Verification of ICON/MIGHTI wind by comparison with meteor radar wind: Effect of airglow on ICON/MIGHTI wind observations

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Abstract

The Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI) onboard the NASA Ionospheric Connection Explorer (ICON) has retrieved neutral winds at altitudes of 88 km ~ 300 km with limb-scanning using the OI green line (557.7 nm) since November 2019. Neutral winds measured by MIGHTI are helpful information for studying the dynamics in the thermosphere and mesosphere. On the other hand, it is essential to verify the wind data from MIGHTI, which is a relatively new and most up-to-date instrument, using reliable data such as wind from a meteor radar. This study compared winds at altitudes of 91 km and 94 km over the Korean Peninsula measured from 2020 to 2021 by two instruments: the MIGHTI and the meteor radar operated by the Korea Astronomy and Space Science Institute (KASI-MR). We found that the MIGHTI and MR winds were generally similar at night, but there was a significant discrepancy between the two winds during the day. To understand why the two wind measurements are similar at night and differ significantly during the day, we investigated the maximum altitude and slope of the green-line airglow. As a result, it was confirmed that the effect of airglow on the limb scan of the MIGHTI, that is, the vertical difference in airglow emission during day and night, is one factor contributing to the nighttime similarity and daytime discrepancy between the MIGHTI and KASI-MR winds. Therefore, especially when using the daytime MIGHTI wind, it is suggested that special attention is required in using it, recognizing that the effect of this factor is included.

1. Introduction

- A wind in the MLT region (70 km – 150 km) where the ionospheric E layer exist is too high to be measured by ground based instruments, while it is too low to be measured by satellites.
- There is a limit to study the effect of wind on Sporadic-E using only meteor radars although, the remote observation using a meteor radar which is one of the ground instruments is a well-known method of measuring the wind in the MLT region (Kam et al., 2021).
- MIGHTI, satellite instrument, is able to measure neutral winds in altitudes higher than the 100 km.
- MIGHTI has measured neutral winds since December 2019 and some studies validated MIGHTI winds (Chen et al., 2022; Dhadly et al., 2021; Harding et al., 2021; Makela et al., 2021).
- However, only Chen et al. (2022) validated the horizontal winds of MIGHTI but, they did not mention what makes differences between the winds during the day and at night.
- we intend to reveal the reason what gives rise to the difference in agreements between MIGHTI and meteor radar horizontal winds.

2. Instruments

- **MIGHTI** (Michelson Interferometer for Global High resolution Thermospheric Imagine)
  - ✓ MIGHTI onboard ICON satellite launched on October 10, 2019 (inclination: 27°, orbit: ~600 km)
  - ✓ MIGHTI has two same sensors (MIGHTI-A and -B) that are installed having 90° offsets and toward the northern limb direction (Harding et al., 2017).
  - ✓ MIGHTI-B observes the same volume 5 to 8 minutes later than the MIGHTI-A observed it.
  - ✓ The sensors observe an oxygen atomic emission (557.7 nm green line and 630.0 nm red line) by limb-scanning.
  - ✓ Version 05 uses the on-orbit calibration processes to determine zero wind.
- **KASI-Meteor Radar specification**
  - ✓ KASI has operated the MR since October 2017
  - ✓ Data resolution: 1 hour
  - ✓ Data range: 80 – 100 km (bin: 2km)

Parameter	Value
Location	36.2°N, 127.1°E
Frequency	40.8 MHz
Transmit power	24 kW

Table 1. Meteor Radar spec

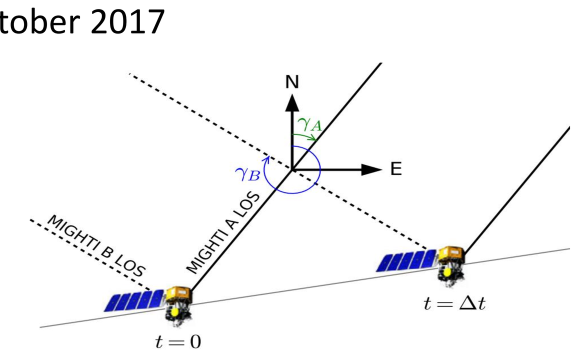


Figure 1. *Observation geometry of MIGHTI. [Harding et al. (2017)]*

3. Data Analysis

- **Data period:** January 2020 – December 2021
- **Data boundary**: near the Korea Peninsula (36.2°N ±5°, 127.1°E ±5°)
- **KASI-MR winds**
- ✓ 6-time segment
  - ➢ KASI-MR winds at 91 km and 94 km were estimated using only meteor echoes observed for 10, 20, 30, 40, 50, and 60 minutes (e.g. 60 min.: 30 min. before and after the MIGHTI observation time).

