RC3 Comments

Specific Comments:

1. The title could be made more informative by indicating the specific updates or changes that the paper addresses. As written, it is hard to guess the details of the study contained in the paper.

Changed to "Atmospheric Chemistry Experiment (ACE) v.5.3 Winds: Validation and Model Comparisons"

2. Overall, the introduction currently reads as a list of different datasets and models that describe winds across various atmospheric regions. As written, it is somewhat difficult for the reader to discern the main focus of the paper. Certain details—such as the spatial resolution of specific models—feel out of place for an introduction, while broader contextual framing is missing. The introduction should more clearly establish what this paper contributes and why it matters within the broader landscape of neutral wind research.

Made some large changes here. Removed "duplicate" examples to condense this section. Duplicate meaning different instruments that used similar techniques and/or covered the same region. The emphasis is that ACE provides wind data across all the ranges covered by the other instruments, and that it is still operating after 20 years. Also moved details unnecessary in the introduction about the models to their respective sections.

The changes in the introduction now reads as:

"Wind measurements by ACE are taken from the lower stratosphere through the lower thermosphere; however, most instruments only cover a small altitude range in comparison. Horizontal wind speeds are available in the troposphere and lower stratosphere through measurements from airplanes (Khelif et al., 1999) and balloons (Duruisseau et al., 2017; Kumer et al., 2014), ground-based lidar (Martner et al., 1993), and satellite lidar from the ADM-Aeolus (Atmospheric Dynamics Mission Aeolus) (Stoffelen et al., 2005; Lux et al., 2020). Ground-based lidar measurements have also been successful in the middle atmosphere (Baumgarten, 2010; Liu et al., 2002). Vector wind measurements in the upper mesosphere lower thermosphere (UMLT) can be recorded from space using Doppler shifts in airglow lines such as from atomic oxygen. A current example of this is ~~Examples of this are~~ the TIMED Doppler Interferometer (TIDI) instrument on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite (Killeen et al., 2006). Previously, the ~~and previously from the~~ Michelson Interferometer for Global-High-resolution Thermospheric Imaging (MIGHTI) instrument on the Ionospheric Connection Explorer (ICON) satellite used a similar technique. (Englert et al., 2017).~~ and the Wind Imaging Interferometer (WINDII) on the Upper Atmosphere Research Satellite (UARS)~~

~~\citep{shepherd1993}. Also on UARS,~~ On Upper Atmosphere Research Satellite (UARS), the High Resolution Doppler Imager (HRDI) used O_2 emission to measure winds in the UMLT (Hays et al., 1994; Grassl et al., 1995). Ground-based meteor radar (Liu et al., 2002; Tang et al., 2021) can also provide winds in the mesosphere. Line-of-sight winds near the mesopause have also been derived from the Doppler shift in O_2 emission lines by the Microwave Limb Sounder (MLS) instrument on the Aura satellite (Wu et al., 2008). ~~Note that, since many of these missions are inactive, ACE winds are especially valuable in this region.~~ Since many of the missions mentioned are inactive, only measure a portion of the altitudes ACE covers, or only cover a small portion of the globe, the line-of-sight winds from ACE are especially valuable.

~~There have previously been technical issues preventing wind measurements in the middle atmosphere (around 30$~$\unit{km} to 70$~$\unit{km}) \citep{baumgarten2010, rufenacht2018}. There has been some success with ground-based lidar \citep{baumgarten2010, liu2002} and microwave Doppler wind radiometers \citep{kumar2015}, but only up to the lower stratosphere. Sounding rockets \citep{schmidlin1985} can be used but are expensive and do not provide continuous measurements over long periods of time. Ground-based meteor radar \citep{liu2002, tang2021} can also provide winds in the mesosphere. There have been successful space-based missions that have provided line-of-sight winds in the middle atmosphere, such as the Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment flown on the Spacelab 3 shuttle \citep{vanCleef1987} and the Superconducting Submillimeter-Wave Limb Emission Sounder (SMILES) mission \citep{baron2013} on the International Space Station.~~

In this work, three wind datasets are directly compared to the new v.5.3 of ACE winds. The Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) produced by NASA's Global Modeling and Assimilation Office (GMAO) is an atmospheric reanalysis model based on modern satellite observations. MERRA-2 provides various data collections that contain information about many climate indicators, including atmospheric wind speeds. An ~~in depth~~ in-depth explanation of the model is available from Gelaro et al. (2017). MERRA-2 uses the Goddard Earth Observing System (GEOS) atmospheric model (Rienecker et al., 2008; Molod et al., 2015) and the Gridpoint Statistical Interpolation (GSI) analysis scheme (Kleist et al., 2009). ~~The model uses a cubed-sphere horizontal discretization giving an approximate resolution of $0.5\degree \times 0.625\degree$ and 72 hybrid-eta (altitude) levels \citep{putman2007}. These levels reach from the surface up to $0.01$$~$\unit{hPa} (around 75$~$\unit{km}) \citep{gelaro2017},~~ The model reaches to near 75 km, overlapping with ~~which overlaps~~ the lower half of ACE data.

