

ICON Data Product 4.1: HME Amplitudes and Phases

This data product contains HME tidal amplitudes and phases of zonal wind, meridional wind, temperature from 0-400 km in the latitude range of 10°S-40°N. Tidal structures obtained from ICON-MIGHTI observations are fitted to Hough Mode Extension (HME). ICON-MIGHTI winds and temperature from 94 km to 102 km in the latitude range of 10°S-40°N and SABER in the latitude range of 5°S-50°S are used to fit to the HME. To cover all local time for tidal analysis, ICON-MIGHTI and SABER data are accumulated with a 45-day window and a 60-day window, respectively. HME has been widely used and tested before, and detailed HME methodologies are summarized in Forbes *et al.* [1994] and Oberheide *et al.* [2011]. HME for ICON is summarized in Forbes *et al.* [2017], and a sensitivity analysis of HME fitting to the local-time and altitude coverage and variables can be found in Cullens *et al.* [2020]. HME is only consider vertical propagation from below and do not include in-situ generations and non-linear interactions. For obtaining realistic tidal structures including in-situ generated tides, propagation, and nonlinear interaction, TIE-GCM simulations forced by ICON-HME, ICON data product 4.3, is recommended to use.

History

v01: Released in 2021, C. Y. Cullens

v02: In order to have enough data points for continuous tidal analysis, a window size is changed from 35 days to 45 days. In addition, 10-day running smooth is applied to tidal amplitudes before fitting HME for better TIE-GCM simulations. Released in 2022, C. Y. Cullens

V03: Updated Version 5 MIGHTI winds data and Version 5 MIGHTI temperature data are used for V03 HME product. In addition, ICON – MIGHTI data covers from 10°S to 40°N and SABER temperature data is added for the Southern Hemisphere from 5°S to 50°S to constrain tides for HME fitting.

V04: Version 6 MIGHTI winds and temperatures are used in the V04 HME product. The V04 HME product includes TW3 (westward-propagating terdiurnal tides with zonal wavenumber 3).

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.

Dimension Name	Nominal Size
Latitude	30
Altitude	300
Date	45

Variables

Variables in this file are listed below.

Variable Name	Description	Unit	Dimension
DAMP_XX_T	Diurnal tidal temperature amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward	K	Latitude, Altitude

	propagating diurnal tides with zonal wavenumber 3.		
SDAMP_XX_T	Semi-diurnal tidal temperature amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.	K	Latitude, Altitude
TDAMP_XX_T	Ter-diurnal tidal temperature amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating ter-diurnal tides with zonal wavenumber 3.	K	Latitude, Altitude
DAMP_XX_U	Diurnal tidal zonal wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward propagating diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude
SDAMP_XX_U	Semi-diurnal tidal zonal wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude
TDAMP_XX_U	Ter-diurnal tidal zonal wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating ter-diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude
DAMP_XX_V	Diurnal tidal meridional wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward propagating diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude

SDAMP_XX_V	Semi-diurnal tidal meridional wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude
TDAMP_XX_V	Ter-diurnal tidal meridional wind amplitudes. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating ter-diurnal tides with zonal wavenumber 3.	m/s	Latitude, Altitude
DPHASE_XX_T	Diurnal tidal temperature phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. The phase is defined as the time when the maximum is observed at 0 longitude.	hour	Latitude, Altitude
SDPHASE_XX_T	Semi-diurnal tidal temperature phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
TDPHASE_XX_T	Ter-diurnal tidal temperature phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating ter-diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
DPHASE_XX_U	Diurnal tidal zonal wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward propagating diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
SDPHASE_XX_U	Semi-diurnal tidal zonal wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a	hour	Latitude, Altitude

	westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.		
TPHASE_XX_U	Ter tidal zonal wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward propagating ter-diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
DPHASE_XX_V	Diurnal tidal meridional wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, E3 will be a eastward propagating diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
SDPHASE_XX_V	Semi-diurnal tidal meridonal wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating semi-diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
TDPHASE_XX_V	Ter-diurnal tidal meridonal wind phases. XX represents different tidal components. The notation Ws or Es are used to indicate a westward or eastward-propagating diurnal tide, respectively, with zonal wavenumber s. For example, w3 will be a westward propagating ter-diurnal tides with zonal wavenumber 3.	hour	Latitude, Altitude
MissingData	MIGHTI tides are calculated using 45 days of observations. Missing Data indicate which days are used to estimated MIGHTI tidal structures for HME fit. 0: data is not missing 1: data is missing.	None	Date

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>

Immel, T.J., England, S.L., Harding, B.J. et al. Space Sci Rev (2023) 219: 41.

<https://doi.org/10.1007/s11214-023-00975-x>

Responsibility for the validation of the L1 data products falls to the instrument lead investigators/scientists.

EUV: Dr. Martin Sirk and Dr. Eric Korpela : <https://doi.org/10.1007/s11214-023-00963-1>, and

<https://doi.org/10.1007/s11214-017-0384-2>

FUV: Dr. Harald Frey : <https://doi.org/10.1007/s11214-023-00969-9>, and <https://doi.org/10.1007/s11214-017-0386-0>

MIGHTI: Dr. Christoph Englert : <https://doi.org/10.1007/s11214-023-00971-1>,

<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/N2 ratio : Dr. Robert Meier : <https://doi.org/10.1007/s11214-018-0477-6>

* Daytime (EUV) O+ profiles: Dr. Andrew Stephan : <https://doi.org/10.1007/s11214-022-00933-z>, and <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. Brian Harding : <https://doi.org/10.1007/s11214-017-0359-3>, and <https://doi.org/10.1029/2020JA028947>

* Neutral Temperature profiles: Dr. Michael Stevens : <https://doi.org/10.1007/s11214-022-00935-x>, and <https://doi.org/10.1007/s11214-017-0434-9>

* Ion Velocity Measurements : Dr. Roderick Heelis : <https://doi.org/10.1007/s11214-017-0383-3>

Additional theoretical work in support of these products was supported by Dr. Robert Meier

Daytime O/N2 product : <https://doi.org/10.1029/2020JA029059>

Daytime (EUV) O+ profiles : <https://doi.org/10.1029/2023JA031533>

Additional validation work was performed by Dr. Jonathan Makela, Dr. Gilles Wautelet, and Dr. Yen-Jung (Joanne) Wu:

Neutral wind profiles : <https://doi.org/10.1029/2020JA028726>

Nighttime (FUV) O+ profiles : <https://doi.org/10.1007/s11214-023-00970-2>

Daytime (EUV) O+ profiles : <https://doi.org/10.1007/s11214-022-00930-2>

Ion Velocity Measurements : <https://doi.org/10.1007/s11214-023-00993-9>

Responsibility for Level 4 products falls to those scientists responsible for those products.

* Hough Modes : Dr. Chihoko Cullens : <https://doi.org/10.1186/s40645-020-00330-6> and <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 (2018-2022), Dr. Ruth Lieberman (2022-2025) and Dr. Douglas Rowland (2025-2026).

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>).