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The 12th Swarm Data Quality Workshop

Summary and Recommendations Report

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1 CONTEXT AND MEETING SCOPE

The Swarm Data Quality Workshop (SDQW) is a yearly event organized by ESA and the Swarm data quality team with the participation of multidisciplinary scientists and instruments' experts that focusses on innovative ideas for future Swarm-based activities and products, targeting new processing algorithms, correction improvements, emerging applications, and multi-mission synergies. The SDQW#12 was hosted by the Swedish Institute of Space Physics in Uppsala, Sweden, from 10 to 14 October 2022. To allow the attendance of colleagues not allowed to travel due to still present Covid-19 situation, the virtual attendance to the meeting was allowed as well.
The event reached the participation of more than 150 people, with about 100 of them joining in person.

The scope of this document - based on contributions from SDQW#12 session chairs- is to summarize the main points discussed during this workshop and compile key user recommendations and feedback, which should be translated into future Swarm-based product evolutions, services, and scientific activities.

Technical sessions cover Swarm data quality status and algorithm improvements for magnet, plasma and orbit/accelerometer data products. Besides that, the SDQW#12 offers unique opportunities to further discuss with the Swarm community on key technical challenges, on new Swarm products and science topics related to Internal/external field variations and applications in the areas of Near-Earth Space Sciences and Space Weather.
Based on these interactions, key objectives of the workshop are to compile recommendations (see **Section 3** of this report): in view of reshaping the content of the Swarm data product portfolio, in identifying new data products and services based on an enhanced synergy with other satellite missions and ground-based observations. The workshop is also instrumental in demonstrating the growing importance of Swarm-based virtual research environment used in support to innovating data processing approaches as well as in collecting inputs for the optimization of the orbital constellation.
To achieve these goals, the SDQW#12 was structured in 10 sessions including large time slots for discussions and brainstorming (see detailed agenda in **Appendix I**):

- Session 1: Mission overview
- Session 2: Magnetic field measurements
- Session 3: Swarm FAST data assessment
- Session 4: GPSR and accelerometer
- Session 5: Electric field measurements
- Session 6: Swarm-based L2 data products and services
- Session 7: Multimission synergies
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- Session 9: Science projects and applications
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2 SESSION SUMMARY

2.1 Introduction

Session 1 presented an overview of the Swarm Mission illustrating the Mission Status, a brief overview of Swarm data quality and characteristics, and the meeting objectives. After almost 9 years in space, the three satellites are in excellent shape, being able to address new scientific challenges and operational applications and are ready for collecting data for several more years. Moreover, the Mission Extension by ESA's Member states recommended the mission extension through 2025. The status of the mission remains green, regarding both Platforms, Payload systems, data quality and PDGS infrastructures. To enable full exploitation of the Swarm constellation, the processing algorithms as well as the ground and flight operating segments are constantly improved, taking advantage of experience gained by ESA and the Swarm user community in the past years. Thanks to these joint efforts, the Swarm mission has already achieved remarkable scientific results also opening the door for many innovative applications beyond its original scope. This is particularly true in the area of Near- Earth Space physics where Swarm data exploitation should benefit of new opportunities of synergies with other ESA science missions. The combination of Swarm with complementary satellites is indeed promising as it increases the scientific value of the mission, enhancing temporal and spatial coverage. In this respect the status of current Swarm-Echo mission was also presented as part of the Swarm mission overview session.

2.2 Magnetic Field Measurements

Session 2 of the Swarm DQW#12 was dedicated to the data quality, improvements, and applications of the magnetic field measurements from Swarm constellation. During this session, the excellent performance of the Magnetic package instruments, i.e., the Vector Field Magnetometer (VFM), the Absolute Scalar Magnetometer (ASM) and the Star Tracker (STR), on-board the spacecraft was reported.

During the last year, major improvements have been introduced on the Swarm L1B data processing chain, mainly i) application of a revised model of the Sun induced magnetic disturbance (dB_Sun) correction on Vector Field Magnetometer (VFM) data; ii) introduction of a new Sun induced magnetic disturbance (dF_Sun) correction model on Absolute Scalar Magnetometer (ASM) data; iii) improvement of the generation of 1Hz ASM data during ASM Burst Mode sessions; iv) use of Precise Orbit Determination files as input for MAGNET (only for reprocessing campaigns); v) application of an improved thermal model for Inter Boresight Angle (IBA) variation. The L1B operational processor containing such improvements has been first deployed into operations in the Swarm reprocessing platform and a full reprocessing campaign of Swarm L1B and L2 (IBI, TEC and FAC) since the beginning of the mission has been performed. After the positive feedback received from the DQW community, the same improved version of L1B operational processor has been successfully deployed into operations on 28 September and the full mission reprocessed dataset (e.g., MAGNET data with product baseline 06) has been made available on ESA Swarm dissemination server for the benefit of the whole Swarm scientific community.

Among the many improvements introduced in this new product baseline, particular attention was given to the new sun-induced disturbance correction now implemented for both ASM (i.e., dF_Sun based on physical model of P. Brauer, only y-axis) and VFM (i.e., dB_Sun, the remaining part from scalar calibration) instruments. During this session of DQW#12, the significant improvement that the new correction models have introduced to the magnetic scalar residuals was showed.

The IPGP team presented both an overview of the status of ASM Burst Mode (BM) 250 Hz science dataset and the ASM-V data processing. For both these processing chains, a lot of effort has been put on the automatization of the process to minimize the manual intervention for the generation of the data. Moreover, the ASM 250 Hz dataset has been made available to the Swarm Cal/Val community for further quality assessment and to allow them to take advantage of this high frequency scalar field data for their independent studies. The reprocessing of these two datasets took also advantage of the improvements introduced in the new L1B baseline data. More precisely, the team confirmed that the implementation of the new dB_Sun and dF_Sun corrections on MAGNET v0602, improved the overall quality of ASM-BM and ASM-V data.

Always regarding the sun induced disturbance, the Romanian Academy (RA) team presented the results of the magnetic perturbations at ASM and VFM locations investigated through theoretical analysis and multi-physics numerical simulations. The simulations validated the correlation between VFM dB_Sun –x and –y components assumed in new baseline 0602 residual model.

Overall, the feedback on the new dB_Sun correction models has been very positive. However, from all the assessments performed so far, it was pointed out that there is still room for further improvements. For this reason, the community will continue to spend effort for further improving such models in the future.

During this session, it was also reported on the Swarm Echo MGF instrument performance, data processing and quality. The Iowa team has presented the improvements introduced in the Swarm Echo magnetic field instrument calibration process. Such improved process has been used to reprocess the MGF 1Hz and 160 Hz data in a "Swarm-like L1b CDF" format. The full dataset is now available on both Calgary FTP server and ESA Swarm dissemination server.

2.3 Swarm FAST data assessment

Session 3 of Swarm DQW#12 was dedicated to Swarm FAST L1B data quality. The session started from a joined presentation from Swarm PDGS and Data Quality team. The teams presented the status of the new FAST chain, i.e., the activities performed so far in terms of end-to-end assessment, development, and delivery of the first software, testing and first implementation. From such chain a first test data set has been generated, i.e., 6 months of data covering the time-period from 1st December 2021 to end May 2022 from the three Swarm spacecraft. Such TDS has been shared with the Swarm DQW#12 community and the same has been asked to help for the full assessment. In the following a summary of the use the community did of such TDS and the thoughts shared with all.

P. Alken used the FAST data for performing a full assessment for the L2 EEJ (Equatorial Electrojet) FAST data between +/- 40 degree QD latitude together with other AUX data have been used to produce both EEF and EEJ obtaining results comparable with the one obtained by the use of the Swarm L1B operational data. From a performance point of view, the processor took 1 minute to produce such data.

G. Balasis used the FAST data for the detection of ULF wave pulsation and compared the results obtained with the one obtained by the use of Swarm L1B operational data. Evident differences were detected while comparing the two results. However, a double-check of the versioning of the Swarm L1B OPER data has been asked. If baseline 05 is used instead of the Baseline 06, this could explain the differences obtained.

N. Gomez Perez instead used the FAST data to produce the Swarm MMA_SHA_2F Dst-like proxy. The authors stated that FAST data look suitable for Dst-like index. However, some issues with differences in MMA_SHA_2F versus FAST data have been spotted earlier in 2022. Post DQW#12 analysis confirmed that the two OPER-FAST Dst-like indices match very well, (i.e., an error introduced in the code could have been the source of the previous mismatch).

N. Olsen instead presented some thoughts about FAST data processing, and FAST data downlink operation. An assessment of the L2 data that could be generated as soon as the FAST L1B data are available. A particular thought has been put to the availability of a FAST MMA, product needed for running most of the L2 data production chains. Currently such product is updated daily while we should target to have an hourly update of MMA (by making use of RC and most updated Dst indices). Moreover, it was commented the Swarm data downlink latency. Somehow the data retrieved from Kiruna and Svalbard stations introduced a sort of delay of around 1 orbit.

G. Kervalishvili presented the results of the assessment done for the generation of FAST L2 GFZ products (i.e., Swarm-AEBS and Swarm-PRISM). To produce such data not only the Swarm L1B FAST data are needed but also FAST MMA, TECxTMS_2F, FACxTMS_2F, AOBxFAC_2F products are required.

W. Miloch showed the simulation of a FAST IPIR data production starting from the L1B FAST data. Overall. The good quality of the Swarm L1B data was confirmed. However, the team stated that such data production chain is dependent not only on L1B FAST data but also on some Swarm L2 data like IBI, TEC and others. In case such L2 data would not be available, much of the IPIR product can anyhow calculated even though the product would then be missing IBI_flag, and "part" of Ionopshere_region flag and such data could be made available to all the community in less than 10 minutes.

S. Buchert instead proposed to implement a LP FAST data production. This data production chain as well is dependent on some L2 data availability, mainly IBI.

J. Burchill proposed to implement a FAST 2Hz and 16Hz Ion Drift data production useful for Flow & density features (e.g. irregularities, boundaries), TII imagery, energy spectra, GCRs, anomalies (TRACIS) useful for Energetic particle monitoring (GCRs), TII health monitoring and Ion temperature estimates (SITE) and Effective ion mass, along-track drift data production useful for Ionospheric heating studies, vertical transport and composition changes.

Overall, during the session it was iterated the good quality of the first TDS produced. More in general, it was asked to the community to comment the way-forward and to come up with proposals on how to improve and what to change for being more attractive with such new service. The first point raised was related to the Swarm L1B data optimization. All the community agreed that the L1B FAST data production chain is good as is, i.e., no changes to be introduced. On the data latency instead, the community confirmed that if the Swarm L1B Fast data are made available with the 3 hours from sensing, such data production will be very useful for space weather monitoring. If such timing is not possible to target than provided the data with at max 24 hours latency could still be useful for modelling purposes. If we go above the 24 hrs instead, such data are no more useful. To produce Swarm L2 FAST products instead, the community is available to spend effort in preparing such new data chain. However, there are some dependencies with other Swarm L2 products or external AUX information that need to be further investigated.

