ICON Data Product 2.2: Cardinal Vector Winds

This document describes the data product for ICON MIGHTI Cardinal Vector Winds (DP 2.2), which is in NetCDF4 format.

This data product contains cardinal (i.e., zonal and meridional) thermospheric winds obtained by combining Level 2.1 (line-of-sight winds) from MIGHTI A and MIGHTI B. The cardinal winds are given as a function of time (spanning 24 hours) and altitude (spanning nominally 90-300 km). In addition to the cardinal vector wind data and the corresponding ancillary data, such as time and location, this product contains supporting data, such as fringe amplitude profiles and relative volume emission rate profiles. Absolute calibration and MIGHTI-A/B cross calibration of these data is not necessary to obtain the wind data, and therefore any direct analysis of these supporting data requires caution. There is one file per emission color (red or green).

Cardinal wind observations are enabled by the ~90-degree offset between the two MIGHTI sensors. First, MIGHTI A measures a wind component along its line of sight. Five to eight minutes later, depending on tangent point altitude, the spacecraft has moved to a position such that MIGHTI B measures a nearly orthogonal wind component at approximately the same location. A coordinate rotation is performed on the two line-of-sight components to obtain the northward and eastward components reported in this file. The assumption is that the thermospheric wind has not changed during this time interval. Because the Level 2.1 data are naturally on an irregular grid, they are first interpolated to a regular, pre-defined grid of longitude and altitude before the coordinate rotation is performed. See Harding et al. [2017, doi:10.1007/s11214-017-0359-3] for more details of the Level 2.2 algorithm. Further discussion of the calibration and performance of MIGHTI after launch can be found in a forthcoming paper in Space Science Reviews [Englert et al., 2022, in preparation].

Known issues with the v05 data release are listed below. Work is in progress to resolve or mitigate these issues in future data releases.

Known issues with v05:
* When ICON is in the South Atlantic Anomaly (SAA), radiation effects on the detector cause poor data quality. The quality control algorithm adequately flags and masks most of the affected samples, but some outliers remain, especially near the edge of the SAA. Other uncaught outliers are rare but can occur due to cosmic rays, stars in the field of view, moonlight, etc.
* The bottom row of data (corresponding to an altitude of ~88 km) is masked out as the signal is rarely strong enough to permit a wind estimate, and calibrations have large uncertainties. It is unlikely but possible that this altitude will be reported in future releases, pending further investigation.
* Airglow brightness observations are not a required mission product, and no effort was yet made to absolutely calibrate the brightness observations for MIGHTI-A and MIGHTI-B, and thus the Relative_VER variable should be treated with caution. In v05, MIGHTI-A and B are cross-calibrated using a conversion factor derived from on-orbit data. However, there are some indications that this cross-calibration may be changing with time, which is not accounted for in v05.
* As discussed in the variable notes below, a new zero wind phase determination has been implemented in v05. However, during the period from 2021 Apr 26 to Aug 14, data gaps and one period of southward ("Reverse LVLH") pointing cause errors in this determination. The accuracy is estimated to be degraded by a factor of two. See the *_Accuracy variable.
* During the one orbit per day when the calibration lamp is on, the wind data can be noisier and have a slight bias. Although this issue is much improved since v04, for the sake of conservatism, these orbits are still labeled with quality=0.5 (i.e., caution).
* Some data gaps appear on days when the sun passes near MIGHTI's field of view. Most of these gaps are located near the terminator, but some are longer lasting.
* In some cases, there are indications that the *_Precision_1_Sample variables are underestimating the true sample-to-sample noise, suggesting that, in addition to shot noise, there is a second source of noise. It is recommend that any quantitative use of the reported error estimates (i.e., precision and accuracy) should treat those estimates as uncertain. It is believed that most error estimates are correct to within a factor of 2. The largest problems with error reporting occur where the airglow signal is weakest.
* Imperfect daily calibration data lead to small discontinuities in the zero wind phase at the boundaries between days (i.e., between 23:59:59 and 00:00:00 UT), which are not accounted for by the reported error variables.

This was estimated to be a 2-5 m/s (root-mean-square) error early in the mission, but is growing over time, possibly reaching 5-10 m/s by mid-2022.
* A signal-dependent phase shift is seen in atmospheric and calibration lamp fringes, possibly caused by a charge trapping effect in the CCD. This is the subject of ongoing investigation, but a first-order correction is implemented in the v05 dataset. The correction increases linearly with time to match the effect seen in on-orbit calibration data. The variable *_Precision_Low_Signal_Effect is an estimate of the remaining uncertainty due to an imperfect correction. Where this uncertainty is large, caution is recommended. For example, for winds in the core science region (90-105 km altitude, away from the terminator), the magnitude of the correction is small or zero, but data in the red channel during the night and twilight are subject to a large correction (many tens of m/s) and the uncertainty is correspondingly large. A goal for future releases is to characterize and correct this effect more accurately.
* Data near the solar terminators are subject to a variety of errors, including those described above and others related to the rapidly varying illumination. Not all errors near the terminator are accounted for by the reported error. Users are encouraged to use extra caution with these data.
See the documentation below for more information.

