INGV Documentation of Released Products

Last Update: 21 Nov 2023

Color code:

- In red: main folder
- In blue: sub-folders
- In **bold**: sub-sub-folders

Product release

History:
- On 19 July 2023 a HD was delivered to NODE 2000 with a first release of INGV products.
- On 17 November 2023 a HD was delivered to NODE 2000 with a second release of INGV products.

The listed items in this document reflect the name of directories provided in all releases.

NOTES:

- All file formats comply with the requests following the CHOWDP Meeting held in February 2023 and the CHOWDP documentation released on 10 March 2023 by NODE 2000.
- ADDITIONAL files might be present in sub-folders, but no documentation is provided for them. Documentation is provided only for those files inherent to the release of declared products.
- For a brief scientific description of products (for the Wiki Pages) for which a specific file was not submitted, please refer to the RA2 documentation in sub-Sections WP1410 and WP1420. Es: How to compute parallel electrical conductivity with satellite data

In the main folder "**Products**" the following sub-folders are present[1]:

CSES_Electric (id 46)
Yearly and orbital data from EFD instrument onboard CSES-01 from 1 January 2019 to 30 September 2021 (based on availability of continuous data).

Each file contains 6 columns: 1) UTC (ISO format); 2) Geographic Latitude (deg); 3) Geographic Longitude (deg); 4-6) electric field vector time series (Ex, Ey and Ez components) with a 0.5 Hz sampling in NEC coordinates and units mV/m.

Sub-Sub-folders:

1 The id number in parenthesis refers to the CAESAR's official list of products.

- "**csv**": Yearly and orbital .csv data.
- "**FIGURE**": Statistical maps of vector electric field (three components) in .fits format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Ex_DAY_…". Low-resolution maps are tagged, e.g., "Ex_Mean_DAY_…". In both cases the mean value within each bin is representative of the bin itself.
- "**npy**": Statistical maps of vector electric field (three components) in .npy format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Ex_DAY_…". Low-resolution maps are tagged, e.g., "binned_5x5_Ex…_DAY…". Maps are available with two different values representative of each bin: the mean and the median, respectively.

References:

CSES_Magnetic (id 46)

Yearly data from HPM instrument onboard CSES-01 from 11 July 2018 to 31 May 2021 (based on availability of continuous data).

Each file contains 6 columns: 1) UTC (ISO format); 2) Geographic Latitude (deg); 3) Geographic Longitude (deg); 4-6) magnetic field vector time series (Bx, By and Bz components) with a 1 Hz sampling in NEC coordinates and units nT.

Sub-Sub-folders:

- "**csv**": Yearly .csv data.
- "**FIGURE**": Statistical maps of vector magnetic field (three components) in .fits format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Btot_x_DAY_…". Low-resolution maps are tagged, e.g., "Bx_Mean_DAY_…". In both cases the mean value within each bin is representative of the bin itself.
- "**nc**": Yearly netCDF data.
- "**npy**": Statistical maps of vector magnetic field (three components) in .npy format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Btot_x_DAY_…". Low-resolution maps are tagged, e.g., "binned_5x5_Bx…_DAY…". Maps are available with two different values representative of each bin: the mean and the median, respectively.

References:
https://link.springer.com/article/10.1007/s11431-018-9242-0

CSES_Plasma (id 45)

Yearly and orbital data from LAP instrument onboard CSES-01 from 1 January 2019 to 30 September 2021 (based on availability of continuous data).

Each file contains 5 columns: 1) UTC (ISO format); 2) Geographic Latitude (deg); 3) Geographic Longitude (deg); 4) electron density (m^-3); 5) electron temperature (K) with variable sampling (1.5 Hz and 3 Hz).