2.4 GPSR and Accelerometer

The Swarm accelerometer data continue to be disturbed by several perturbations, where the “top 10 list of perturbations” was presented. Despite these anomalies, the accelerometer data processing advanced so much that now also the first parts of Swarm A and Swarm B accelerometer data were successfully processed. The current availability is:

- Swarm A: the entire year 2014 (on Swarm FTP server)
- Swarm B: March 2015 (containing the St. Patrick’s Day storm), only internally
- Swarm C: from Feb 2014 until now (on Swarm FTP server)

A first test dataset of Swarm B accelerometer data was produced. It is still very noisy (of the order of 30-50 nm/s^2), and the processing needs to be further improved before the Swarm B corrected accelerometer data can be released to users. Nevertheless, the analysis of the accelerometer data revealed that the large gravity waves generated during the St. Patrick’s Day storm in March 2015 were detected well by the Swarm B accelerometer. Therefore, Swarm B data processing should focus first on geomagnetic storms, where the neutral density variations due to gravity waves generated by Joule heating are very large. Generally, writing a paper on the Swarm accelerometer data processing as a proper reference for data users is recommended.

The GPS receiver data continues to be of high quality. The GPS receiver setting of the L2 PLL shows that wider bandwidths are more robust against ionospheric scintillations. However, there is currently no need to adjust the L2 PLL bandwidth, which is different on all three Swarm satellites.

Newly reprocessed precise orbits show very nice improvements over the previous version. The SLR validation of the reduced-dynamic orbits shows an RMS of about 10 mm and kinematic orbits of 13 mm.

Currently, 5 GPS block III satellites are not tracked by the Swarm GPS receivers. We recommend that the available patch should be implemented soon onboard the satellites.

The signal in the neutral density derived from the GPS receiver data is significantly lower due to the orbit raise in spring/summer 2022. However, the signal is still larger than during the deep solar minimum in 2018/2019, where the signal was so low that the density observations were sometimes fictitiously negative due to the noise in the observations. In that case, we advise using the orbit mean density only, which is provided in the same data product file.

The application of the COST-G Fitted Signal Models (FSM) showed that the maximum degree of 90 for the gravity field models is not high enough within the context of Swarm precise orbit determination.

2.5 Electric Field measurements

Session 5 was dedicated to the Swarm Electric Field Instrument (EFI) measurements. The EFI is composed by two Thermal Ion Imagers (TII) and two Langmuir Probes (LPs).

For what concerns the LPs it has been showed that the instruments performances are good, delivering good quality data nearly uninterruptedly since the beginning of the mission. A new processor version and product baseline for L1BOP and L2-Cat2 has been transferred to operations on 28th September 2022, after positive data quality assessment from the Cal/Val community.

The new baseline includes a new calibration for plasma densities and temperatures (Ne and Te) for mid-latitude regions obtained with Incoherent Scatter Radars (ISRs) measurements. A future improvement for densities measurements will regard renaming of the Ne parameter into Ni since it is actually computed at negative voltages (thus being ion density), and a different computation of Ne will be also introduced.

Another future improvement under development is the definition of a new quality flag identifying the artificial spikes in electron temperature measurements (Te), which are demonstrated to be related to the orientation of the spacecraft solar panels with respect to the Sun (SPETTRALE project). New data product released via the Swarm Dissemination server has been described: "Swarm Langmuir Probes Ion Drift, Density and Effective Mass" (SLIDEM) dataset provides additional estimations of along-track ion velocity and effective ion mass, from Swarm LP and FP. A validation test has been performed through comparison with other satellite and ground-based observations as well as with the IRI-2016 model, showing good agreement with long-term statistical predictions of the model.

For what concerns the TII, it has been showed that the instrument performances are continuously improving, via scrubbing procedures, gain map calibrations and different kind of tests. TII data processing and dissemination is performed by University of Calgary, and data are available on Swarm Dissemination Server. During the workshop it has been presented the new "TII Raw And Corrected Imagery / Spectra" (TRACIS) dataset, which represents the official archive of L0 and L1B TII full images, at low and high resolution.

Moreover, a validity assessment of the baseline 0302 of the "TII Cross Track Flow" (TIICT) dataset has been presented, with reference to cross-track and along-track ion drifts values. The analysis shows that TII cross-track data can be considered reliable in good agreement with Weimer (2005) empirical model while TII along-track data does not reproduce well the meridional ion convection. A promising technique was also implemented to estimate 2D ion convection from Swarm TII horizontal cross-track ion drift measurements only and thus obtaining complete information about the horizontal ion convection climatology.

Several studies concerning the assessment of EFI data have been presented:

- Differences observed in densities derived from Swarm measurements at LP and Face Plate (FP) are ascribed to solar flux dependence, since measurements at LP (assumed pure O+ plasma) seems to overestimate values, and a scaling factor can be defined based on these remarks.
- Further comparison of LP and FP densities measurements with ISRs observations and with COSMIC data leads to the proposal of a correction factor produced trough a Neural Network method.
- 3D Simulation-regression techniques applied to Swarm LP measurements, to account for realistic geometry and physical processes, show that spacecraft potential and plasma parameters values can be derived through inference model with a good qualitative agreement.

2.6 Swarm-based L2 data products and services

The session consisted of 12 presentations regarding the delivery, development, and use of Swarm Level2 products and services.

In the past three years, new products capturing the occurrence of Field Aligned Currents (FACs) at high latitudes have been developed. Blagau and Wang describe products and software to evaluate FACs. Vanhamäki presented work on the Dipole Spherical Elementary Current Systems (DSECS) and the supporting software package in Python; this interpolates the magnetic field over a wider area than covered directly by satellite paths. Similarly, the Time-Frequency Analysis (TFA) toolbox was described by Balasis. This tool analyses magnetic data for pulsations using wavelets. He further elaborated on a new deep learning framework using convolutional networks to classify Swarm signals. A presentation by Smith provided an explanation of the VirES interface to DSECS and TFA-toolbox packages and described new methods of working with Swarm data using SwarmPAL and Python Notebooks.

Olsen looked at the remaining dB_Sun effects in the latest 0602 release. He suggests that different disturbance effects occur for β angle increasing vs. β decreasing. The difference could be due to "thermal inertia" of the system which is not accounted for in present dB_Sun correction model and a correction would require filtering in time of dB_Sun disturbance.

Styp-Rekowski and Finley describe methods for improving and correcting non-Swarm datasets (from ESA platform magnetometers and Swarm-E) using machine learning and frequency analysis. Beggan outlined the ground observatory data processing and holdings available, along with the GVO product outputs. Chulliat gave an update on the ionospheric (DIFI-& and xDIFI) product and improvements in the past few years. Siddiqui investigated the occurrence of plasma depletions in the equatorial ionosphere. Finally, Coïsson described the ASM Whistler product, currently only available to Cal/Val users, which uses machine learning to identify occurrence in the ASM Burst Mode datasets. They recover the global lightning distribution well though with some as-yet unexplained local time effects.

2.7 Multimission Synergies

The session covered several aspects of multi-satellite missions: It contained overviews of the status of a wide variety of future LEO missions, that are in different stages of planning or preparation, including NanoMagSat, activities in the frame of the MagQuest, and also the Geospace Dynamics Constellation (GDC) by NASA. Examples of inter-spacecraft data comparison activities and science applications of multi-mission data were presented, e.g., regarding ULF wave investigations or thermospheric and equatorial electrojet observations using, e.g., Cluster or CSES data together with Swarm data. The integration of Swarm results into the Aurora-X online platform for data and tools regarding auroral studies and observations from ground and space were presented. All sky imagers, now moving forward in connection to the upcoming SMILE mission, came with the significant news that the Canadian ASIs are now facilities directly supported by CSA. Visualization of this data via Swarm Aurora and Aurora X also provide invaluable conjunction finding capabilities. Moreover, improvements to the Swarm-E (e-POP) data products were presented.

There was a great interest from the Swarm Community in the future missions and all information on the progress of these missions are eagerly awaited. The presentations demonstrated that multi-mission comparisons provide invaluable calibration opportunities but also enhance science, e.g., through improved local time data coverage. Tools to aid the community to readily identify added value from multi-mission connections, in particular including satellite conjunctions and ground- based connections are important assets. Commonality in data formats and comprehensive ephemeris and support data (including flags) is of utmost importance, to facilitate better cross- mission analysis (to reduce 'education' or learning time for users unaccustomed to new data sets). This is particularly relevant for archive data – to widen the user community and bring swarm data to other community's science activities.

This is also relevant for types of data products. However, care must be taken to ensure 'the shoe fits' wrt pipeline and algorithm use.

Swarm connection and extrapolation to current and future missions (and ground-based facilities) should be a focus for community activity, to underpin Swarm data and product output, but also to benefit the future missions. Considering in particular the planned GDC mission, it seems that connections between ESA and NASA regarding future magnetic / magnetosphere / ionosphere missions could be beneficial. This is also reflected in the recent Geospace Dynamics Constellation Independent Review Board Recommendations[1] (for example recommendation 11 and in particular 12):

[1] https://www.nasa.gov/sites/default/files/atoms/files/gdc-irb-final-report-and-response_oct-2022_ public-release-1.pdf

"*11. Given the international interest in the science that GDC will address, NASA should investigate plausible future collaboration with international partners, such as ESA, to augment and extend GDC science. Collaborations could include, instruments, hosted payloads, additional spacecraft and GB support*

12. NASA should investigate the additional benefit from existing and soon-to-be- launched, international magnetospheric and ionospheric missions to provide long-term continuous, synergistic and important contextual measurements as well as CAL/VAL, including SMILE (specifically the auroral imager) and Swarm missions within ESA and the JAXA FACTORS mission "

2.8 Swarm - CSES synergies

This session was an opportunity to discuss recent progress on the performances of the CSES payload as well as on joint CSES/Swarm team CSES data Cal/Val activities. Scientific applications mainly based on CSES data were also presented.

Jianping Huang (National Institute of Natural Hazards, Ministry of Emergency Management of China, NINH MEMC) made the first presentation and introduced the current status of the CSES mission. It was pointed out that, based on contributions from China and abroad, the China Seismo-Electromagnetic Satellite (CSES-01) data have been much downloaded and widely used for natural hazards and space weather events investigations. The data quality of CSES-01 appears to be good. The follow-up CSES-02 mission will be launched in 2023, to provide more data with higher resolution in time and space.

Dr. Zhima Zeren gave the second presentation (NINH MEMC) to introduce recent progress in the cross-calibration of most payloads onboard CSES, including the electromagnetic field detection payloads and the plasma and high energy particle payloads. Cross-calibration of EFD and SCM was discussed, considering the sampling time difference between them. As for the high-energy particle detection, the energy spectra and pitch angle distribution were displayed. The contamination rate of protons to MeV electrons was evaluated based on solar proton events, which indicated that the high-energy particle detection is at a high level and can meet the design requirements. Earthquake monitoring research based on CSES data was also introduced, mainly discussing strong global earthquakes. The statistical correlation analysis shows that the methods to establish forecasting methods based on CSES data are promising.

