ICON Data Product 4.4: SAMI3

This document describes the SAMI3 output files.

There are three types of SAMI3 output files in the SAMI3 ZIP file: ICON_L4-4_SAMI3_YYYY-MM-DD_vXXrXXX.ZIP

Type I-0: ICON_L4-4_SAMI3_I-0_YYYY-MM-DD_vXXrXXX.NC

The 'I-0' denotes that the data set is in the native SAMI3 grid. The header file for the SAMI3 I-0 netcdf file is

```
dimensions:
        nz = 204 ;
        nf = 80 ;
        nl = 144 ;
        nt = UNLIMITED ; // (25 currently)
variables:
        float alt_0(nl, nf, nz) ;
                alt_0:units = "km" ;
        float lat_0(nl, nf, nz) ;
                lat_0:units = "degrees" ;
        float lon_0(nl, nf, nz) ;
                lon_0:units = "degrees" ;
        float dene_0(nt, nl, nf, nz) ;
                dene_0:units = "cm-3" ;
        float denHp_0(nt, nl, nf, nz) ;
                denHp_0:units = "cm-3" ;
        float denOp_0(nt, nl, nf, nz) ;
                denOp_0:units = "cm-3" ;
        float tHp_0(nt, nl, nf, nz) ;
                tHp_0:units = "K" ;
        float tOp_0(nt, nl, nf, nz) ;
                tOp_0:units = "K" ;
        float te_0(nt, nl, nf, nz) ;
                te_0:units = "K" ;
        float vsHp_0(nt, nl, nf, nz) ;
                vsHp_0:units = "m/s" ;
        float vsOp_0(nt, nl, nf, nz) ;
                vsOp_0:units = "m/s" ;
        float exbp_0(nt, nl, nf, nz) ;
                exbp_0:units = "m/s" ;
        float exbh_0(nt, nl, nf, nz) ;
                exbh_0:units = "m/s" ;
        float time(nt) ;
                time:units = "hrs" ;
```

The indices are described as follows:

- nz is the number of grid points along the magnetic field (from the southern hemisphere to the northern hemisphere)
- nf is the number of 'magnetic field lines' (corresponds to the altitude grid in the magnetic equatorial plane)
- nl is the number of grid points in the zonal direction.
- nt is the number of time steps: 1 hour cadence

The variables are described as follows:

- alt_0: altitude above the earth (km)
- lat_0: geographic latitude ($\sim$ -90° to +90°)
- lon_0: geographic longitude (0° to 360°)
- dene_0: electron density (cm^{-3})
- denHp_0: hydrogen ion (H^+) density (cm^{-3})
- denOp_0: oxygen ion (O^+) density (cm^{-3})
- tHp_0: hydrogen ion (H^+) temperature (cm^{-3})
- tOp_0: oxygen ion (O^+) temperature (cm^{-3})
- te_0: electron temperature (K)
- vsHp_0: hydrogen ion (H^+) velocity along the magnetic field (m/s)
- vsOp_0: oxygen ion (O^+) velocity along the magnetic field (m/s)
- exbp_0: E $\times$ B velocity perpendicular to the magnetic field in the dipole 'p' direction (in the magnetic longitude plane) (m/s)
- exbh_0: E $\times$ B velocity perpendicular to the magnetic field in the dipole 'h' direction (zonal) (m/s)
- time: UT (hrs) with 1 hour cadence

Type I-1: ICON_L4-4_SAMI3_I-1_YYYY-MM-DD_vXXrXXX.NC

The ‘I-1’ denotes that the data set is interpolated to a more ‘regular’ grid: the variables are interpolated to a constant altitude plane. The header file for the SAMI3 I-1 netcdf file is

```
dimensions:
        nl = 144 ;
        nt = UNLIMITED ; // (25 currently)
        nx = 90 ;
        ny = 100 ;
variables:
        float alt_1(ny) ;
                alt_1:units = "km" ;
        float lat_1(nl, ny, nx) ;
                lat_1:units = "degrees" ;
        float lon_1(nl, ny, nx) ;
                lon_1:units = "degrees" ;
        float dene_1(nt, nl, ny, nx) ;
                dene_1:units = "cm-3" ;
        float denHp_1(nt, nl, ny, nx) ;
                denHp_1:units = "cm-3" ;
        float denOp_1(nt, nl, ny, nx) ;
                denOp_1:units = "cm-3" ;
        float tHp_1(nt, nl, ny, nx) ;
                tHp_1:units = "K" ;
        float tOp_1(nt, nl, ny, nx) ;
                tOp_1:units = "K" ;
        float te_1(nt, nl, ny, nx) ;
                te_1:units = "K" ;
        float vsHp_1(nt, nl, ny, nx) ;
                vsHp_1:units = "m/s" ;
        float vsOp_1(nt, nl, ny, nx) ;
                vsOp_1:units = "m/s" ;
        float exbp_1(nt, nl, ny, nx) ;
                exbp_1:units = "m/s" ;
        float exbh_1(nt, nl, ny, nx) ;
                exbh_1:units = "m/s" ;
        float tec_1(nt, nl, nx) ;
                tec_1:units = "m-2" ;
        float nmf2_1(nt, nl, nx) ;
                nmf2_1:units = "cm-3" ;
        float hmf2_1(nt, nl, nx) ;
                hmf2_1:units = "km" ;
        float time(nt) ;
                time:units = "hrs" ;
```

The indices are described as follows:

- nx is the number of grid points in latitude
- ny is the number of grid points in altitude
- nl is the number of grid points in the zonal direction.
- nt is the number of time steps: 1 hour cadence

