ICON Data Product 2.3: MIGHTI Retrieved Temperatures and Brightnesses

This document describes the data product for ICON MIGHTI-A Level 2.3 Retrieved Temperature File, which is in NetCDF4 format.

MIGHTI samples the O2 A band spectral region at five different wavelengths in order to both measure the shape of the band and to specify a background radiance that is subtracted from the signal. The wavelengths of the filter passbands are selected to maximize the sensitivity to lower thermospheric temperature variations. Two filter channels sample either end of the band to define a background (754.1 nm and 780.1 nm) and three more sample its shape (760.0 nm, 762.8 nm and 765.2 nm). Using three filters that sample the band shape allows the simultaneous retrieval of the atmospheric temperature and common shifts in the center wavelengths of the pass bands due to thermal drifts of the filters [Stevens et al., 2018; Englert et al., 2017].

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.

Dimensions

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
`Wavelength`	5
`Epoch`	1848
`Altitude`	18

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_L23_MIGHTI_A_Temperature`	Derived temperatures from A band by altitude Derived temperatures from A band by altitude. Temperatures are retrieved from the rotational distribution of emission lines in the O2 A band. The measurement is made at 5 spectral channels. 3 channels measure the A band and 2 others on either side of the band measure a background, which is subtracted from the 3 signal channels. An entire altitude profile is observed simultaneously. An onion-peeling inversion is used on the raw observations to remove the effects of the integration along the line of sight. See Stevens et al. (Space Science Reviews (2018) 214:4. https://doi.org/10.1007/s11214-017-0434-9). O2 A band spectra are pre-calculated from 100-400 K in 20 K increments based on the HITRAN 2016 database [Gordon et al., JQSRT (2017), 203:3-69.https://doi.org/10.1016/j.jqsrt.06.038] and smoothed filter functions with FWHM of ~2.0 nm. The filter functions are based on Gaussian fits to laboratory measurements and are a function of channel, row (altitude), and column. The fits are separately done for each pixel as a function of peak wavenumber (wavelength), width, and transmittance. For each of the three signal channels the fitted Gaussians are co-added over 51 pixels where the transmittance is largest for a representative filter function for that channel. The transmittances are not absolutely calibrated in photometric units, but the relative transmittance between channels and between detectors is maintained, which allows for the retrieval of temperature at the tangent altitude.	`K`	`Altitude, Epoch`
`ICON_L23_MIGHTI_A_Temperature_Statistical_Uncertainty`	Statistical uncertainties in derived temperatures by altitude Statistical uncertainties (one sigma) in derived temperatures by altitude	`K`	`Altitude, Epoch`

