Local-time Variations of Low Latitude Lower Thermospheric SABER CO_2 during Equinoctial Solar Minimum

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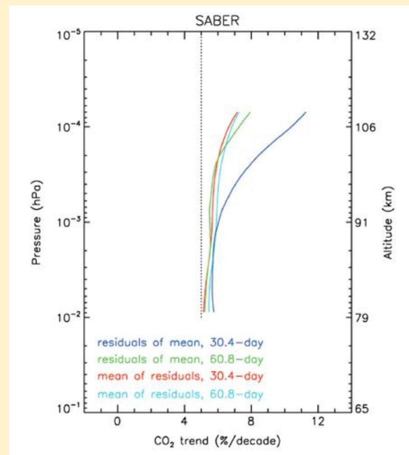
(I) IMPORTANCE OF LOCAL TIME VARIATIONS OF CO_2

Accurate Calculation of Long-term Trend from Satellite-based CO_2 Observations

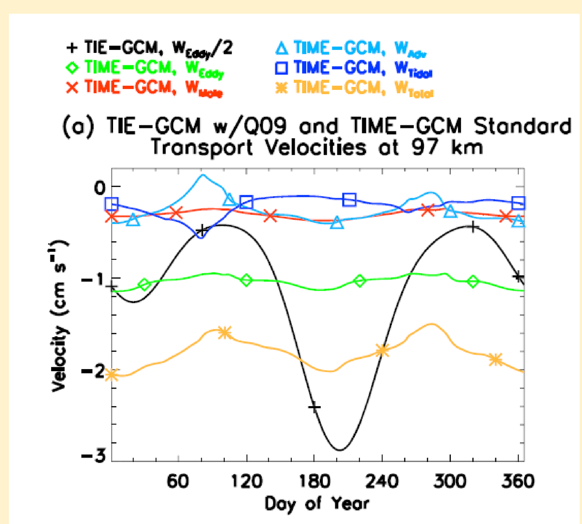
- Long-term trend of SABER CO_2 is dependent on sampling window.
- Dependence in sampling window implies a never before reported local-time variation in SABER CO_2.



[*Qian et al*, 2017]

Untangling Advection and Diffusion in the MLT Region

- Local-time variations in the MLT region are controlled by tides.
- CO_2 is an ideal tracer in the MLT region whose local-time variations can help estimate the complicatedly tangled tide-induced advection and diffusion.



[*Jones et al*, 2017]

Objectives of the Study:

1. To present, explain and model, for the first time, the local time-variations of SABER CO_2.
2. To determine the contributions of advection and diffusion to the local-time variations of SABER CO_2.
3. To relate the local-time variations of SABER CO_2 and SABER temperature via vertical motion.

(II) DATASETS

SABER v2.0 CO_2 and Temperature Profiles

All profiles for March and April 2008 are gridded into local-time and latitude bins. Local-time coverage is between 0600 am to 1800 pm [*Rezac et al*, 2015].