History

v1.0: First release of MIGHTI L2.1/L2.2 software, B. J. Harding, 05 Mar 2018

v2.0: First run of on-orbit data, using external zero wind reference and smooth daily-averaged profiles, B. J. Harding, 01 May 2020

v3.0: Correction for long-term mechanical drift, B. J. Harding, 04 Jun 2020

v4.0: Updated correction for long-term mechanical drift to handle settling after ~May 2020 and precession cycle variation. LoS winds have changed by a bulk offset of up to 30 m/s. Studies using only perturbations from the mean (e.g., non-migrating tidal retrievals) are unlikely to be affected. B. J. Harding 21 Oct 2020

v5.0: The ad-hoc, HWM-based correction for the zero wind phase has been replaced with a self-calibration based on comparing data from the ascending and descending orbits (see the notes for the wind variables below for details). Long-term trends in the zero wind phase degraded the accuracy of version 4 over time, and the accuracy of version 4 data was tied to the accuracy of HWM. In version 5, errors on these long time scales (>100-150 days) are now accounted for, improving the accuracy to 10-25 m/s (see the "Accuracy" variable for more details) and removing the dependence on external models. A long window of data is required to implement this self-calibration, so v05 data are processed at least 100 days behind real time. For errors on precession-cycle time scales (48 days), the previous ad-hoc correction using initial red-vs-green comparisons has been replaced with a more comprehensive red-green cross-calibration (165-185 km altitude during the day) that accounts for the time-dependence of mechanical drifts of the optics. This result is consistent with a first-principles analysis of the fiducial notch positions (see Marr et al., 2020 and subsequent publications). A mission-average fiducial notch analysis is also used to correct mechanical drifts on an orbital time scale (97 minutes, or 24 hours of local time), which could affect migrating tide estimates. The RMS difference due to this effect is estimated at 5-10 m/s (root mean square). Analysis of waves with periods that do not coincide with these new corrections are not likely to be different than in version 4 (e.g., nonmigrating tides, planetary waves, and gravity waves). New variables related to error (i.e., uncertainty) estimates from various sources are now included, whereas version 4 error estimates only included the effects of shot, read, and dark noise. MIGHTI-A and MIGHTI-B variables related to emission brightness are now cross-calibrated, though not absolutely calibrated. Exposures affected by solar and lunar stray light are now flagged. Some data during periods in May and July 2020 when the sun approached the MIGHTI field of view was marked as unavailable in v04, but is now available in v05 with the exception of a few days. The data from the second row in the green channel (~91 km) is now available when the signal strength permits a wind estimate. An error in the local time calculation has been corrected, which changes the local time by up to 20 min. A new algorithm to identify cosmic ray spikes has been implemented, improving precision. A preliminary algorithm has been implemented to to correct a wind bias associated with low signal levels, and associated uncertainties are estimated (see the "Precision_Low_Signal_Effect" variable for more details). Finally, various quality control parameters have been optimized. More description is provided in the notes below. A full history of software changes can be found on

Github: https://github.com/bharding512/airglowrsss/commits/master/Python/modules/MIGHTI_L2.py B. J. Harding 08 Sep 2022

Dimensions

NetCDF files contain **variables** and the **dimensions** over which those variables are defined. First, the dimensions are defined, then all variables in the file are described.

The dimensions used by the variables in this file are given below, along with nominal sizes. Note that the size may vary from file to file. For example, the "Epoch" dimension, which describes the number of time samples contained in this file, will have a varying size.

Dimension Name	Nominal Size
`Epoch`	unlimited
`ICON_L22_Altitude`	84
`N_Flags`	34

Variables

Variables in this file are listed below. First, "data" variables are described, followed by the "support_data" variables, and finally the "metadata" variables. The variables classified as "ignore_data" are not shown.