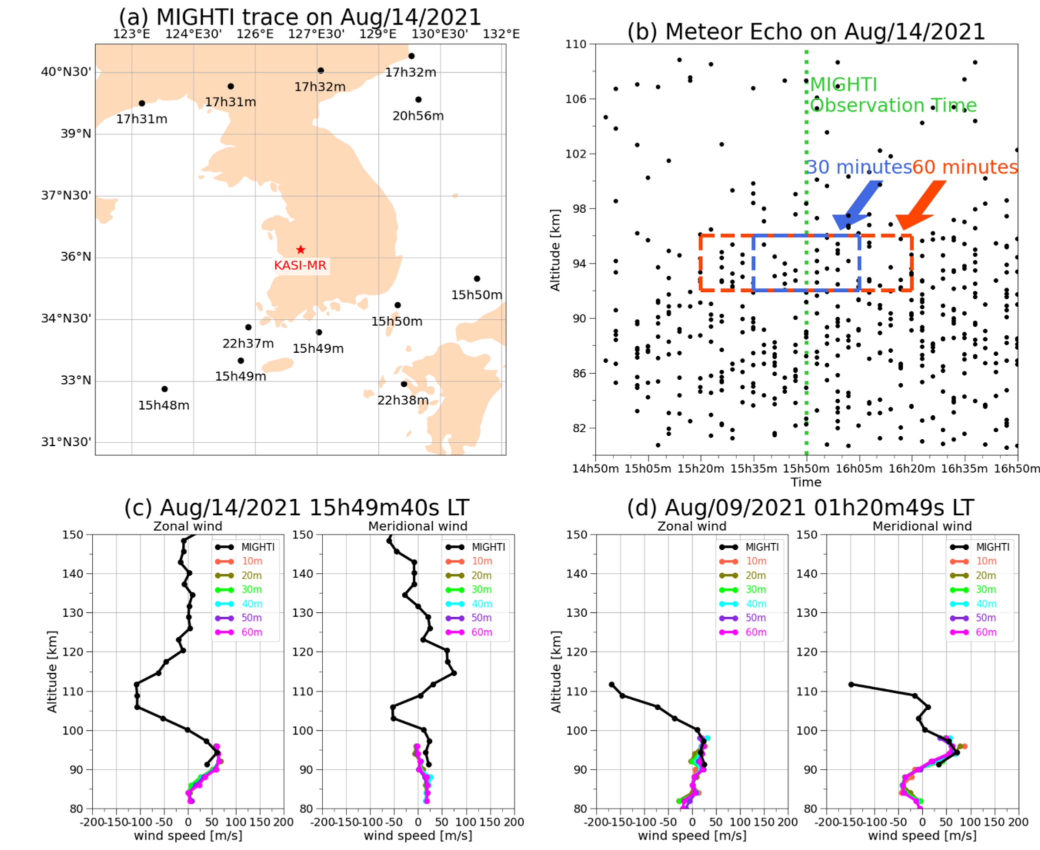
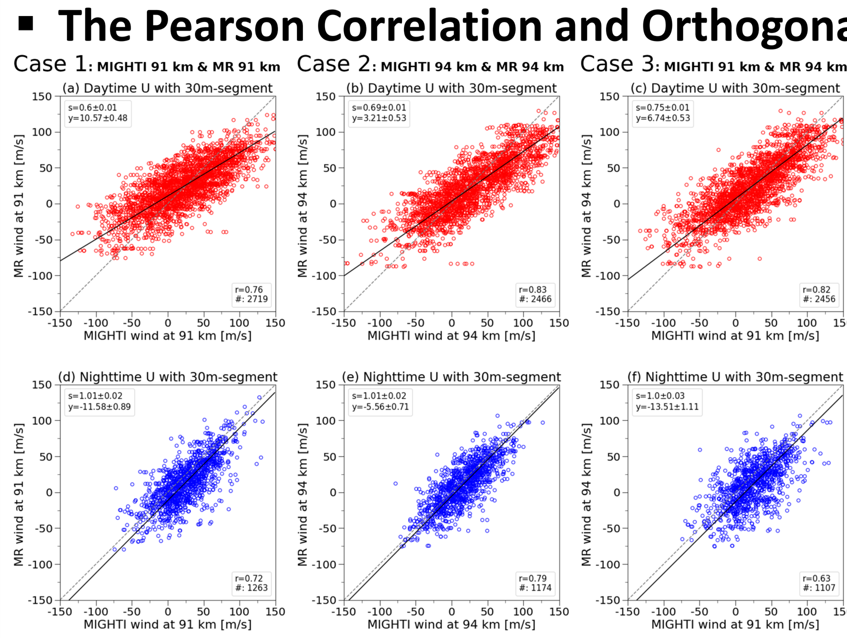


