

Abstract

Earth's upper mesosphere and lower thermosphere (UMLT) is a dynamic environment where the waves generated from the lower atmosphere are amplified and dominate variabilities at a wide range of scales. The solar migrating diurnal tide (DW1) is one of the most dominant waves in the UMLT that is known to propagate from the lower atmosphere and peak in the UMLT region. Despite recent advances in high-altitude observations, a full understanding of the DW1 in UMLT from observations remains challenging and physics-based models still struggle to simulate tidal variations. In this study, we present the seasonal and QBO variations of the DW1 in temperature, H₂O and CO as simulated by the Specified Dynamics – Whole Atmosphere Community Climate Model – Ionosphere/Thermosphere eXtension (SD-WACCM-X) and as observed by Aura/MLS and TIMED/SABER instruments. Bi-monthly DW1 amplitudes and phases are calculated from TIMED/SABER temperatures profiles. Bi-monthly (1,1) Hough mode regression coefficients are calculated from Aura/MLS temperatures, H₂O and CO profiles. Analyzing the (1,1) Hough mode from H₂O and CO give us more information on the dynamics because these are dynamical tracers at appropriate altitudes in the UMLT region. We analyzed the simulated and observed zonal-mean temperature, H₂O, and O₃ fields, and found that DW1 variabilities are driven by lower atmospheric heating sources and the background atmosphere. Our future work will focus on a comprehensive analysis of thermal, momentum, and tracer budget of the diurnal migrating tide in SD-WACCM-X.