data

Variable Name	Description	Units	Dimensions
ICON_L22_Zonal_Wind	Zonal component of the horizontal wind. Positive Eastward. The zonal (positive eastward) and meridional (positive northward) winds are the primary data product in this file. They are defined on a grid with dimensions of time and altitude, spanning 24 hours and nominally 90-300 km (150-300 km for the red channel). The altitude, time, latitude and longitude corresponding to each point in the grid are given by other variables in this file. It should be noted that while each measurement is ascribed to a particular latitude, longitude, altitude, and time, it is actually an average over many hundreds of kilometers horizontally and 2.5-30 kilometers vertically (depending on the binning). It also assumes stationarity over the 5-8 minutes between the MIGHTI-A and B measurements used for each point. See Harding et al. [2017, doi:10.1007/s11214-017-0359-3] for a more complete discussion of the inversion algorithm. Knowledge of the "zero wind phase" is needed for any instrument using Doppler shifts to determine winds. The zero wind phase is defined as the measured interference fringe phase that corresponds to the rest wavelength of the emission. For the v05 data release, the zero wind phase has been determined by considering a window of LoS wind data spanning two precession cycles (96 days). Assuming that on average the real zonal and meridional winds do not depend on the aspect angle with which MIGHTI observes the atmosphere (an angle which is significantly different between the ascending and descending portions of the orbit), a matrix equation can be constructed which combines data from both MIGHTI-A and MIGHTI-B and both the ascending and descending orbits. This equation is solved for the average zonal and meridional wind, and the zero wind phase for MIGHTI-A and MIGHTI-B. This window is moved in time to determine the appropriate zero wind phase for each date. The value of the zero wind phase depends on emission color (red or green), aperture mode (day or night), calibration lamp status (on or off) and row (i.e., altitude). An additional zero-mean signal is added to this result to ensure that 48-day (i.e., 1 precession cycle) average winds are smooth in altitude. Adjustments are smaller than the reported accuracy, so this adjustment is not expected to change any scientific conclusions, although it does ensure more realistic wind profiles. This is a less restrictive assumption than the smoothness criterion used in v04, which relied on the Horizontal Wind Model 2014 and also enforced smoothness on 1-day averages. It is thus expected that the amplitude of tidal structures in the lower thermosphere are subject to less suppression in v05+ than in v04. This version of the MIGHTI zero wind phase is independent of any external data or models (such as the Horizontal Wind Model 2014, which was used in v04 and earlier versions). The zero wind phase used for each wind sample is saved in the _Zero_Wind_Phase variable below. The 1-sigma uncertainty in the winds incurred by the inaccuracy in the zero wind phase is estimated and reported in the *_Wind_Accuracy variable below.	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Meridional_Wind	Meridional component of the horizontal wind. Positive Northward. The zonal (positive eastward) and meridional (positive northward) winds are the primary data product in this file. They are defined on a grid with dimensions of time and altitude, spanning 24 hours and nominally 90-300 km (150-300 km for the red channel). The altitude, time, latitude and longitude corresponding to each point in the grid are given by other variables in this file. It should be noted that while each measurement is ascribed to a particular latitude, longitude, altitude, and time, it is actually an average over many hundreds of kilometers horizontally and 2.5-30 kilometers vertically (depending on the binning). It also assumes stationarity over the 5-8 minutes between the MIGHTI-A and B measurements used for each point. See Harding et al. [2017, doi:10.1007/s11214-017-0359-3] for a more complete discussion of the inversion algorithm. Knowledge of the "zero wind phase" is needed for any instrument using Doppler shifts to determine winds. The zero wind phase is defined as the measured interference fringe phase that corresponds to the rest wavelength of the emission. For the v05 data release, the zero wind phase has been determined by considering a window of LoS wind data spanning two precession cycles (96 days). Assuming that on average the real zonal and meridional winds do not depend on the aspect angle with which MIGHTI observes the atmosphere (an angle which is significantly different between the ascending and descending portions of the orbit), a matrix equation can be constructed which combines data from both MIGHTI-A and MIGHTI-B and both the ascending and descending orbits. This equation is solved for the average zonal and meridional wind, and the zero wind phase for MIGHTI-A and MIGHTI-B. This window is moved in time to determine the appropriate zero wind phase for each date. The value of the zero wind phase depends on emission color (red or green), aperture mode (day or night), calibration lamp status (on or off) and row (i.e., altitude). An additional zero-mean signal is added to this result to ensure that 48-day (i.e., 1 precession cycle) average winds are smooth in altitude. Adjustments are smaller than the reported accuracy, so this adjustment is not expected to change any scientific conclusions, although it does ensure more realistic wind profiles. This is a less restrictive assumption than the smoothness criterion used in v04, which relied on the Horizontal Wind Model 2014 and also enforced smoothness on 1-day averages. It is thus expected that the amplitude of tidal structures in the lower thermosphere are subject to less suppression in v05+ than in v04. This version of the MIGHTI zero wind phase is independent of any external data or models (such as the Horizontal Wind Model 2014, which was used in v04 and earlier versions). The zero wind phase used for each wind sample is saved in the _Zero_Wind_Phase variable below. The 1-sigma uncertainty in the winds incurred by the inaccuracy in the zero wind phase is estimated and reported in the *_Wind_Accuracy variable below.	