Sub-Sub-folders:

- "**csv**": Yearly and orbital .csv data.
- "**FIGURE**": Statistical maps of electron density and temperature in .fits format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Ne_DAY_…". Low-resolution maps are tagged, e.g., "Ne_Mean_DAY_…". In both cases the mean value within each bin is representative of the bin itself.
- "**nc**": Orbital netCDF data.
- "**npy**": Statistical maps of electron density and temperature in .npy format. Maps are available at two spatial resolutions: 1x1 deg^2 (high resolution) and 5x5 deg^2 (low resolution). For practical purposes use low-resolution maps. High-resolution maps are tagged, e.g., "Ne_DAY_…". Low-resolution maps are tagged, e.g., "binned_5x5_Ne…_DAY…". Maps are available with two different values representative of each bin: the mean and the median, respectively.

References:
https://link.springer.com/article/10.1007/s11431-018-9242-0
https://ieeexplore.ieee.org/document/9763362
https://www.mdpi.com/2072-4292/14/18/4679

Fits_images_LoL (id 49)
Map of LoLs occurred from December 2013 to December 2022 derived from the three satellites of the Swarm constellation (Alpha, Bravo and Charlie satellites) in geographic coordinates.

Fits_images_Ne_Te_RODI_ROTEI_ROTI (id 32, id 33, id 34)
Electron density and temperature and ionospheric indices (RODI, ROTI, ROTEI) maps from LP instruments onboard the Swarm constellation (Alpha, Bravo and Charlie satellites) obtained from data between 1 January 2014 and 31 December 2022.

Sub-sub-folders:

- "**Swarm_A**"
- "**Swarm_B**"
- "**Swarm_C**"

For each satellite (sub-sub-folder), maps in magnetic coordinates (QD-Lat vs MLT) of the following quantities are present as .fits files:

- Electron density standard deviation during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).

- RODI standard deviation during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- ROTEI standard deviation during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- ROTI standard deviation during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Electron temperature standard deviation during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Mean electron density during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Mean RODI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Mean ROTEI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Mean ROTI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Mean electron temperature during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Median electron density during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Median RODI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Median ROTEI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Median ROTI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Median electron temperature during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Electron density bin counts during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- RODI bin counts during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- ROTEI bin counts during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- ROTI bin counts during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- Electron temperature bin counts during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 25th percentile of electron density during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 25th percentile of RODI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 25th percentile of ROTEI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 25th percentile of ROTI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 25th percentile of electron temperature during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).

- 75th percentile of electron density during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 75th percentile of RODI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 75th percentile of ROTEI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 75th percentile of ROTI during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).
- 75th percentile of electron temperature during different seasons (equinoxes, summer, winter), three different levels of solar activity (high, middle and low).

Link to GitHub:
https://github.com/pignalberi/TITIPy

References:
https://www.mdpi.com/2218-1997/7/8/290
https://www.mdpi.com/2072-4292/13/20/4077
https://www.nature.com/articles/s41598-021-84985-1
https://www.mdpi.com/2072-4292/13/4/759
https://ieeexplore.ieee.org/document/9763362
https://doi.org/10.1016/j.cageo.2020.104675

Fits_images_SigmaPar (id 38)
Parallel electrical conductivity maps from LP instruments onboard the Swarm constellation (Alpha, Bravo and Charlie satellites) obtained from data between 1 January 2014 and 31 December 2022.

References:
https://doi.org/10.1029/2020JA028452
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JA029138

Ionosonde_data (id 12, id 13)
Autoscaled (15 min time resolution for Rome and Gibilmanna observatories; 10 min time resolution for Bahia Blanca observatory; 5 min time resolution for Tucuman observatory) and validated (1 hr time resolution, available only for Rome and Gibilmanna observatories) ionosonde time series for some specific SWEs.

Specifically, autoscaled data:
- from Bahia Blanca refer to SWE in September 2017.
- from Gibilmanna refer to SWEs in March 2012, July 2012, March 2013, September 2014, June 2015.
- from Rome refer to SWEs in March 2012, July 2012, March 2013, September 2014, June 2015, September 2017.
- from Tucuman refer to SWEs in March 2012, July 2012, September 2014, September 2017.

Specifically, validated data:

- from Gibilmanna refer to SWEs in March 2012, July 2012, March 2013, September 2014, June 2015.
- from Rome refer to SWEs in March 2012, July 2012, March 2013, September 2014, June 2015, September 2017.