The variables have the same meaning as those of Type I-0 with the addition of the following:

- tec_1: total electron content (TEC) (m^{-2})
- nmf2_1: electron density at the F peak (cm^{-3})
- hmf2_1: altitude of the F peak (km)

Type I-2: ICON_L4-4_SAMI3_I-2_YYYY-MM-DD_vXXrXXX.NC

The 'I-2' denotes that the data set is interpolated to a regular grid: the variables are interpolated to a single indexed altitude, latitude, and longitude. The header file for the SAMI3 I-1 netcdf file is

```
dimensions:
        nl = 144 ;
        nt = UNLIMITED ; // (25 currently)
        nx = 90 ;
        ny = 100 ;
variables:
        float alt_2(ny) ;
                alt_2:units = "km" ;
        float lat_2(nx) ;
                lat_2:units = "degrees" ;
        float lon_2(nl) ;
                lon_2:units = "degrees" ;
        float dene_2(nt, nl, ny, nx) ;
                dene_2:units = "cm-3" ;
        float denHp_2(nt, nl, ny, nx) ;
                denHp_2:units = "cm-3" ;
        float denOp_2(nt, nl, ny, nx) ;
                denOp_2:units = "cm-3" ;
        float tHp_2(nt, nl, ny, nx) ;
                tHp_2:units = "K" ;
        float tOp_2(nt, nl, ny, nx) ;
                tOp_2:units = "K" ;
        float te_2(nt, nl, ny, nx) ;
                te_2:units = "K" ;
        float vsHp_2(nt, nl, ny, nx) ;
                vsHp_2:units = "m/s" ;
        float vsOp_2(nt, nl, ny, nx) ;
                vsOp_2:units = "m/s" ;
        float exbp_2(nt, nl, ny, nx) ;
                exbp_2:units = "m/s" ;
        float exbh_2(nt, nl, ny, nx) ;
                exbh_2:units = "m/s" ;
        float tec_2(nt, nl, nx) ;
                tec_2:units = "m-2" ;
        float nmf2_2(nt, nl, nx) ;
                nmf2_2:units = "cm-3" ;
        float hmf2_2(nt, nl, nx) ;
                hmf2_2:units = "km" ;
        float time(nt) ;
                time:units = "hrs" ;
```

The indices and variables have the same meaning as those of Type I-1.

SAMI3 model and run time parameters

SAMI3 (Sami3 is A Model of the Ionosphere) is a seamless, three-dimensional, physics-based model of the ionosphere. It is based on SAMI2 (*Huba et al.*, 2000), a two-dimensional model of the ionosphere. SAMI3 models the plasma and chemical evolution of seven ion species (H^+, He^+, N^+, O^+, N_2^+, NO^+ and O_2^+). The temperature equation is solved for three ion species (H^+, He^+ and O^+) and for the electrons. Ion inertia is included in the ion momentum equation for motion along the geomagnetic field. This is important in modeling the topside ionosphere where the plasma transitions from collisional to collisionless. Ion inertia allows ion acoustic waves to balance pressure variations along the magnetic field and constrain the ion velocity. The $\mathbf{E} \times \mathbf{B}$ drifts are computed to obtain motion transverse to the field. The neutral composition, temperature, and winds are nominally specified using the empirical models NRLMSISE00 [*Picone et al.*, 2002] and HWM14 [*Drob et al.*, 2015]. However, for the ICON mission SAMI3 uses the thermosphere specified by TIEGCM (e.g., *Huba et al.*, 2017). SAMI3 includes 21 chemical reactions [*Huba et al.*, 2000] and radiative recombination, and uses the EUVAC model for the solar EUV spectrum [*Richards et al.*, 1994]. SAMI3 use an empirical photoelectron heating model developed by Bailey and Balan (1996). The Hardy model [it Hardy et al., 1987] is used in conjunction with the auroral ionization model of Rees (1963) to calculate the ionization from precipitating electrons in the high latitude ionosphere.

SAMI3 uses a time step of 4 sec for the ICON data set. The magnetic latitude ranges from 6.85° to 88°. The necessary geophysical parameters used in the runs are obtained from those used in TIEGCM (i.e., F10.7, F10.7A, day-of-year, year). The high-latitude potential is specified by the Weimer model [*Weimer*, 2005] and is also obtained from TIEGCM.

Note 1: The Type I-2 data set is the easiest to work with for data analysis and visualization because the altitude, latitude, and longitude are 1D arrays. However, the magnitude of the variables (e.g., electron density, TEC) are smaller than the actual variables because of the additional interpolation.

Note 2: The SAMI3 data set has a daily time period 00:00 UT to 24:00 UT for years 2019, 2020, 2021, and for January 01-04, 2022. The remainder of January, 2022 has a daily time period 01:00 UT to 01:00 UT (following day). The TIEGCM data set has a daily time period 01:00 UT - 24:00 UT. for all years.

History

Version 01: initial release using TIEGCM v02

References

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Hardy, D. A., M. S. Gussenhoven, R. Raistrick, W. J. McNeil, Statistical and functional representations of the pattern of auroral energy flux, number flux and conductivity, *J. Geophys. Res., 92*, 12275, 1987.

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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/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/s11214-017-0385-1
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. 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

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

Hough Modes: Dr. Chihoko Cullens: 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) and Dr. Ruth Lieberman (2022-present).
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These data are openly available as described in the ICON Data Management Plan available on the ICON website (http://icon.ssl.berkeley.edu/Data)