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Zonal_Wind_Precision_1_Sample	1-sample precision in the zonal wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "1 sample" error variable quantifies errors that are uncorrelated from one exposure to the next, dominated by shot and dark noise in the detectors. The correlation time of this error source is 30-60 seconds (i.e., the measurement cadence). The reported error is estimated from the fringe intensity and background. This is the recommended variable to use for analyses of wind fluctuations within a single day and a single altitude (e.g., gravity waves). Because the Level 2.2 data include interpolation of Level 2.1 data, some correlation remains between consecutive samples. Errors are slightly correlated across small altitude gaps as a result of the inversion.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Zonal_Wind_Precision_1_Day	1-day precision in the zonal wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "1 Day" error variable quantifies the error introduced by daily calibrations, which is correlated for an entire 24-hour period (00:00 - 23:59 UT). This is estimated from the magnitude of fluctuations in the daily-averaged phase, propagated through the inversion. Errors in day mode and night mode are nearly uncorrelated. For studies pertaining to atmospheric tidal modes that combine data from many days, this error can be treated as uncorrelated across time.	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Zonal_Wind_Precision_Low_Signal_Effect	Low-signal precision in the zonal wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "Low Signal Effect" error variable quantifies the error introduced by the imperfect correction for the signal-dependent phase shift, which is an effect seen in atmospheric and calibration-lamp fringes where the phase of the fringes is biased at very low signal levels. This is under investigation but could be caused by a charge trapping effect in the CCD. A correction has been implemented based upon the empirical relationship between measured phase and signal level of the calibration lamps for the first ~30 months of the mission. However, especially for cases with low signal levels, this correction is uncertain. The uncertainty in the resulting winds is estimated from the signal level and reported in this variable. It is likely to be correlated across samples nearby in time and space, but the correlation between different channels (red and green), sensors (MIGHTI-A and MIGHTI-B), and operating modes (Day and Night) is not known. Depending on the analysis being used, it could be treated as a systematic error or as a statistical error. Where this uncertainty is large, caution is recommended. For example, for winds in the core science region (90-105 km altitude), the magnitude of the correction is small or zero, but data in the red channel during the night and twilight are subject to a large correction (many tens of m/s) and the uncertainty is correspondingly large. A goal for future releases is to characterize and correct this effect more accurately.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Zonal_Wind_Accuracy	Accuracy of the zonal wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "Accuracy" variable quantifies the error introduced by the zero-wind phase estimate. It is strongly correlated across time lags of days to weeks and becomes increasingly decorrelated for time lags longer than 2 precession cycles (96 days). This error is estimated from the discrepancy between various techniques of determining the zero-wind phase. This error source is irrelevant for most users studying perturbations from the mean (e.g., tides, waves), but may be important for studies of zonal mean winds, point comparisons with other data sets, and seasonal/long-term trends thereof. Errors are moderately correlated across small altitude gaps. Errors in day mode and night mode are nearly uncorrelated, implying there could be different offsets for day mode and night mode. This could be important for error propagation of odd-numbered migrating tides (e.g., DW1).	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Zonal_Wind_Error	Error in the zonal wind estimate. For robust error propagation, users are encouraged to consider the individual error variables: "Precision_1_Sample," "Precision_1_Day," and "Accuracy." The "Wind_Error" variable is included for backwards compatibility and is equal to the quadrature sum of the "1 Sample" error and the "1 Day" error. This is the recommended uncertainty to use for analyses that collect data from several weeks and compute perturbations from the mean (e.g., for estimating tides and planetary waves). This error is uncorrelated across time lags larger than 24 hours. Errors are slightly correlated across small altitude gaps. Errors in day mode and night mode are nearly uncorrelated.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Meridional_Wind_Precision_1_Sample	1-sample precision in the meridional wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "1 sample" error variable quantifies errors that are uncorrelated from one exposure to the next, dominated by shot and dark noise in the detectors. The correlation time of this error source is 30-60 seconds (i.e., the measurement cadence). The reported error is estimated from the fringe intensity and background. This is the recommended variable to use for analyses of wind fluctuations within a single day and a single altitude (e.g., gravity waves). Because the Level 2.2 data include interpolation of Level 2.1 data, some correlation remains between consecutive samples. Errors are slightly correlated across small altitude gaps as a result of the inversion.