Impact of SABER CO_2-based Eddy Diffusion Coefficients in the Mesosphere and Lower Thermosphere (MLT) on the Ionosphere/Thermosphere (I/T) Region

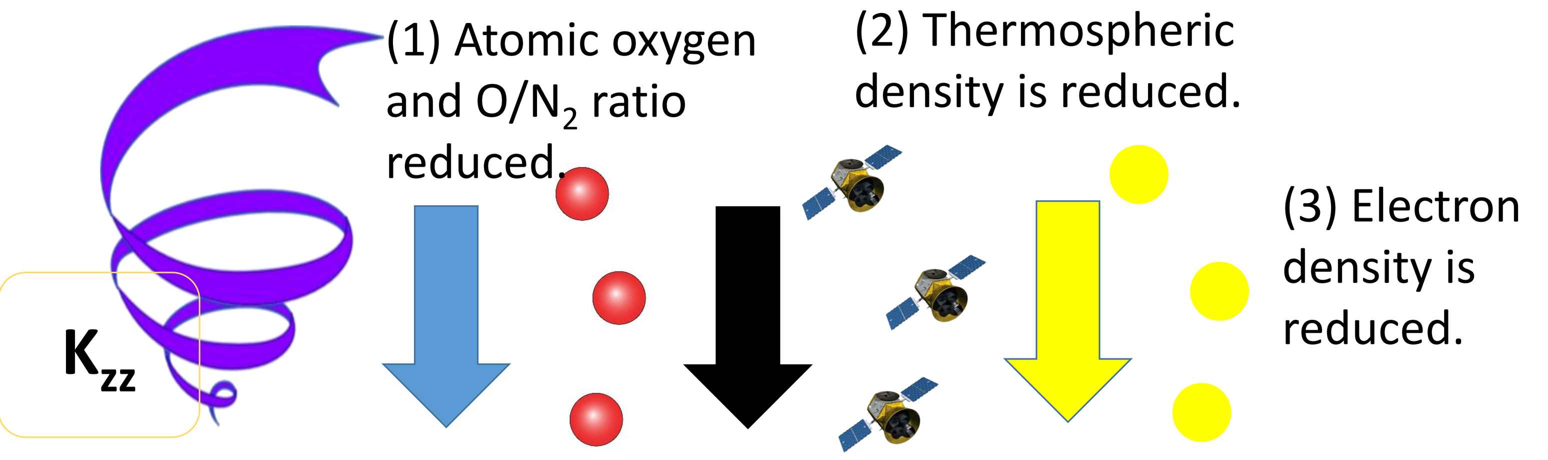
Cornelius Csar Jude Hisole Salinas[1,2,*], Loren C. Chang[1,3], Mao-Chang Liang[1,4], Jia Yue[5,6], James Russell III[5] and Martin Mlynczak[7]

[1]Taiwan International Graduate Program- Earth Systems Science, Academia Sinica, Taipei, Taiwan; [2]Department of Atmospheric Sciences, National Central University, Zhongli, Taiwan; [3]Graduate Institute of Space Science, National Central University, Zhongli, Taiwan; [4]Research Center for Environmental Change, Academia Sinica, Taipei, Taiwan; [5]Hampton University, Hampton, Virginia, USA; [6]ESSIC, University of Maryland, USA; [7]NASA Langley Research Center, Hampton, Virginia, USA

[*]corresponding author: ccjsalinas@gmail.com

I. Proposed Effect of K_{zz} in MLT on Global-mean I/T Region

Eddy diffusion coefficients (K_{zz}) is a parameterization for gravity wave breaking [*Lindzen*, 1981]. *Qian et al* [2009, 2013] successfully fitted observational and modeled Annual (AO) and Semi-annual Oscillation (SAO) of global-mean I/T region by adjusting K_{zz} in the model (TIE-GCM) lower boundary (97 km). **PROPOSED MECHANISM:**



PROBLEMS:
1. **Will K_{zz} estimated using other methods also fit observational and modeled AO and SAO of I/T region?**
2. **Proposed mechanism has other possible sources in the lower atmosphere ranging from different wave-breakings to different wave-wave interactions.**

II. Objectives of the Study

1. **To estimate eddy diffusion coefficients from CO_2 profiles.**

Global-mean CO_2 is chemically inert in the MLT region and is an ideal tracer for eddy diffusion due to gravity wave breaking. [*Lopez-Puertas et al*, 2000; *Garcia et al*, 2014]

2. **To determine its impact on the global-mean I/T region.**

III. Estimate K_{zz} due to gravity wave breaking using CO_2 profiles

✓ **Use global-mean CO_2 profiles.**

SABER/TIMED CO_2 Profiles [*Rezac et al*, 2015] in the MLT region encompassing latitudes 50S to 50N and local times 0800 to 1800 LT are used to calculate global mean CO_2 profiles per month from January 2003 to December 2012.