Climatology of diurnal temperature difference

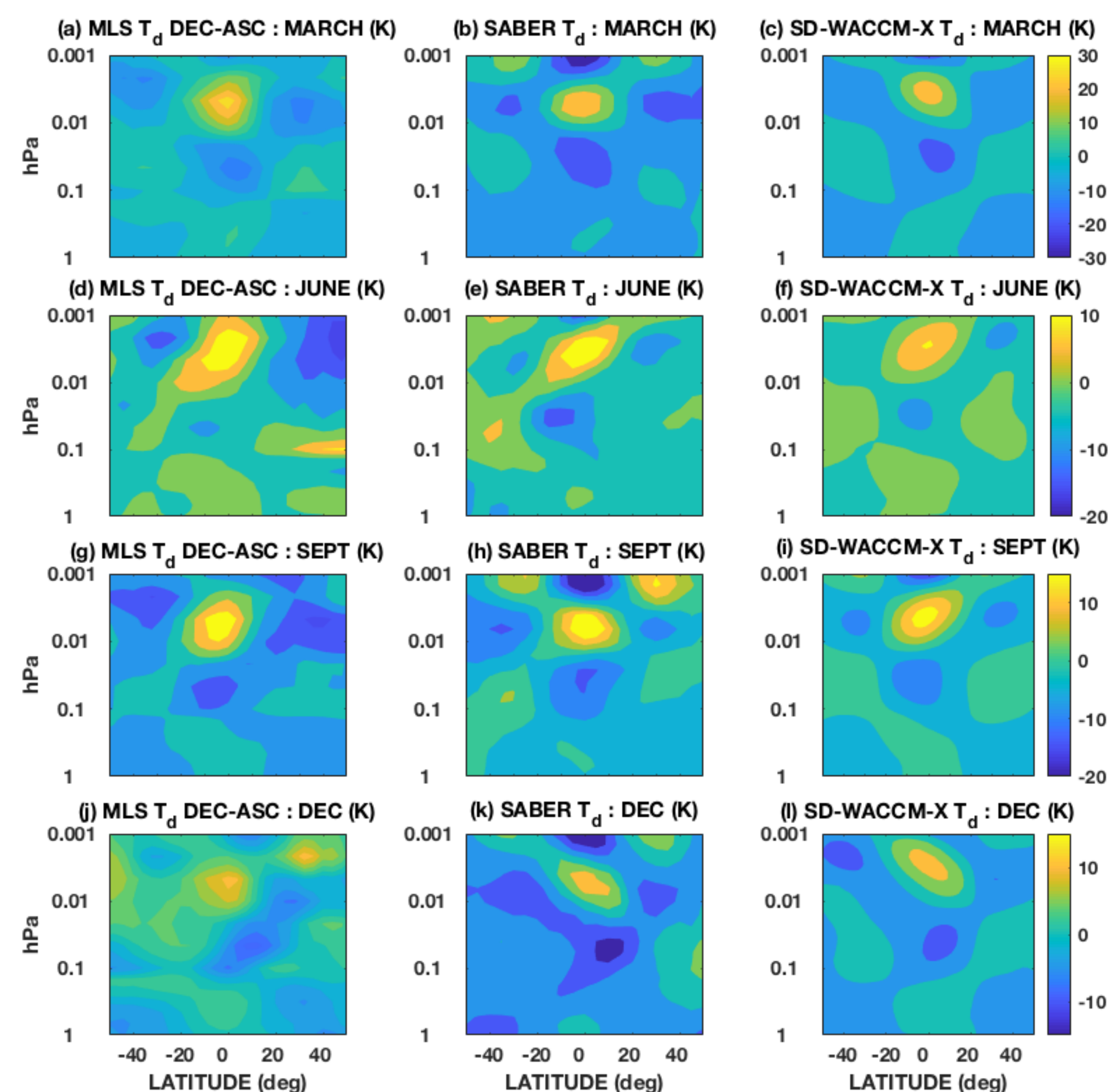


Figure 1. Fifteen year (2005-2019) mean climatology of zonal mean diurnal temperature difference (in K), $T(D-A) = [T_{\text{descending}} - T_{\text{ascending}}]$ from MLS, SABER, and SD-WACCM-X.

Interannual variations of (1,1) mode

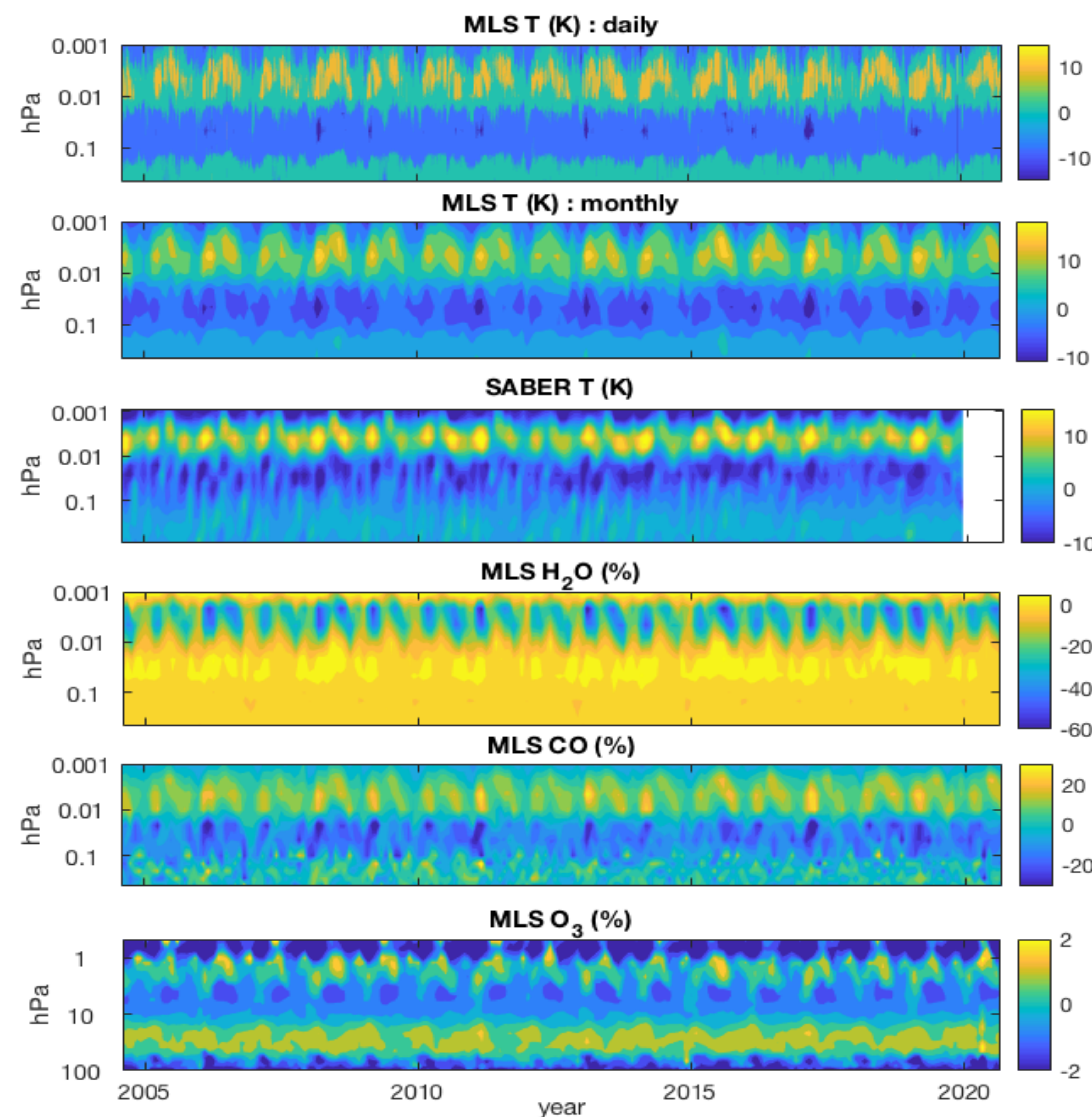


Figure 2. The (1,1) amplitude time series from daily and monthly MLS T (K), and monthly mean SABER T (K), H₂O (%), CO (%), and O₃ (%). The seasonal cycle of the diurnal tide in the mesosphere and its strong semiannual component, and contrast of tidal amplitudes between lower and upper mesosphere are well presented in the time series. In comparison with SABER T amplitudes, MLS T, H₂O, and CO amplitudes positive maxima are located relatively lower than SABER amplitudes.

