The 7th Framework Programme

Theme SPACE

Project POPDAT

D1.1 Catalogue of identified sources of original satellite observations of wave processes

Version 1

Version: 1.0

Date: November 30, 2011

Project ref. no.	263240
Project title	POPDAT Problem-oriented Processing and Database Creation for Ionosphere Exploration

Deliverable status	**Final**
Contractual date of delivery	Project Month 6
Actual date of delivery	Month 6
Deliverable number	D1.1
Deliverable title	Catalogue of identified sources of original satellite observations of wave processes
Type	Report
Status & version	Version 1
Number of pages	14
WP contributing to the deliverable	WP1
WP / Task responsible	ELTE
Author(s)	Project Consortium
EC Project Officer	Paula MOTA-ALVES
Keywords	Ionospheric research catalogue waves satellte missions

Introduction

Table 1.1.1 in "**Description of Work**" of POP-DAT:

Main ionosphere satellite missions (from the work-plan of the project)

№	Mission	Year	Orbit	Payload
1	Atmosphere Explorer - A	1963	255 - 916 km, i = 57°	Sensors for neutral and ionized species of atmospheric gazes
2	Atmosphere Explorer - B	1966	276 - 2725 km, i = 64°	-"-
3	**Atmosphere Explorer - C**	**1973**	149 - 4294 km, i = 68°	-"-, optical and UV spectrometers
4	Atmosphere Explorer - D	1975	154 - 3816 km, i = 90°	-"-
5	**Atmosphere Explorer - E**	**1975**	156 - 2983 km, i = 20°	-"-
6	**Dynamics Explorer 2**	**1981**	309 - 1012 km, i = 90°	-"-, sensors for quasi DC magnetic field, DC and AC electric field
7	SAN MARCO D/L	1988	262 - 619 km, i = 2°	Neutral wind probe, plasma probes, electric field probe
8	Active	1989	500 - 2500 km, i = 82°	Plasma probes, sensors for quasi DC electric and magnetic fields, wave probes, energetic particle probe, VLF-transmitter
9	APEX	1991	440 - 3000 km, i = 82°	-"-, electric beam and plasma injectors
10	FREJA	1992	650 - 1800 km, i = 65°	Plasma probes, high data rate wave probes, energetic particle probes, UV imager
11	ROCSat-1	1999	600 km, i = 35°	Plasma probes
12	CHAMP	2000	454 km, i = 87°	Magnetic field probes, precise accelerometer
13	**Variant (on Sich-1M S/C)**	**2004**	280 - 650 km, i = 83°	Electric probes, wave probes, electric current probes, fluxgate magnetometer
14	**DEMETER**	**2004**	~ 710 km, changed to 660 km, i = 98°	Plasma probes, electric field and AC magnetic field probes
15	**Compass-2**	**2006**	~ 400 km, i = 79°	Wave probes

The Table 1.1.1 contains the list of satellites which could be important for the POP-DAT project. After a detailed investigation of the necessities and possibilities in the POP-DAT the community selected 7 satellites from the Table and added another satellite group to the actual work-plan of the POP-DAT.

In the POP-DAT project the missions having basic importance are the ***AE-C*** and ***AE-E***, the ***Dynamic Explorer 2***, the ***Active***, the ***Variant***, the ***DEMETER*** and the ***Compass-2***, which were listed in the Table 1.1.1 and the ***GPS satellite system*** which was not listed in the Table 1.1.1. The first 7 are ionospheric satellite mission, and the last one has important capability for ionospheric investigations beside the main service goal of this system. The details of these satellite missions are presented in the following.

1) Ionosphere satellite mission:

