ASSIMILATION OF TEMPERATURES AND COLUMN DUST OPACITIES MEASURED BY EXOMARS TGO-ACS-TIRVIM DURING THE MY34 GLOBAL DUST STORM.

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Between March 2018 and December 2019 the ExoMars Trace Gas Orbiter Atmospheric Chemistry Suite Thermal Infrared channel (TIRVIM) made nadir observations of the Martian atmosphere, measuring atmospheric and surface temperatures as well as column-integrated opacities of dust and water ice over the full 24-hour range of local times. At the beginning of this period, a global dust storm (GDS) occurred during Mars Year 34 (Kass et al. 2019). To understand the meteorology of this dust storm, in particular those atmospheric properties that cannot be measured directly, such as wind, we make use of data assimilation to synthesise observations of Mars during this period with a numerical simulation.

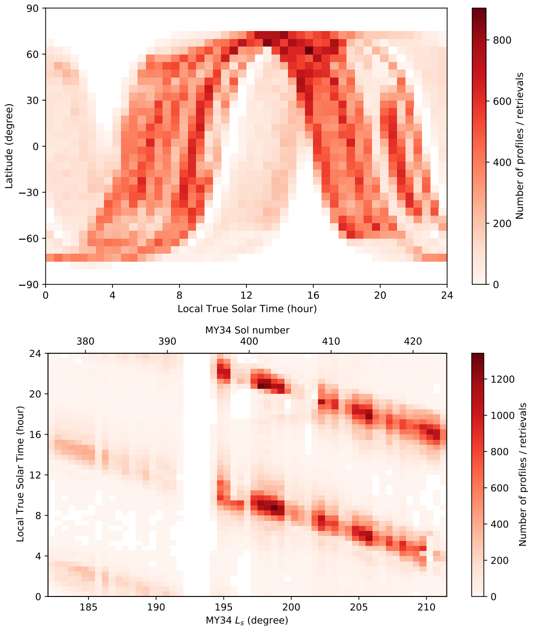

Fig. 1. Number of atmospheric temperature retrievals assimilated as a function of (top) Local True Solar Time and latitude, and (bottom) MY34 L_s and Local True Solar Time.

We use the Laboratoire de Météorologie Dynamique Mars Global Climate Model (LMD Mars GCM, Forget et al., 1999) and the Local Ensemble Transform Kalman Filter (LETKF, Hunt et al., 2007) with 36 ensemble members to assimilate atmospheric temperature profiles and column dust optical depth measurements retrieved from TIRVIM radiance spectra between $L_s = 182.3 - 211.4°$ of MY34.

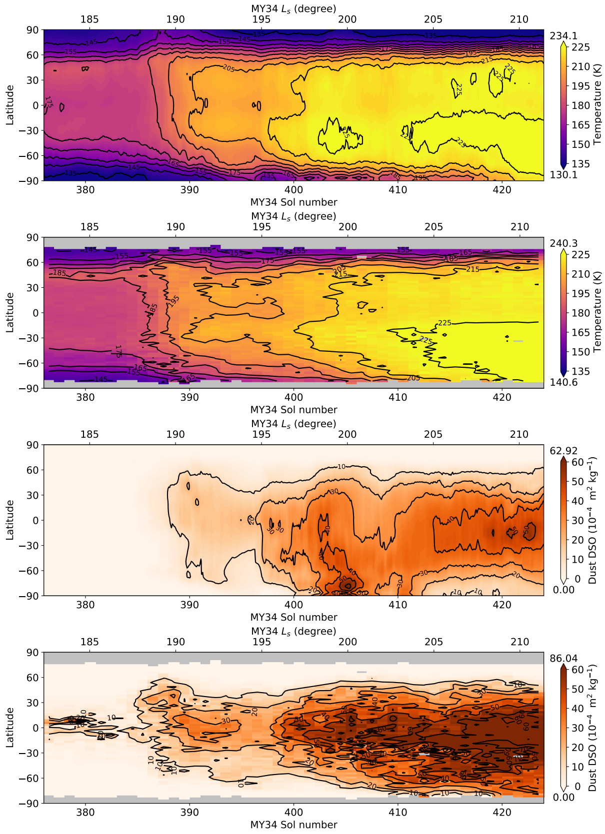

Fig. 2. Hovmöller diagrams at 30 Pa at 3 PM Local Mean Solar Time showing, from top to bottom: temperature analysis, MCS observations, dust density-scaled opacity analysis, MCS dust density-scaled opacity observations.

The model forecasts the atmospheric state every three hours, mapping the temperature forecast to the observation locations and times by using the retrieval averaging kernel matrix and prior to ensure a like-for-like comparison between forecast and observations (Rodgers & Connor, 2003). The observations used are shown in Fig. 1.