Figure 2.
(a) Data boundary
(b) Examples of 6-time segment method, 60-minute segment (red), 30-minute segment (blue), the MIGHTI observation time is 15:50 on August 14, 2021
(c) Examples of wind profiles of MIGHTI and KASI-MR at 15:49 on August 14, 2021. zonal wind (left) and meridional wind (right)
(d) Same as Fig 2c but for MIGHTI observation time at 01:20 on August 9, 2021.

- **The Pearson Correlation and Orthogonal Distance Regression (ODR) analysis**



- ➢ Use neutral winds at 91 km and 94 km altitude
- ➢ Avoid wind data around terminator (± 2 hours)
- ➢ **Case 1**: MIGHTI and KASI-MR winds at 91 km
  - **Case 2**: MIGHTI and KASI-MR winds at 94 km
  - **Case 3**: MIGHTI winds at 91 km and KASI-MR winds at 94 km
- ➢ Repeat analysis every time segments

Figure 3. *Examples of ODR analysis, X-axis and Y-axis represent MIGHTI winds and KASI-MR winds with 30-minute segment, respectively. (a, b, and c) zonal wind component in the day (red) and (e, f, and g) at night (blue) in each case.*

4. Results and Discussion

- **ODR analysis**
  - ✓ Figure 4 shows the results of the ODR slopes for each of 6-time segments and cases.
  - ✓ The MIGHTI winds show better agreement with the KASI-MR winds at night than day.
  - ✓ The zonal component of the MIGHTI winds more matches the KASI-MR winds compared to the meridional component.
  - ✓ In the daytime, the ODR analysis in case 3 shows that the MIGHTI winds better agreement with the KASI-MR winds than the other cases, which used winds measured at the same altitudes (case 1 and case 2).
  - ✓ At night, the MIGHTI winds coincide the most with the KASI-MR winds in case 2.