The third presentation was given by Dapeng Liu (NINH MEMC), who introduced the Ionospheric in-situ ion parameters measurements and performances of the Plasma Analyzer Package (PAP) onboard CSES-01. The PAP suffered contaminations after launch, which caused absolute value biases. But the corrected PAP data display good performance for detecting ionospheric disturbances caused by artificial (e.g., ground-based VLF transmitters) and natural sources (e.g., geomagnetic storms and earthquakes). Moreover, lessons have been learned to ensure improvements in the expected performances of the forthcoming CSES-02 satellite. More remarkable observation results of the PAP onboard the CSES-02 satellite should thus be expected.

The fourth presentation was given by Xuemin Zhang (Institute of Earthquake Forecasting, CEA), who showed examples of ionospheric responses at middle and lower latitudes during magnetic storms. Joint observations onboard CSES and Swarm were used, with wide frequency band electric field and plasma parameters. These illustrated the penetration of electric fields and the large-scale equatorward movement of mid-latitude trough in Ne during the main phase and slow recovery phase. The trend of Ne and TEC in the topside ionosphere was found to be closely related to the longitude and local time. The solar wind pressure and speed also showed high correlations with middle latitude variations, especially during the recovery phase, which demonstrates that these quantities play some roles in the mid latitude coupling processes besides electric field penetration.

The fifth presentation was given by Zhenxia Zhang (NINH MEMC), who introduced the CSES-01 high energy particle data and their use in space weather applications. The status of the particle detectors (HEPP/HEPD) of CSES (ZH-1) was discussed, and the data validation and product quality introduced. The proton contamination to MeV electrons was evaluated with Solar Proton Events during the occurrence of solar flare X-ray, using comparison of observations from ZH-1, POES and GOES. A study of relativistic electron accelerations by chorus and MS waves at low L-shells during 2018 geomagnetic storms based on ZH-1 and RBSP was also presented.

The sixth presentation was given by Wei Chu (NINH MEMC). By using numerical simulations and considering the variation trend of the Earth's main field as provided by the International Geomagnetic Reference Field (IGRF) model as well as the energetic particles' windows (EPWs), the variation characteristics of the cut-off rigidities of energetic particles in the vertical direction between 1965 and 2025 were studied. A close relationship between the cut-off latitude corresponding to the cut-off rigidities and the background magnetic field intensity was found, but not through a simple linear relationship. The changes in the cut-off rigidities and geomagnetic field in the northern and southern hemispheres appear to be asymmetric.

Four poster presentations were also displayed in this session. The first, by Sasha Koustov, was about Swarm plasma density and incoherent scatter radar at high latitudes. The second was by Rui Yan (NINH, MEMC), who presented the correlation between Ne and Te around 14:00 LT in the topside ionosphere observed by CSES, Swarm, and CHAMP satellites. The third, by Yanyan Yang (NINH, MEMC), introduced the Status of the CSES high-precision magnetometer. It illustrated the fact that CSES HPM generally works very well. However, more efforts still need to be made on the in-flight calibration of the FGM. The last poster, by Qiao Wang (NINH, MEMC), dealt with lightning whistler observations made by CSES.

2.9 Science projects and applications

Part I: Wood et al. presented models where the variability of ionospheric plasma, as observed by Swarm, was predicted from heliogeophysical proxies. It was shown that the inclusion of the thermospheric density (observed by Swarm) improved the model performance and that such models can outperform TIE-GCM. The potential for further enhancements (by varying the lags used with the heliogeophysical proxies) was discussed. Jenner et al. used the ASM in burst mode to study whistlers. NanoMagSat can provide better frequency range (up to 800 Hz) to perform TREC estimations.

Fillion et al. showed that the magnetospheric field exhibits LT asymmetries during active times, but it is uncertain whether this also occurs at quiet times. Fillion et al. showed how magnetic field data from Swarm could be used to answer this question.

Truhlik et al. Te proposed models for both hemispheres during all four seasons enable constructing sub-models for individual longitudinal intervals.

Marghuti et al. presented observations of Joule heating and estimated the Joule heating rate. Comment from audience: There is in general a lack of understanding of Joule heating which was also stressed during the COSPAR 2022 conference as a topic with research priority.

Encarnação et al. showed that swarm can deliver max. d/o 20 gravity field solutions that breached the gap between GRACE and GRACE-FO and can be useful in future observation gaps between GRACE-FO and successor missions. Comment from audience: It is advised to make use of the available Swarm A & C calibrated accelerometer data for the generation of the gravity field solutions instead of POD-derived or model-derived non-gravitational accelerations.

Part II: Slominska et al. detected lightning with Swarm A and C, using the 50 Hz data product from the VFM. Maximum / minimum variance analysis was used to find the direction and the polarisation of the wave. Monitoring of the thermosphere remains a major scientific challenge.

Perrone et al. used thermospheric density measurements from Swarm to study quiet time F-layer disturbances.

Aoi et al. used the 16 Hz electron density measurements from Swarm to study plasma structures in the equatorial region which formed from Equatorial Plasma Bubbles.

Bi et al. used high resolution magnetic field data from the VFM to find anomalous geomagnetic signatures.

Hoque et al. used Swarm A and C in combination to monitor gradients in the ionospheric plasma density. A spatial electron density product was introduced.

De Santis et al. used a multi-instrument approach to search for pre-earthquake ionospheric anomalies. They showed that the occurrence of such anomalies in the time before an earthquake was more frequent than would be expected from random chance.

Part III: Presentations by Yau et al., Watson et al., Deng et al. and Pačes et al. focused on a variety of topics from past and ongoing studies presented scientific results gained from synergies between Swarm and other satellite missions, as well as thermospheric/ionospheric models.

Scope of analysis:

- Topside ionospheric plasma: ion composition and ion velocity
- Dynamics of sub-kilometer plasma structures in auroral regions
- Traveling atmospheric disturbances (TADs) and neutral response on Swarm to strong space weather events

Data exploitation:

- New functionalities of the ViRES platform
- Data products form Swarm-Echo: new high-level user-friendly GPS data, ion time-of-flight and plasma current data from the IRM instrument

General discussion

- NanoMagSat projected performances can be included in the future Swarm scientific project to showcases potential improvements on specific science topics. Swarm exploitation phase shall contribute in preparing the ground for future geomagnetic missions.
- Time frame for the publishing of the ITTs is Q2 2023
- Use long time series from Swarm and preceding missions for improvements of empirical models of quiet thermosphere-ionosphere-magnetosphere (TIM) system.
- Use long time series of data for construction of new satellite-based, inter-calibrated products, for global representation of certain phenomena.
- Enhance more cross-disciplinary science goals, as well as a multi-mission approach:
- Synergies of the Swarm and Cluster constellations focusing on the ionosphere-magnetosphere (I-M) boundary and I-M coupling
- Synergies between Swarm and other mission from the Earth Explorers programme for continuation of 4D-Earth and 4D-Ionosphere Initiatives
- There is a high demand for robust empirical models that could be used for precise prediction of disturbances in the TIM system (e.g., GPS loss of lock events).

2.10 Prospectives on Space Weather

The session consisted of 6 presentations on products and activities related to space weather.

In the first presentation, Eelco Doornbos presented a new space weather tool running in a web browser, with which users can pan and zoom on a timeline while viewing space weather time series, indices and images. The tool is suitable (and currently in use at KNMI) for monitoring real-time space weather observations, but also for learning about past space weather events. As part of a new Swarm-DISC ITT 4.4 project, Swarm thermosphere densities and IPIR observations have recently been added to the viewer. These observations will be used to demonstrate how observations by Swarm and future constellations with similar instrumentation can contribute to the operational use of thermosphere-ionosphere models. Eelco ended his presentation with recommendations on Swarm data latency and orbit evolution from the perspective of a space weather user.

The second presentation was by Luca Spogli, who provided perspectives on a Swarm-based ionospheric scintillation index. Ionospheric scintillation is caused by small-scale irregularities in the ionosphere and can cause disruption of satellite navigation and communication signals using radio frequencies. This can lead, for example, to degraded satellite positioning accuracy, or even (temporary) loss of services. The Swarm 16 Hz faceplate data shows when irregularities occur and is therefore suitable for building scintillation models and a scintillation index. The need for high-rate data and the benefit of global coverage from satellite measurements were highlighted in the presentation.

The third and fourth presentations were made by Wojciech Miloch. His first presentation provided examples of scientific use and validation of the IPIR products, for case studies, statistical studies and modelling. Examples were shown of plotting the IPIR data together with GNSS-based global ionospheric maps from CODE, investigations of how the Swarm-measured rate-of-density index coincides with known regions of scintillation and how the data can be used to study hemispheric asymmetries, climatology, etc. In his second presentation, Wojciech presented results from the Swarm-VIP (Variability of Ionospheric Plasma) project. This included analyses of variations at different spatial scales using the Fast Iterative Filtering method, and scintillation models developed during the project. A model for high latitudes was compared with data from GNSS scintillation receivers, as well as with the TIE-GCM model. The model based on Swarm data was able to capture more variability at smaller scales, providing a moderate improvement over TIE-GCM in the polar, auroral and mid-latitude sectors.

The fifth presentation, on "Polar cap patches and the related magnetic signature" was provided by Yaqi Jin. He presented observations by a variety of instruments (airglow emissions, GPS scintillation, Swarm plasma and magnetic measurements), showing strong enhancements of the plasma parameters during passage through the polar cap patch. The magnetic data reflected the large to meso-scale density variations, but not the smallest scale variations.

In the final presentation of the session, Artem Smirnov talked about his neural network model of electron density in the topside ionosphere (NET). This model was constructed by fitting vary-Chapman functions through COSMIC, CHAMP and GRACE electron density data and fitting a neural network model to it. Using independent data for validation, the model showed significant improvements with respect to IRI models. The model can be further enhanced using electron density profiles from Swarm Echo.

Feedback to the Swarm FAST products: space weather wish list

- FAST Swarm products will be very useful for quick awareness of space weather events in the thermosphere-ionosphere. Products with up to a few hours' latency (best achievable for most LEO satellites) will be most valuable for data assimilation (but upstream solar wind data latency will remain a major limiting factor in model performance for some time to come)
- A good local time separation between A-C and B will add to global knowledge of the thermosphere-ionosphere. But other satellites will be used for this as well (COSMIC-2, GDC).
- Some vertical separation between A-C and B could be helpful in data assimilation and for developing future products based on scale height calculations.
- But the data is also most useful if the satellites are kept below the upper-pressure level boundary of popular models like TIE-GCM, and if processing assumptions (such as ion/neutral composition) are valid.