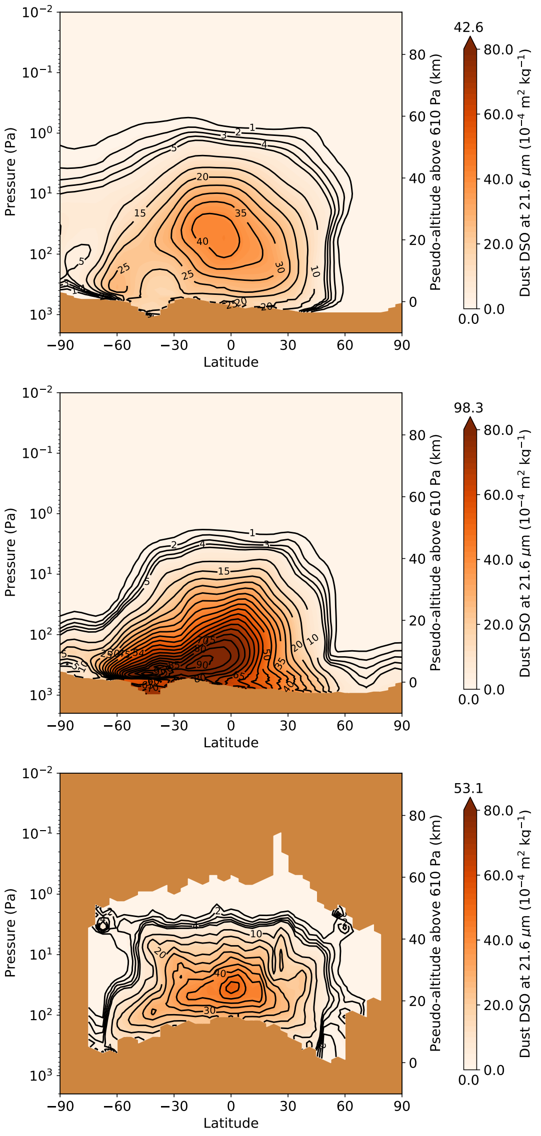

Fig. 3. Vertical section through the dust density-scaled opacity field at 3 AM local time at 21.6 μm, averaged over MY34 sols 416–420, at the peak of the Global Dust Storm. Top is the TuTD-CuD analysis, middle is the GCM ensemble, and bottom are the MCS observations.

The assimilation period began about 5 L_s before the onset of the GDS, and ended shortly after its peak (just before a long gap in the observations). We ran four configurations of the assimilation and model. In run TuTD we assimilated temperature profiles and used them to update the model temperature, as well as dust profiles under certain conditions, by using the Kalman gain for temperature (Navarro et al., 2017). In run TuT-CuD we assimilated temperature profiles to update the model temperature, and column dust opacities to update the dust column and hence the dust profiles. In run TuTD-CuD we did the same as TuT-CuD but also updated the dust profiles (first) based on the Kalman gain for temperature.

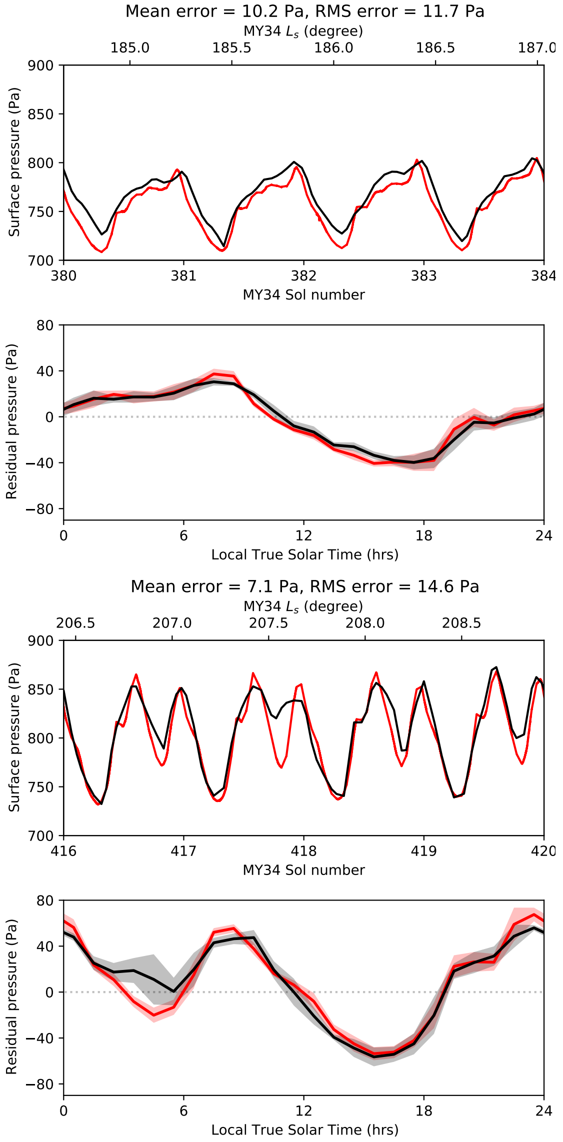

Fig. 4. Time series and diurnal cycle of surface pressure at the Curiosity rover location. Time series are corrected for surface elevation using the pressure scale height based on the temperature at 1 km altitude, and the diurnal cycle is averaged over the corresponding 4-sol period and has the running diurnal mean removed. From top to bottom: Time series and diurnal cycle for analysis TuTD-CuD before the onset of the GDS, (sols 380–384); time series and diurnal cycle for analysis TuTD-CuD at the peak of the GDS (sols 416–420).

In all three cases we used the Kalman gain from the temperature assimilation to update the surface pressure and horizontal velocities. Finally, we ran an ensemble of GCM simulations constrained by column dust optical depth maps based on MCS dust observations (Montabone et al., 2020), the so-called “MY34 dust scenario”.

We verified our analyses against in-sample TIRVIM measurements and independent MCS temperature and dust profiles. Figure 2 shows the TuTD-CuD analysis compared with independent MCS temperature and dust retrievals at 30 Pa. Our reanalysis matched the MCS vertical dust distribution at the peak of the storm particularly well during night-time (Fig. 3). By reconstructing the atmospheric wind field via the assimilation process, we found that at the peak of the storm a strong asymmetry develops in the mid-latitude jets, and the diurnal and semi-diurnal tides change significantly. Finally, we verified the surface pressure analysis against independent Curiosity observations; the diurnal cycle at the Curiosity location (corrected for the surface elevation in the model) is shown in Fig. 4. The work summarised in this abstract is currently under review (Young et al., 2022).

References

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