minimum conditions.

Numerical Model Simulations:

Corresponding Mars Global Ionosphere Thermosphere Model (M-GITM, Bougher et al., 2015b) outputs are subsequently compared to NGIMS wind measurements along both the inbound and outbound legs of orbit tracks below ~250 km. This MGITM model is thusfar primarily driven by solar EUV-UV forcing at thermospheric altitudes. However, lower to upper atmosphere coupling is also accommodated by a model domain that extends from the surface to ~250 km. These model simulations are used to provide a first comparison with the climatic trends (and orbit-to-orbit variations) gleaned from these NGIMS wind datasets. However, the present lack of gravity wave processes (e.g. momentum and energy deposition) in the M-GITM framework suggests that these simulated wind trends can be further modified. In this regard, the M-GITM incorporation and testing of a suitable gravity wave momentum deposition scheme is planned for the near future.

Results:

NGIMS Temp Variations (Ls ~ 130-230).

March-April 2016 dayside temperature profiles are extracted from NGIMS argon and CO_2 densities and illustrated in Figure 1. Both ~100 orbit averaged temperatures and corresponding ±1-σ variability bars about these means are provided. Temperatures are nearly isothermal above ~160 km, and approach ~190-210K at 200 km. These aphelion (solar moderate) dayside conditions give rise to the thermospheric winds that are measured in interval #1 (P2930 to P2933) (Red Orbits in Table 1).

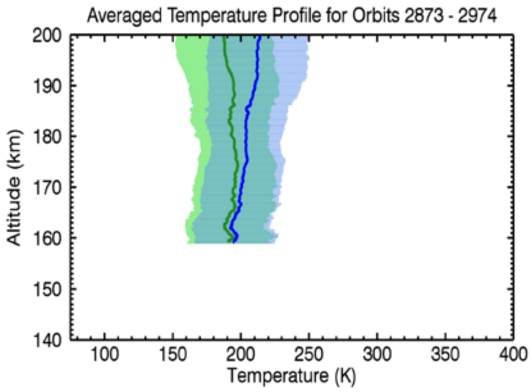

***Figure 1**. Near Aphelion dayside mean temperature profiles from NGIMS Argon (blue) and CO_2 (green) densities. Season (Ls = 126-135); SZA = 49-74°; LAT = 66-74°N; LT = 12-19 Hrs. Variations (1-σ) about the mean temperature profile are given by cross-bars of similar colors (see Bougher et al 2016).*

Mid-March 2015 dayside temperature profiles are extracted from NGIMS argon and CO_2 densities and illustrated in Figure 2. Both 19-orbit averaged temperatures and corresponding ±1-σ variability bars about these means are provided. Temperatures are now nearly isothermal above ~180 km, and approach ~260-270K at 200 km. These near perihelion (solar moderate) conditions are also generally consistent with September 2016 and yield the thermosphere winds that are measured in interval #2 (P3861-P3865) (Purple orbits in Table 1).

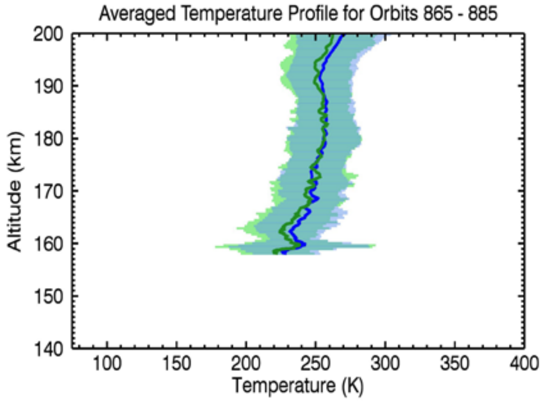

***Figure 2**. Near Perihelion dayside mean temperature profiles from NGIMS Argon (blue) and CO_2 (green) densities. Season (Ls ~ 300); SZA ~ 54-69°; LAT = 10-24°N; LT = 15-16 Hrs. Variations (1-σ) about the mean temperature profile are given by cross-bars of similar colors (see Bougher et al. 2016. These dayside conditions are similar to those of September 2016).*

Orbit#	LST	LAT	SZA
2777	19-23	74-48N	74-108
2930	12.5-19.00	65-74N	47-78
2931	13.0-18.9	68-74N	51-77
2932	12.0-20.2	60-73N	43-91
2933	11.9-19.9	61-74N	43-87
3320	4.6-5.5	17-47N	108-92
3321	4.7-6.4	19-61N	107-83
3322	4.6-5.4	16-44N	108-93
3323	4.6-5.8	14-53N	110-88
3588	0.00-0.51	22S – 6N	151-172
3589	0.05-0.5	18S – 6N	155-173
3861	18.3-19.7	59S- 26S	76-103
3862	18.2-19.6	59S -26S	76-103
3863	18.2-19.6	60S-26S	76-102
3864	18.4-19.6	58S-26S	77-102
3865	18.2-19.5	60S-29S	75-100

***Table 1**. MAVEN neutral wind campaigns thusfar (March-September 2016). Relevant parameters for sampling. Red (post aphelion) and purple (approaching perihelion) intervals are analyzed in this paper. Latitude (LAT), local solar time (LST) and solar zenith angle (SZA) information is given by orbit number.*

NGIMS Wind Variations (Ls ~ 130-230).