Horizontal Wind Model Version: 2014 (HWM14) is an empirical climatology model of horizontal winds ranging from the troposphere up through the thermosphere. A detailed description of the climatology is available from Drob et al. (2015). ~~The model began as HWM87 \citep{hedin1988} and has had multiple iterations since, each time adding more data from new instruments \citep{drob2015, hedin1996, drob2008}. The newest version, HWM14,~~ HWM14 uses 73 x 10^6

observation measurements from 44 different instruments and a set of spherical harmonics to provide a statistical view of vector winds ranging from near the surface up to 1000 km. Because HWM14 is an empirical climatology, vector winds can be found for any given latitude and longitude.

The Whole Atmosphere Community Climate Model with thermosphere and ionosphere eXtension (WACCM-X) is produced by the National Center for Atmospheric Research (NCAR). WACCM-X is a comprehensive numerical model of the whole atmosphere, ranging from Earth's surface up to around 700 km (Liu et al., 2018). The model is an altitude extension of WACCM6 (Gettelman et al., 2019), which reaches up to ~140 km. WACCM outputs many climate and weather data products and is unique in that the model can be coupled with others to include ocean, sea ice, and land components.

Using CESM2 as a framework, WACCM is a mesh of NCAR projects: High Altitude Observatory (HAO) in the upper atmosphere, Atmospheric Chemistry Observations & Modeling (ACOM) in the middle atmosphere, and Climate & Global Dynamics (CGD) in the lower atmosphere. ~~*WACCM-X provides global vector winds on a $1.9\degree \times 2.5\degree$ grid.*~~*"*

The changed MERRA-2 section now reads as:

"MERRA-2 provides instantaneous 3-dimensional 3-hourly horizontal vector winds. The model uses cubed-sphere horizontal discretizations, giving an approximate resolution of 0.5° x 0.625° and 72 hybrid-eta (altitude) levels ~~*(Putman and Lin, 2007). The model is*~~ *that are best constrained up to ∼ 40 km, but extend~~s~~ up to ∼ 70 km (Putman and Lin, 2007). Because the model is a reanalysis, we …"*

The changed WACCM-X section now reads as:

"Specified Dynamics WACCM-X Version 2.2 provides global vector winds in 3 hour intervals on a 1.9 ◦ × 2.5 ◦ 300 grid. This SD version of WACCM-X uses observational data to produce wind speeds closer to the actual atmospheric state. WACCM-X vector winds were compared with ACE-FTS line-of-sight winds for all of 2019 in a similar fashion as HWM14…."

3. In the discussion of Figure 2, a brief description of the satellite's orbit and precession would also help orient readers attempting to interpret the figure.

Added clarity to this in the introduction of the paper. Now reads as: "The Atmospheric Chemistry Experiment (ACE) mission on board the Canadian satellite SCISAT is used for remote sensing Earth's atmosphere (Bernath et al., 2005; Bernath, 2017). The SCISAT satellite operates in a low Earth near polar orbit with an inclination of 73.9°. The ACE mission uses limb geometry …"

4. Lines 200–201: The terms "similar agreement" and "better agreement" should be supported with quantitative similarity metrics rather than qualitative, visual judgments. This comment applies throughout the paper wherever such comparisons are discussed. Since a quantitative comparison was performed for the MERRA-2 results, a comparable level of quantitative analysis would also be expected for the MIGHTI, meteor radar, and other model comparisons.

Added figures similar to the MERRA-2 bias plot (Fig.9 in preprint) for the other models and instruments. Have also adjusted / added text accordingly.