TIME-GCM Model Outputs

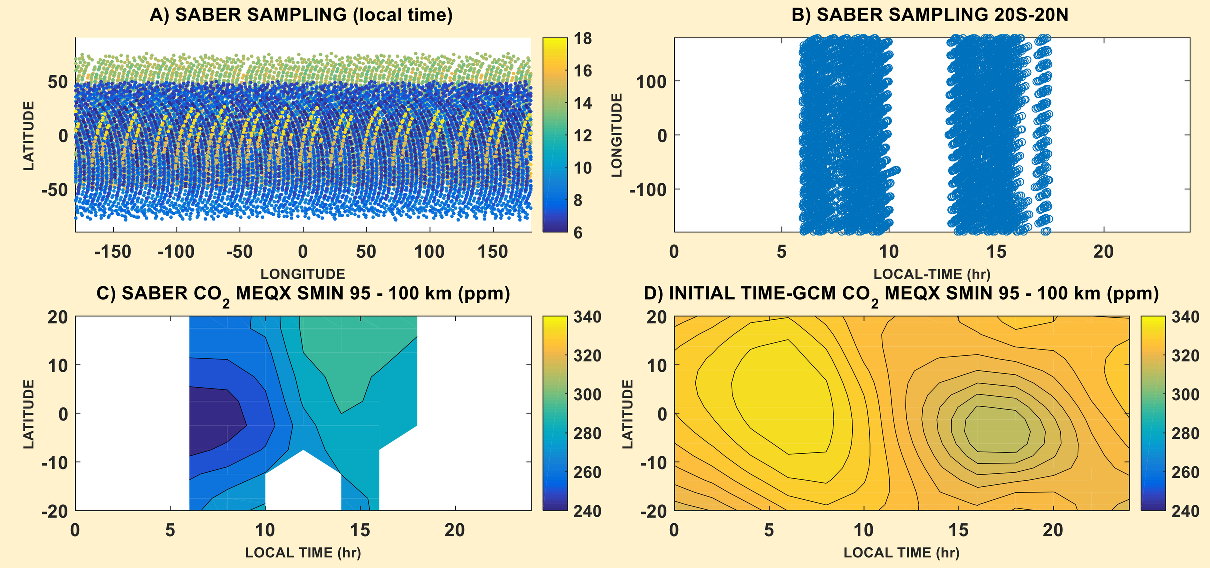
TIME-GCM was ran at double resolution for day 80 under solar minimum and geomagnetically quiet conditions with GSWM migrating diurnal and semidiurnal tides specified at the lower boundary of the model.

SD-WACCM Model Outputs

WACCM nudged with MERRA up to ~50 km. Outputs for March 2008 are used.

(III) LOCAL-TIME VARIATIONS OF SABER CO_2 AND ITS PHYSICAL MECHANISMS: TENDENCY ANALYSIS WITH TRANSFORMED EULERIAN MEAN (TEM) AND 3D CONTINUITY EQUATION FOR CO_2

