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Investigation of inter-annual and seasonal variations of the Martian convective PBL by GCM simulations

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Content

Abstract

The Martian planetary boundary layer (PBL) is an important component of the Martian climate. It is the lowest portion of the atmosphere where the strong buoyant and shear forces influence the interaction between surface and atmosphere [Hinson et al., 2008]. The Martian PBL exhibits extreme events compared to the Earth's PBL, such as global dust storms, local dust devils, turbulent gusts and strong updraughts. Due to the thinner atmosphere of Mars and lower surface thermal inertia, the Martian planetary boundary layer shows stronger diurnal variations compared to its terrestrial counterpart. Moreover, as a result of the thinner atmosphere, radiative heat forcing is stronger, such that the Martian planetary boundary layer height can reach up to 10 km. Radiative forcing on Mars is affected by the atmospheric cycles, i.e. CO_2, water and dust cycles. In this study, we perform GCM simulations, using dust climatologies corresponding to the last 11 Mars years and present the inter-annual and seasonal variations in the convective planetary boundary layer height. To perform these GCM simulations, the Mars version of planetWRF (MarsWRF) model [Richardson et al., 2007] is utilized, that solves the fully-compressible, non-hydrostatic Euler equations in a finite difference framework.

Methodology

GCM set-up

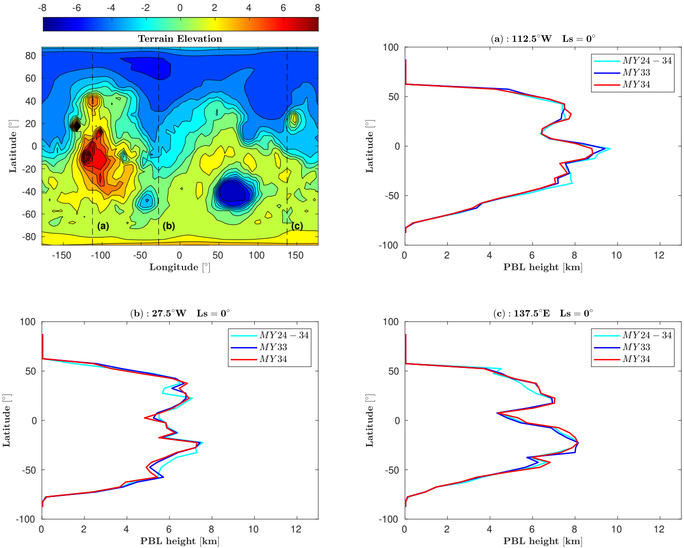
- GCM simulations are performed via MarsWRF model [Richardson et al., 2007]
- The horizontal grid resolution is 5° along the longitude and latitude, having 52 vertical grid layers.
- Mars-specific k-distribution model [Mischna et al., 2012] is used for the shorthwave and longwave radiative transfer.
- Boundary-layer turbulence is parameterized by an algebraic model, i.e. Medium Range Forecast (MRF) scheme [Hong and Pan, 1996]. The convective PBL height is determined as the bulk Richardson number Ri_b exceeds a threshold of 0.5
- Revised MM5 scheme is used for the surface layer modelling [Jiménez et al., 2012].

Description of GCM simulations

- In the present study, we performed 3 different GCM simulations depending on different dust scenarios in terms of the atmospheric dust content, from [Montabone et al., 2015, Montabone et al., 2020].
  - The average of last 11 Martian years between 24-34 $\rightarrow$ MY24-34
  - Martian year 33 $\rightarrow$ MY33
  - Martian year 34 $\rightarrow$ MY34 where a global dust event (GDE) has been observed [Montabone et al., 2020]
- Time integration for each simulation is 2 years where the first year is removed (initial spin-up year).

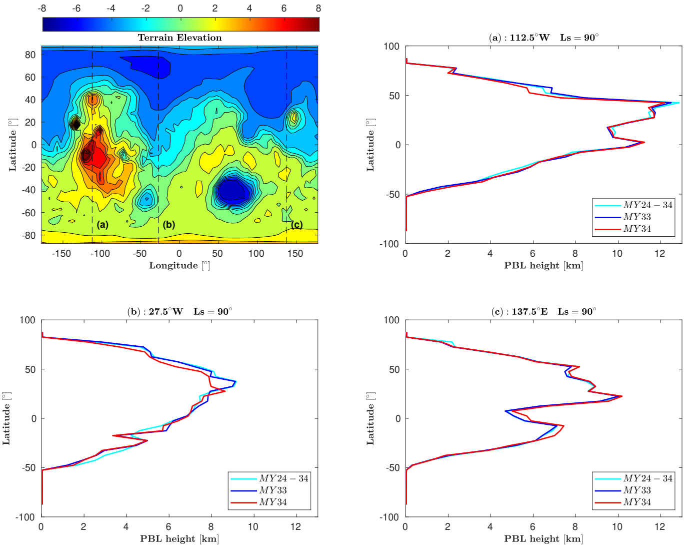
Inter-annual variations of planetary boundary layer height for Ls=0°