name: **Atmosphere Explorer-C / AE-C**
launch date: 16.12.1973
orbit: (perigee, apogee, inclination, other characteristic remarks):
During first year of operation AE-C's geocentric orbit was elliptical with a closest perigee of **158** km and an apogee of **4303** km, as well as **circular** at the rest times with an inclination of **68.1** degrees.
start of measurements: 13.12.1973
end of measurements: (mission), 18.12.1978
data structure: *geomagnetic data:* $\mathbf{A_p}$, $\mathbf{K_p}$, $\mathbf{F_{10.7}o}$, $\mathbf{F_{10.7}}$ (in header record),
(UT running data): **GLAT**, **GLONG**, **ALT**, **LST**+
local magnetic time (**MLT**), L-shell parameter (**L**),
magnetic inclination (**INCL**), solar zenith angle (**SZA**)
+ observational data records
data composition: *electromagnetic data* : N/a
*electromagnetic bands:*N/a
thermal plasma measurements: ion/electron density and temperature, ion drift and ion mass-spectrometry **MIMS**, **BIMS**, **CEP**, **RPA**
neutral atmosphere measurements: neutral density and temperature, neutral wind and neutral mass-spectrometry **NACE**, **NATE**, **OSS**
airglow emissions: **VAE, UVNO**
particle measurements: **LEE**/**PES** electrons/protons 30eV-15KeV/electrons 2-500eV,
active experiment: N/a
distribution of the measurements in time: selected parts of orbits recorded
distribution of the measurements above the Earth surface: global
time step of data (on-board time): 15s (average data)

2) Source data:

main experimenter (PS): E.R. Schmerling, NASA HQ
location of the recorded, stored data:
ftp://nssdcftp.gsfc.nasa.gov/spacecraft_data/ae/
general form of data (raw, preprocessed, etc.): processed

3) Other information:

Publication: Special issue of Planetary and Space Sci.,

4) Remarks:

Onboard experiments of interest to POPDAT project are ***MIMS, BIMS, RPA, NACE, NATE, OSS***. First year of operation at elliptical orbit permits detailed study of the bottom side F-region AGW and TID. Rest years of AE-C circular orbit operation are very convenient for near F-peak AGW/TID registration.

1**) Ionosphere satellite mission:**

name: **Atmosphere Explorer-E / AE-E**
launch date: 20.11.1975
orbit: (perigee, apogee, inclination, other characteristic remarks):
During first year of operation AE-C's geocentric orbit was elliptical with a closest perigee of **157** km and an apogee of **2983** km, as well as **circular** at the rest times with an inclination of **19.7** degrees.
start of measurements: 01.12.1975
end of measurements: (mission), 06.06.1981
data structure: *geomagnetic data:* $\mathbf{A_p}$, $\mathbf{K_p}$, $\mathbf{F_{10.7}o}$, $\mathbf{F_{10.7}}$ (in header record),
(UT running data): **GLAT**, **GLONG**, **ALT**, **LST**+
local magnetic time (**MLT**), L-shell parameter (**L**),
magnetic inclination (**INCL**), solar zenith angle (**SZA**)
+ observational data records
data composition: *electromagnetic data* : N/a
*electromagnetic bands:*N/a
thermal plasma measurements: ion/electron density and temperature, ion drift and ion mass-spectrometry **BIMS**, **CEP**, **RPA**
neutral atmosphere measurements: neutral density and temperature, neutral wind and neutral mass-spectrometry **MESA**, **NACE**, **NATE**, **OSS**
airglow emissions: **VAE**
particle measurements: **PES** electrons 2-500eV,
active experiment: N/a
distribution of the measurements in time: selected parts of orbits recorded
distribution of the measurements above the Earth surface: global
time step of data (on-board time): 15s (average data)

2) Source data:

main experimenter (PS): E.R. Schmerling, NASA HQ
location of the recorded, stored data:
ftp://nssdcftp.gsfc.nasa.gov/spacecraft_data/ae/
general form of data (raw, preprocessed, etc.): processed

3) Other information:

Publication: Special issue of Planetary and Space Sci.,

4) Remarks:

Onboard experiments of interest to POPDAT project are ***MESA, BIMS, RPA, NACE, NATE, OSS***. First year of operation at elliptical orbit permits detailed study of the bottom side F-region AGW and TID. Because of low orbital inclination, circular orbit in the rest years is very convenient for near F-peak AGW/TID registration in zonal direction.

1) Ionosphere satellite mission:

name: **DEMETER**
launch date: 29.06.2004
orbit: (perigee, apogee, inclination, other characteristic remarks):
LEO, near Sun-syncronous polar orbit, 98°inclination, 710 km initial alt., lowered to 660km in 2005
start of measurements: 08.2004
end of measurements: (mission), 12.2010
data composition: *electromagnetic data* – bursts and survey, electric and magnetic
– derivative products, e.g. spectra
electromagnetic bands ULF-HF, B: 10Hz-17kHz, E: DC-3.5 MHz
geomagnetic data
particle measurements: electrons 30keV-10MeV, ion/electron density and temperature
active experiment: Langmuir, thermal plasma parameters (electron density and temperature), 1second temporal resolution.