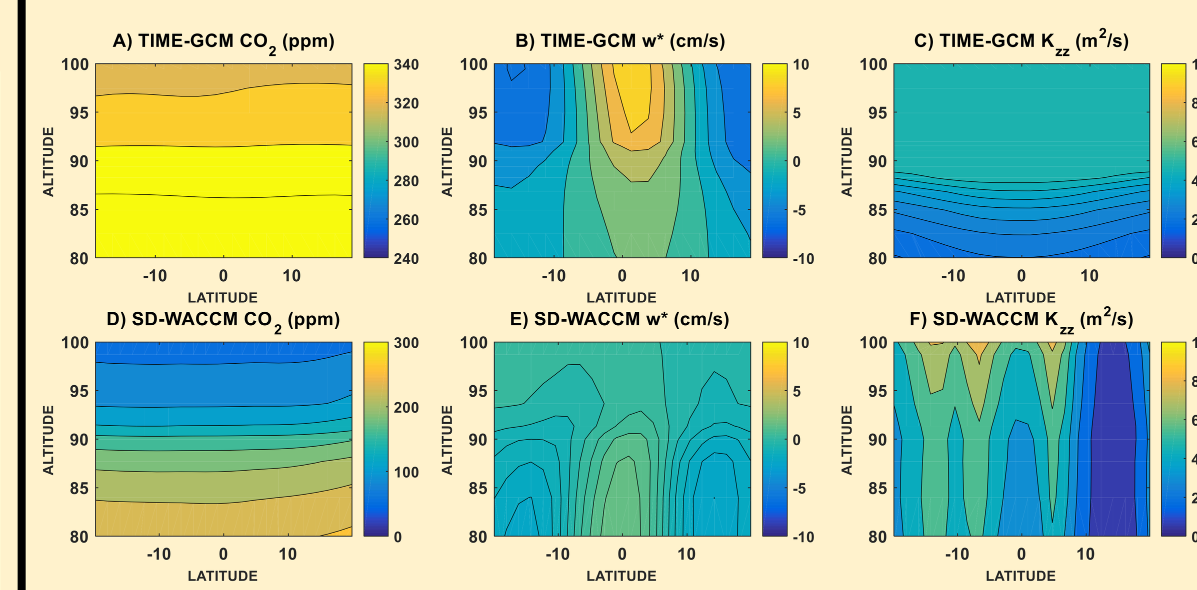
(A) SABER CO_2 vs TIME-GCM CO_2



HIGHLIGHTS

- SABER CO_2 has local min in morning and local max in afternoon.
- TIME-GCM CO_2 local-time variation is opposite of SABER CO_2.
- Zonal-mean TIME-GCM CO_2 is higher than zonal-mean SABER CO_2.

(B) PHYSICAL MECHANISM OF ZONAL-MEAN CO_2

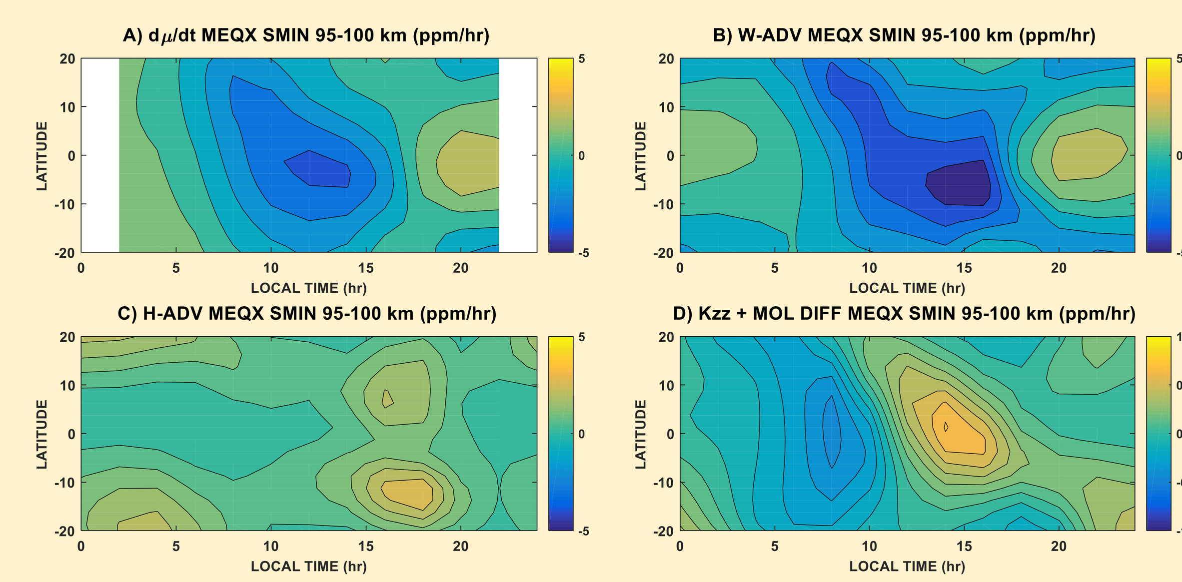


HIGHLIGHTS

- Zonal-mean TIME-GCM CO_2 is predominantly controlled by TEM vertical advection.
- TIME-GCM CO_2 has higher zonal-mean because of the presence of TEM upwelling.
- SD-WACCM zonal-mean CO_2, and TEM circulation are more realistic.

$$\frac{\partial\bar{\mu}}{\partial t}+\frac{\bar{v}^*}{a}\frac{\partial\bar{\mu}}{\partial\phi}+\bar{w}^*\frac{\partial\bar{\mu}}{\partial z}-\overline{\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0K_{zz}\frac{\partial\mu}{\partial z}\right)}-\overline{\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0D_{\mu}\frac{\partial\mu}{\partial z}\right)}+\overline{\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0\mu w_D\right)}=0$$