3. Recommendations

3.1 List of ongoing recommendations

TOPICS	RECOMMENDATIONS	STATUS	MAIN UPDATES AT DQW#12
Magnetic Field	[DQW8_Rec 3.] Generate new Swarm Product from ASM 250 Hz Burst mode science data.	**Ongoing**	IPGP have processed all the available Burst mode data and made them available to ESA and DISC first for final validation and then open the access to all the Swarm expert ("Mission") users (in July 2022). Discussion on -going on when to open the access of such dataset to all Swarm user community.
	[DQW8_Rec 4.] Produce a new Swarm STR L1B "particle flux" product	**Ongoing**	A paper containing the description of the "Particle flux" product has been prepared by DTU-MI team and currently sent for publication (https://link.springer.com/article/10.1007/s11214-022-00925-z). On-going instead the preparation of a technical document containing the description of such new product.
	[DQW8_Rec 5.] Implement a Time-jitter correction in the MAGNET processor to remove systematic spikes in ASM power spectrum	**On-hold**	Action on DTU. Activity put on hold.
	[DQW10_Rec1.] IPGP to validate the dB_Sun_ASM correction model proposed by DTU	**Done**	IPGP tested the global dB_Sun correction proposed for L1b data MAGx_LR version 0601 by investigating the impact on estimates of F-region local currents (presentation of G. Hulot at DQW12). Conclusion was that although there are still some features that need to be further investigating, overall, the correction model proposed by DTU is good enough for being implemented info L1B data processing chain.
	[DQW10_Rec2.] DTU to consolidate the new dB_Sun correction model and transfer it into operations.	**Done**	Updated model provided by DTU, first tested offline and then used as input for Magnet data v0601 and v0602. After the endorsement received by the Swarm community, the same correction model was transferred into operations together with the updated L1BOP in Sept. 2022.
	[DQW11_Rec1.] Transfer To Operations the new L1b product baseline	**Done**	Transfer to operations performed 28 Sept. 2022.
	[DQW11_Rec2.] Release Swarm-Echo MGF dataset to the whole Swarm community	**Done**	Improved MGF 1 Hz and 160 Hz CDF products shared through the Swarm dissemination server in Feb. 2022.
	[DQW11_Rec3.] IPGP to generate and distribute ASM-V data version 06	**Ongoing**	Production of ASM-V data version 06 currently on-going. ESA-IPGP to agree if to share such data with the Swarm data community.
	[DQW11_Rec4.] IPGP to process and release future burst data version 0301	**Ongoing**	Production of ASM 250 Hz science data with version 0301 currently on-going. As soon as the regeneration of such data is completed, IPGP to release the new data via Swarm dissemination server.
	[DQW12_Rec1.] Continue the investigation aimed at improving	**Open**	

	the ASM and VFM dB_Sun correction models		
	DQW12_Rec2.] Process and release new e-POP MGF TDS after removing the reaction wheel and solar panel current noise.	**Open**	
Swarm FAST data	**[DQW12_Rec3.] Go-ahead with the implementation of the FAST data processing and transfer it into operation**	**Ongoing**	
	[DQW12_Rec4.] Set up a direct distribution from the Swarm PDGS to VirES for the FAST products in order to minimise the latency	**Open**	
	[DQW12_Rec5.] Use VirES for ingesting and distributing Swarm L1b FAST data	**Open**	
Electric Field	[DQW8_Rec 8.] To implement a new firmware to adopt an updated version of the TII automatic gain control, and to download TII images at higher frequencies (16 Hz). During such high frequency TII acquisitions, the number of pixels can be reduced to 32, instead of 64, in order to limit telemetry problems.	**Ongoing**	Tests on the AGC functioning and firmware are ongoing. Frequent updates on these activities during the TII-ARBs. UCalgary has modified the firmware at revision X and has programmed the EFI EQM. Bench operation of the EQM with revision X confirms the software runs. A few additional tests are needed as prerequisite to issuing a version control document update for this revision, which UCalgary will carry out on the EQM. Software change in the imaging AGC, namely removing the inner AGC control loop acting on the shutter duty cycle, thus limiting the loop to the control of the MCP voltage, is to be tested on ground, before implementation on-board. Revised analysis about increasing the TII image rates indicate that 8 reduced image pairs per second per sensor should be attainable. No progress has been made on revising the software. TII Lab test to investigate water issue, peripheral anomalies will use a spare sensor from the development program which will be fit into the EFI EQM.
	[DQW9_Rec 7.] To improve the computation of the electron density.	**Ongoing**	Since the DQW#9, 6 meetings took place to discuss these and other LP anomalies. SB showed comparison of different method to estimate the electron density Ne. The faster and most effective way is through the comparison between LP data and Faceplate (FP) data. This suggestion has been passed to the users. At DQW#11 SB presented results of the comparison between Ni estimated with LP and with FP and they show a quite good correlation. While the comparison between Ni and Ne shows a disagreement, probably due to instrumental issues. Further investigation on cross-calibration is ongoing.
	[DQW10_Rec3.] To include the TIICT dataset in the ViRes platform	**Done**	TII Cross Track flow data products at 2 Hz are available in the ViRes platform.

		[DQW10_Rec4.] To analyse the data as outcome of the LP bias setting tests	Ongoing	The dataset is continuously produced by IRFU and available via ESA's dissemination server for "mission users". Data analysis is ongoing by IRF.
		[DQW11_Rec5.] Define a new quality flag for artificial Te spikes observed in LP data	Ongoing	Issue analysed within the SPETTRALE project: Spike-trains in electron temperature measured from Swarm Langmuir probes. A clear correlation with specific orientation of Swarm solar panels with respect to the sun has been observed, for all the three s/c during the entire mission. A detailed investigation on HK data from solar panels has been performed. The result of this investigation is that HK does not have the required resolution to be used for the flagging. A new algorithm to provide a new quality flag identifying the artificial spikes in Te has been developed and tested for a number of representative events.
		[DQW11_Rec6.] Open discussion on how to operate between TII science acquisition vs Faceplate science acquisition	Done	Discussion currently ongoing during EFI Science Discussion Group meetings. The focus of the discussion is the planning of FP mode in Sw-C during the particular constellation configuration (temporarily conjunction of Sw-A and Sw-C), so to have simultaneously TII regime on swA and FP regime on swC and obtain simultaneous measurement of along-track and cross-track ion drift velocity, useful for science purposes. **Can be considered closed. Status reported in [DQW12_Rec.6]**
		[DQW12_Rec6.] The acquisition of as many FP measurements as possible, to obtain Ni data at 16 Hz to be compared with LP measurements.	Open	AN increase of FP measurements is advised from the scientific community, in order to have Ni data at 16 Hz that can be used to compare and validate LP measurements, to perform further investigations on LP data calibration, to continue the improvements of ionospheric models and for Space Weather application.
		[DQW12_Rec7.] The definition of a release note for final users regarding the future introduction of Ni parameter	Open	Users community suggested that a release note accompanying the introduction of the new Ni parameter will be helpful for final users, to describe the different computation of Ni vs Ne and to recommend the usage of *Ni* for most scientific studies.
GPS and ACC	**ACC data**	[DQW8_Rec 13.] Improve the flagging and daily quality index of the ACCxCAL data products.	Done	Some improvements were implemented after the discussions at DQW#8. However, this should be considered a standing recommendation. Since this is a standing action, there is no need to track this.
		[DQW10_Rec6.] Investigate dependency of density observations on errors in the concentration of Helium in thermosphere models.	Open	Observations of mass density rely on the atmospheric composition derived from density models. Often NRLMSISE is used, which overestimates density during solar minimum conditions. Thus, there could be bias in the composition, which leads to a bias in the mass density observations. In particular the concentration of Helium could be important as it may change the effective aerodynamic coefficient.
		[DQW11_Rec7.] Investigate Swarm B data (early mission phase) for possible dissemination.	Open	The release of Swarm A calibrated accelerometer data and its comparison with Swarm C demonstrated that there is signal, comparable also to other instruments data. The availability of Swarm B data would give a complete picture, especially on Joule heating estimation

				(secondary mission objective). After consideration within the ACC team, we decided to focus on geomagnetic storms, i.e., the largest signals of phenomena with high dynamics.
		[DQW12_Rec8.] To write a paper on the Swarm accelerometer data processing as a proper reference for data users	**Open**	
		[DQW12_Rec9.] 5 GPS block III satellites are not tracked by the Swarm GPS receivers. Recommended to implement asap onboard the satellites the available patch	**Open**	
	A/B/C GPS	[DQW8_Rec 15.] Exploit integer ambiguity fixing when determining the non-gravitational acceleration from GPS receiver data.	**Done**	Level 2 precise orbits were reprocessed with integer ambiguity fixing. There are no plans to implement integer ambiguity fixing in the processing chain for aerodynamic accelerations.
		[DQW10_Rec7.] Make RINEX observation and precise orbit (SP3) files of AIUB with an empirical correction for L2 phase observations available in a dedicated folder on the Swarm ftp.	**Open**	The Astronomical Institute of the University of Bern (AIUB) produced RINEX observation files, which are corrected for an artifact resulting from the L2 PLL. Further, improved precise kinematic orbits were produced. The files should be distributed to other users, in particular all groups producing precise orbits and gravity field models, via the Swarm ftp in a dedicated folder.
		[DQW10_Rec8.] Distribute all files needed for generating mass density observations in near real-time and develop a near real-time mass density observations product, to be distributed also in near real-time.	**Open**	Operational orbit prediction is expected to benefit from near real-time mass density observations, which can be assimilated in density models. All required input files need to be made available in near real-time. A near real-time mass density product needs to be developed.
Internal Fields		[DQW8_Rec 24.] Develop new data processing/ modelling approaches using Swarm data to get better mantle conductivity models and understanding of core dynamics on sub-decadal timescale.	**Ongoing**	ESA STSE Project "4D core" has been kicked off Swarm DISC ITT on "Internal strength of magnetic field in core from quasi-geostrophic model of core dynamic" planned for 2.5 years and starting in Sept. 2019, has been extended to 5 years (until August 2024). More details https://eo4society.esa.int/projects/the-4d-earth-swarm-project/.
		[DQW9_Rec 12.] Extension of [DQW8_Rec 23.] and [DQW8_Rec 24.] towards the use of platform magnetometer data.	**Ongoing**	The Swarm DISC GVO project was successfully completed in June 2020, GVO products are now operational. No bid was accepted for the DISC ITT on "Internal strength of magnetic field in core from quasi-geostrophic model of core dynamics". 4D core project is beginning to use GVO products for core flow determination and work on core dynamics models is ongoing. CryoSat-2 and Grace data have been used for internal field studies, but further calibration efforts needed on Grace.
		[DQW10_Rec9.] Investigate annual signals in GVO series	**Open**	To be discussed and updated during Swarm DQW#13.
		[DQW10_Rec10.] Explore more realistic prior information for external fields, to be used in field	**Open**	To be discussed and updated during Swarm DQW#13.

