ICON Data Product 2.5: FUV Nighttime O+ profile

This document describes the data product for ICON FUV Nighttime O+ profiles (DP 2.5), which is in NetCDF4 format.

This data product contains (nominally) 24 hours of data, including O+ density profiles of the nighttime ionosphere as well as ancillary data such as satellite locations and measurement times. In this data product, all the time variables and time dependent variables (with dimension Epoch) contain only the nighttime measurements. We neither use any daytime measurements nor output them in this data product. The O+ density profiles are estimated from the measured brightness profiles of 135.6 nm emissions by solving a regularized linear inverse problem. Due to multiple scattering (yields non-linearity) and low brightness (yields low SNR), we do not use the brightness measurements having tangent altitudes below 150 km, consequently we do not estimate the O+ density profile at tangent altitudes below 150 km (i.e. on the disk). The Altitude dimension is the maximum number of tangent points that are above 150 km for the entire 24-hour period. The Stripe dimension represents the dimension from left to right along the horizon for any one given image. Nominally 6 stripes are used, and each stripe samples a 3-degree wide field of view. O+ density profiles are estimated separately for each stripe.

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**
`Epoch`	2475
`Altitude`	107
`Stripe`	6

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_L25_VER	VER of 135.6-nm emission as a function of altitude The volume emission rates (VER) are estimated from the brightness profiles of the 135.6 nm emissions by solving a regularized linear (multiple scattering is negligible) inverse problem. In the inverse problem, atmosphere is divided into spherical shells with boundaries determined by the tangent altitudes, and VER is assumed to be uniform inside those shells. Solving the inverse problem, VER value for each shell is estimated. The details of the inversion are given in Kamalabadi et al. [2018, doi: 10.1007/s11214-018-0502-9].	ph/cm^3/s	Epoch, Altitude, Stripe
ICON_L25_VER_Error	Error in VER of 135.6-nm emission as a function of altitude The statistical 1-sigma errors computed for the estimated VER values. Errors are obtained by propagating the uncertainties in the given brightness profiles (provided in the L1 input file) through the VER estimation process. Some other error sources are not included in this variable (such as the bias introduced by the regularization, or the errors due to the assumption that the VER is uniform between two adjacent tangent altitudes).	ph/cm^3/s	Epoch, Altitude, Stripe
ICON_L25_O_Plus_Density	O+ density as a function of altitude The O+ profiles are obtained from the estimated volume emission rate (VER) profiles assuming the emission arises from radiative recombination and mutual neutralization. The NRLMSISE00 model is used to characterize the oxygen density needed to model the mutual neutralization contribution.	1/cm^3	Epoch, Altitude, Stripe
ICON_L25_O_Plus_Density_Error	Error in O+ density as a function of altitude The statistical 1-sigma errors computed for the estimated O+ density profiles. Errors are obtainedby propagating the uncertainties in the estimated VER profiles through the O+ density profile calculations. Some other error sources are not included in this variable (such as the bias introduced by the regularization, or the errors due to the assumption that the VER is uniform between two adjacent tangent altitudes).	1/cm^3	Epoch, Altitude, Stripe
ICON_L25_HMF2	Altitudes of the peak O+ densities The altitudes of the peak O+ densities that are obtained by performing cubic spline interpolation on each profile.	km	Epoch, Stripe

Variable Name	Description	Units	Dimensions
ICON_L25_Latitude	Latitudes of the peak O+ densities in WGS84 The geodetic latitudes of the peak O+ densities that are obtained by performing nearest neighbor interpolation on each profile.	degrees North	Epoch, Stripe
ICON_L25_Longitude	Longitudes of the peak O+ densities in WGS84 The geodetic longitudes of the peak O+ densities that are obtained by performing nearest neighbor interpolation on each profile.	degrees East	Epoch, Stripe
ICON_L25_Magnetic_Latitude	Magnetic latitudes of the peak O+ densities The magnetic latitudes of the peak O+ densities that are obtained by performing nearest neighbor interpolation on each profile.	degrees North	Epoch, Stripe
ICON_L25_Magnetic_Longitude	Magnetic longitudes of the peak O+ densities The magnetic longitudes of the peak O+ densities that are obtained by performing nearest neighbor interpolation on each profile.	degrees East	Epoch, Stripe
ICON_L25_HMF2_Error	Error in estimated altitudes of the peak O+ densities The propagated statistical errors from the O+ density profiles through the hmF2 estimation. Errors are propagated through the cubic spline interpolation using a Monte Carlo method. The details can be found in Kamalabadi et al. [2018, doi: 10.1007/s11214-018-0502-9].	km	Epoch, Stripe
ICON_L25_NMF2	Estimated peak O+ densities The peak O+ densities that are obtained by performing cubic spline interpolation on each profile.	1/cm^3	Epoch, Stripe
ICON_L25_NMF2_Error	Error in estimated peak O+ densities The propagated statistical 1-sigma errors from the O+ density profiles through the NmF2 estimation . Errors are propagated through the cubic spline interpolation using a Monte Carlo method. The details can be found in Kamalabadi et al. [2018, doi: 10.1007/s11214-018-0502-9].	1/cm^3	Epoch, Stripe
ICON_L25_Local_Solar_Time	Local solar times at the retrieved peak O+ density locations Local solar times (0-24 hours decimal) at the locations of the retrieved peak O+ densities.	hours	Epoch, Stripe

