Large bolide impacts on the Martian surface load the atmosphere with long-lived, fine-scale particles by direct injection and ballistic fallout [Pierazzo et al., 1998]. When the particles enter the middle atmosphere, the vertically stable region above the troposphere (0 to ~50 km altitude), they remain aloft for very long times of months to years depending on the particle size. There, the emplaced particles are dispersed in a highly complex spatial pattern by the strong, prevailing winds. The detailed evolution of dispersion and mixing of particles in the middle atmosphere has not been addressed. This is due in part to the high resolution and complexity required to accurately track the dispersion for longer than very short times (~minutes to ~hours).

We study the nonlinear dispersion of aerosols over meteorologically significant time of ~10 sols using a high-resolution (~30 km) atmospheric flow model. The model uses the spectral method to solve the atmospheric dynamics equations (the primitive equations) and is capable of resolving the dynamical structures (waves, eddies, and turbulence) critical for accuracy. The model is loaded with the MOLA topography [Smith et al., 1999], winds from a full Mars general circulation model of Richardson and Wilson [2002] at different seasons, and starting particle coverage similar to those in Kring and Durda [2002] for shallow and steep velocity distributions. Using the model, we study the spreading rates, mixing extent, and potential for global transport in events from ~10 to ~100 km-sized impactors in many different physical conditions (e.g., season, impact location, spatial-temporal distribution of injected particles, strength of topographic waves, etc.).

Because of the mechanics of the vapor plume expansion and factors having to do with different particle sizes, the material entrained into the plume is not initially distributed homogeneously in the middle atmosphere. There, in the presence of high-amplitude jets (of up to 180 m s⁻¹) and thermotidally and topographically excited waves, the long aloft-times allow the starting distribution’s unevenness to persist and increase in complexity over time. This is significant for studies of the distribution of volatiles and environmental consequences from impacts.

We find that, in general, while the transport distances can be global and timescales fast, the spreading is not uniform (Fig. 1). Because fine-scale particles couple radiatively to the atmosphere, the unevenness also presents an important and non-uniform feedback, by unevenly heating and thus modifying the winds that chaotically advect them. Even in the very energetic impact case, where the starting area coverage is wider and includes preferential injection at the antipode, the strong jets, waves, and turbulence in the middle atmosphere lead to markedly uneven and patchy distributions (Fig. 2). The particles are diffusively distributed in very low column density over a large fraction of the globe (in low- to mid-latitudes), but most of the material remains concentrated in complex, localized patches over days.

In the more frequent, smaller cratering events, the distribution of long-lived aerosol particles evolves chaotically – often producing concentrated patches persisting over meteorologically significant time scale within the impacted hemisphere. If mixed into the troposphere, the persistent areas may still serve as possible markers for impact-driven volatiles transported by the strong interaction with the atmosphere.

**Fig. 1.** Evolution of ejecta plume following an impact from a high-resolution (30 km) simulation, initialized with winds at northern hemisphere summer solstice (Ls = 90°). The impact location is at (lon = 180° E, lat = 30° S). The starting distribution (representing few hours after the impact) is a patch near the impact location. The aerosol column density (g cm⁻²) is shown at four different times (A–D), t = (0, 2.5, 6.0, and 10 sols) in stereographic projection centered on the South Pole.
Fig. 2. Evolution of column density distribution of material originating at the impact location (lon = 90° E, lat = 30° N) and the impact antipode. Ejecta are added at the antipode in pulses with time, as found in Kring and Durda [2002]. The aerosol column density (scale as shown in Fig. 1) is shown at six different times, \( t = (0, 1, 2, 3, 4 \text{ and } 5 \text{ sols}) \) after impact. The frames are in Mollweide projection with center longitude of 180° E and the winds are as in Fig. 1. For clarity, contours of lowest column density not shown.

References