✓ **Use 1D model with vertical velocity set to zero.**

By setting vertical velocity to zero, all vertical motion is attributed to molecular and eddy diffusion (K_{zz}). A 1D photochemical and transport model [*Allen et al*, 1981] is used. It solves the continuity equation of mass from 0 to 130 km:

$$\frac{\partial \mu_i}{\partial t} + \frac{\partial \phi_i}{\partial z} = P_i - L_i$$

For $w_i = 0$, the vertical flux is given as:

$$\phi_i = -\frac{d\mu_i}{dz}(D_i + K_{zz}) - \mu_i\left[\frac{D_i}{H_i} + \frac{K_{zz}}{H_{atm}}\right] - \frac{\mu_i dT}{dz}\left[\frac{(1+\alpha_i)D_i + K_{zz}}{T}\right].$$

✓ **Model each global-mean CO_2 profile by modifying model CO_2 lower boundary with observed value and by modifying 1D model K_{zz}.**

Simple iterative algorithm is used in adjusting K_{zz} in model until general features of CO_2 profile is captured.

IV. Annual and Semi-annual Oscillation in MLT global-mean CO_2 and CO_2-based K_{zz}

HIGHLIGHTS:

- **There is an AO and SAO in global-mean CO_2.**
- **AO and SAO in global-mean CO_2 is modeled by AO and SAO in K_{zz} which is consistent with past studies.**
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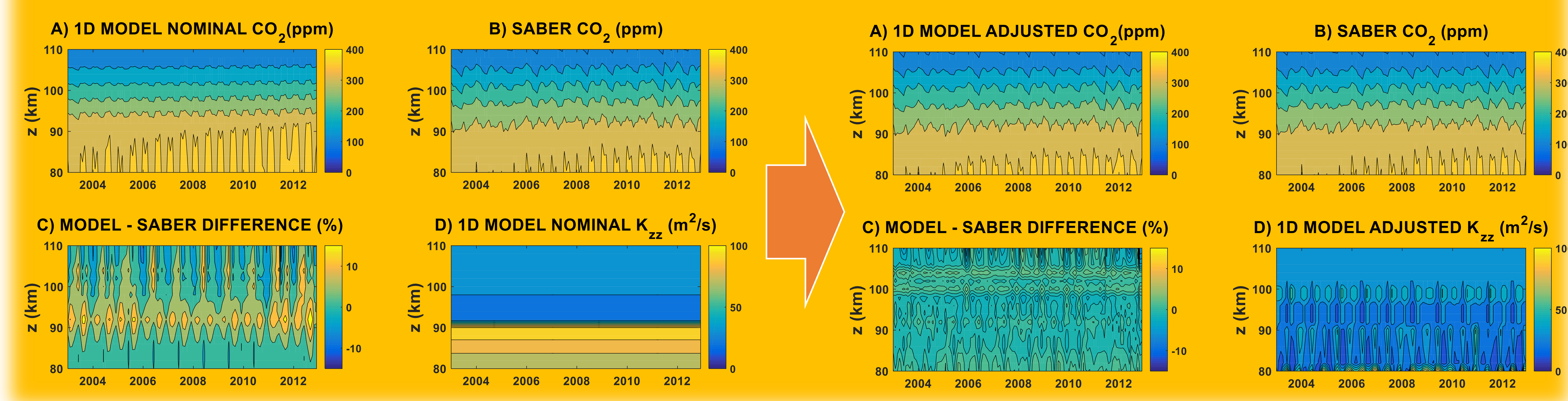
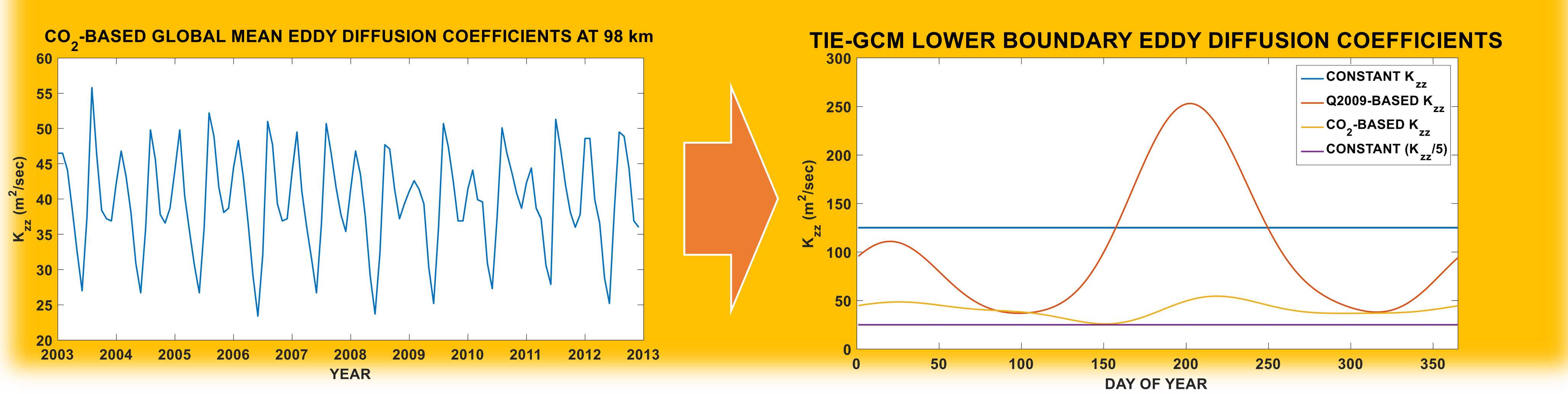
- **Percent differences improved from 10% to 5% when K_{zz} in model is adjusted.**

Adjust CO_2 concentration lower boundary: **Adjust K_{zz} profile:**



V. Estimated Contribution of Gravity Waves and Tides to the Annual and Semi-annual Oscillation in the global-mean I/T region.