NGIMS extracted neutral winds (both zonal and meridional components) are extracted and plotted in Figure 3 for interval #1 (April 2016). Winds are provided as a function of altitude below ~200 km. Vertical resolution is coarse due to the ~40-sec cadence of wind measurements. All 4-available orbits of wind data are averaged together to yield mean zonal and meridional profiles. Notice that these wind magnitudes generally decrease with increasing altitude, but not always. This behavior is not expected, unless one considers horizontal variations in these winds along the orbit track for these afternoon, high latitude conditions. Maximum winds are +200 m/s (zonal) and -200 m/s (meridional).

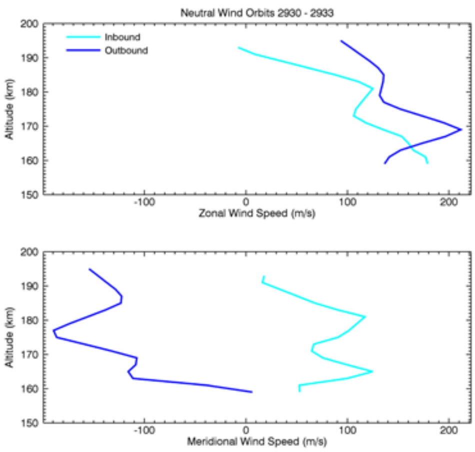

Figure 3. *Neutral winds April 1-2, 2016 demo campaign for 4-Orbits (P2930-P2933). Zonal and meridional neutral wind profiles are extracted (m/s). Averaged profiles (over 4-orbits) are plotted. Binning of 2 km altitude is used for aligning individual profiles for averaging.*

Next, NGIMS extracted neutral winds (both zonal and meridional components) are extracted and plotted in Figure 4 for interval #2 (September 2016). Winds are provided as a function of altitude, now below ~220 km. Vertical resolution is largely the same as interval #1. All 5-available orbits of wind data are now averaged together to yield mean zonal and meridional profiles. For this interval, the wind magnitudes generally increase with altitude up to ~220 km, but not always. Once again, horizontal variations in these winds are evident in the profiles provided along the orbit track. Maximum winds are +200 m/s (zonal) and +340 m/s (meridional).

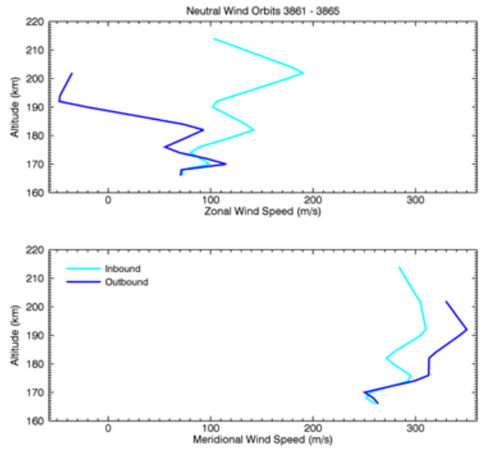

Figure 4. *Neutral winds September 22-23, 2016 full campaign for 5-Orbits (P3861-P3865). Zonal and meridional neutral wind extraction (m/s). Averaged profiles (over 5-orbits) are plotted.*

Conclusions:

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The first in-situ measurements of neutral thermospheric zonal and meridional winds at these altitudes in the Martian thermosphere are presented. Two early NGIMS wind campaigns are isolated for study. Extracted wind magnitudes sometimes increase with altitude (as expected). At other times (when horizontal variations along the orbit track are important), winds decrease in magnitude with height. Wind variations from orbit-to-orbit (not shown) are generally substantial. Detailed comparisons with solar driven MGITM model simulations will be presented in the talk. Thusfar, general comparisons suggest that: (a) inbound-outbound wind trends (data vs model) are broadly consistent for interval #2 (at the evening terminator), (b) observed wave-like variability of winds with altitude is not simulated by MGITM, and (c) simulated wind magnitudes are reduced from current NGIMS measured winds.

NGIMS wind sampling will continue on an approximate 1-month cadence with measurements spanning 10-consecutive orbits (5-neutrals followed by 5-ions) for each campaign. Ongoing measurements are slated for an entire Martian year during the EM-2 portion of the MAVEN mission (October 2016 to September 2018).

References:

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