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Meridional_Wind_Precision_1_Day	1-day precision in the meridional wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "1 Day" error variable quantifies the error introduced by daily calibrations, which is correlated for an entire 24-hour period (00:00 - 23:59 UT). This is estimated from the magnitude of fluctuations in the daily-averaged phase, propagated through the inversion. Errors in day mode and night mode are nearly uncorrelated. For studies pertaining to atmospheric tidal modes that combine data from many days, this error can be treated as uncorrelated across time.	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Meridional_Wind_Precision_Low_Signal_Effect	Low-signal precision in the meridional wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "Low Signal Effect" error variable quantifies the error introduced by the imperfect correction for the signal-dependent phase shift, which is an effect seen in atmospheric and calibration-lamp fringes where the phase of the fringes is biased at very low signal levels. This is under investigation but could be caused by a charge trapping effect in the CCD. A correction has been implemented based upon the empirical relationship between measured phase and signal level of the calibration lamps for the first ~30 months of the mission. However, especially for cases with low signal levels, this correction is uncertain. The uncertainty in the resulting winds is estimated from the signal level and reported in this variable. It is likely to be correlated across samples nearby in time and space, but the correlation between different channels (red and green), sensors (MIGHTI-A and MIGHTI-B), and operating modes (Day and Night) is not known. Depending on the analysis being used, it could be treated as a systematic error or as a statistical error. Where this uncertainty is large, caution is recommended. For example, for winds in the core science region (90-105 km altitude), the magnitude of the correction is small or zero, but data in the red channel during the night and twilight are subject to a large correction (many tens of m/s) and the uncertainty is correspondingly large. A goal for future releases is to characterize and correct this effect more accurately.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Meridional_Wind_Accuracy	Accuracy of the meridional wind estimate. Various sources of error in MIGHTI winds are quantified with 1-sigma estimates and organized by their temporal persistence. These error sources are nearly uncorrelated with each other and can thus be added in quadrature. Users are encouraged to contact the MIGHTI team for assistance with error propagation. The "Accuracy" variable quantifies the error introduced by the zero-wind phase estimate. It is strongly correlated across time lags of days to weeks and becomes increasingly decorrelated for time lags longer than 2 precession cycles (96 days). This error is estimated from the discrepancy between various techniques of determining the zero-wind phase. This error source is irrelevant for most users studying perturbations from the mean (e.g., tides, waves), but may be important for studies of zonal mean winds, point comparisons with other data sets, and seasonal/long-term trends thereof. Errors are moderately correlated across small altitude gaps. Errors in day mode and night mode are nearly uncorrelated, implying there could be different offsets for day mode and night mode. This could be important for error propagation of odd-numbered migrating tides (e.g., DW1).	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Meridional_Wind_Error	Error in the meridional wind estimate. For robust error propagation, users are encouraged to consider the individual error variables: "Precision_1_Sample," "Precision_1_Day," and "Accuracy." The "Wind_Error" variable is included for backwards compatibility and is equal to the quadrature sum of the "1 Sample" error and the "1 Day" error. This is the recommended uncertainty to use for analyses that collect data from several weeks and compute perturbations from the mean (e.g., for estimating tides and planetary waves). This error is uncorrelated across time lags larger than 24 hours. Errors are slightly correlated across small altitude gaps. Errors in day mode and night mode are nearly uncorrelated.	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Wind_Quality	A quantification of the quality, from 0 (Bad) to 1 (Good) A quantification of the overall quality of the wind data. While the intent is that the XXX_Wind_Error variable accurately characterizes the statistical error in the wind data, it is possible that systematic errors are present, or that the statistical error estimation is not accurate. If this is suspected to be the case, the quality will be less than 1.0. If the data are definitely unusable, the quality will be 0.0 and the sample will be masked. Users should exercise caution when the quality is less than 1.0. Currently, the quality can take values of 0 (Bad), 0.5 (Caution), or 1 (Good).		Epoch, ICON_L22_Altitude
ICON_L22_Fringe_Amplitude	Fringe Amplitude An approximate volume emission rate (VER) profile in arbitrary units, estimated by combining MIGHTI-A and MIGHTI-B data. Technically this is not the VER, but rather the amplitude of the fringes, which has a dependence on thermospheric temperature and background emission. Thus, it does not truly represent volume emission rate. However, it is a useful proxy. The units are arbitrary, as the fringe amplitudes are not calibrated. See also variables Fringe_Amplitude_Relative_Difference, Fringe_Amplitude_A, and Fringe_Amplitude_B.	arb	Epoch, ICON_L22_Altitude