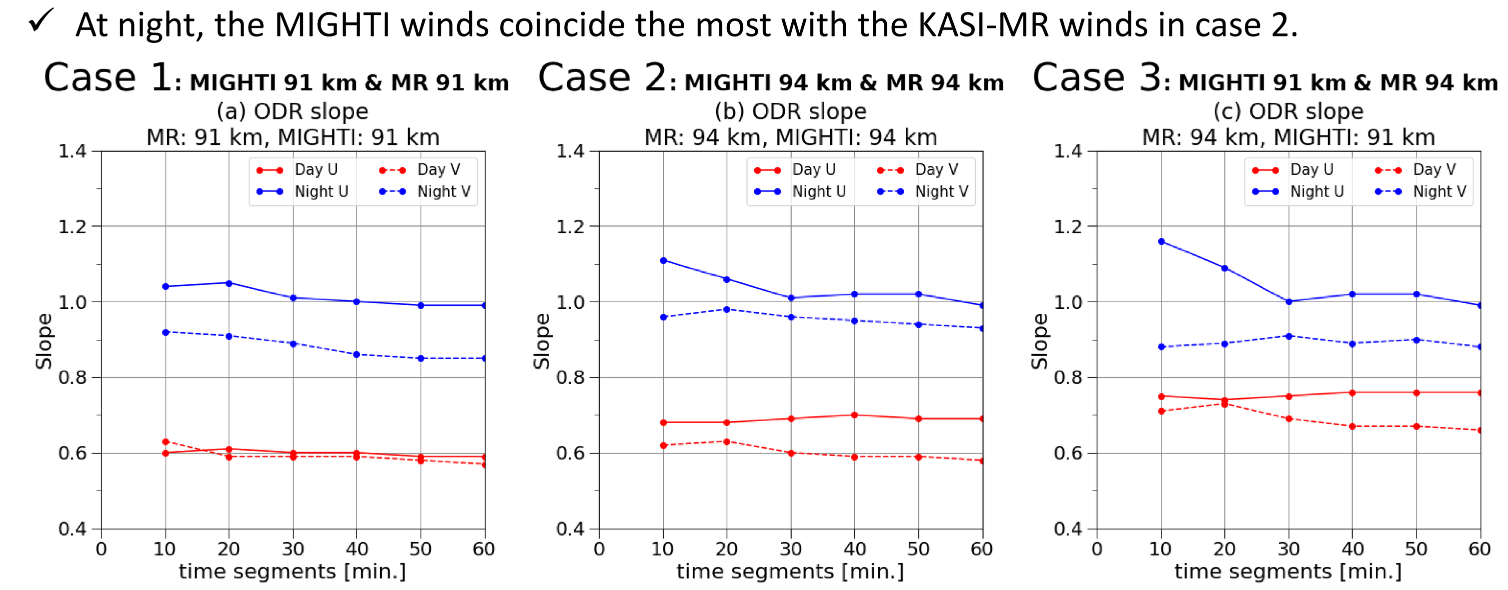


Figure 4. *The results of the ODR analysis using MIGHTI winds and KASI-MR winds with 6-time segment in the day (red) and at night (blue).*

- **Volume Emission Rate profiles and Illustration of MIGHTI observation**
  - ✓ The intensity of the green line (557.7 nm) during the day is stronger than that during the night since the number of oxygen ions increase due to the solar radiation.
  - ✓ The maximum intensities appear at 100 km in the daytime and at 94 km in the nighttime (Figure 5a).
  - ✓ The altitude change of maximum intensity would be a result of an atmospheric motion during day and night.
  - ✓ From Figure 5b, if the intensity of airglows changes rapidly in the width (Δh), the wind estimated by weak airglows could be contaminated by strong airglows (daytime).
  - ✓ On the other hand, during the nighttime, winds at an altitude other than 94 km would not much affect on the MIGHTI winds at 94 km because the intensity of airglows is a maximum at 94 km.
    - ➢ The difference between the ODR slopes of the daytime and nighttime (shown in Figure 4) comes from the characteristics of each instruments.
    - ➢ KASI-MR provides winds steadily at 94 km regardless of observation time but the MIGHTI winds at 94 km are affected of the observation time.

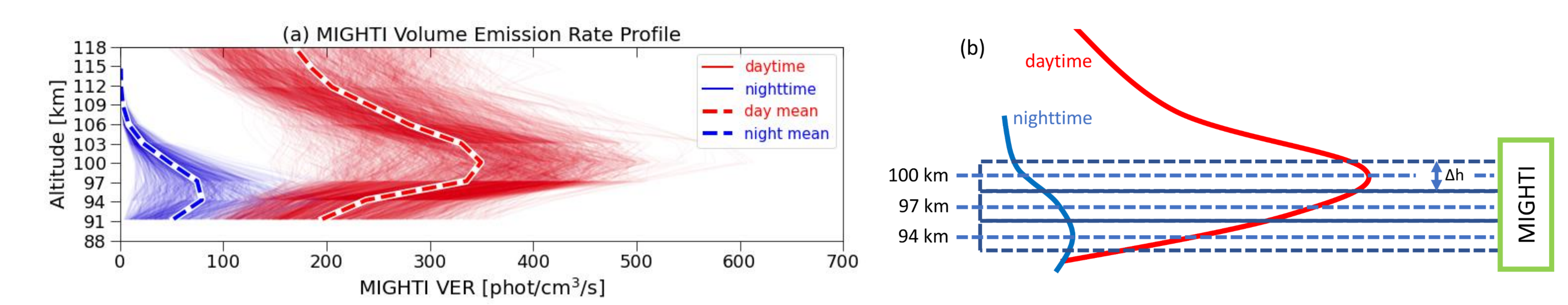


Figure 5. *(a) The Volume Emission Rate (557.7 nm wavelengths) profiles measured by MIGHTI in the day (red lines) and at night (blue lines). The thick red and blue line represent mean VER during day and night. (b) Illustration of MIGHTI observation.*