Changes to MIGHTI text:
"The sunset comparison shows good agreement for both versions from 90 to 110$~$\unit{km} and then deviates. ~~There is a sunrise (sunset) bias of around $+15$$~$\unit{m/s} ($-15$$~$\unit{m/s}), shown in pink in Fig. \ref{fig:MIGHTIdataset2}.~~
We are also able to derive a sunrise-sunset bias with this comparison. To do this, we shift the MIGHTI altitude to the nearest ACE altitude (maximum of ±0.5 km) and find the difference between ACE and MIGHTI wind speeds. The differences are then averaged at each altitude over all occultations in Data Set 2 and the results are shown in Fig. 5(a) for v.5.2 and (c) for v.5.3. We then subtract the sunrise and sunset averages from the total average to find the bias. The average bias at each altitude is displayed in Fig. 5(b) for v.5.2 and (d) for v.5.3. We find that the sunrise (sunset) bias for v.5.2 is generally within ±5 m/s of the previously found -15 m/s (+15 m/s) up to 120 km. The bias for v.5.3 is within ±2 m/s of the -15 m/s (+15 m/s) bias up through the same altitude. The sunrise-sunset bias is shown in pink in Fig. 4."

Changes to Meteor Radar text:
For the sunrises, we again see well matching profiles. The sunsets we see general agreement but with ACE showing more prominent features. ~~The sunrise (sunset) bias of about $+15$$~$\unit{m/s} ($-15$$~$\unit{m/s}) is evident in this comparison.~~
"Similar to Fig. 5 for MIGHTI, we display the average sunrise-sunset bias when comparing with meteor radar in Fig. 8. Focusing on the center of the altitude window, the sunrise (sunset) bias for ACE v.5.2 is within ±2 of -9 m/s (±3 of +18 m/s). For v.5.3, the bias is the same but with less variability, within ±1 m/s (±2 m/s).

Changes to MERRA-2 text:

“~~We are also able to derive a sunrise-sunset bias by comparing with MERRA-2. To do this, we shift the MERRA-2 altitude to the nearest ACE altitude (maximum of $\pm$0.5$~$\unit{km}) and find the difference between ACE and MERRA-2 wind speeds. The differences are then averaged over all measurements by ACE in 2019 and the results are shown in Fig. \ref{fig:MERRA2vsACE_bias}(a) for v.5.2 and (c) for v.5.3. We then subtract the sunrise and sunset averages from the total average to find the bias. The average bias at each altitude is displayed in Fig. \ref{fig:MERRA2vsACE_bias}(b) for v.5.2 and (d) for v.5.3.~~ Similar to MIGHTI and meteor radar, we are able to derive the sunrise-sunset bias, displayed in Fig. 10. We find that MERRA-2 and ACE differ by less than 10 m/s up to 50 km with v.5.3, which is about half of the difference with v.5.2. We also find that the sunrise (sunset) bias has strongly improved. It is now within +5 m/s (-5 m/s) up through 50 km, but largely within +3 m/s (-3 m/s). Above 50 km the bias does grow to about +15 m/s (-15 m/s), as seen in v.5.2. However, this higher altitude region is not well constrained within the MERRA-2 reanalysis.

Changes to HWM14 text:

“This average of ACE v.5.2 and v.5.3 wind speeds from 2019 and their corresponding HWM14 wind speeds are shown in Fig. 11. For v.5.2 (v.5.3), 1037 (1032), 410 (418), and 945 (945) sunrise occultations were used for northern, tropical, and southern latitudes. For sunsets, 1300 (1294), 396 (402), and 924 (923) were used, respectively. The displayed HWM14 wind speeds are calculated using the v.5.3 heading angles. We see general profile agreement for both processing versions, with v.5.3 being slightly improved. Both versions of ACE processing show more prominent features than those found in HWM14~~. ACE v.5.2 shows more prominent features than HWM14~~, best seen at the ~90 and ~60 km features in Fig. 11(a) and (e), respectively.~~ ACE v.5.3 still displays a prominent feature, but better matches the model in both cases.~~ ~~The sunrise-sunset bias is not clear at lower altitudes, but does become more notable above ~80 km~~. The sunrise-sunset bias relative to HWM14 is shown in Fig. 12, similar to Fig. 9 relative to MERRA-2. We see a similar shape to that of MERRA-2, but the bias in v.5.2 appears less significant than in v.5.3. At low altitudes the bias begins at less than 5 m/s, but increases to 17 m/s at 60 km for v.5.2 and 20 m/s at 70 km for v.5.3. It then decreases through 90 km before rising to its maximum of 22 m/s and 37 m/s at 100 km for v.5.2 and v.5.3, respectively.”