For 3 different longitudes: 112.5°W, 27.5°E, 137.5°E at 14:00 LMST



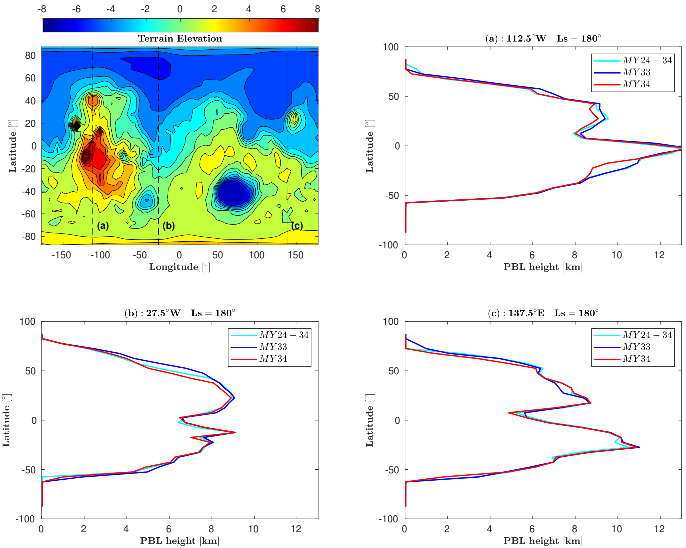
Inter-annual variations of planetary boundary layer height for Ls=90°

For 3 different longitudes: 112.5°W, 27.5°E, 137.5°E at 14:00 LMST



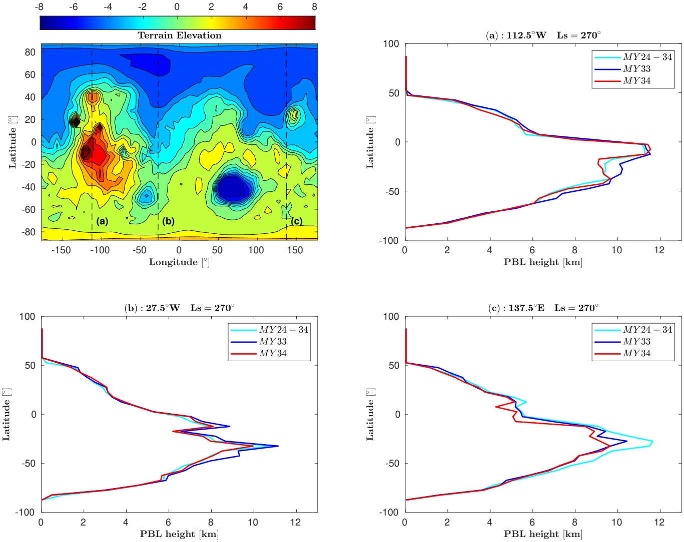
Inter-annual variations of planetary boundary layer height for Ls=180°

For 3 different longitudes: 112.5°W, 27.5°E, 137.5°E at 14:00 LMST



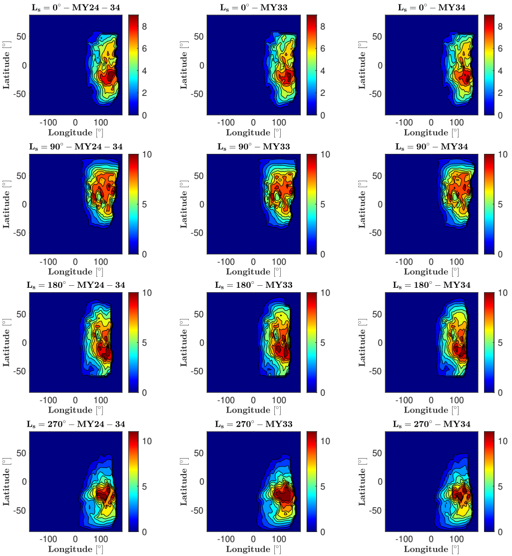
Inter-annual variations of planetary boundary layer height for Ls=270°