QBO variations of (1,1) mode

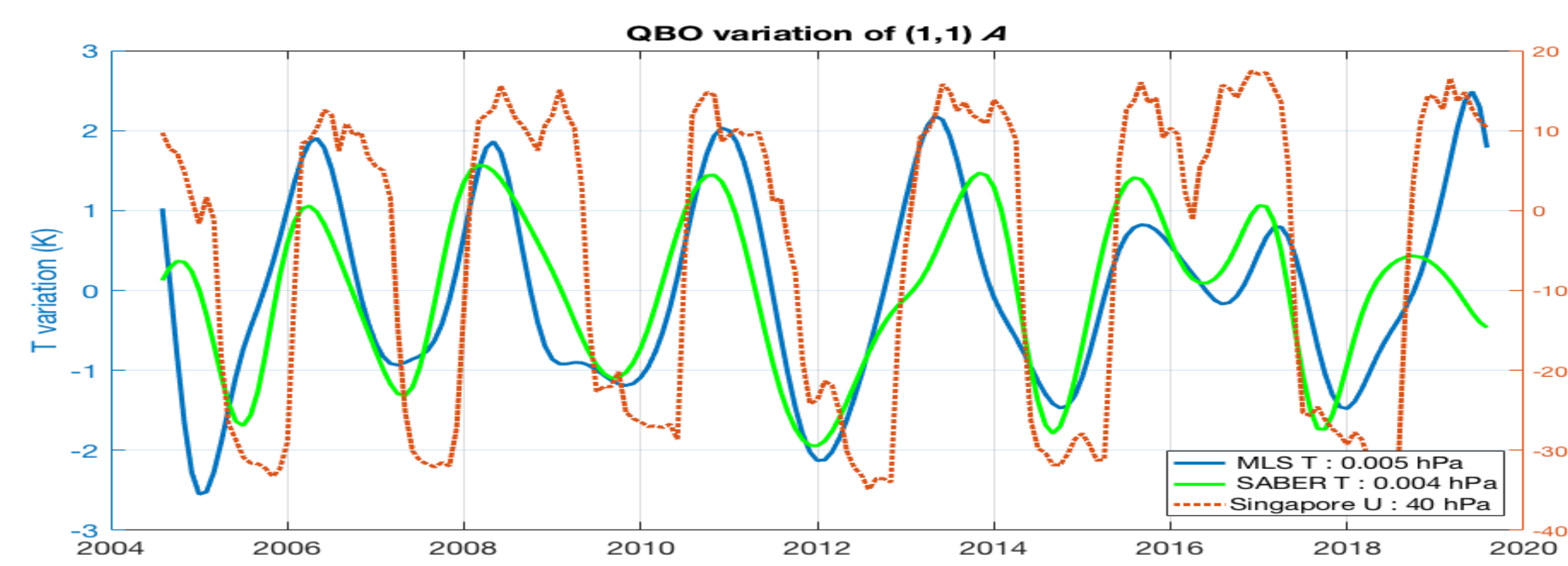


Figure 9. QBO like interannual variations of (1,1) tide amplitudes extracted by EEMD analysis from MLS and SABER temperature data. The overlaid red dot line is a lower stratospheric zonal wind (U (m/s)) at 40 hPa observed from Singapore station.