Changes to WACCM-X text:

“... WACCM-X vector winds were compared with ACE-FTS line-of-sight winds for all of 2019 in a similar fashion as HWM14. The resulting line-of-sight winds are shown in Fig. 13. There is notably less agreement between both ACE versions and the WACCM-X profiles compared with HWM14. Both ACE sunrise and sunset averages for v.5.2 and v.5.3 in the northern and southern latitude region show additional features not found in the WACCM-X model~~, although v.5.3 agrees more than v.5.2~~. The model and ACE data show the best profile agreement in the tropical region. ~~The eastward bias in v.5.2 has also slightly decreased with v.5.3, particularly at lower altitudes.~~ Comparing the sunrise-sunset biases, shown in Fig. 16(b) and (d) for v.5.2 and v.5.3,

respectively, we see a similar shape as before when compared with HWM14. The sunrise (sunset) bias varies up through 80 km, but is less than -8 m/s (+7 m/s). It then increases drastically to -34 m/s (+32 m/s) at 103 km before dropping to near zero at 120 km."

Changes to conclusion:

ACE v.5.3 wind speeds have been validated by instrument observations from MIGHTI and meteor radar. Wind speed profiles from ACE v.5.3 for sunrise and sunset occultations show improved profile agreement with MIGHTI and meteor radar measurements. The approximate -15 m/s (+15 m/s) sunrise (sunset) bias previously found is still seen ~~at these higher altitudes (~~above 80 km~~)~~.

ACE v.5.2 and v.5.3 line-of-sight wind speeds have been compared with vector winds from the MERRA-2, HWM14, and WACCM-X models. The new wind speeds have better profile agreement than v.5.2 does with each model. The v.5.3 processing has particularly strong profile agreement with MERRA-2 below 40 km, where the model is well constrained. The MERRA-2 comparison shows a decreased sunrise (sunset) bias of less than -5 m/s (+5 m/s) below 50 km. ~~The previously found -15 m/s (+15 m/s) bias is still seen with v.5.3 at higher altitude.~~ At higher altitudes, the bias is nearer to -15 to -20 m/s (+15 to +20 m/s), with a sharp increase close to 100 km.

Changes to abstract:

We also compare line-of-sight winds from ACE-FTS v.5.2 and v.5.3 with vector winds from the MERRA-2, HWM14, and WACCM-X models. A -15 to -20 m/s (+15 to +20 m/s) sunrise (sunset) bias persists in v.5.3 winds above 80 km but decreases to less than -5 m/s (+5 m/s) below 50 km.

5. The ±15 m/s adjustment described is somewhat unclear. In Figure 4, it appears that 15 m/s has been added to the sunrise case and subtracted from the sunset case to produce the pink curve. Unlike the individual example in Figure 3, the average agreement between MIGHTI and ACE appears to worsen at sunrise between versions 5.2 and 5.3; if so, this should be explicitly acknowledged and, if possible, explained. The authors should also specify how the ±15 m/s offset was determined—was it chosen by eye or by optimizing an objective measure of agreement? The latter approach would strengthen the analysis and make it more reproducible. Moreover, rather than saying "There is a sunrise–sunset bias of around ±15 m/s," the phrasing should clarify the directionality, e.g., "At sunrise (sunset), there is a bias of approximately –15 m/s (+15 m/s)." This clarification should be applied in the Figure 4 caption, the abstract, and anywhere else this statement appears.

Changed to suggested format: "sunrise (sunset)" and "+15 m/s (-15 m/s)" throughout the paper. In context where we are discussing the "sunrise-sunset" bias without specific values, I have left *it as is. As for how the bias was determined, refer to comment 4 as we have further quantified each model / dataset similar to what was done with MERRA-2.*

Technical Corrections:

Line 26: Typo. Should read "atomic oxygen"

Corrected.

Line 64: The acronym CESM2 is used without being defined earlier in the text.

Now reads as: "... Using CESM2 (Community Earth System Model 2) as ..."

In Figure 2, the x-axis should be limited to 0–360 rather than extending to 400 to avoid confusion.

Updated x-axis to 0-365 days and the y-axis to 0-360 degrees, rather than 0-400 for both.

In the description of the MIGHTI data, the authors should additionally cite Englert et al. (2023), which describes the v05 MIGHTI wind product used in the comparisons.

Citation now includes Englert et al. (2017) and (2023).

Line 190: specify that the winds retrieved are horizontal vector winds, not the full 3D wind vector.

Added "horizontal" for clarity: "These measurements can be used to determine horizontal vector winds due to ..."