ICON_L22_Fringe_Amplitude_Error	Error in the fringe amplitude estimate The statistical (1-sigma) error in the fringe amplitude estimate, propagated from error in the MIGHTI-A and MIGHTI-B inversions. The units are arbitrary, as the fringe amplitudes are not absolutely calibrated. Systematic errors, such as those arising from airglow gradients or cross-calibration, are not included in this variable, but are probably the dominant source of total error.	arb	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Relative_VER	Relative volume emission rate The volume emission rate (VER) obtained by averaging the VER from MIGHTI-A and MIGHTI-B, which is obtained by scaling the fringe amplitude by a calibration factor, as described in Data Product 2.1. Pre-flight calibrations and on-orbit comparisons with ground-based instruments are used to determine the best possible calibration. The fringe amplitude has a dependence on temperature, which is corrected using the MSIS model. Because the on-orbit calibration is uncertain, and because the MSIS temperature correction is not perfect, caution should be exercised when absolute calibration is required, or when precise comparisons are being made between samples at very different temperatures. Please contact the MIGHTI team before performing any studies that require absolute calibration. The statistical (1-sigma) error for this variable is provided in the variable ICON_..._Relative_VER_Error, though it is expected that systematic calibration errors dominate the total error.	ph/cm^3/s	Epoch, ICON_L22_Altitude
ICON_L22_Relative_VER_Error	Error in VER estimate (statistical) The statistical (1-sigma) error in the relative VER estimate, propagated from error in the MIGHTI-A and MIGHTI-B inversions. This error arises mostly from shot noise. Importantly, it is expected that systematic errors (e.g., calibration errors) dominate the total error, but they are not included in this variable.	ph/cm^3/s	Epoch, ICON_L22_Altitude
ICON_L22_VER_Quality	A quantification of the quality, from 0 (Bad) to 1 (Good) A quantification of the overall quality of the VER data. While the intent is that the XXX_VER_Error variable accurately characterizes the statistical error in the VER data, it is possible that systematic errors are present, or that the statistical error estimation is not accurate. If it is suspected that this is the case, the quality will be less than 1.0. If the data are definitely unusable, the quality will be 0.0 and the sample will be masked. Users should exercise caution when the quality is less than 1.0. Currently, the quality can take values of 0 (Bad), 0.5 (Caution), or 1 (Good).		Epoch, ICON_L22_Altitude
ICON_L22_Magnetic_Field_Aligned_Wind	Magnetic field-aligned component of the wind The component of the wind in the direction of the magnetic field line, assuming vertical winds are negligible. This variable is calculated by taking the geographic zonal and meridional wind (the primary data products in this file) and expressing the wind vector in a local magnetic coordinate system defined using the Python package OMMBV (https://github.com/rstoneback/OMMBV). The coordinate system used here is orthogonal and is identical to the coordinate system used to express the ion drifts in the ICON IVM data product 2.7 (i.e., the variables ICON_L27_Ion_Velocity_Meridional, ICON_L27_Ion_Velocity_Zonal, and ICON_L27_Ion_Velocity_Field_Aligned).	m/s	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Magnetic_Meridional_Wind	Magnetic meridional component of the wind The component of the wind in the magnetic meridional direction, assuming vertical winds are negligible. This variable is calculated by taking the geographic zonal and meridional wind (the primary data products in this file) and expressing the wind vector in a local magnetic coordinate system defined using the Python package OMMBV (https://github.com/rstoneback/OMMBV). The magnetic meridional unit vector is orthogonal to the magnetic field line but within the plane of the magnetic meridian (defined by the apex of the field line and its footpoint). At the magnetic equator, the meridional direction points up, while away from the equator it has a poleward component (north in the northern hemisphere, south in the southern hemisphere). Note that in some ion-neutral coupling models, a definition of magnetic meridional is often used that is horizontal (i.e., perpendicular to gravity) and generally northward. The definition used here is perpendicular to B and thus has primarily a vertical component at ICON latitudes. Note also that the definition of magnetic meridional and zonal used here differs from quasi-dipole and apex coordinate bases. The coordinate system used here is orthonormal and is identical to the coordinate system used to express the ion drifts in the ICON IVM data product 2.7 (i.e., the variables ICON_L27_Ion_Velocity_Meridional, ICON_L27_Ion_Velocity_Zonal, and ICON_L27_Ion_Velocity_Field_Aligned).	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Magnetic_Zonal_Wind	Magnetic zonal component of the wind The component of the wind in the magnetic zonal direction, assuming vertical winds are negligible. This variable is calculated by taking the geographic zonal and meridional wind (the primary data products in this file) and expressing the wind vector in a local magnetic coordinate system defined using the Python package OMMBV (https://github.com/rstoneback/OMMBV). At the magnetic equator, the zonal direction points horizontally, while away from the equator it can have a slightly vertical component. Note that the definition of magnetic meridional and zonal used here differs from quasi-dipole and apex coordinate bases. The coordinate system used here is orthonormal and is identical to the coordinate system used to express the ion drifts in the ICON IVM data product 2.7 (i.e., the variables ICON_L27_Ion_Velocity_Meridional, ICON_L27_Ion_Velocity_Zonal, and ICON_L27_Ion_Velocity_Field_Aligned).	m/s	Epoch, ICON_L22_Altitude
ICON_L22_Orbit_Number	ICON orbit number The ICON orbit number corresponding to each grid point. This is usually an integer, but when samples from two different orbits are used, an interpolated (fractional) value is used.		Epoch, ICON_L22_Altitude
ICON_L22_Orbit_Node	ICON orbit ascending/descending flag A flag indicating whether ICON is in the ascending (0) or descending (1) part of the orbit. For some grid points, samples from MIGHTI-A are on the descending part of the orbit, while samples from MIGHTI-B are ascending. In these cases an interpolated value is used (between 0 and 1).		Epoch, ICON_L22_Altitude