- **Interquartile Range (IQR) analysis**
  - ✓ Figure 6 shows scatter plots of a difference between the KASI-MR winds and the MIGHTI winds and airglow difference between a $VER_{91\ km\ or\ 94\ km}$ and the VER_{max}.
  - ✓ During the day, the IQR value decreases from case 1 to case 3 in both components.
    - ➢ The daytime MIGHTI winds at 91 km altitude are interfered with by winds measured at higher altitudes such as 94 km.
  - ✓ On the other hand, at night, the IQR value decreases from case 1 to case 2 and then reaches a MAX. in case 3.
    - ➢ The nighttime MIGHTI winds at 914 km altitude produce winds that are not interfered with by wind measured at other altitudes.
  - ✓ A large IQR value occurs when there is a significant vertical difference in airglow intensity between an altitude where the maximum airglow intensity exists and a specific altitude.

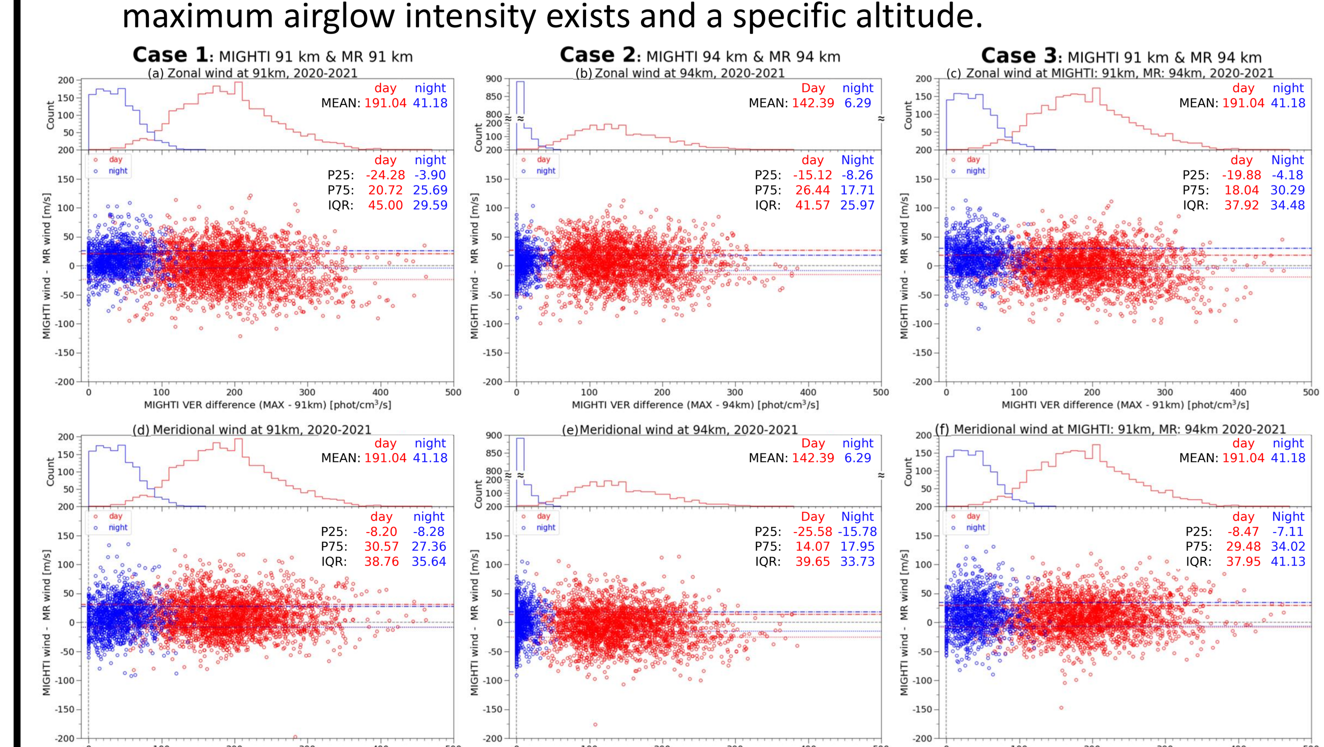


Figure 6. *Scatter plots of wind difference (MIGHTI winds – KASI-MR winds) as a function of airglow difference (VER_{max} – $VER_{91\ km\ or\ 94\ km}$) in the day (red) and night (blue) with histograms of wind differences (upper panel). The zonal and meridional components are displayed in upper and lower panel, respectively.*

5. Summary and Conclusion

- ✓ We compared and analyzed neutral winds measured by KASI-MR and MIGHTI from January 2020 to December 2021 at an altitude of 91 km and 94 km near the Korean Peninsula.
- ✓ From the Orthogonal Distance Regression (ODR) analysis
  - ➢ The nighttime winds measured by MIGHTI are pretty similar with those measured by KASI-MR.
  - ➢ But, there are disagreement between the MIGHTI winds and KASI-MR winds during the day.
- ✓ The airglow intensity reaches a maximum at 94 km in night and at 100 km in day.
- ✓ The Interquartile Range (IQR) of wind differences between MIGHTI winds and KASI-MR winds
  - ➢ The IQR value decreases in the day from case 1 to case 3.
  - ➢ While, at night, the IQR value decreases from case 1 to case 2 and then reaches a MAX. in case 3.
  - ➢ Observational evidence that the airglow intensity is one factor reducing the accuracy