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_Temperature_Bias_Uncertainty	Bias uncertainties in derived temperatures by altitude Estimated bias uncertainties in derived temperatures by altitude; aka systematic uncertainties. These uncertainties are present in each temperature profile and are primarily due to 1) a 1 cm-1 uncertainty in the common shift applied to pre-flight laboratory determined filter positions. This uncertainty was tested in the retrieval and a derived fixed uncertainty of 12 K is propagated at all altitudes and 2) the lack of measurements above the top altitude sampled, and altitude dependent, with the topmost altitudes of the retrieval affected the most. The temperature bias uncertainty is found by a root sum square of these two. At most altitudes the estimated bias uncertainty is dominated by the uncertainty in the common shift.	K	Altitude, Epoch
ICON_L23_MIGHTI_A_Temperature_Total_Uncertainty	Total uncertainties in derived temperatures by altitude Total uncertainties in derived temperatures by altitude: Here the statistical temperature uncertainty has been linearly added to the estimated temperature bias.	K	Altitude, Epoch
ICON_L23_MIGHTI_A_Filter_Wavenumber_Shift	Common shift of all filter center wavenumbers. Common shift of all filter center wavenumbers due to thermal drift that is added to laboratory measured filter center wavenumbers. The three channels measuring the A band overdetermines the temperature such that the wavenumber registration due to any thermal drift of the instrument can be additionally inferred. This is typically fixed with altitude and determined (along with temperature) from the signal originating from the O2 A band as measured from 3 signal channels.	cm^-1	Altitude, Epoch
ICON_L23_MIGHTI_A_Filter_Wavenumber_Shift_Uncertainty	Uncertainties in the shift of all filter center wavenumbers. Uncertainties (1-sigma) in the shift of all filter center wavenumbers. If the common wavenumber shift is fixed with altitude and prescribed, then this uncertainty is zero everywhere.	cm^-1	Altitude, Epoch
ICON_L23_MIGHTI_A_ABand_Intensity_Scaled	Derived scaling of O2 A Band to Radiances by altitude Derived common scaling of O2 A Band radiances in the 3 signal channels by altitude. Calculated forward radiances are fit to the observations from each of the three signal channels. The scaling is done at each tangent altitude separately and interatively until a best fit solution is found. The intensity of each signal channel relative to the other two determines the temperature, so the scale factor is unitless. The scaling is derived using pre-calculated spectra from the HITRAN 2016 database [Gordon et al., JQSRT, 203, 3-69 (2017)].		Altitude, Epoch
ICON_L23_MIGHTI_A_ABand_Intensity_Scaled_Uncertainty	Uncertainty in Scaling of O2 A Band to Radiances by altitude Derived uncertainty (1-sigma) in derived common scaling of O2 A Band to emergent intensity by altitude.		Altitude, Epoch

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_Relative_Radiance	Relative radiance by filter and altitude Observed relative radiance by filter and altitude. The retrieval is based on a forward modeling approach to these observed radiances as reported in electrons/s from the MIGHTI L1 product. These are converted to electrons based on the integration time during day (30 s) or night (60 s).	Electrons	Wavelength, Altitude, Epoch
ICON_L23_MIGHTI_A_Relative_Radiance_Uncertainty	Uncertainties in relative radiance by filter and altitude Uncertainty (1-sigma) in relative radiance by filter by altitude and filter. These are calculated by taking the square root of the total number of electrons in each of the three signal channels, which are 51 pixels wide for MIGHTI-A or MIGHTI-B (day or night).	Electrons	Wavelength, Altitude, Epoch
ICON_L23_MIGHTI_A_Background_Signal	Background Signal Subtracted Background Signal by altitude and filter. This background is interpolated across the 3 signal channels from two background channels located spectrally on either side of the O2 A band.	Electrons	Wavelength, Altitude, Epoch
ICON_L23_MIGHTI_A_Background_Slope	Slope of background Derived slope of subtracted background. The slope of the background is saved here for diagnostic purposes. It is calculated by taking the difference of the flatfielded signal from the two background channels and dividing by the difference of the the channel center wavelengths (in nm) of the two background channels (approximately 780 nm - 754 nm). This is done explicitly by [bg2 - bg1]/flatfield/[wavelength2 - wavelength1], where bg2 and bg1 are the observed background signals in electrons.	/nm	Altitude, Epoch

support_data

Variable Name	Description	Units	Dimensions
Epoch	Milliseconds since 1970-01-01 00:00:00 UTC at middle of image integration This variable contains the time corresponding to the temperature profiles reported in this file. The variable is in milliseconds since 1970-01-01 00:00:00 UTC at middle of image integration. A human-readable version of the time can be found in the variable ICON_...UTC_Time.	ms	Epoch
ICON_L23_MIGHTI_A_Tangent_Altitude	Tangent point altitudes Tangent point altitudes. These altitudes are the tangent altitude of the line of sight of each pixel.	km	Altitude, Epoch