Autoscaled ionospheric characteristics that will be found are the following:

foF2: the ordinary critical frequency reflected by the ionospheric F2 layer;

MUF(3000)F2: the maximum usable frequency for a 3000 km path length whose middle point is the one where the ionosonde is located;

M(3000)F2: conversion factor for obtaining the MUF(3000)F2 for a 3000 km path length once the foF2 is known;

foF1: the ordinary critical frequency reflected by the ionospheric F1 layer;

ftEs: the top frequency reflected by the ionospheric sporadic E layer;

h'Es: the lowest virtual height of the ionospheric sporadic E layer.

Validated ionospheric characteristics that will be found are the following:

foF2: the ordinary critical frequency reflected by the ionospheric F2 layer;

MUF(3000)F2: the maximum usable frequency for a 3000 km path length whose middle point is the one where the ionosonde is located;

M(3000)F2: conversion factor for obtaining the MUF(3000)F2 for a 3000 km path length once the foF2 is known;

foF1: the ordinary critical frequency reflected by the ionospheric F1 layer;

h'F2: the lowest virtual height of the ionogram trace related to the ionospheric F2 layer and associated to the ordinary wave component;

h'F:the lowest virtual height of the ionogram trace related to the ionospheric F layer and associated to the ordinary wave component;

foE: the ordinary critical frequency reflected by the lowest thick stratification of the ionospheric E layer;

h'E: the lowest virtual height of the ionospheric E layer;

foEs: the ordinary critical frequency reflected by the ionospheric sporadic E layer;

h'Es: the lowest virtual height of the ionospheric sporadic E layer;

fbEs: the blanketing frequency of the sporadic E layer, that is the first frequency at which the sporadic E layer allows reflections from the upper layers;

fmin: the lowest frequency reflected by the ionosphere.

Link to database:
http://www.eswua.ingv.it/

References:

Wakai et al., 1987. Manual of ionogram scaling, Third Version, MInistry of Posts and Telecommunications, Japan. https://www.sws.bom.gov.au/IPSHosted/INAG/scaling/japanese_manual_v3.pdf

Pezzopane M, Scotto C (2007) Automatic scaling of critical frequency foF2 and MUF(3000)F2: a comparison between Autoscala and ARTIST 4.5 on Rome data. Radio Sci 42(4):RS4003. doi:10.1029/2006RS003581

Pezzopane M, Pietrella M, Pignatelli A, Zolesi B, Cander LR (2011) Assimilation of autoscaled data and regional and local ionospheric models as input sources for real-time 3-

D International Reference Ionosphere modeling. Radio Sci 46(5):RS5009. doi:10.1029/2011RS004697
Spogli L, Cesaroni C, Di Mauro D, Pezzopane M, Alfonsi L, Musico` E, Povero G, Pini M, Dovis F, Romero R, Linty N, Abadi P, Nuraeni F, Husin A, Le Huy M, Thi Lan T, Vihn La T, Pillat VG, Floury N (2016) Formation of ionospheric irregularities over Southeast Asia during the 2015 St. Patrick's Day storm. J Geophys Res 121(12):12211–12233. doi:10.1002/2016JA023222

Swarm_LOL_events (id 49)

List of LOLs occurred between December 2013 and December 2022 for all three satellites of the Swarm constellation (Alpha, Bravo and Charlie satellites) in geographic coordinates.

Each of the three files (one for satellite) is in netCDF format and contains the position of each satellite (geographic and magnetic coordinates, height of the satellite) at the specific UT and LT, the list of GPS satellites in the FoV, the list of GPS satellites experiences LOLs and the duration of LOLs in seconds.

The corresponding images are in .fits format.

References:
https://www.mdpi.com/2072-4292/13/11/2209
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022SW003129

Swarm_LP_products (id 33, id 34, id 38)

Monthly time series from the LP instrument onboard the Swarm constellation (all three satellites A, B and C) from December 2013 to December 2022 with a 1 Hz sampling.

