# FORCED & FREE ATMOSPHERIC WAVES IN MRO/MCS DATA: OBSERVATIONS AND E-P FLUX DIVERGENCES

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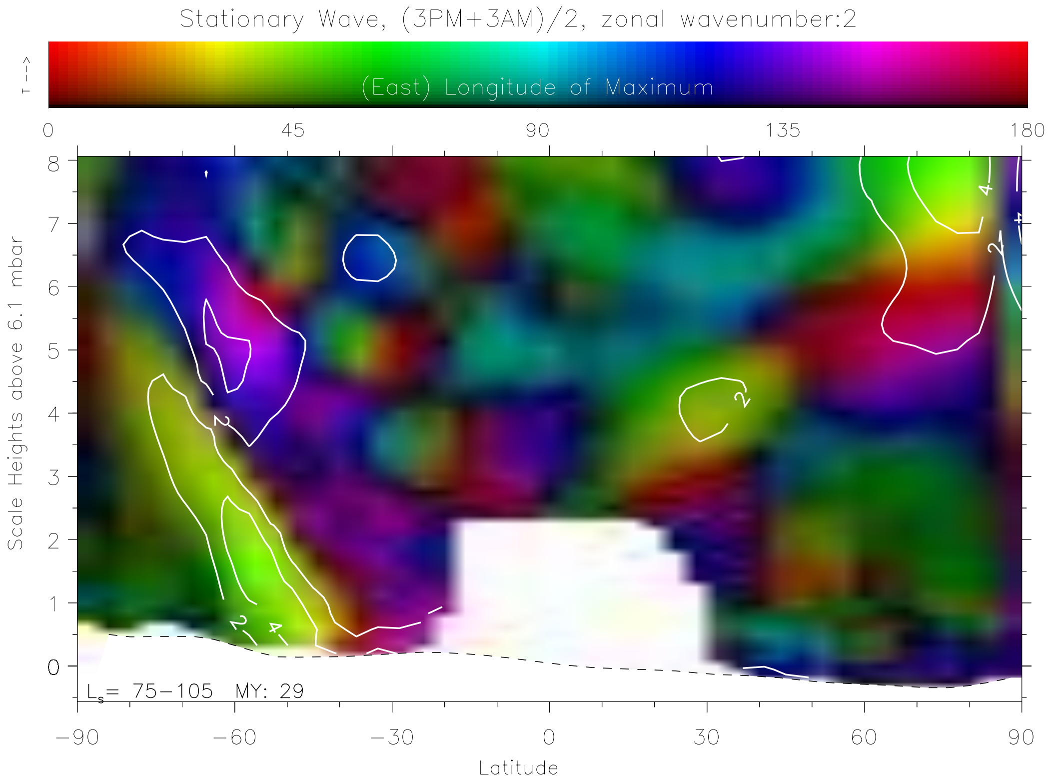


**Figure 1. m=2 stationary wave during southern winter solstice.**

**Introduction:**

While MRO/MCS has been obtaining atmospheric profiles from Mars for roughly 10 Earth years, it is only recently that the retrievals have been able to successfully handle the strong meridional gradients near the polar vortex edge. The strongest atmospheric waves (and thus the most dynamically influential) are found along the polar vortex edge, and thus were mainly unavailable to analysis until recently, because of these challenges with the retrieval algorithm. Because the MCS Science Team has made these 2-D retrievals available, clarifying MCS' view into the polar vortex edge, we have finally been able to reveal the wave structures in this important region of Mars atmosphere. We have adapted the analysis tools first used in Banfield et al. (2003, 2004) with MGS TES data to quantify the forced and free waves and to estimate their forcing onto the zonal mean circulation.

**Stationary Waves:**

MGS TES data revealed that stationary waves dominate the southern winter hemisphere (while traveling waves are more important in the North). The MCS data have finer vertical resolution (about 0.5H versus 1-2H for MGS TES) and extend about twice as high (to 8H above 6 mbar). We find that the results reported previously for MGS TES data analysis of these waves was surprisingly accurate, in spite of relatively fine vertical structure evident in the stationary waves.