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_Filter_Center_Wavenumber	Filter Center Wavenumber Filter Center Wavenumber used in temperature retrieval as measured in the laboratory and fitted by a Gaussian. These filter center wavenumbers vary with detector (MIGHTI A and MIGHTI B), with altitude as well as with channel. They are also difference for daytime and nighttime operations. It is from these center wavenumbers that the common wavenumber shift (across all channels) is calculated.	cm^-1	Altitude, Wavelength, Epoch
ICON_L23_MIGHTI_A_Filter_Center_Wavelength	Filter Center Wavelength Filter Center Wavelength used in temperature retrieval (=1e7/FilterCWN).	nm	Altitude, Wavelength, Epoch
ICON_L23_MIGHTI_A_Tangent_Latitude	Tangent point latitudes by altitude Tangent point latitudes by altitude. Note that these are a function of both epoch and altitude. Note also that due to the nature of the limb observations these latitudes are typically an average over many hundreds of kilometers.	degrees North	Altitude, Epoch
ICON_L23_MIGHTI_A_Tangent_Longitude	Tangent point longitudes by altitude Tangent point longitudes (0-360) by altitude. Note that these are a function of both epoch and altitude. Note also that due to the nature of the limb observations these longitudes are typically an average over many hundreds of kilometers.	degrees East	Altitude, Epoch
ICON_L23_MIGHTI_A_Tangent_Magnetic_Latitude	Tangent point magnetic latitudes by altitude Tangent point magnetic latitudes by altitude. 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). Note that these are a function of both epoch and altitude. Note also that due to the nature of the limb observations these latitudes are typically an average over many hundreds of kilometers.	degrees North	Altitude, Epoch
ICON_L23_MIGHTI_A_Tangent_Magnetic_Longitude	Tangent point magnetic longitudes by altitude Tangent point magnetic longitudes by altitude. 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). Note that these are a function of both epoch and altitude. Note also that due to the nature of the limb observations these longitudes are typically an average over many hundreds of kilometers.	degrees East	Altitude, Epoch

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_Tangent_Local_Solar_Time	Local solar time at tangent point Local solar time (0-24 h) at tangent point calculated using the equation of time. LST is a function of both epoch and altitude.	hour	Altitude, Epoch
ICON_L23_MIGHTI_A_Tangent_Solar_Zenith_Angle	Solar zenith angle at tangent point Solar zenith angle at tangent point. SZA is a function of both epoch and altitude.	degrees	Altitude, Epoch
ICON_L23_MIGHTI_A_Field_of_View_Azimuth_Angle	Field of view azimuth angle Field of view azimuth angle	degrees	Altitude, Epoch
ICON_L23_MIGHTI_A_Boresight_Sun_Angle	Total boresight to sun angle Total boresight to sun angle	degrees	Epoch
ICON_L23_MIGHTI_A_Thermal_Electric_Cooler_Cold_Temperature	Cold-side temperature of the thermoelectric cooler attached to the camera head Cold-side temperature of the thermoelectric cooler attached to the camera head	C	Epoch
ICON_L23_Orbit_Number	Integer orbit number at middle of exposure Integer orbit number at middle of exposure		Epoch
ICON_L23_Observatory_Latitude	Spacecraft latitude at middle of exposure Spacecraft latitude at middle of exposure	degrees North	Epoch
ICON_L23_Observatory_Longitude	Spacecraft longitude at middle of exposure Spacecraft longitude (0-360) at middle of exposure	degrees East	Epoch
ICON_L23_Observatory_Altitude	Spacecraft altitude at middle of exposure Spacecraft altitude at middle of exposure	km	Epoch
ICON_L23_Observatory_Local_Solar_Time	Spacecraft local solar time at middle of exposure Spacecraft local solar time (0-24) at middle of exposure	hour	Epoch
ICON_L23_Observatory_Solar_Zenith_Angle	Spacecraft solar zenith angle at middle of exposure Spacecraft solar zenith angle at middle of exposure	degrees	Epoch
ICON_L23_MIGHTI_Aperture_1_Position	MIGHTI-A camera aperture 1 position sense flag. Aperture Position 1: 0=OPEN, 1=CLOSED, 2=15% OPEN, 3=UNKNOWN. Note that when OPEN (0) the integration time is 60 s for nighttime observations and when 15% OPEN (2) the integration time is 30 s for daytime observations.		Epoch
ICON_L23_MIGHTI_Aperture_2_Position	MIGHTI-A camera aperture 2 position sense flag. Aperture Position 2: 0=OPEN, 1=CLOSED, 2=15% OPEN, 3=UNKNOWN. Note that when OPEN (0) the integration time is 60 s for nighttime observations and when 15% OPEN (2) the integration time is 30 s for daytime observations.		Epoch

