Further Examination of the Role of Atmospheric Eddies in Wintertime Polar Argon Enhancement and CO_2 Supersaturation. J. R. Barnes[1], A. L. Sprague[2], D. P. Hinson[3,4], D. Tyler[1], and W.V. Boynton[2], [1]College of Oceanic and Atmospheric Sciences, 104 COAS Admin. Bldg., Oregon State University, Corvallis, OR, 97331 (barnes@oce.orst.edu), [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721 (sprague@lpl.arizona.edu), [3]Department of Electrical Engineering, Stanford University, 350 Serra Mall, Stanford, CA, 94305 (dhinson@stanford.edu), [4]Carl Sagan Center, SETI Institute, Mountain View, CA, 94043.

Introduction: Previous studies have shown that large-scale atmospheric eddies are of considerable importance for two basic processes which are known to take place in the winter polar regions of Mars. These are the enhancement of Argon and other noncondensing gases as a result of the condensation of CO_2 on the surface and within the atmosphere [1,2,3,4], and the presence of atmospheric regions which are significantly supersaturated with respect to CO_2 [5,6,7]. The latter may be associated with the occurrence of CO_2 convection in the winter polar regions [7]. We have been pursuing further studies of the role of atmospheric eddies in controlling the enhancement of Argon in the winter polar regions by analyzing additional TES temperature data, as well as MGS RS data. We are also carrying out studies of CO_2 supersaturation in the winter polar atmosphere, especially that in northern winter, using TES temperature data as well as MGS RS temperature data.

Winter Polar Argon Enhancement: Measurements made by the Gamma Ray Spectrometer (GRS) on the Mars Odyssey spacecraft have been analyzed to show that the absolute and relative column abundances of Argon and other noncondensing gases maximize in the winter polar regions [1,3]. These gases are left behind as CO_2 condenses on the ground and in the atmosphere. The relative enhancement of Argon is considerably larger in southern winter than in northern winter: peak enhancements are by a factor of ~ 6 in the south polar region in winter, but are only a factor of ~ 1.5-3 above the ambient mixing ratios in northern winter. Given the elevation differences between the south and the north, as well as the seasonal CO_2 cycle, the actual maximum winter column abundances of Argon in the north are quite similar to the corresponding amounts in the south. Based upon a simple model without any atmospheric mixing (condensation only), the peak Argon enhancement factors in the south polar region would be ~ 9, whereas those in the north would be only ~ 3.5 [3,4]. In both cases the actual maximum enhancements are observed to occur close to winter solstice, whereas the no-mixing model predicts maximum enhancements at spring equinox. Atmospheric mixing of Argon (and the other noncondensing gases) from the polar regions into lower latitudes is required to explain this seasonal variation and the reduced enhancements. Viewed in this way, the atmospheric mixing of Argon out of the polar region in northern winter is actually fairly comparable to that in the south during southern winter. In a GCM study of the Argon enhancements, the model mixing was found to be overly strong in both the north and the south, resulting in smaller than observed winter polar enhancements [4]. A basic aspect of the northern winter GRS measurements is that the Argon abundances exhibit substantially greater "high frequency" variability (on time scales of ~ 25 sols and longer) than in the south. No such variability is present in the GCM results, and it is of interest to try to determine if there are plausible dynamical mechanisms associated with the eddies which might be able to produce such variations.