Sub-sub-folders:

- "**Swarm_A**"
- "**Swarm_B**"
- "**Swarm_C**"

Each of the three files (one for satellite) is in netCDF format and contains the following information:

- Position of the satellite (satellite height, both geographic and magnetic coordinates at UT, LT and MLT times).
- Electron density and quality flag.
- Electron temperature and quality flag.
- Parallel electrical conductivity.
- Electron density and temperature gradients.
- LP measurement-derived ionospheric indices ROD, RODI, ROTE, ROTEI.

Link to GitHub:
https://github.com/pignalberi/TITIPy

References:
https://www.mdpi.com/2218-1997/7/8/290

https://www.mdpi.com/2072-4292/13/20/4077
https://www.nature.com/articles/s41598-021-84985-1
https://www.mdpi.com/2072-4292/13/4/759
https://ieeexplore.ieee.org/document/9763362
https://doi.org/10.1016/j.cageo.2020.104675
https://doi.org/10.1029/2020JA028452
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JA029138

Swarm_MagField (id 35, id 36, id 37)

Daily and yearly geomagnetic field time series from the vectorial magnetometer onboard the Swarm constellation (three satellites) from 1 January 2014 to 31 December 2022 at 1 Hz sampling.

Sub-sub-folders:

- "**Swarm_A**"
- "**Swarm_B**"
- "**Swarm_C**"

Each file contains 14 columns: 1) UTC (ISO format); 2) Geographic Latitude (deg); 3) Geographic Longitude (deg); 4) QD latitude (deg); 5) QD longitude (deg); 6) MLT; 7-9) observed magnetic field vector time series (Bx, By and Bz components) with a 1 Hz sampling in NEC coordinates and units nT; 10-12) magnetic field vector of external origin (subtraction of internal core+crust field) time series (Bex, Bey and Bez components); 13) magnetic field of external origin projected in direction parallel to the observed magnetic field; 14) magnetic field of external origin projected in direction perpendicular to the observed magnetic field.

Sub-Sub-Sub- folders:

- "**csv**": Daily and yearly .csv data.
- "**FIGURE**": Statistical maps of vector geomagnetic fields (all the quantities listed above) in .fits format. Maps are available at 1x1 deg^2 spatial resolution. The mean value within each bin is representative of the bin itself.
- "**nc**": Daily netCDF data.
- "**npy**": Statistical maps of vector geomagnetic fields (all the quantities listed above) in .npy format. Maps are available at 1x1 deg^2 spatial resolution with two different values representative of each bin: the mean and the median, respectively.

References:

Swarm_TEC_products (id 49)

Monthly time series of slant TEC from the Swarm constellation (all three satellites A, B and C) from December 2013 to December 2022 with a 1 Hz sampling.

Sub-sub-folders:

- “**Swarm_A**”
- “**Swarm_B**”
- “**Swarm_C**”

Each file is in netCDF format and contains the following information for each of the GPS satellites in view:

- Position of the satellite (satellite height, both geographic and magnetic coordinates at UT, LT and MLT times).
- Slant TEC measurement.
- TEC measurement-derived ionospheric indices ROT and ROTI.

References:
https://doi.org/10.1016/j.cageo.2020.104675

Acronyms

EFD: Electric Field Detector
FoV: Field of View
HD: Hard Disk
HPM: High Performance Magnetometer
hr: hour
LAP or LP: Langmuir Probe
Lat: Latitude
LOL: Loss Of Lock
LT: Local Time
min: minute
MLT: Magnetic Local Time
MUF: Maximum Usable Frequency
NEC: North-East-Center
QD: Quasi Dipole
ROD: Rate Of change of electron Density
RODI: Rate Of change of electron Density Index
ROTE: Rate Of change of electron TEmperature
ROTEI: Rate Of change of electron TEmperature Index
ROT: Rate Of change of TEC
ROTI: Rate Of change of TEC Index
SWE: Space Weather Event
TEC: Total Electron Content
UT: Universal Time