	modelling for example in the MCM model of Lesur and co-workers		
	[DQW10_Rec11.] Further studies of merging satellite and near-surface data, exploring band-limiting of near-surface data, in the extended dedicated crustal field product	**Open**	To be discussed and updated during Swarm DQW#13.
	[DQW10_Rec12.] Clarify difference between ground and satellite Q-matrix in induction studies for mantle conductivity	**Open**	To be discussed and updated during Swarm DQW#13.
	[DQW10_Rec13.] Continue efforts to calibrate platform magnetometers, using house-keeping data, if possible (e.g., GRACE), to aid induction studies	**Ongoing**	Activity continuously ongoing.
	[DQW10_Rec14.] VRE-based dashboards for exploring ground observatory data and magnetic field models	**Ongoing**	Ongoing
External Fields	[DQW8_Rec 28.] Develop a well-documented toolbox to facilitate wider usage of innovative methods for Swarm-based FAC determinations.	**Ongoing**	The codes that explores the FAC system using Swarm observations are now part of the SwarmFACE package, available on GitHub (here), with detailed documentation (here). Furthermore, the SIFACIT Team is now working on: - to develop a new data processor based on the dual-sat Least Square algorithm for batch-processing Swarm data during the nominal orbit separation of the lower satellites (1.4° longitudinal difference in their Ascending Nodes) - to generate daily time-series of dual-sat LS FAC data for May-Dec 2014 interval (approx. first 8 months of the mission).
	[DQW10_Rec15.] Expand the number of products for space science and space weather e.g., by combination of different parameters (B, Ne, E, TEC, …) and multi-mission approach	**Ongoing**	To be discussed and updated during Swarm DQW#13.
Swarm-based L2 data products and services	**[DQW12_Rec10.] A wider angular separation of Swarm A/C would be beneficial to the DSECS product (up to 3°)**	**Open**	

	[DQW12_Rec11.] Use Swarm ASM Burst Mode data to investigate signals associated with natural hazards (e.g., earthquakes, tsunamis, volcanos)	**Open**	
	[DQW12_Rec12.] Innovative tools and techniques for Swarm analyses based on Artificial Intelligence and, in particular, Machine Learning show promise in many cases, and could be further explored for Swarm studies, considering the large amount of available data from the mission.	**Open**	
	[DQW12_Rec13.] Swarm community could take advantage of the newly developed SwarmPAL package within VirES. There is scope for creating tools for new research communities to access Swarm data too (e.g. heliosphere studies, ecological animal movement)	**Open**	
Space physics and weather applications	[DQW9_Rec 13.] Further analyse and investigate LP based Te and Ne features potentially impacted by instrumental issues.	**Done**	See status of [DQW9_Rec7.] and [DQW11_Rec6.].
	[DQW10_Rec16.] Investigate the potential of Swarm for Space Weather research and application	**Ongoing**	A lot of progress done on this field. See discussion done during "Swarm FAST data" session.
	[DQW10_Rec17.] Evaluate the potential of fast access of Swarm data with respect to reduced processing time and/or more frequent download	**Done**	A table of specific requirements is prepared at https://docs.google.com/spreadsheets/d/1-fr5z_DA_5-vRDqRrKAtWaqHqRjKSwqjaigGGA7IhXc/edit#gid=0
	[DQW11_Rec8.] Implement a Swarm Fast processing chain (extension of [DWQ10_Rec17.])	**Ongoing**	Preliminary tests on Fast processing products are ongoing.
	[DQW11_Rec9.] Process and distribute "Fast-track" L1b data (magnetics, plasma, GPS …) with latency as short as possible (< 3 hrs ?), accept "data gaps"	**Ongoing**	First TDS produced and shared with the community rpior to
	[DQW11_Rec10.] Process and distribute "Fast-track" L2 data (where it makes sense)	**Open**	To be discussed and updated during Swarm DQW#13.
	[DQW11_Rec11.] Identify new "Space-weather–related" higher level data products	**Open**	To be discussed and updated during Swarm DQW#13.
	[DQW11_Rec12.] More long-term: Investigate possibility of more frequent data downlink ideally using stations in N and S	**Open**	To be discussed and updated during Swarm DQW#13.

	hemisphere to achieve data latency of shorter than ½ hour, although Northern hemisphere probably more interesting for European Space Weather applications		
	[DQW11_Rec13.] Take advantage of Swarm measurements and available models to understand the solar cycle	**Open**	To be discussed and updated during Swarm DQW#13.
Swarm - CSES Synergies	[DQW8_Rec 29.] Foster collaboration between CSES and Swarm experts' team for cross-calibration and validation activities.	**Done**	Dedicated magnet and plasma cal/val core teams have been established, resulting in already three dedicated joint papers published with the magnet cal/val core team (Yang et al., EPS, 2020; Yang et al., JGR Space Physics, in revision; Wang et al., Science China Technological Sciences, 2020) and already three papers published with the plasma cal/val core team (Huang et al. JGR-Space Physics, 2020; Yan et al., et al. JGR-Space Physics, 2020; Piersanti et al., Advances in Space Research, 2020). Results of both groups have progressively been presented at the 3rd CSES workshop in Beijing (November 2018), at a joint CNSA-ESA Earth Observation Workgroup Meeting in Changsha (April 2019), at the Living Planet Symposium in Milan (May 2019), at the 9th Swarm Data Quality Meeting in Prague (September 2019) and at the 4th International Workshop of CSES mission in Changsha October 2019) and at this SDQW#10 (5-9 October 2020). In addition, an ISSI-BJ Team on "The electromagnetic data validation and scientific research based on CSES satellite", has been set-up, which already met once in November 2019 in Beijing, and an independent proposal was successfully included in the Dragon-5 project, approved in June 2020 and kicked-off in July 2020. The status of this Rec. continues in [DQW12_Rec14.].
	[DQW8_Rec 30.] Make available appropriate level of CSES data to Swarm experts for starting such activities to as soon as possible.	**Done**	Effort spent by both the Swarm and CSES teams aimed at continuing sharing CSES HPM Level-2 data files and further improved by Swarm DISC. CSES CDF L1b-like data products currently available on ESA Swarm dissemination server, and accessible by Swarm Cal/Val users only.
	[DQW9_Rec 15.] Organise a joint CSES-Swarm Data Quality or Science workshop	**Ongoing**	Several sessions have been organized, and an ISSI-BJ science team set-up. After the Covid-19 pandemic, a new meeting of this ISSI-BJ science team is to be organized.
	[DQW10_Rec18.] CSES-Swarm collaboration: Coordinate activities of Swarm DISC, ISSI-BJ science team and proposal included in the Dragon-5 project (also clarifying what can be funded by the Dragon-5 program), to ensure full advantage is taken of both tools (also ensuring possibility of mixed "physical" and "remote" attendance). Collaborate further on improving data CAL/VAL. Ensure the possibility of long-enough	**Ongoing**	Collaboration on Cal/Val activities continuously on-going while the cross-visit activities ahs been put on-hold due to Covid-19 pandemic situation. Activity to be resumes soon.

	cross-visits for spending significant joint working time in same location, for allowing quick exchange of practical (hence critical) information.		
	[DQW10_Rec19.] CSES data: Streamline CSES data access to make all of them (not only HPM FGM2 data, but data from all payloads) accessible from outside China, including auxilliary data, by e.g., using ESA ftp site (as is currently done for HPM data). Provide relevant documentation (file format, data content, etc...) in English.	**Done**	See [DQW12_Rec 14.].
	[DQW10_Rec20.] CSES data: Produce and provide high-latitude (above 65° latitudes) HPM scalar data (at least).	**Done**	See [DQW12_Rec 14.].
	[DQW12_Rec14.] To continue and strengthen the Swarm/CSES collaboration in order to: **- maintain and improve the quality of the data provided by CSES** **- ensure CSES data is kept available in a suitable format and in a timely manner for scientific investigations by the international scientific community**	**Open**	
Swarm - Echo	[DQW8_Rec 31.] Update data format of new MAG and GAP Swarm Echo products to better match with Swarm L1b and L2 data product formats	**Done**	MAG data products has been improved using enhanced attitude information provided by Ch. Siemes. Results for 2018 are currently exploited. See also [DQW9_Rec 3.] [DQW9_Rec 4.].
	[DQW8_Rec 32.] Coordinate Swarm Echo and Swarm A/B/C activities regarding data cross-calibration and scientific validation	**Done**	See also [DQW9_Rec 3.] [DQW9_Rec 4.]
	[DQW11_Rec 14.] Release Swarm-Echo MGF dataset to the whole Swarm community	**Done**	Swarm Echo MGF data already shared with the community through the Swarm Dissemination server
Swarm and Multi-mission Synergies	[DQW8_Rec 35.] Develop multi-mission, consistent, reliable and well-calibrate multi-mission datasets to address key scientific challenges related to upper atmosphere “climate” trend analysis, studies of longer-term secular variation vs solar cycle effects, quantification of energy transports by waves and other phenomena.	**Ongoing**	Multi-mission ionospheric data (TEC and Ne of CHAMP, GRACE, GRACE-FO) developed in DISC TIRO. While thermospheric data of GRACE, GRACE-FO and CHAMP missions developed in DISC TOLEOS project.

	[DQW9_Rec 17.] The Swarm DQW#8 Rec.34 to Rec.39 have been replaced by the new Rec i.e., [DQW9_Rec 18.] - [DQW9_Rec 23.], here below	**Done**	
	[DQW9_Rec 18.] Exploit needs and new research opportunities from multi-mission approaches in the areas of core field evolution, mantle conductivity, ionosphere-atmosphere, ionosphere-magnetosphere, and thermosphere-atmosphere coupling, climate trends, geodesy, and gravity, among others.	**Ongoing**	To be discussed and updated during Swarm DQW#13.
	[DQW9_Rec 19.] Prepare and provide calibrated data of (platform) satellite magnetometers in support for Swarm. These data may include those from ESA missions (Aeolus, Cryosat-2, GOCE, e-POP, Sentinels, …), new missions (Daedalus, SMILE, Macao, NanoMagSat, …), none-ESA scientific missions (DMSP, GRACE, GRACE-FO, …), and commercial missions (AMPERE, SPIRE, …). It is aimed that these data are provided in daily CDF files (time, position, calibrated B_FGM, STR data, B_NEC, flags, …) and available to the scientific community.	**Ongoing**	Fully calibrated Cryosat-2 magnetic data for August 2010 to March 2022 available as daily CDF files at Swarm PDGS (ftp://swarm-diss.eo.esa.int/%23CryoSat-2). Fully calibrated GRACE-FO magnetic data available from the start of the mission until October 2020 and continuously updated at ftp://isdcftp.gfz-potsdam.de/grace-fo/MAGNETIC_FIELD/0201/ Peer-reviewed papers collected in a special issue at EPS: https://www.springeropen.com/collections/leo.
	[DQW9_Rec 20.] Continue effort in expert group for "Multi-mission data calibration and application": Compile a peer-review publication describing data products and calibration process, and several publications on the multi-mission potential and applications in a special issue.	**Ongoing**	An article describing data product and calibration processes of magnetic LEO data is expected to be a contribution of the special issue with submission deadline in 2020: https://www.springeropen.com/collections/leo. To be discussed and updated during Swarm DQW#13.
	[DQW9_Rec 21.] Further investigate new data sources (e.g., platform magnetometers) to fill the gap between CHAMP and Swarm	**Ongoing**	See [DQW9_Rec 19.] Several articles collected in https://www.springeropen.com/collections/leo To be discussed and updated during Swarm DQW#13.
	[DQW9_Rec 22.] Enhance the potential synergy of thermosphere – ionosphere data of Swarm and other satellite missions, such as GRACE(-FO), Sentinels, e-POP, SPIRE, …).	**Ongoing**	Multi-mission ionospheric data (TEC and Ne of CHAMP, GRACE, GRACE-FO) currently developed in DISC TIRO. New DISC call open for generation of thermospheric data of GRACE or similar missions. GOCE TEC data is available at http://eo-virtual-archive1.esa.int/GOCE-Thermosphere.html, first results were presented at DQW#8. Synergies between Swarm and Sentinel's TEC presented at Swarm DQW #9.