distribution of the measurements in time: cont. in survey mode, burst mode confined to active natural hazard regions
distribution of the measurements above the Earth surface: between invariant magnetic latitudes ±65°
time data (on-board time): order of seconds

2) Source data:

main experimenter (PI): Michel Parrot
location of the recorded, stored data: demeter.cnrs-orleans.fr, CNRS (Orleans, France), from 2012 moved to http://cdpp.cesr.fr/ (Toulouse, France);
general form of data (raw, preprocessed, etc.):
Level-1, preprocessed (decommutated, converted to physical values, frame structured, IEEE binary);
Level 2 quicklook data products

3) Other information:

Publication: Special issue of Planetary and Space Sci., 54, 2006.
The records of the AWDANet system are in more cases simultaneous ground-based recorded data sets.

4) Remarks:

IAP instrument Ni, Ti and Vi could be used for TID processing of data at DEMETER altitude.
DEMETER has been the 1st microsatellite in the Myriade series, followed by ***Taranis*** satellite.

1) Ionosphere satellite mission:

name: **Compass-2 / Kompas2**
launch date: 26.05.2006
orbit: (perigee, apogee, inclination, other characteristic remarks):
LEO, 400-488 km, 79°inclination
start of measurements:
end of measurements (mission) :
data composition: *electromagnetic data* – burst measurements
– the malfunction of the satellite housekeeping systems stopped the test of the goal-oriented data collection modes
electromagnetic bands – ULF-VLF, B and E: 10Hz – 20kHz
geomagnetic data –
particle measurements: ion mass spectrometer, RPA
active experiment: no
distribution of the measurements in time: fragmental (house-keeping problems)
distribution of the measurements above the Earth surface: fragmental
time data (on-board time): GPS

2) Source data:

main experimenter (PI): IZMIRAN
location of the recorded, stored data: recordings of the very limited number of successful sessions is available at ELTE
general form of data (raw, preprocessed, etc.): decommutated raw binary, frame structured data set

3) Other information:

Publications:

Ferencz Cs., Lichtenberger J., E. Ferencz O., Hamar D., Bodnár L., Steinbach P., Korepanov V., Mikhajlova G., Mikhajlov Y., Kuznetsov D. (2008): **Test of the SAS2 ULF-VLF electromagnetic wave analyzer in space environment - on board of the Compass-2 satellite**. *Infocommunications Journal* **63**(7), 21-29

Ferencz, O. E., Bodnár, L., Ferencz, Cs., Hamar, D., Lichtenberger, J., Steinbach, P., Korepanov, V., Mikhaylova, G., Mikhaylov, Yu., Kuznetsov, V. (2009): **Ducted whistlers propagating in higher order guided mode and recorded on board of Compass-2 satellite by the advanced Signal Analyzer and Sampler SAS2**. *Journal of Geophysical Research*, **114**, A03213, doi: 10.1029/2008JA013542

4) Remarks:

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5) Planned ionosphere satellite missions in the near future:

No confirmed information.

1) Ionosphere satellite mission:

name: **ACTIVE / ACTIVNYI, Interkosmos-24**
launch date: 09. 1989
orbit: (perigee, apogee, inclination, other characteristic remarks):
excentric LEO, 500-2500 km, 82°inclination
start of measurements: 28th. 09. 1989
end of measurements: (mission), 13th 10. 1993
data composition: *electromagnetic data* – ULF-VLF, B and E: 20Hz – 22kHz,
electromagnetic bands – measurements with 900Hz bandwidth in steps of 500Hz; and in broad-band operating mode burst data in 20Hz – 5kHz band
geomagnetic data –
particle measurements: ion mass spectrometer, RPA
active experiment: YES
distribution of the measurements in time: during the satellite passing over the real-time receiving stations (see in section 2)
distribution of the measurements above the Earth surface: above the receiving territory of the tracking stations
time data (on-board time): onboard quartz time standard calibrated in UT

2) Source data:

main experimenter (PI): N. A. Eysmont, IKI
location of the recorded, stored data: data received in Budapest, Hungary and at GSFC (Wallops Island, USA) are stored digitally, available at the ELTE SRG. Recordings received at the IZMIRAN, Moscow, Russia – its availability is unknown
general form of data (raw, preprocessed, etc.): decommutated raw data archived on digital magnetic tapes, CDs; frame structured data set

3) Other information:

Publication:

Lichtenberger J., Tarcsai Gy., Pásztor Sz., Ferencz Cs., Hamar D., Molchanov O.A. and Golyavin A.M. (1991): **Whistlers doublets and hyperfine structure recorded digitally by the signal analyzer and sampler on the ACTIVE satellite**. *Journal of Geophysical Research,* **96(A12)**, 21 149- 21 158.