Fig. 1 shows the meridional cross-section of the m=2 stationary wave from MRO/MCS data from its first year of operation during southern winter solstice ($L_s$=75-105). Here, amplitudes of 4-6K are found below the polar jet, with a sharp phase reversal and amplitude reduction along the polar jet core, and an eastward phase tilt with height and amplitudes growing again to 4-6K above that.

Fig. 2 shows a meridional cross-section of the m=1 stationary wave at the same time of year (southern winter), again using brightness to depict amplitude and color to show the longitude of maximum.

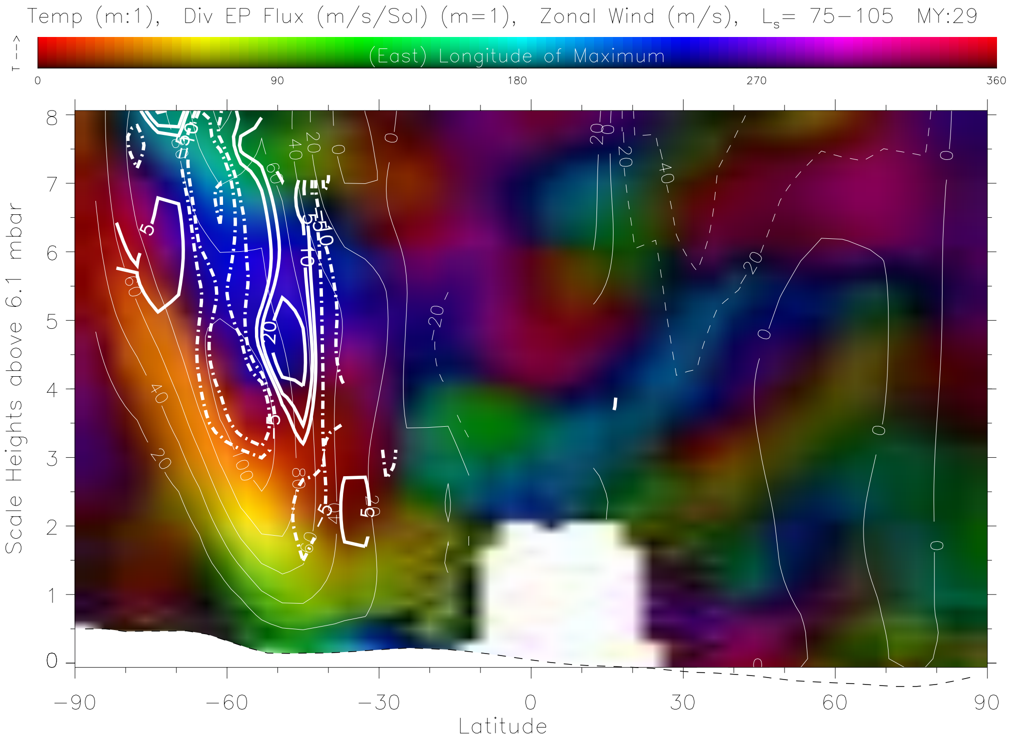


**Figure 2. m=1 stationary wave, zonal mean zonal wind and E-P Flux divergence from m=1 wave**

The E-P flux divergence (in m/s/Sol) is also shown as the heavy contours, and the thin contours show the zonal mean zonal wind. Amplitudes of 8-10K are found along the polar vortex edge, with a strong westward tilt of phase with height. This is very similar to that of the MGS/TES analysis shown in Banfield et al. (2003), except the wave features extend all the way up to 8H. At this time of year, the m=1 stationary wave appears to be acting to broaden and decrease the intensity of the polar jet, with negative accelerations occurring in the jet core, and positive accelerations occurring on either side of the core to the North and South. These accelerations are significant, reaching as high as ~20m/s/Sol, i.e., enough to damp the jet out completely in about 5 Sols.