(C) PHYSICAL MECHANISM OF LOCAL-TIME VARIATIONS IN CO_2

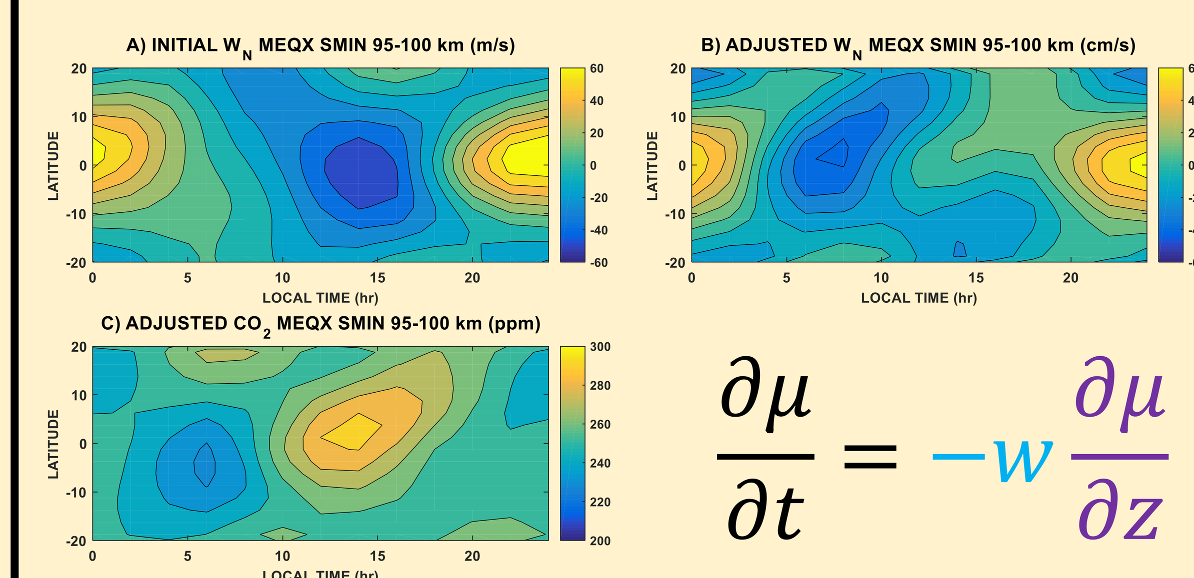


HIGHLIGHTS

- Local-time variations of low latitude lower thermospheric SABER CO_2 are predominantly controlled by vertical advection.
- Vertical motion values can be derived from low latitude lower thermospheric CO_2 during equinox.

$$\frac{\partial\mu}{\partial t}+\left(\frac{u}{a\cos\phi}\right)\frac{\partial\mu}{\partial\lambda}+\left(\frac{v}{a}\right)\frac{\partial\mu}{\partial\phi}+w\frac{\partial\mu}{\partial z}-\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0K_{zz}\frac{\partial\mu}{\partial z}\right)-\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0D_{\mu}\frac{\partial\mu}{\partial z}\right)+\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0\mu w_D\right)=0$$