Variable Name	Description	Units	Dimensions
ICON_L23_Orbit_Node	Flag indicating that the spacecraft is ascending (0) or descending (1) node Flag indicating that the spacecraft is ascending (0) or descending (1) node.		Epoch
ICON_L1_MIGHTI_A_Quality_Flag_South_Atlantic_Anomaly	Quality Flag indicating that the spacecraft is within the South Atlantic Anomaly Quality Flag indicating that the spacecraft is within the South Atlantic Anomaly (0 = not in SAA)		Epoch
ICON_L1_MIGHTI_A_Quality_Flag_Bad_Calibration	Quality Flag indicating an inappropriate calibration file has been used or was missing Quality Flag indicating an inappropriate calibration file has been used or was missing		Epoch
ICON_L23_MIGHTI_A_UTC_Time	ISO 9601 formatted UTC timestamp (at middle of image integration). This variable is the same as Epoch but is formatted as a human-readable string.		Epoch
ICON_L23_MIGHTI_A_UTC_Time_Start	Milliseconds since 1970-01-01 00:00:00 UTC at start of image integration. Milliseconds since 1970-01-01 00:00:00 UTC at start of image integration. Derived from original GPS values reported from spacecraft (Time_GPS_Seconds and Time_GPS_Subseconds). Time calculation is offset by 615ms (flush time) for the first image in the series and for all other images are adjusted by subtracting (integration time + 308 milliseconds) from the reported GPS time.		Epoch
ICON_L23_MIGHTI_A_UTC_Time_Stop	Milliseconds since 1970-01-01 00:00:00 UTC at end of image integration. Milliseconds since 1970-01-01 00:00:00 UTC at end of image integration. Derived from original GPS values reported from spacecraft (Time_GPS_Seconds and Time_GPS_Subseconds). Time calculation is offset by 615ms (flush time) for the first image in the series and for all other images are adjusted by subtracting (integration time + 308 milliseconds) from the reported GPS time.		Epoch
ICON_L23_MIGHTI_A_GPS_Time	Milliseconds since 1980-01-06 00:00:00 TAI (coincident with UTC) at middle of image integration. Milliseconds since 1980-01-06 00:00:00 TAI (coincident with UTC) at middle of image integration. Derived from original GPS values reported from spacecraft (Time_GPS_Seconds and Time_GPS_Subseconds). Time calculation is offset by 615ms (flush time) for the first image in the series and for all other images are adjusted by subtracting (integration time + 308 milliseconds) from the reported GPS time.		Epoch

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_GPS_Time_Seconds	GPS seconds count when FSW received image packet header. The header of the first image received in a series 615 ms after start of image processing. Following headers are adjusted by subtracting (integration time + 308 ms) from the reported GPS time.		Epoch
ICON_L23_MIGHTI_A_GPS_Time_Subseconds	20MHz clock (50 nanosecond) offset from GPS seconds. GPS Time in sub seconds, 50 nanosecond offset from GPS seconds from 20 MHz clock.	50 Nanoseconds	Epoch
ICON_L23_MIGHTI_A_Integration_Time	Time to integrate MIGHTI-A region of interest (ROI) image. MIGHTI Integration Time in millieconds	ms	Epoch

metadata

Variable Name	Description	Units	Dimensions
ICON_L23_MIGHTI_A_Filter_Wavelengths	Wavelength labels corresponding to the five filters Wavelength labels corresponding to the five filters. These are for guidance. Actual values used in retrieval for MIGHTI-A and MIGHTI-B (day/night) are in ICON_L23_MIGHTI_(A or B)_Filter_Center_Wavelength.		Wavelength

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).

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