	[DQW9_Rec 23.] Investigate new funding schemes enabling consistent calibrations of multimission data.	Open	To be discussed and updated during Swarm DQW#13.
	[DQW10_Rec21.] Combine magnetic observations from LEO satellites (dedicated and platform) distributed at different local times to characterise the asymmetry of the magnetospheric ring current signal, and for induction studies.	Ongoing	To be discussed and updated during Swarm DQW#13.
	[DQW#10_Rec22.] Express strong support for exciting contribution Daedalus mission can make to lithospheric studies	Open	To be discussed and updated during Swarm DQW#13.
Science projects and applications	**[DQW12_Rec15.] Statistical models of ionospheric plasma have the potential to be operationalised can complement, and have the potential to improve upon, physical models such as TIE-GCM. Swarm observations of the thermospheric density can be used within statistical models to increase the understanding of the physical system. ITTs in these areas are recommended.**	**Open**	
	[DQW12_Rec16.] The unique configuration of Swarm A and C enable studies of the 2D horizontal structures in both the ionospheric plasma and the magnetic field. The high temporal resolution of both the plasma and magnetic field observations is enabling novel studies. ITTs in these areas are recommended.	**Open**	
	[DQW12_Rec17.] There is in general a lack of understanding of Joule heating which was also stressed during the COSPAR 2022 conference as a topic with research priority. An ITT in this area is recommended.	**Open**	
	[DQW12_Rec18.] Ocean applications from Swarm shall distinguish between ocean circulation and ocean tide electrical conductivity. It is recommended to have separate ITT's addressing these two Swarm applications.	**Open**	

	[DQW12_Rec19.] Regarding core field studies, specific long-term vision for advancing our understanding of core dynamics and the origin of changes in Earth's magnetic field shall be to determine a physically consistent, time-dependent, model of core dynamics and Earth's magnetic field based on Swarm long-term observations.	**Open**	
	[DQW12_Rec20.] Foster synergies between other EO missions by including related activities in future science ITTs.	**Open**	
	[DQW12_Rec21.] The lengthy, and growing, temporal extent of the Swarm data set is enabling excellent, novel scientific results. The continuation of this mission as solar activity increases in the coming years will further add to the value of this dataset. ITTs are recommended which exploit this dataset by building on current or previous projects are recommended.	**Open**	
Swarm SPACE4.0I, Data Visualization and Analysis	[DQW8_Rec 36.] Provide lessons learned from the Swarm community to the Daedalus MAG	**Ongoing**	To be discussed and updated during Swarm DQW#13.
	[DQW8_Rec 37.] Investigate whether the science objectives of Daedalus could be broadened to Swarm areas of science	**Ongoing**	To be discussed and updated during Swarm DQW#13.
	[DQW8_Rec 38.] Enhance the use of Machine Learning / AI methods applied to emerging Swarm Data applications	**Ongoing**	The Machine Learning approach has been adopted recently by Papadimitriou for automatic detection of ULF waves in Swarm data. Moreover, Yaxin Bi adopted a Deep Learning approach for Anomaly detection. In addition, in ESRIN Phi-Lab is applying a supervised Machine Learning approach to investigate the possible relation of some magnetic perturbation measured by Swarm with Earthquake activity on Earth. This study is currently ongoing.
	[DQW8_Rec 39.] Make easier the access / manipulation of Swarm data and facilitate collaborations via the development of VRE	**Done**	Swarm VRE made available to Swarm user community in 2019 and since then continuously updated.
	[DQW8_Rec 40.] Redesign and improve the content of the Swarm website to make it fully align with the scientific community expectations	**Ongoing**	The Swarm DISC team is intensively working on improvements and extension of scientific information provided for the Swarm mission. In parallel the Swarm DISC team continue to work in close collaboration with ESA EO web team on the design and content of the new ESA EO website (https://earth.esa.int/eogateway/missions/swarm).

Future Missions	[DQW11_Rec 15.] Consider the possibility to align orbits of future satellites or constellations with Swarm satellites	**Open**	It would be beneficial to align orbits of future satellites or constellations (large & small) with Swarm. Depending on the launch date with Swarm A & C or Swarm B.
	[DQW11_Rec 16.] Define cross-mission objectives	**Open**	Aim at defining cross-mission objectives, which may not be possible by one or the other mission or enhance existing objectives. This strengthens the position of all individual missions and implicitly provides objectives for future extension of Swarm
	[DQW11_Rec 17.] Start generating and elaborating post-Swarm mission ideas	**Open**	Start generating and elaborating post-Swarm mission ideas, which can be submitted to the future Earth Explorer 12 call (2023 TBC). Potentially use the principle of designed and controlled constellations recently developed for time variable gravity field missions.
	[DQW11_Rec 18.] Ensure that data from complementary missions are open and free	**Ongoing**	Ensure that all data of complementary missions (e.g., Daedalus, Swarm, Macao, CSES, NanoMagsat, MagQuest) provide data open and free to the science community for validation and science.
	[DQW11_Rec 19.] Explore the possibility for a workshop to align existing and future missions	**Open**	
	[DQW11_Rec 20.] Swarm and beyond: Swarm is the backbone of “Geomagnetism and Geospace Satellite Fleet” … … synergy with other existing and future satellite missions	**Open**	
	[DQW11_Rec 21.] Ensure a Swarm mission extension for the future, in order to allow the scientific community to rely on long time series data, for Space "climatology" applications	**Open**	The physical processes underlying Swarm observations are becoming clearer, and new insights are being gained. The benefits of long time series are starting to be appreciated as we move from ‘weather’ towards ‘climatology’. Thus, a further recommendation is that Swarm be extended for as long as possible.
	[DQW11_Rec 22.] Create a series of “Swarms ideas workshop"	**Open**	A number of projects presented during SDQW#12 study similar phenomena from different ‘angles’ (e.g., physics-based models, empirical models, data led) and in different ways (e.g., different datasets, methods of analysis), and additional synergies will come from bringing related studies together. It is recommended that ESA facilitate this, perhaps with a series of Workshops.

3.2 List of recommendations completed during past Data Quality Workshops

TOPICS	RECOMMENDATIONS	STATUS	LAST STATUS UPDATE
Magnetic Field	[DQW8_Rec 1.] Adapt the L1BOP in order to be able to process L1B MAG data with ASMxBUR_0_ data as input	**Done**	Action completed. Improved version of L1BOP deployed in operations in Feb. 2020. Activity completed.
	[DQW8_Rec 2.] Run ASM on Swarm Alpha and Swarm Bravo in Burst mode more frequently (two weeks sessions).	**Done**	On-going regular monthly 1-week burst sessions since August 2019 and bi-monthly 1-week sessions from July 2020.
	[DQW8_Rec 6.] Test the improvement that can be obtained by the use of POD rather than MODx_SC_1B as input positions for MAGx_.._1B	**Done**	Action completed. C. Siemes perform such investigation. By replacing the MOD with POD a difference of max 10-20 cm in the position was obtained. I.e., no improvement in mag data is expected. Action closed.
	[DQW8_Rec 7.] Use the ASM correction model to investigate impacts on field modelling (external fields).	**Done**	DTU performed this investigation and confirmed the new ASM correction model do not have any impact on core field, on data misfit, on quite time magnetospheric estimations. This model instead slightly impacts the Euler angles.
	[DQW9_Rec 1.] In case of reprocessing POD data to be used as input for magnetic data processing	**Done**	L1B MAGNET processor adapted to read as input, when available, POD (SP3_COM) files. Implementation validated. This functionality has been used during the 2nd Swarm L1B data full reprocessing campaign.
	[DQW9_Rec 2.] Move MGF comparison model to CHAOS	**Done**	The MGF comparison wrt Chaos-7 model has been implemented. Such change has reduced drastically the residuals.
	[DQW9_Rec 3.] Create a Level 1b product of Cassiope spacecraft house -keeping data to aid with MGF calibration	**Done**	The L1B Cassiope products have been created as Swarm-like product. The consistency has been tested using the ingestion on Vires.
	[DQW9_Rec 4.] MGF output products to be in a CDF format similar to Swarm A/B/C products. Consider having daily files for both 1 Hz and 160 Hz products.	**Done**	Activity on track via the MGF team meeting.
Electric Field	[DQW8_Rec 9.] To implement new tests for LP bias, with higher voltages (+5V).	**Done**	Sweep cycle mode tests have been performed together with other tests (FP bias, Ne computed via electron current). Data are currently on IRF database, TBD if they will disseminate those via ESA's dissemination server.
	[DQW8_Rec 10.] To define a new e-POP science mode in order to	**Done**	e-POP IRM data will be reprocessed and delivered to the EFI community for joint Cal/Val activities. A

		collect data during conjunctions with Swarm that would allow cross-calibration of cross track plasma velocity between the two spacecraft.		first meeting between Swarm/e-PoP teams took place and it was agreed to share the list of spacecraft conjunctions, but it is too early to plan further joint activities.
		[DQW9_Rec 5.] To release new cross-track velocity dataset TIICT 0201 with latest improved calibration	**Done**	After the yaw and pitch tests, the calibration coefficients have been updated and the new TIICT 0301 dataset has been delivered for all the Swarm spacecraft, covering from Dec 2013 to June 2020 at 2 Hz and 16Hz .
		[DQW9_Rec 6.] Release of the new dataset TIIVI 0101 (3D flows) with quality info in the Flags.	**Done**	The dataset has been already validated via comparison with DMSP data and Weimer 2005 model. Action completed as a revision on the cross-track flow dataset, which is now at revision 0302, and covers 10 December 2013 through 11 September 2020 for all three satellites. Quality flags have been revised and extended to include more information about the quality of the data processing. The next step will be to keep providing 0302 data at regular intervals (1 week to 1 month, say). Then we would like to have feedback and recommendations from users on the TII ion drift data quality.
		[DQW9_Rec 8.] To make a complete statistical analysis from BOM to characterize the evolution of the EFI L1B data quality and related anomalies to identify possible improvements.	**Done**	The Review of the Swarm L1B data quality has been published. The document describes the past issues, recent achievements, and future objectives.
GPS and ACC	**ACC data**	[DQW8_Rec 11.] Release to users the Swarm C along-track accelerations covering the period from May to November 2016	**Done**	
		[DQW8_Rec 12.] Continue to correct Swarm C along-track accelerometer data. Focus next on Swarm C cross-track accelerometer data of the second half of 2014 (motivations: large signals at beginning of mission; no large manoeuvres; Swarm C at lower altitude; 1 Hz GPS receiver data available).	**Done**	Swarm C along-track processing is current now and focus will remain on this. Experimental dataset of calibrated Swarm C cross-track accelerations was produced and published. Swarm A along-track acceleration data was calibrated and compared to Swarm C. Since the signal content appears to be identical and the noise level as well as the artefacts are twice as worse compared to Swarm C, the additional value of Swarm A accelerometer data is being able to distinguish better between signals and artefacts features in Swarm C acceleration data.