support_data

Variable Name	Description	Units	Dimensions
Epoch	Sample time, average of A and B measurements. Number of msec since Jan 1, 1970. A one-dimensional array defining the time dimension of the two-dimensional data grid (the other dimension being altitude). This is the average of the MIGHTI-A and MIGHTI-B sample times, which differ by 5-8 minutes. Where MIGHTI-A or MIGHTI-B samples are missing, data are reported as missing, but gaps in Epoch are interpolated over to adhere to the netCDF4 standard that coordinate variables should have no missing values. The matchup between MIGHTI-A and B happens at slightly different times at different altitudes, a complication which is ignored by this variable. The effect is small (plus or minus 30-60 seconds), but in cases where it is important, it is recommended to use the alternative time variable Epoch_Full, which is two dimensional and captures the variation with altitude.	ms	Epoch
Epoch_Full	Sample time, midpoint of A and B measurements. Number of msec since Jan 1, 1970. See the notes for the variable Epoch. This variable is the same as Epoch but contains a second dimension, which captures the small (30-60 second) variation of time with altitude. For most applications this is expected to be negligible, and Epoch can be used instead of this variable. Also see the variable Time_Delta, which contains the difference between the MIGHTI-A and MIGHTI-B times that contributed to each point. Epoch_Full contains the average time.	ms	Epoch, ICON_L22_Altitude
ICON_L22_UTC_Time	Sample time, average of A and B measurements. This variable is the same as Epoch but is formatted as a human-readable string. Missing grid points are labeled with empty strings.		Epoch
ICON_L22_Altitude	WGS84 altitude of each wind sample A one-dimensional array defining the altitude dimension of the data grid (the other dimension being time). Altitude is defined using the WGS84 ellipsoid.	km	ICON_L22_Altitude
ICON_L22_Longitude	WGS84 longitude of each wind sample A two-dimensional array defining the longitude (0-360 deg) of the two-dimensional data grid. In the initial implementation, the longitude is constant with altitude, but this may change in the future to capture the slight (few deg) variation with altitude. Longitude is defined using the WGS84 ellipsoid. It should be noted that while a single longitude value is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers.	deg	Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Latitude	WGS84 latitude of each wind sample A two-dimensional array defining the latitude of the two-dimensional data grid. The latitude varies only slightly (a few deg) with altitude, but this variation is included. Latitude is defined using the WGS84 ellipsoid. It should be noted that while a single latitude value is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers.	deg	Epoch, ICON_L22_Altitude
ICON_L22_Magnetic_Latitude	Magnetic quasi-dipole latitude of each wind sample A two-dimensional array defining the magnetic quasi-dipole latitude of the two-dimensional data grid. The latitude varies only slightly (a few deg) with altitude, but this variation is included. It should be noted that while a single latitude value is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers. Quasi-dipole latitude and longitude are calculated using the fast implementation developed by Emmert et al. (2010, doi:10.1029/2010JA015326) and the Python wrapper apexpy (doi.org/10.5281/zenodo.1214207).	deg	Epoch, ICON_L22_Altitude
ICON_L22_Magnetic_Longitude	Magnetic quasi-dipole longitude of each wind sample A two-dimensional array defining the magnetic quasi-dipole longitude of the two-dimensional data grid. The longitude varies only slightly (a few deg) with altitude, but this variation is included. It should be noted that while a single longitude value is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers. Quasi-dipole latitude and longitude are calculated using the fast implementation developed by Emmert et al. (2010, doi:10.1029/2010JA015326) and the Python wrapper apexpy (doi.org/10.5281/zenodo.1214207). Quasi-dipole longitude is defined such that zero occurs where the geodetic longitude is near 285 deg east (depending on latitude).	deg	Epoch, ICON_L22_Altitude
ICON_L22_Solar_Zenith_Angle	Solar zenith angle of each wind sample Angle between the vectors towards the sun and towards zenith, for each point in the grid.	deg	Epoch, ICON_L22_Altitude
ICON_L22_Local_Solar_Time	Local solar time of each wind sample Local solar time at each point in the grid, calculating using the equation of time.	hour	Epoch, ICON_L22_Altitude
ICON_L22_Time_Delta	Difference between MIGHTI-A and B times contributing to each point To determine the cardinal wind at each point, a MIGHTI-A line-of-sight wind is combined with a MIGHTI-B line-of-sight wind from several minutes later. This variable contains this time difference for every point. During standard operations (LVLH Normal), this variable should be positive, but can potentially become negative during conjugate operations or when ICON is observing to the south (LVLH Reverse).	s	Epoch, ICON_L22_Altitude

metadata

Variable Name	Description	Units	Dimensions
ICON_L22_Fringe_Amplitude_A	Fringe Amplitude from MIGHTI-A See Fringe_Amplitude. This variable contains the fringe amplitude measured by MIGHTI-A, interpolated to the reconstruction grid. This is one of two variables used to create Fringe_Amplitude.	arb	Epoch, ICON_L22_Altitude
ICON_L22_Fringe_Amplitude_B	Fringe Amplitude from MIGHTI-B See Fringe_Amplitude. This variable contains the fringe amplitude measured by MIGHTI-B, interpolated to the reconstruction grid. This is one of two variables used to create Fringe_Amplitude.	arb	Epoch, ICON_L22_Altitude
ICON_L22_Relative_VER_A	Relative VER from MIGHTI-A See Relative_VER. This variable contains the VER measured by MIGHTI-A, interpolated to the reconstruction grid. This is one of two variables used to create Relative_VER. When A and B are significantly different, large horizontal gradients are suspected, and the quality is reduced.	ph/cm^3/s	Epoch, ICON_L22_Altitude
ICON_L22_Relative_VER_B	Relative VER from MIGHTI-B See Relative_VER. This variable contains the VER measured by MIGHTI-B, interpolated to the reconstruction grid. This is one of two variables used to create Relative_VER. When A and B are significantly different, large horizontal gradients are suspected, and the quality is reduced.	ph/cm^3/s	Epoch, ICON_L22_Altitude
ICON_L22_VER_Relative_Difference	Difference in MIGHTI A and B's VER estimates, divided by the mean The absolute value of the difference between Relative_VER_A and Relative_VER_B, divided by the average. Ideally, MIGHTI A and B should measure the same VER. When they do not, this is an indication of potential violations of the spherical symmetry assumption inherent to the inversion. This is the parameter used to determine if the spherical asymmetry flag is raised.		Epoch, ICON_L22_Altitude