Ozone and (1,1) mode

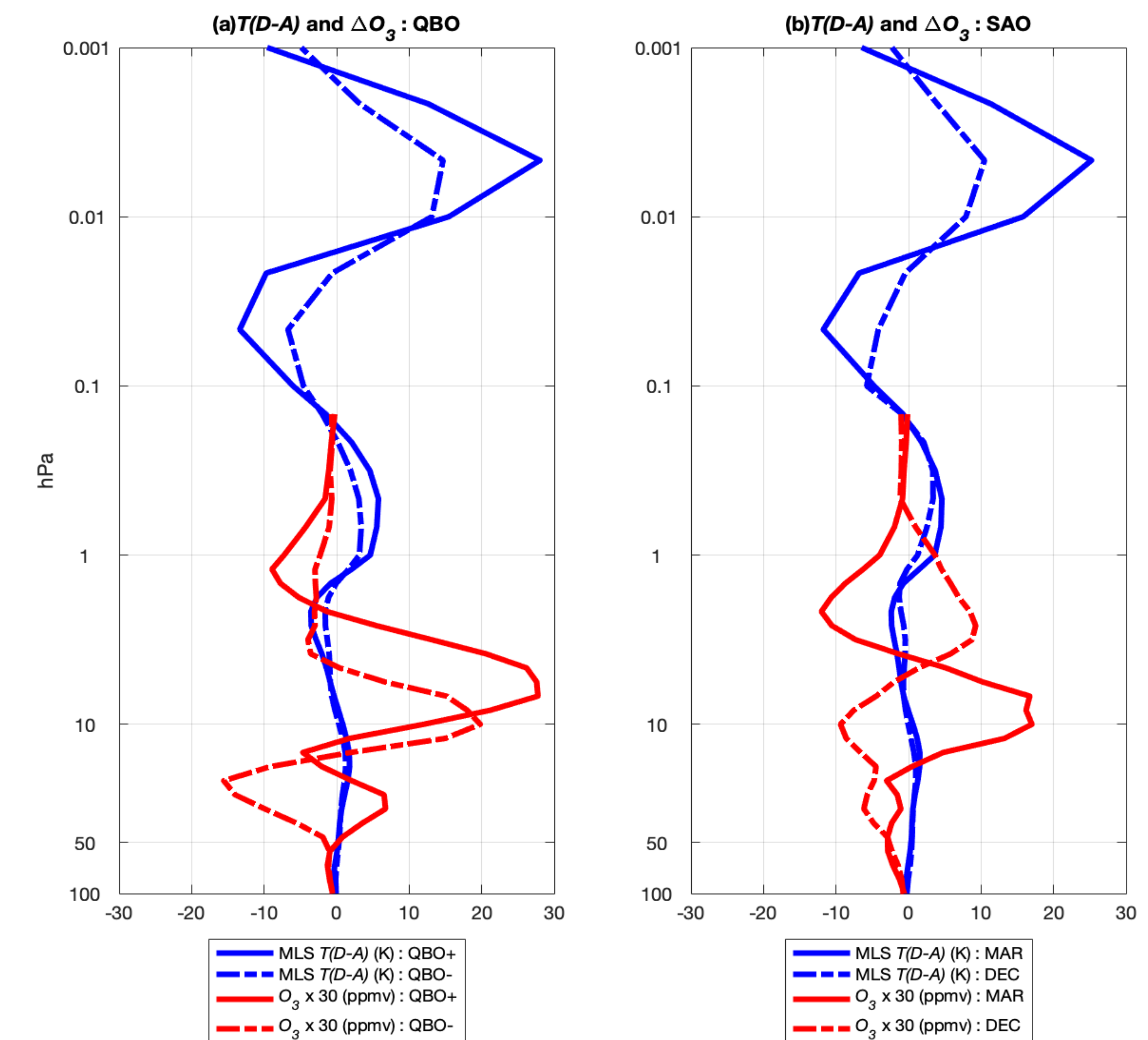


Figure 4. Composites of equatorial MLS $T(D-A)$ (K) and perturbed ozone (ppmv) profiles for (a) QBO+ phase (in blue) and QBO- phase (in blue dots) and for (b) March and December. (a) The difference in the ozone composites shows that there exists more ozone in the stratosphere during QBO+ phase than QBO- phase. (b) During March, diurnal tide SAO maximum, ozone profile shows a positive peak at ~ 10 hPa and a negative peak at ~ 3 hPa. During December, the O₃ profile is an out of phase with that of March by showing a negative peak at ~ 10 hPa and a positive peak at ~ 3 hPa.

SD-WACCM-X contribution

There is a significant improvement in the simulation of SD-WACCM-X on the seasonal variation of the solar migrating diurnal tide (DW1) in MLT temperature, water vapor and CO. Since SD-WACCM-X now satisfactorily simulates the seasonality of DW1, we will utilize the model to untangle the complexity of the physical mechanisms behind the seasonality of DW1 in temperature, water vapor and CO. In particular, the thermodynamic and tracer budgets are analyzed from the model outputs. Our analysis on the thermodynamic budget will determine the contributions of solar forcings (e.g. IR cooling, short-wave heating), gravity wave heating, adiabatic heating/cooling and advection on the seasonality of DW1 in MLT temperatures. Our analysis on the tracer budget will determine the contributions of chemistry, advection and diffusion on the seasonality of DW1 in water vapor and CO.

Please contact Jae.n.lee@nasa.gov for more discussions. Thank you!