		[DQW8_Rec 14.] Implement geophysical meaningful sanity checks based on presence of gravity waves (statistics with respect to latitude, local time, solar and geomagnetic activity, season, plasma bubbles, day/night side, etc.) that help to assess the quality of ACCxCAL data products before release.	**Done**	Prototype for sanity check at eclipse transitions based on model radiation pressure signal (ACCx_FMi2 product) was implemented.
		[DQW9_Rec 9.] Release as much calibrated Swarm accelerometer data as possible, i.e., also fractions of days when part of the day is judged to be not usable	**Done**	Implemented in the disseminations since DQW#9.
		[DQW10_Rec5.] Check cut-off in mass density variations	**Done**	The assessment of mass density data showed that variations appear to be truncated at a threshold. This needs to be cross-checked independently.
	E GAP	[DQW8_Rec 16.] Maximize the duty cycle of the GAP-A instrument; noting that one receiver at a 0.1 Hz data rate is sufficient.	**Done**	CASSIOPE team implemented onboard procedure to maximize the duty cycle.
		[DQW8_Rec 17.] Make star tracker data available and try to collect star tracker data when GAP data is collected, noting accurate spacecraft attitude data is needed for macro models (radiation pressure modelling, etc.).	**Done**	See technical note ESA-EOPSM-SWRM-TN-3487 (the tech note should be placed on the Swarm webpage when we decided to make available the data)
		[DQW8_Rec 18.] Collect GAP-A data once per orbit, preferably at low altitudes (high drag signal) and also some at apogee (constrains orbit)	**Done**	Satisfied with the improved GAP duty cycle.
		[DQW8_Rec 19.] Avoid too much segmentation of GAP-A data (ambiguity fixing, etc.) and data gaps longer than one orbit (accuracy gets much worse for long interpolations).	**Done**	Satisfied with the improved GAP duty cycle.
		[DQW8_Rec 20.] Determine the GPS antenna phase centre location with respect to the spacecraft CoM (from documentation, verify with in-flight data), which should be used conventionally by all groups	**Done**	Work completed by O. Montenbruck, A. Hauschild, and R. Langley. Submitted a paper recently to GPS Solutions.

		performing precise orbit determination for Swarm E.		
		[DQW8_Rec 21.] Determine GPS antenna phase centre variations with respect to the antenna phase centre location for Swarm E, potentially supported by dedicated campaigns GPS antenna calibration.	**Done**	Work completed by O. Montenbruck, A. Hauschild, and R. Langley. Submitted a paper recently to GPS Solutions.
		[DQW8_Rec 22.] Focus first on precise orbit determination for Swarm E and assess the feasibility of the determination of neutral density at a later stage.	**Done**	Precise orbits are available for 2018 and 2019. CASSIOPE team is implemented precise orbit determination. Papers on thermosphere density observations published by Andres Calabia et al.
		[DQW9_Rec 10.] Make the new CASSIOPE orbit and attitude data available on Swarm dissemination server	**Done**	POD Cassiope product available for the year 2019 in the Swarm dissemination server.
		[DQW9_Rec 11.] Place technical note on CASSIOPE attitude determination on Swarm webpage	**Done**	TN has been published in the Swarm webpage (see here)
		[DQW9_Rec 12.] Extension of [DQW8_Rec 23.] and [DQW8_Rec 24.] towards the use of platform magnetometer data.	**Done**	GVO dataset released in June 2021.
Internal Fields		[DQW8_Rec 23.] Generate and distribute Swarm-based VO products	**Done**	Geomagnetic Virtual Observatories (GVO) DISC project started in June 2019 to derive monthly and 4-monthly magnetic field values at satellite altitude on an equally spaced grid of 300 points. First GVO data products will be published in June 2020.
		[DQW8_Rec 25.] Justify rationale for 3D Earth approach using Swarm data	**Done**	Irrelevant recommendation.
		[DQW9_Rec 12.] Extension of [DQW8_Rec 23.] and [DQW8_Rec 24.] towards the use of platform magnetometer data.	**Done**	The Swarm DISC GVO project was successfully completed in June 2020, GVO products are now operational. No bid was accepted for the DISC ITT on "“Internal strength of magnetic field in core from quasi-geostrophic model of core dynamics”. 4D core project is beginning to use GVO products for core flow determination and work on core dynamics models is ongoing. CryoSat-2 and Grace data have been used for internal field studies, but further calibration efforts needed on Grace.
External Fields		[DQW8_Rec 26.] Update the Swarm cross-track velocity data archive with a quality flag characterizing the intensity of along-track velocities	**Done**	The quality Flag of the TIICT have been reviewed and updated in agreement with this Rec (see related TN).

	[DQW8_Rec 27.] Improve the description on the linkage of electron density and TEC fluctuation rates to GNSS phase and amplitude scintillations to further enhance the use of Swarm for space weather applications	**Done**	See presentations by L. Schreiter at DQW#9.
Space physics and weather applications	[DQW9_Rec 14.] Investigate the potential use of vertical velocity measured by EISCAT radars for the calibration of Swarm TII data.	**Done**	This activity consisted on the identification of 15 conjunction events among EISCAT radar and Swarm Alpha when TII was measuring good quality science data. Among these events, after the verification of good velocity data measured by EISCAT, a subset of 12 events have been selected, delivered to TII team, and illustrated to them in a number of dedicated meetings. The TII team will consider these events when they will focus on calibration of vertical cross track velocity component.
Swarm - Echo	[DQW8_Rec 31.] Update data format of new MAG and GAP Swarm Echo products to better match with Swarm L1b and L2 data product formats	Done	MAG data products has been improved using enhanced attitude information provided by Ch. Siemes. Results for 2018 are currently exploited. See also [DQW9_Rec 3.] [DQW9_Rec 4.]
	[DQW9_Rec 16.] e-POP related data quality status should be now reported into Swarm L1B data sessions.	**Done**	As full member of Swarm family, presentation and discussion on e-POP data quality already was done in session 1, 2 and 3 of Swarm DQW#9.
Swarm and Multi-mission Synergies	[DQW8_Rec 33.] Structure a “Magnetometer calibration expert group” and organise a workshop on “Multimission data calibration and application” (about 6 months after the SDQW#8) for identification and coordination of the multi-mission potential and corresponding formulation of needs and procedures.	**Done**	A dedicated workshop has been conducted on May 21-23, 2019 in Potsdam. A special issue is open in EPS: https://www.springeropen.com/collections/leo
	[DQW8_Rec 34.] Foster cooperation and exchange experience between ACC data processing experts from GRACE-FO & Swarm missions	**Done**	C. Siemes analysed a sample dataset from GRACE-FO and provided feedback in form of a document to the GRACE-FO team.
	[DQW9_Rec 17.] The Swarm DQW#8 Rec.34 to Rec.39 have been replaced by the new Rec i.e., [DQW9_Rec 18.] - [DQW9_Rec 23.], here below	**Done**	

Appendix I: SDQW#12 AGENDA

Day 1	Monday 10/10/2022		
		Location: Lecture Hall X	
09:00	10:45	Registration & Coffee	
10:45	11:00	Welcome	
		Session 1: Mission overview	**Chairs: Anja Stromme / Jerome Bouffard**
11:00	11:15	Swarm mission status	Anja Stromme
11:15	11:30	Swarm DISC view on Swarm and beyond	Nils Olsen*
11:30	11:40	Swarm Echo Mission status	Andrew Howarth
11:40	11:55	Flight Operations Segment Status	Giuseppe Albini
11:55	12:10	Constellation status of the Swarm mission	Francesco Petrucciani
12:10	12:40	Swarm Constellation Evolution - Discussion	
12:40	14:00	Lunch	
		Session 2: Magnetic field measurements	**Chairs: Leda Qamili / Nicola Comparetti**
14:00	14:15	Magnetic package instruments and processors	Leda Qamili
14:15	14:30	The Vector Field Magnetometer (VFM) status	Jose M. G. Merayo
14:30	14:45	Calibration of Magnetic Data Version 0602	Lars Tøffner-Clausen
14:45	15:00	Status of ASM Burst data and Impact of new dBSun correction	Louis Chauvet
15:00	15:30	Coffee break	
15:30	15:45	Time dependent simulations of ASM/VFM magnetic field disturbances	Gabrela Blaga
15:45	16:00	Status of Swarm ASM-V data	Gauthier Hulot
16:00	16:15	The Released e-POP/Swarm-Echo Level 1B Data Product and Future Plans	David Miles
16:15	16:30	The Swarm-Echo Magnetic Field Instrument calibration status	Robert Broadfoot
16:30	17:00	Discussion and Recommendations	

*remote participant

Day 2	Tuesday 11/10/2022		
		Location: Lecture Hall X	
		Session 3: Swarm FAST data assessment	**Chairs: Antonio de la Fuente**
08:30	08:45	FAST data production: PDGS status	Antonio de la Fuente/Leda Qamili
08:45	09:40	FAST data assessment and suggestions	Natalia Gomez Perez, George Balasis, Guram Kervalishvili, Patrick Alken, David Knudsen, Nils Olsen, ...
09:40	10:10	Discussion and Recommendations	
10:10	10:40	Coffee break	
		Session 4: GPSR and accelerometer	**Chairs: Christian Siemes / Elisabetta Iorfida**
10:40	10:55	Advances in Swarm accelerometers data processing	Sergiy Svitlov
10:55	11:10	Swarm accelerometer data analysis	Elisabetta Iorfida
11:10	11:25	Status of Swarm L2 orbit and thermospheric density products	Jose van der Ijssel
11:25	11:40	Usage of the new COST-G fitted signal models for Swarm precise orbit determination	Heike Peter
11:40	12:10	Discussion and Recommendations	
12:10	14:00	Lunch & VirES Demo	
		Session 5: Electric field measurements	**Chairs: Roberta Forte / Lorenzo Trenchi**
14:00	14:15	Swarm Electric Field Instrument and Processor: status and updates	Roberta Forte
14:15	14:30	Status of the Swarm Langmuir Probes	Stephan Buchert
14:30	14:45	EFI Science Update and Overview	David Knudsen
14:45	15:00	Effective ion masses in the upper ionosphere as measured by Swarm	Matthias Foerster
15:00	15:30	Coffee break	
15:30	15:45	Solar flux influence on the in-situ plasma density at topside ionosphere measured by Swarm satellites	Chao Xiong*
15:45	16:00	Simulation-regression techniques: application to Swarm spherical Langmuir probes measurements	Richard Marchand*
16:00	16:15	Thermal Ion Imager performance update	Johnathan Burchill *
16:15	16:30	Retrieval and validation of 2D horizontal ion drifts from Swarm EFI TII data	Levan Lomidze
16:30	16:45	Calibration of Swarm plasma densities using neural networks	Artem Smirnov
16:45	17:00	Discussion and Recommendations	
17:00	18:30	Poster session	