Variable Name	Description	Units	Dimensions
ICON_L25_Quality	A quantification of the inversion quality, from 0 (Bad) to 1 (Good) While the intent is that the variable ICON_L25_O_Plus_Density_Error accurately characterizes the statistical error in the O+ density 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, which is determined based on the brightness values and other considerations. If the data are definitely unusable, the quality will be 0.0. Users should exercise caution when the quality is less than 1.0.		Epoch, Stripe
ICON_L25_Quality_Flags	Provides description about the observed inversion quality This variable is intended to provide a description to the user why `ICON_L25_Quality` is less than 1, if that is the case. This is a binary coded integer whose binary representation indicates the quality conditions which were present during or before the inversion. Here are the quality conditions represented by each digit: 1: Error occurred during inversion. Makes the quality 0, no retrieval available. 2: No reliable quality L1 data available (see L1 quality flag). Makes the quality 0, no retrieval produced. 4: Very low input signal level (very low brightness). Makes the quality 0, retrieval available. 8: Low input signal level (low brightness). Makes the quality 0.5, retrieval available. 16: Unexpected hmF2 value. Makes the quality 0.5, retrieval available.		Epoch, Stripe

support_data

Variable Name	Description	Units	Dimensions
Epoch	Milliseconds since 1970-01-01 00:00:00 UTC at middle of measurement integration The center times of the exposures, measured as milliseconds after 1970-01-01/00:00:00 UT. There might be time jumps that are larger than the nominal measurement integration time between two consecutive elements of this array, which is because we neither include daytime measurements nor their times. There also could be larger time jumps due to calibration maneuvers or turret movements.	ms	Epoch
ICON_L25_UTC_Time	Center time of 12-second profile integration The center times of the exposures. Different than Epoch, array elements are not in milliseconds, but they are strings of the date in UT, with the format YYYY-MM-DD HH:MM:SS.FFFZ		Epoch

Variable Name	Description	Units	Dimensions
ICON_L25_Start_Times	Start time of 12-second profile integration The start times of the exposures, in UT, with the format YYYY-MM-DD/HH:MM:SS.		Epoch
ICON_L25_Stop_Times	Stop time of 12-second profile integration The stop times of the exposures, in UT, with the format YYYY-MM-DD/HH:MM:SS.		Epoch
ICON_L25_Observatory_Position_Latitude	Spacecraft WGS84 latitude The geodetic latitudes of the spacecraft, evaluated using the WGS84 ellipsoid.	degrees North	Epoch
ICON_L25_Observatory_Position_Longitude	Spacecraft WGS84 longitude The geodetic longitudes of the spacecraft, evaluated using the WGS84 ellipsoid.	degrees East	Epoch
ICON_L25_Observatory_Position_Altitude	Spacecraft WGS84 altitude The geodetic altitudes of the spacecraft, evaluated using the WGS84 ellipsoid.	km	Epoch
ICON_L25_Orbit_Number	ICON Orbit Number Integer orbit numbers for each measurement.		Epoch
ICON_L25_O_Plus_Profile_Latitude	O+ latitude in WGS84 The latitudes of each point in the O+ profile, evaluated using the WGS84 ellipsoid. It should be noted that while a single latitude value (the tangent latitude) is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers.	degrees North	Epoch, Altitude, Stripe
ICON_L25_O_Plus_Profile_Longitude	O+ longitude in WGS84 The longitudes of each point in the O+ profile, evaluated using the WGS84 ellipsoid. It should be noted that while a single longitude value (the tangent longitude) is given for each point, the observation is inherently a horizontal average over many hundreds of kilometers.	degrees East	Epoch, Altitude, Stripe
ICON_L25_O_Plus_Profile_Altitude	O+ altitude in WGS84 The altitudes of each point in the O+ profile, evaluated using the WGS84 ellipsoid. These altitudes are one half sample above the tangent altitudes of each pixel's line of sight (consistent with the assumption implicit in the inversion that the emission rate is constant within the layer between tangent altitudes).	km	Epoch, Altitude, Stripe
ICON_L25_Celestial_Azimuth_Angle_Profile	FOV Celestial Azimuth Celestial azimuth angles associated with the brightness measurements. Each pixel of the instrument has its own azimuth angle associated with its line of sight.	degrees	Epoch, Altitude, Stripe

Variable Name	Description	Units	Dimensions
ICON_L25_Celestial_Zenith_Angle_Profile	FOV Celestial Zenith Celestial zenith angles associated with the brightness measurements. Each pixel of the instrument has its own zenith angle associated with its line of sight.	degrees	Epoch, Altitude, Stripe
ICON_L25_Solar_Zenith_Angle	Solar zenith angles of NmF2 points Solar zenith angles of the retrieved NmF2 points.	degrees	Epoch, Stripe

metadata

Variable Name	Description	Units	Dimensions
ICON_L25_Inversion_Method	Used inversion method to get VER from brightness This string specifies the inversion method used in the estimation of the VER profiles from the brightness profiles. It has the form Tikhonov_k where k (0,1, or 2) specifies the order used in the Tikhonov regularization. Since the brightness profiles are noisy, we incorporate our prior knowledge on the characteristics of the VER profiles into the inverse problem for regularization. The order k is determined by what kind of prior knowledge we want to incorporate. The estimation of VER profile can be considered as choosing one among infinitely many: order 0 (zero) penalizes VER profiles with high l2 norm, but does not incorporate any structural information about the profile ; order 1 (one) penalizes VER profiles whose first derivatives have high l2 norm (meaning that it penalizes high VER variations through altitudes) ; order 2 (two) penalizes VER profiles whose second derivatives have high l2 norm (meaning that it penalizes VER profiles with high VER curvatures through altitudes).		

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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