Variable Name	Description	Units	Dimensions
ICON_L22_Quality_Flags	Quality flags This variable provides information on why the Quality variable is reduced from 1.0. Many quality flags can be raised for each grid point, and each flag takes values 0 or 1. More than one flag can be raised per point. This variable is a three-dimensional array with dimensions time, altitude, and number of flags. Each entry is 0 or 1. Most quality flags are passed through from the L1 and L2.1 algorithms (after interpolation to the L2.2 grid). Some additional quality flags are created in L2.2. The N_Flags dimension is defined below: * 0 : (From L1 A) SNR too low to reliably perform L1 processing * 1 : (From L1 A) Proximity to South Atlantic Anomaly * 2 : (From L1 A) Bad calibration * 3 : (From L1 A) Calibration lamps are on * 4 : (From L1 A) Solar/lunar contamination * 5 : (From L2.1 A) Not enough valid points in profile * 6 : (From L2.1 A) SNR too low after inversion * 7 : (From L2.1 A) Significant airglow above 300 km * 8 : (From L2.1 A) Line of sight crosses the terminator * 9 : (From L2.1 A) Thermal drift correction is uncertain * 10: (From L2.1 A) S/C pointing is not stable * 11: (From L2.1 A) SNR is low after inversion, but maybe usable * 12: (From L1 B) SNR too low to reliably perform L1 processing * 13: (From L1 B) Proximity to South Atlantic Anomaly * 14: (From L1 B) Bad calibration * 15: (From L1 B) Calibration lamps are on NOTE: Var_Notes truncated. See NC file for full description.		Epoch, ICON_L22_Altitude, N_Flags

Acknowledgement

This is a data product from the NASA Ionospheric Connection Explorer mission, an Explorer launched at 21:59:45 EDT on October 10, 2019, from Cape Canaveral AFB in the USA. Guidelines for the use of this product are described in the ICON Rules of the Road (http://icon.ssl.berkeley.edu/Data).

Responsibility for the mission science falls to the Principal Investigator, Dr. Thomas Immel at UC Berkeley:
Immel, T.J., England, S.L., Mende, S.B. et al. Space Sci Rev (2018) 214: 13. https://doi.org/10.1007/s11214-017-0449-2

Responsibility for the validation of the L1 data products falls to the instrument lead investigators/scientists.
* EUV: Dr. Eric Korpela : https://doi.org/10.1007/s11214-017-0384-2
* FUV: Dr. Harald Frey : https://doi.org/10.1007/s11214-017-0386-0
* MIGHTI: Dr. Christoph Englert : https://doi.org/10.1007/s11214-017-0358-4, and https://doi.org/10.1007/s11214-017-0374-4
* IVM: Dr. Roderick Heelis : https://doi.org/10.1007/s11214-017-0383-3

Responsibility for the validation of the L2 data products falls to those scientists responsible for those products.
* Daytime O and N2 profiles: Dr. Andrew Stephan : https://doi.org/10.1007/s11214-018-0477-6
* Daytime (EUV) O+ profiles: Dr. Andrew Stephan : https://doi.org/10.1007/s11214-017-0385-1
* Nighttime (FUV) O+ profiles: Dr. Farzad Kamalabadi : https://doi.org/10.1007/s11214-018-0502-9
* Neutral Wind profiles: Dr. Jonathan Makela : https://doi.org/10.1007/s11214-017-0359-3
* Neutral Temperature profiles: Dr. Christoph Englert : https://doi.org/10.1007/s11214-017-0434-9
* Ion Velocity Measurements : Dr. Russell Stoneback : https://doi.org/10.1007/s11214-017-0383-3

Responsibility for Level 4 products falls to those scientists responsible for those products.
* Hough Modes : Dr. Chihoko Yamashita : https://doi.org/10.1007/s11214-017-0401-5
* TIEGCM : Dr. Astrid Maute : https://doi.org/10.1007/s11214-017-0330-3
* SAMI3 : Dr. Joseph Huba : https://doi.org/10.1007/s11214-017-0415-z

Pre-production versions of all above papers are available on the ICON website.
http://icon.ssl.berkeley.edu/Publications

Overall validation of the products is overseen by the ICON Project Scientist, Dr. Scott England.

NASA oversight for all products is provided by the Mission Scientist, Dr. Jeffrey Klenzing.

Users of these data should contact and acknowledge the Principal Investigator Dr. Immel and the party directly responsible for the data product (noted above) and acknowledge NASA funding for the collection of the data used in the research with the following statement : "ICON is supported by NASA's Explorers Program through contracts NNG12FA45C and NNG12FA42I".

These data are openly available as described in the ICON Data Management Plan available on the ICON website (http://icon.ssl.berkeley.edu/Data).

This document was automatically generated on `2022-10-18 10:25` using the file:
`ICON_L2-2_MIGHTI_Vector-Wind-Green_2022-01-01_v05r001.NC`
Software version: `ICON SDC > ICON UIUC MIGHTI L2.2 Processor v5.05`