Use least-squares fit to estimate seasonal coefficients of CO_2-based K_{zz}:



HIGHLIGHTS:

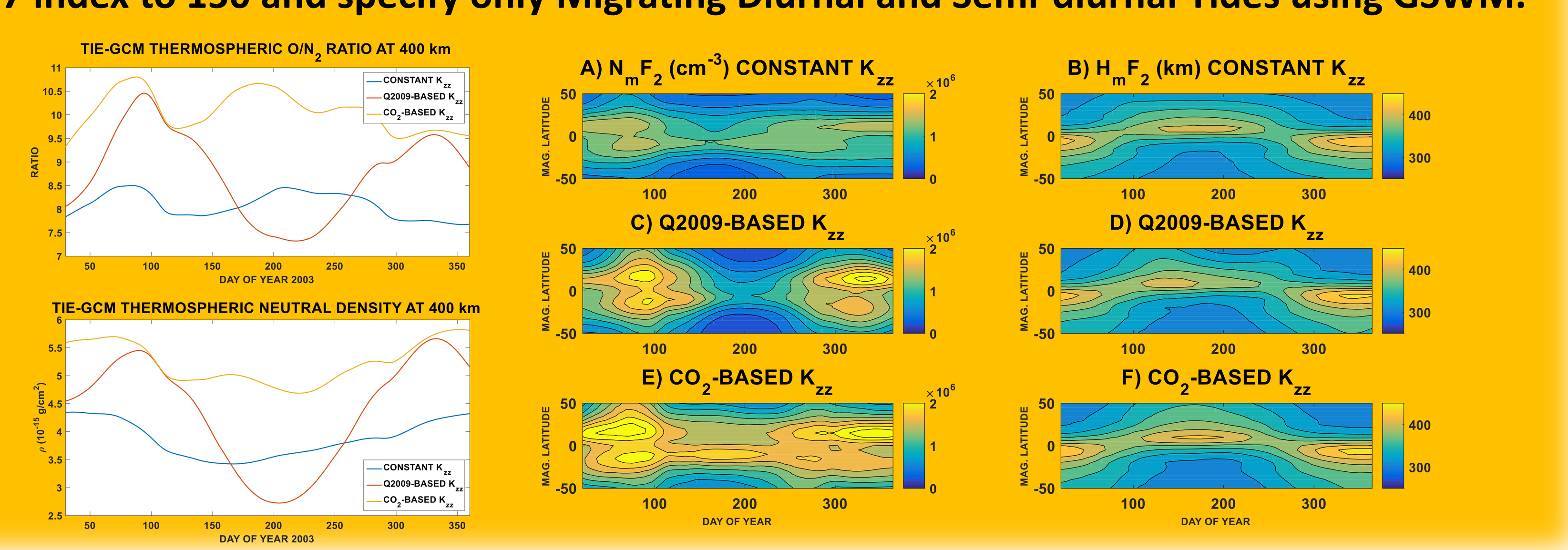
- **CO_2-based K_{zz} is similar to K_{zz} in TIE-GCM with migrating and non-migrating tides specified [*Siskind et al*, 2014].**
- **CO_2-based K_{zz} is similar to K_{zz} in SD-WACCM with gravity wave parameterization [*Garcia et al*, 2014].**

VI. Impact of Gravity Wave Breaking on the Annual and Semi-annual Oscillation in the I/T region.

HIGHLIGHT:

- **CO_2-based K_{zz} specified in TIE-GCM lower boundary cannot model the annual and semi-annual oscillation of the global-mean I/T region.**

Use Thermosphere-Ionosphere Electrodynamics – GCM (TIE-GCM) to simulate O/N_2 ratio (at 400 km), thermospheric neutral density (at 400 km), NmF2 and HmF2 using CO_2-based K_{zz}. Set F10.7 index to 150 and specify only Migrating Diurnal and Semi-diurnal Tides using GSWM.



VII. Conclusions

- **Our work builds on *Qian et al* [2009] by suggesting an estimate of eddy diffusion possibly solely due to gravity wave breaking.**
- **Our work suggests that eddy diffusion due to gravity wave breaking is insufficient in driving AO and SAO in global-mean I/T region.**

VIII. Future Works

- **Estimate seasonal and latitudinal variation of the vertical transport time-scales of eddy diffusion due to gravity wave breaking in the MLT region.**
- **Analyze the inter-annual variations of global-mean CO_2 and CO_2-based K_{zz} in the MLT region.**
- **Calculate climatological trend of K_{zz} in the MLT region.**

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