Further studies: Additional Odyssey GRS data have now been analyzed to yield the polar Argon abundances, such that the Argon enhancements during three winters (MY26, 27, and 28) in both the north and the south have been determined. To first order, the basic behavior in the three different winter seasons is quite similar in both the north and the south. The MY26 winter seasons are the only ones for which there are also MGS TES data, which can be analyzed to characterize the basic behavior of the atmospheric eddies responsible for the Argon mixing. There is also an excellent set of MGS RS temperature profiles for northern autumn in MY26 [8], as well as data for the MY27 northern autumn and winter seasons. The RS data have been analyzed so as to characterize aspects of the low-level transient and stationary eddy activity [8]. Some analyses of the MY26 northern winter TES data have previously been carried out to characterize the transient eddy activity in relation to flushing dust storms [9]. We are pursuing much more extensive analyses of these data, as well as data from the MY26 southern winter season, for comparisons with the Argon results. Analysis of the eddy activity during MY24 and 25 is also being completed, to permit an assessment of the MY26 eddies in comparison to the eddy activity in these other years. One aspect that we are particularly focusing on is whether or not there is any "high frequency" variability in the eddy activity that could possibly be correlated with that observed in the Argon enhancements during northern fall and winter.

Winter Polar CO_2 Supersaturation: Previously, the TES temperature data for the MY24 northern winter season were examined in order to assess the extent and magnitude of polar CO_2 supersaturation; TES data for southern winter in MY25 were also analyzed [7]. MGS RS data for MY24, 25, and 26 were analyzed to look at polar supersaturation in both northern and southern winter [7]. It was found that supersaturation was relatively common in both polar regions during winter. The magnitude and vertical extent of supersaturation can be expressed in terms of a convective available potential energy or CAPE, and a potential convective energy flux [7]. The latter was found to reach a maximum value around the time of solstice in both winter polar regions, with the northern maximum value being roughly twice as large as the southern maximum. The region in which significant supersaturation was present was found to be larger – extending further equatorward – in northern winter. GCM simulations were performed and these yielded fairly good agreement with the bulk winter polar supersaturation cycle determined from the TES data, when effects of CO_2 convection (represented by a parameterization) were incorporated in the model [7]. Simulations of the distributions of noncondensing gases were also done, and these yielded generally smaller winter polar enhancements than those present in the GRS Argon data, though the intraseasonal variation in the enhancements was not examined [7].

Further studies: TES temperature data for the northern fall and winter seasons of MY25 and 26, the latter being the first year for which GRS Argon data are available, can be analyzed to assess the magnitude and extent of polar supersaturation. TES data for southern winter in MY24 and 26 can be similarly analyzed. MGS RS data for all three years can be examined in this context, to provide a comparison with the TES data. Analyses of the TES and RS temperature data yield the basic characteristics of the atmospheric eddies, and the contribution of these to the observed supersaturations can be assessed. Preliminary examinations of the TES data for MY24 northern winter showed that strong transient eddies were of considerable importance in producing the supersaturated regions, with stationary eddies and thermal tides also playing an important role. In southern winter, the stationary eddies appeared to be of greater importance for this [2]. The interannual variability of polar supersaturation is a very interesting issue, which can be studied most fully using the TES temperature data.

Results: We will present and discuss some of the key results from the various data analyses described above, in the context of both the winter polar Argon enhancements observed by the Odyssey GRS, and the winter polar CO_2 supersaturations. In relation to the Argon enhancements during southern winter, a basic picture for the mixing involving the transient eddies has previously been proposed [6]. This is based upon the substantial intensification in these eddies which takes place at L_s ~ 130-140, according to analyses of the TES temperature data [2]. We will discuss to what extent this picture holds up in the context of our more complete analyses of the TES data for southern winter. The Argon behavior in northern winter will be addressed in relation to the eddy activity as revealed by the TES and RS data analyses, especially those for MY26 and 27. One focus of this will be the high-frequency variations in the Argon enhancements. One speculative hypothesis that can be proposed is that at least some of this variation could be associated with changes in the basic eddy characteristics during northern fall and winter [2,9,10]. We will also present and discuss the most complete assessment to date of the extent and magnitude of atmospheric polar supersaturations, based upon our analyses of the TES and RS temperature data. These are related to dust abundances, eddy activity, and possible CO_2 convection. The latter is potentially very important in connection with the Argon enhancements, in producing strong vertical mixing [7]. The polar supersaturations (and CO_2 convection) are generally very important in the basic context of the winter polar thermal structure, something that circulation models have tended to have difficulty with.

References:

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