*remote participant

Day 3	**Wednesday 12/10/2022**		
		Location: Lecture Hall X	
		Session 6: Swarm-based L2 data products and services	**Chairs: Ciaran Beggan / George Balasis**
08:30	08:45	SwarmFACE: a Python Package for Field-Aligned Currents Exploration with Swarm	Adrian Blagau*
08:45	09:00	Verification of the Swarm dual-spacecraft field-aligned current and radial current estimates at low and middle latitudes	Fengjue Wang*
09:00	09:15	Difference of dBSun magnetic disturbance on Alpha and Charlie - Observation, correction and verification by geomagnetic field modeling	Nils Olsen*
09:15	09:30	Dipolar Spherical Elementary Current Systems (DSECS) toolbox for ionospheric current reconstruction at low	Heikki Vanhamäki
09:30	09:45	Updates to Swarm-based climatological models of non-polar geomagnetic daily variations	Arnaud Chulliat
09:45	10:00	An empirical model of the occurrence rate of equatorial plasma depletions	Tarique Adnan Siddiqui
10:00	10:30	Coffee break	
10:30	10:45	Physics-informed Neural Network for Platform Magnetometer Calibration	Kevin Styp-Rekowski
10:45	11:00	Status of Whistler product and example study of simultaneous detections during joint ASM burst sessions	Pierdavide Coisson
11:00	11:15	Removing Stray Reaction Wheel Magnetic Field from Swarm-Echo via Multichannel Singular Spectrum Analysis	Matthew Finley
11:15	11:30	Ground observatory data supporting Swarm DISC	Ciaran Beggan
11:30	11:45	The Time-Frequency Analysis (TFA) toolbox: a versatile processing tool for the recognition of geophysical signals in Swarm time series	George Balasis
11:45	12:00	Leveraging the Python ecosystem with SwarmX and Notebooks	Ashley Smith
12:00	**12:30**	**Discussion and Recommendations**	
12:30	**14:00**	**Lunch**	
		Location: Lecture Hall IX	
		Session 7: Multimission synergies	**Chairs: Monika Korte / Matthew Taylor**
14:00	14:15	Latest news on the NanoMagSat constellation project	Gauthier Hulot
14:15	14:30	Swarm-Cluster synergetic approach to ULF wave investigations	Constantinos Papadimitriou
14:30	14:45	MagQuest Phase 4 Update	Mike Paniccia
14:45	15:00	Thermosphere Observations from Low-Earth Orbiting Satellites (TOLEOS)	Christian Siemes
15:00	15:15	Geospace Dynamics Constellation: A Mission Overview	Amy Rager
15:15	15:30	Science Operations for the Geospace Dynamics Constellation	Amy Rager

15:30	16:00	Coffee break	
16:00	16:15	Inter-calibration and statistical validation of topside ionosphere plasma density observations made by CSES-01 mission	Alessio Pignalberi*
16:15	16:30	Comparison of Swarm and CSES measurements of the equatorial electrojet	Patrick Alken
16:30	16:45	Swarm-Aurora and AuroraX	Erik Donovan
16:45	17:00	Accessing and filtering the new and updated e-POP data products	Andrew White
17:00	17:15	Improvements to the Swarm-E Ephemeris and Attitude Products	Warren Holley
17:15	**17:45**	**Discussion and Recommendations**	

*remote participant

Dinner at Norrlands Nation at 19:00

Day 4	**Thursday 13/10/2022**		
		Location: Lecture Hall X	
		Session 8: Swarm - CSES synergies	**Chairs: Patrick Alken/Zeren Zhima/Gauthier Hulot**
08:30	08:45	CSES-01 flight operation status and data service	Jianping Huang*
08:45	09:00	CSES's data validation progress	Zeren Zhima*
09:00	09:15	Ionospheric in-situ ion parameters measurement and performance of the China Seismo-Electromagnetic Satellite-01	Dapeng Liu*
09:15	09:30	The topside ionospheric responses at middle and lower latitudes to strong geomagnetic storms	Xuemin Zhang*
09:30	09:45	CSES-01 high energy particle data and applications in space weather	Zhenxia Zhang*
09:45	10:00	Long-Term Variation of Geomagnetic Cutoff Rigidities for Energetic Protons Caused by Long-Term Variation of Geomagnetic Field	Wei Chu*
10:00	10:30	**Discussion and Recommendations**	
10:30	11:00	Coffee break	
		Session 9: Science projects and applications	**Chairs: Ilias Daras / Ewa Slominska / Alan Wood**
11:00	11:15	The Swarm VIP (Variability of Ionospheric Plasma) models: Comparison to TIE-GCM and the need for additional thermospheric observations	Alan Wood
11:15	11:30	Constraining the Ionospheric Composition Using Whistlers Detected by the Swarm Mission	Martin Jenner
11:30	11:45	Modelling the magnetospheric field local time asymmetries using data from Swarm, CHAMP and ground magnetic observatories.	Martin Fillion
11:45	12:00	A global model of the electron temperature with high resolution from the Swarm satellites data	Vladimir Truhlik

12:00	12:15	Swarm observations of Joule heating	Octav Marghitu*
12:15	12:30	Analysis of Swarm gravity field models	João Encarnação
12:30	**14:00**	**Lunch & VirES Demo**	
14:00	14:15	Characteristics of low- and mid-latitude magnetic field disturbances occurring during geomagnetic quiet conditions	Ewa Slominska
14:15	14:30	Daytime mid-latitude F2-layer Q-disturbances: A formation mechanism	Loredana Perrone
14:30	14:45	Spectral properties of sub-kilometer-scale equatorial irregularities as seen by the Swarm satellites	Sharon Aol
14:45	15:00	Detecting Anomalies from Swarm Observations Using Deep Learning Approaches	Yaxin Bi*
15:00	15:15	Monitoring of Ionospheric Gradients At Swarm (MIGRAS)	M. Mainul Hoque*
15:15	15:30	Swarm satellites for detection of pre-earthquake ionospheric anomalies	Angelo De Santis*
15:30	16:00	Coffee break	
16:00	16:15	Swarm Echo Ion Time-of-Flight and Plasma Current Data	Andrew Yau
16:15	16:30	Development of high level Swarm-E GAP data products and applications for science purposes	Chris Watson
16:30	16:45	Meso-scale neutral density observed by the Swarm satellites	Yue Deng*
16:45	17:00	VirES and VRE - 2022 Update	Martin Pačes
17:00	17:15	New challenges for upcoming Swarm scientific projects	Lorenzo Trenchi/ Ilias Daras/ Diego Fernandez
17:15	**17:45**	**Discussion and Recommendations**	

Day 5	Friday 14/10/2022		
		Location: Lecture Hall X	
		Session 10: Prospectives on Space Weather	**Chairs: Guram Kervalishvili / Eelco Doornbos**
08:30	08:45	Incorporating Swarm data in an interactive space weather timeline viewer	Eelco Doornbos
08:45	09:00	Perspectives on a Swarm-based ionospheric scintillation index	Luca Spogli
09:00	09:15	Ionospheric Plasma Irregularities - the scientific usage and validation of the IPIR product	Wojciech Miloch
09:15	09:45	Coffee break	
09:45	10:00	Results from Swarm VIP: Variability of Ionospheric Plasma, the Swarm-4DIonosphere project	Wojciech Miloch
10:00	10:15	Polar cap patches and the related magnetic signature	Yaqi Jin
10:15	10:30	Neural network model of Electron density in the Topside ionosphere (NET)	Artem Smirnov
10:30	11:30	Wrap-Up the Swarm DQW#12	ESA Organising committee
		End of the workshop	

Posters

1	Sounds from Swarm Data	Klaus Nielsen
2	More on Swarm E/ePOP MGF data set: features and usage experiences	Martin Rother
3	Gradient tensor secular variation time series inversions show rapid core flow changes in 2017	Kathy Whaler*
4	Swarm L2 Comprehensive Inversion, Year 8	Lars Toffner Clausen
5	Spectral Properties of Kilometer-scale Equatorial Irregularities as Seen by the Swarm Satellites	Stephan Buchert
6	Status of the GFZ Swarm data products	Monika Korte
7	Calibration and Characterisation of Platform Magnetometers using Analytical Method	Ingo Michaelis
8	Dual radial and field-aligned current data reprocessed by GFZ from 1 Oct 2019 to 2 May 2022	Guram Kervalishvili
9	A Bayesian perspective on Curie depth determination with satellite data	Wolfgang Szwillus
10	Activities connecting VirES/VRE, Python, and more	Ashley Smith
11	MMA_SHA_2E: a Swarm-only external magnetic field model to degree and order 3	Natalia Gómez-Pérez
12	Signatures of the global ocean circulation in geomagnetic secular variation and acceleration	Chris Finlay
13	Three-dimensional models of the mantle electrical conductivity: Combining multiple sources and observations	Jakub Velímský
14	Recent progress in mapping tidal magnetic signals with Swarm data	Alexander Grayver*
15	Using Swarm L1b to produce a daily extended magnetospheric model (MMA_SHA_2E)	Ciaran Beggan
16	Combining Swarm based satellite and airborne magnetic data to reveal the sub-ice geology of Greenland	Jorg Ebbing
17	A lithospheric magnetic field model to spherical harmonic degree 1300	Erwan Thebault
18	Improvements on the CHAOS geomagnetic field model	Clemens Kloss
19	Sequential modelling of the Earth's magnetic field and core surface flow	Vincent Lesur*
20	Comparison of cusp and tail field-aligned currents measured at mid and low altitudes, and GIC variations	Malcolm Dunlop*
21	Radiation pressure modelling for improving the thermosphere density and cross-wind data products.	Natalia Hładczuk
22	Using Machine Learning to Identify Aurora in e-POP Fast Auroral Imager Data	Andrew Howarth
23	Local mapping of polar ionospheric electrodynamics using Swarm data	Karl Laundal

24	GPS Loss of Lock and ionospheric turbulence features: Decomposing solar and geomagnetic activity, interplanetary features, and seasonal dependencies	Giulia Lovati
25	Multi-scale response of the high-latitude topside ionosphere to geospace forcing as probed by Swarm	Luca Spogli
26	Comparison of Swarm plasma density and incoherent scatter radar data at high latitudes	Sasha Koustov*
27	Correlation Between Ne and Te Around 14:00 LT in the Topside Ionosphere Observed by CSES, Swarm and CHAMP Satellites	Rui Yan*
28	Status of CSES high precision magnetometer	Yanyan Yang*
29	The lightning whistler observation by the China Seismo-Electromagnetic Satellite (CSES)	Qiao Wang*
30	Swarm-based model of mid- and low-latitude F-region ionospheric fields and currents and the impact of the Sun-driven disturbance field.	Martin Fillion
31	Outcomes from DISC project SPETTRALE	Matthias Foerster
32	PDGS full repro status	Antonio de la Fuente
33	Calibration of Swarm plasma densities using neural networks (follow-on)	Artem Smirnov