We were unable to compute the E-P Flux divergence from the m=2 stationary wave from the first year of MRO/MCS data during southern winter because the meridional wind wave perturbations were too great for our gradient wind solution to be valid. However in the regions where a solution was possible (i.e., closer to the surface), the accelerations provided by the m=2 stationary wave are comparable in magnitude to those from the m=1 stationary wave. The m=3 stationary waves were not significant.

**Traveling Waves:** We have also characterized the traveling waves in the MRO/MCS data, with results also consistent with those from MGS/TES data as presented in Banfield et al. (2004). Fig. 3 shows a meridional cross-section of the m=1 traveling wave just after Northern winter solstice ($L_s$=285-315). In this figure, amplitude is again shown by brightness and contours, while color codes the period of the wave. In this case, the largest wave amplitude is a ~7-Sol period westward propagating wave with an amplitude of about 10K, centered just north of the northern winter polar vortex edge, but exhibiting (mostly) coherent behavior nearly to the equator.

We may present results of E-P Flux divergence analysis of the traveling waves, including the m=2 and m=3 waves. Additionally, we may discuss the effects of $CO_2$ condensation on the polar vortex, and especially on the growth, decay or stability of the various waves.

**Bibliography:**


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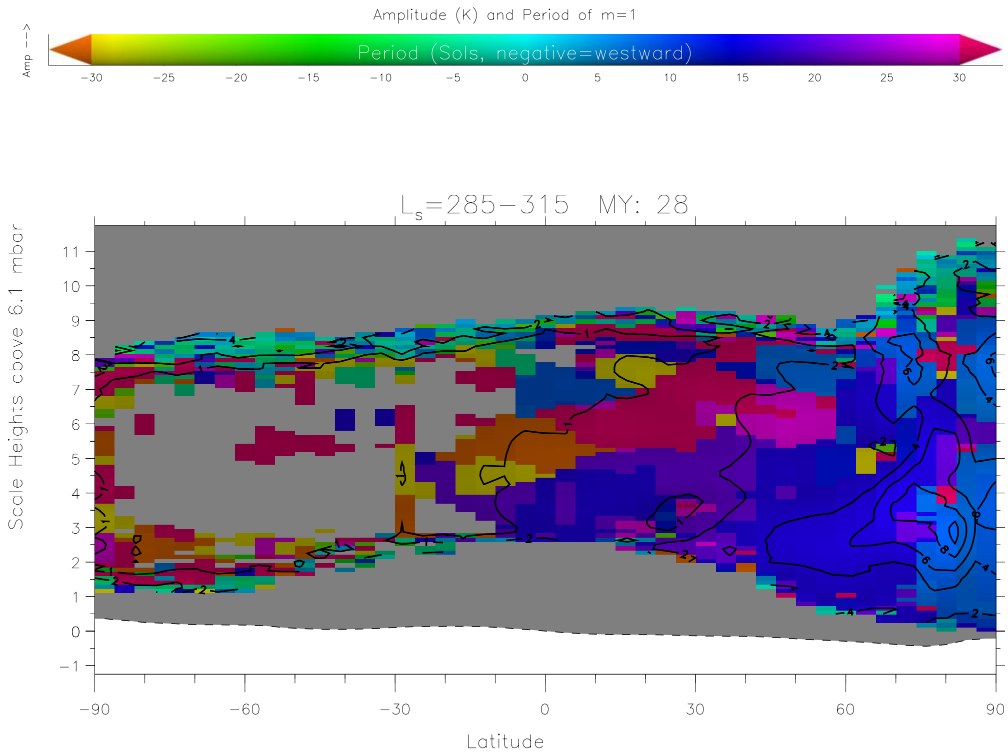


**Figure 3. Amplitude and period of the m=1 traveling wave just after northern winter solstice**