(D) SIMPLIFIED TRANSPORT MODELING OF SABER CO_2



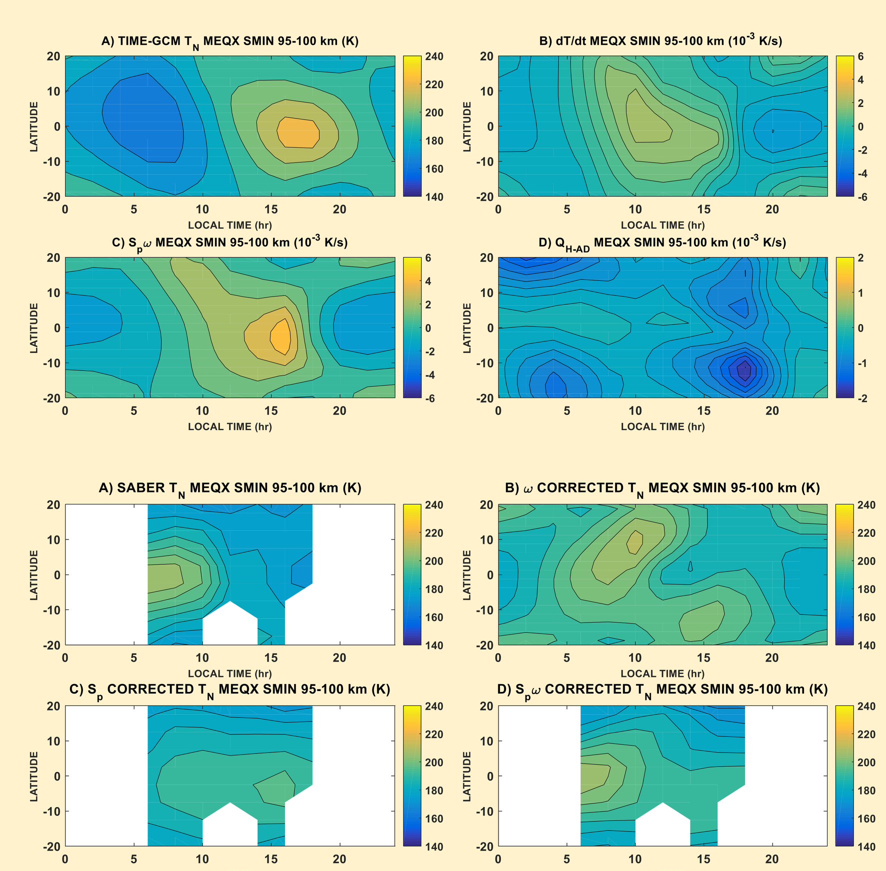
$$\frac{\partial\mu}{\partial t}=-w\frac{\partial\mu}{\partial z}$$

HIGHLIGHTS

- SD-WACCM monthly-mean CO_2 and adjusted TIME-GCM vertical velocity is used as input into our simplified transport model (STM).
- STM captured general features of the local-time variations of SABER CO_2

$$w=\bar{w}+w'_{DW1}\cos\left(\frac{2\pi t}{24}-\psi_{DW1}\right)+w'_{SW2}\cos\left(\frac{2\pi t}{12}-\psi_{SW2}\right)+w'$$

(IV) SABER CO_2 vs SABER T_n



HIGHLIGHTS

$$\left[\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right]+\frac{S_p w\rho_0}{g}=\frac{J}{c_p}$$

Vertical motion significantly affects low latitude lower thermospheric temperatures. This enables relating the SABER CO_2-derived vertical motions to SABER temperatures.

$$\frac{\partial T}{\partial t}=-\frac{wS_p\rho_0}{g}$$

Local-time variations of SABER CO_2-derived vertical velocity and SABER T_n-derived static stability and neutral density induces general features of the local-time variations of SABER T_n. Local-time variations of SABER CO_2 is consistent with that of SABER T_n.

(V) DISCUSSIONS AND CONCLUSION

Upper Atmosphere Climate Change:

- SABER CO_2 has a significant local-time variations that needs to be accounted for in calculating long-term trends. The significant local-time variations of CO_2 may help explain recently suggested local-time variations in upper atmosphere trends [*Danilov*, 2015].

Tide-induced Advection and Diffusion

- To simulate the local-time variations of SABER CO_2, TIME-GCM TEM vertical velocity above 95 km needs to be weakened while the local-time variations of vertical velocity need to be adjusted. Eddy diffusion plays a minor role.
- Local-time variations of SABER CO_2-derived vertical velocity also drives the local-time variations of SABER T_n. Local-time variations of SABER T_n are well accepted [*Zhang et al*, 2006; *Mukhtarov et al*, 2009; *Pancheva et al*, 2009; *Xu et al*, 2009; *Sakazaki et al*, 2012].

This work concludes that there is a significant local-time variation in low latitude lower thermospheric SABER CO_2 during equinoctial solar minimum that is driven predominantly by TEM and tide-induced vertical advection.