4) Remarks

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5) Planned ionosphere satellite missions in the near future:

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1) Ionosphere satellite mission:

name: **Dynamics Explorer 2 / DE 2 / Explorer 63/12625**
launch date: 03.08.1981
orbit: (perigee, apogee, inclination, other characteristic remarks):
excentric polar, 309-1012km, (at the end of the mission satellite orbit became quasi-circular, about 300 km), 90°inclination
start of measurements: 03. 1981
end of measurements (mission): 02. 1983
data composition: *electromagnetic data* – MAG-B, VEFI,
electromagnetic bands – (search coil) B …, E DC-…
geomagnetic data − …
particle measurements: neutral temp., density, vertical / horizontal wind (WATS, FPI), ion drift (IDM), RPA
active experiment: Langmuir
distribution of the measurements in time: *cont.*
distribution of the measurements above the Earth surface: global
time data (on-board time): … (stored on magnetic tapes onboard before transmission)

2) Source data:

main experimenter (PI): M.A. Calabrese, mcalabre@pop100.gsfc.nasa.gov
location of the recorded, stored data:
ftp://nssdcftp.gsfc.nasa.gov/spacecraft_data/de/de2/
general form of data (raw, preprocessed, etc.): preprocessed, *partly* binary and ASCII format

3) Other information:

Publication:

R. A. Hoffman et al. (1981), *Space Sci. Instrum*., **5**, 349. DE-2 reentered the atmosphere on February 19, 1983.

Kramer, H.J., **Observation of the Earth and its environment**. Survey of missions and sensors. *Springer*, 2002

Mayr H.G., I. Harris, F.A. Herrero, N.W. Spencer, F. Varosi, W.D. Pesnell. (1990): **Thermospheric gravity waves: observations and interpretation using the transfer function model (TFM).** *Space Sci. Rev*., **54**, 297-375

Fedorenko, A.K., G.V. Lizunov, H. Rothkaehl (2005): **Satellite observations of wavelike atmosphere perturbations caused by strong earthquakes**. *Geomagnetizm and Aeronomy*, **45**, 403-410

Bankov L. and A. Vassileva (2000): **Helium abundance at 800km height as a possible seismic sffect observed from Dynamics Explorer data**. *Proc. "30 Years of Organized Space Research in Bulgaria"*, October 1999, Sofia, 45-49

Bankov L. and A. Vassileva (2003): **Experimental Evidences of Pre-seismic Effects in the Earth's Ionosphere as a Reason for Neutral Density and Temperature Measurements onboard Microsatellites**. *Recent Advances in Space Technologies*, November 20-22, 2003, Istanbul, 514-518, ISBN:0-7803-8142-4

4) Remarks

NACS, RPA, IDM, data selected/proposed as POP-DAT reference satellite for AGW/TID related recordings

5) Planned ionosphere satellite missions in the near future:

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1) Ionosphere satellite mission:

name: **Variant**
launch date: 24.12.2004
orbit: (perigee, apogee, inclination, other characteristic remarks):
excentric quasi polar, 283-650km, 83°inclination
start of measurements: 01.02.2005
end of measurements (mission): 24.03.2005
data composition: *electromagnetic data* – electric probe (EZ), wave probe (WZ), Rogovsky coil (ZF), Faraday cup (FC), fluxgate
electromagnetic bands – E: DC-200kHz, B: 300Hz-40kHz, current density DC-40kHz
geomagnetic data –
particle measurements: no
active experiment: no
distribution of the measurements in time: fragmental
distribution of the measurements above the Earth surface: random
time data (on-board time): on board time,
(stored on magnetic tapes onboard before transmission)

2) Source data:

main experimenter (PI): Prof. Valery Korepanov
location of the recorded, stored data: On disks, in future on web-portal of Space Research Institute NASU-NSAU, Ukraine
general form of data (raw, preprocessed, etc.): preprocessed, ASCII format

3) Other information:

Publication:

Dudkin, F., V. Korepanov, G. Lizunov (2009): **Experiment VARIANT – First Results from Wave Probe Instrument.** *Adv. Space Res.*, **43**, 1904-1909

4) Remarks:

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5) Planned ionosphere satellite missions in the near future:

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1) Ionosphere satellite mission:

name: **Global Positioning System (GPS)**
launch date: from 1978 continuously
orbit: (perigee, apogee, inclination, other characteristic remarks):
h = 20200 km / 6 orbit (4 satellites by orbits), 55° inclination,
60° between each orbit
start of measurements: 1978
end of measurements (mission): in operation
Measurements are recorded continuously by ground receivers distributed around the world.
GPS can be considered indirectly as an "ionosphere mission", too. Indeed, measurements can be processed to assess Total Electron Content (TEC). TEC is the integrated electron density along the line of sight between a ground receiver and a GPS satellite. By the way, and because of ionosphere profile, TEC data are assumed to be localized at the Ionospheric Piercing Point (IPP). The IPP is the intersection of the straight line between the receiver and the satellite, and a thin shell at 350 km of altitude where the electron density is supposed to be the maximum.

2) Source data:

We can use ionosonde to rebuild the integrated TEC but we have no input to do that.

A way to convert f_{oF2} data in TEC data is:

$$TEC_I = 1.24 \times 10^{13} \left(f_{oF2}\right)^2 \tau$$

Where TEC_I is the Total Electron Content in the ionosphere and τ is the equivalent ionospheric thin shell.

3) Other information:

Publication:

Some works have been done in such way to characterise ***TID***s in the ionosphere seen by the ionosonde:

Morgan, M. G. (1983): **Locating TID sources with a north-south chain of rapid-run ionosondes in western Québec**. *Radio Science*, **18(6)**, 1066–1076, doi:10.1029/RS018i006p01066.

GEOMAGNETISM AND AERONOMY, English Translation, VOL. **34**, NO. 1, AUGUST 1994, Russian Edition: JANUARY--FEBRUARY 1994, **Structure and dynamics of travelling ionospheric disturbances from Doppler ionosonde data** V. P. Ivanov, V. L. Karvetskiy, and N. A. Koren'kova Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Russian Academy of Science

Another way is to use the HF Radar to measure the echoes backscattered from the ground and the E and F regions of the ionosphere:

Nishitani, N., T. Ogawa, Y. Otsuka, K. Hosokawa, and T. Hori (2011): **Propagation of large amplitude ionospheric disturbances with velocity dispersion observed by the SuperDARN Hokkaido radar after the 2011 off the Pacific coast of Tohoku Earthquake**, *Earth Planets Space*, in press.

Hayashi, H., N. Nishitani, T. Ogawa, Y. Otsuka, T. Tsugawa, K. Hosokawa, and A. Saito (2010): **Large-Scale traveling ionospheric disturbance observed by SuperDARN Hokkaido HF radar and GPS networks on 15 December 2006**, *J. Geophys. Res.*, **115**, A06309, doi:10.1029/2009JA014297.

Airglow technique is also used to observe MSTIDs :

Suzuki S., K. Hosokawa, Y. Otsuka, K. Shiokawa, T. Ogawa, N. Nishitani, T. F. Shibata, A. V. Koustov, and B. M. Shevtsov (2009): **Coordinated observations of nighttime medium-scale traveling ionospheric disturbances in 630-nm airglow and HF radar echoes at midlatitudes**, *J. Geophys. Res.,* **114**, A07312, doi:10.1029/2008JA013963.

Shiokawa, K., Y. Otsuka, N. Nishitani, T. Ogawa, T. Tsugawa, T. Maruyama, S. E. Smirnov, V. V. Bychkov, and B. M. Shevtsov (2008): **Northeastward motion of nighttime MSTIDs at middle latitudes observed by an airglow imager**, *J. Geophys. Res.*, 113, A12312, doi:10.1029/2008JA013417.

4) Remarks:

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5) Planned ionosphere satellite missions in the near future:

Other GNSS systems are working or in development:

Glonass	(Russia)	ready for operation,
Galileo	(EU)	under construction,
Beidou	(China)	under construction.

We will not use in the POP-DAT the different systems because it is quite difficult (impossible) in the present state to get some information and data in the following one and half year, especially for the Beidou system.

Galileo is still not operational, but the IGS will provide Galileo data when it will be fully working. The application of Glonass data in the IGS is also still not solved in this moment.