For 3 different longitudes: 112.5°W, 27.5°E, 137.5°E at 14:00 LMST



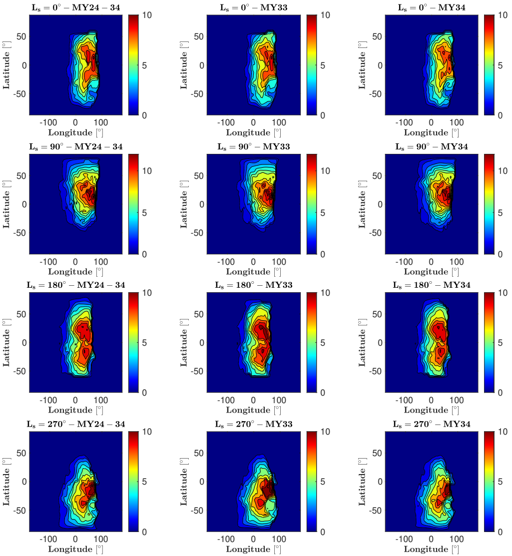
Inter-annual and seasonal variations of planetary boundary layer height

Counter plots are presented for 07:00 MTC



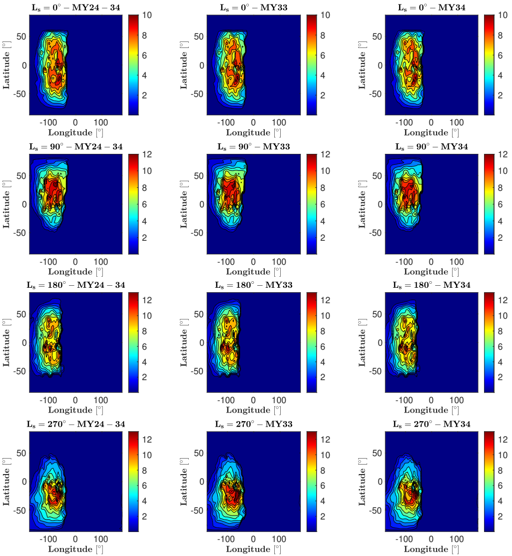
Inter-annual and seasonal variations of planetary boundary layer height

Counter plots are presented for 12:00 MTC

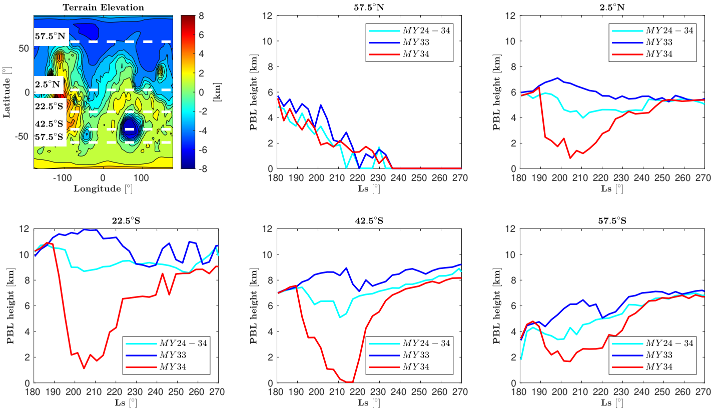


Inter-annual and seasonal variations of planetary boundary layer height

Counter plots are presented for 20:00 MTC



- Inter-annual and seasonal variations during the global dust event at MY34 [Montabone et al., 2020] between Ls=180-270° at 137.5°E for 5 longitudes.



Conclusion

- In the present study, GCM simulations in MarsWRF model [Richardson et al., 2007] are carried out, prescribing three different dust scenarios concerning the last 11 Mars years: (*i*) the average of last 11 years between MY24-34, (*ii*) MY33 and (*iii*) MY34 in which a global dust event has been recorded between the solar longitudes of Ls=180-270° [Montabone et al., 2020].
- GCM runs reveals that the convective PBL height (PBLH), i.e. one of the key characteristics of a planetary boundary layer, is considerably dependent on the seasonal changes, linked to the strength of surface heating and wind shear.
- The depth of convective PBL ranges up to 10 km in overall, consistent with the radio occultation measurements from Mars Express [Hinson et al., 2008]. However, our results show that such extreme values appear (e.g. higher than 12 km) around Tharsis region. This can be related to the existence of mountain waves enhancing the turbulent convection.
- Regarding the inter-annual variations, slight changes appear except for Ls=180-270° where global dust storms arise. This is confirmed by investigating the global dust event recorded at Martian Year 34 where a sharp decrease occurs in the convective PBL height. This is because the presence of dust reduces the surface radiative heating, which in turn weakens the turbulent mixing.

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