- ✓ The airglow intensity can have an impact on the accuracy of wind measurements.
- ✓ We should pay attention to the observation time of MIGHTI when we use MIGHTI winds.

References

- **Chen, Z., Liu, Y., Du, Z., Fan, Z., Sun, H., & Zhou, C. (2022).** Validation of MIGHTI/ICON Atmospheric Wind Observations over China Region Based on Meteor Radar and Horizontal Wind Model (HWM14). Atmosphere, 13(7), 1078. https://doi.org/10.3390/atmos13071078
- **Dhadly, M. S., Englert, C. R., Drob, D. P., Emmert, J. T., Niciejewski, R., & Zawdie, K. A. (2021).** Comparison of ICON/MIGHTI and TIMED/TIDI Neutral Wind Measurements in the Lower Thermosphere. Journal of Geophysical Research: Space Physics, 126(12), e2021JA029904. https://doi.org/10.1029/2021JA029904
- **Harding, B. J., Makela, J. J., Englert, C. R., Marr, K. D., Harlander, J. M., England, S. L., & Immel, T. J. (2017).** The MIGHTI Wind Retrieval Algorithm: Description and Verification. Space Science Reviews, 212(1), 585–600. https://doi.org/10.1007/s11214-017-0359-3
- **Harding, B. J., Chau, J. L., He, M., Englert, C. R., Harlander, J. M., Marr, K. D., et al. (2021).** Validation of ICON-MIGHTI Thermospheric Wind Observations: 2. Green-Line Comparisons to Specular Meteor Radars. Journal of Geophysical Research: Space Physics, 126(3), e2020JA028947. https://doi.org/10.1029/2020JA028947
- **Kam, H., Kwak, Y.-S., Yang, T.-Y., Kim, Y. H., Kim, J., Lee, J., et al. (2021).** Characteristics of Horizontal Winds in the Mesosphere and Lower Thermosphere Region over Korean Peninsula Observed from the Korea Astronomy and Space Science Institute Meteor Radar. Journal of Astronomy and Space Sciences, 38(4), 229–236. https://doi.org/10.5140/JASS.2021.38.4.229
- **Makela, J. J., Baughman, M., Navarro, L. A., Harding, B. J., Englert, C. R., Harlander, J. M., et al. (2021).** Validation of ICON-MIGHTI Thermospheric Wind Observations: 1. Nighttime Red-Line Ground-Based Fabry-Perot Interferometers. Journal of Geophysical Research: Space Physics, 126(2), e2020JA028726. https://doi.org/10.1029/2020JA028726