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The 11th Swarm Data Quality Workshop

Summary and Recommendations Report

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From Jerome Bouffard

Based on contributions from: Anja Stromme, Nicola Comparetti, Jan Miedzik, Enkelejda Qamili, Christian Siemes, Elisabetta Iorfida, Roberta Forte, Lorenzo Trenchi, Nils Olsen, Roger Haagmans, Ilias Daras, Kathy Whaler, Stephan Buchert, Gauthier Hulot, Zeren Zhima.

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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#11 was held as a hybrid event, hosted by the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) at the National Observatory of Athens (NOA), Greece from 11 to 15 October 2021. Due to the Covid-19 pandemic situation, the virtual attendance to the meeting was also allowed.
The event reached the participation of more than 200 people, with 68 of them joining in person and the rest from remote.

The scope of this document - based on contributions from SDQW#11 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 plasma, magnet and orbit/accelerometer data products. Besides that, the SDQW#11 offers unique opportunities to further discuss with the Swarm community on key technical challenges 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 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#11 was structured in 9 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: GPSR and accelerometer
- Session 4: Electric field measurements
- Session 5: Swarm-based L2 data products and services
- Session 6: Future missions
- Session 7: Science projects and applications (divided in two sub-sessions: A and B)
- Session 8: Swarm - CSES synergies
- Session 9: Summaries, Recommendations & Future

2 SESSION SUMMARY

2.1 Introduction

Session 1 was structured to present a general overview of the Mission, starting with the Mission status and continuing with an introductory summary of Swarm data quality, instruments, constellation status and evolution. After 8 years in orbit, the constellation is still providing excellent quality data, being able to address all the mission objectives and beyond, by tackling new scientific challenges and applications, with a continuously growing data product portfolio. The status of the Mission remains nominal on both Platforms and instruments, Ground Segment and Data Quality. Moreover, in order to extend the Mission lifetime and avoid the re-enter of the lower pair in 2024/2025, an orbit raise campaign was announced and depicted, with the ultimate goal of flying the mission through Solar Cycle #25. Concerning the processing algorithms, an improved L1B dataset was made available to the whole DQW#11 participants and officially presented with the scope of collecting feedbacks from the Swarm scientific community. In addition, a plan to develop a parallel processing chain was introduced with the objective to process and deliver Swarm data with a minimum time delay with respect to acquisition. This has been recognized to be instrumental for Space Weather application of Swarm data products. The combination of Swarm data with other data sources as CSES, Swarm Echo and several other missions providing complementary data, has been also addressed and the added value of new synergies has been highlighted and presented during this session.

2.2 Magnetic Field Measurements

Session 2 of the Swarm DQW#11 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 on-board the spacecraft, i.e., the Vector Field Magnetometer (VFM), the Absolute Scalar Magnetometer (ASM) and the Star Tracker (STR) was reported. The overall quality of Swarm L1B Magnetic field products, currently with product baseline and file counter number 0506, remains excellent.

The main evolutions introduced in the L1B operational processor (product baseline 0601) which has been deployed in operations on the reprocessing platform on 7th June 2021, were also presented. After the deployment, an L1B full mission data reprocessing has been performed and the dataset made available to the Cal/Val and SDQW#11 community with the scope of providing an enhanced test dataset prior the workshop to be further validated in preparation to the Transfer To Operations (TTO) in the operational platform, for the benefit of the whole Swarm community. Among the many improvements introduced in this new product baseline, particular attention was given to the new dB_Sun correction scheme implemented for both VFM and ASM instruments, which has been showed to significantly improve the magnetic scalar residuals and to give an overall better description of the Sun induced magnetic disturbance. Thanks to the improved estimation of the Sun-driven disturbance, a new CHAOS model version 7.8 has been derived, allowing to perform a new estimation of the Euler angles describing the rotation from STR to NEC (North-East-Centre) reference frame. As a preliminary result it has been confirmed that the Euler angles currently stored in the CCDB files and used for L1B data processing remains reasonable.

In terms of feedbacks regarding the new product baseline 0601, a comparative study of the worldwide magnetic anomalies carried out using previous Swarm release (0409) and CHAMP data was presented by INGV, suggesting that then most recent dataset from both missions could suppress tiny fluctuation ~1nT around the magnetic equator.

IPGP presented an improved experimental self-calibrated ASM-V vector mode dataset generated in collaboration with CEA-Leti. The dataset is independent from the nominal L1B data generated from VFM measures and allowed to produce a global field model with a very good agreement with analogous models computed from L1B VFM data.
IPGP-Leti also provided an overview of the ASM Burst 250 Hz science data which are regularly generated with ~1week/month cadence and will be soon distributed to a broader community.

During this session it was also reported on the Swarm Echo MGF instrument performance, data processing and quality. Three test datasets reprocessed using a Swarm-like convention has been presented and will be soon made available to the whole Swarm community.

2.3 GPSR and Accelerometer

Session 3 was focused on Swarm A, B, C accelerometer and GPS receiver instrument status and data processing, precise orbit determination, density processing and gravity field models.

The overview presentation of the accelerometer and GPS receiver clarified that angular acceleration measurements about pitch seems to have a scale factor close to one for both Swarm A and C, whereas linear scale factors deviate much more from one. During accelerometer scale factor calibration manoeuvres, an interesting observation is that linear combinations (e.g., sum) of the three linear accelerations can match the expected thrust. This raises the question if the control voltages are correctly distributed. Also, the bias jumps in between thrusts are reduced for these linear combinations. This asks for further investigation. The scientific analysis of Swarm A and C calibrated accelerometer data revealed that the measurements are sensitive to the equatorial mass anomaly. Further, the polar cap indices as well as FACs appear to be good proxies for polar gravity waves. It is recommended to investigate the cusp region as function of magnetic latitude and local time, separately for high and low solar activity. A seasonal analysis would also help to correlate FACs and calibrated accelerations. However, this would require a longer dataset for both satellites, which is not currently available. When analysing Swarm density measurement, and in the context of gas-surface interactions, NRLMSISE-00 and its successor NRLMSIS 2.0 are probably the most accurate models for atmospheric composition, in particular for Helium. Daily ratios of GPS-derived density observations and HASDM and TLE density data show scale differences of only 4% and 3%, respectively. Based on good results from Swarm A density data assimilation in the DTM model, it should be explored to which extend Swarm B orbit mean density data can improve thermosphere models. In view of the altitude dependence of the signal-to-noise ratio of the thermosphere density observations, it is suggested to adapt the smoothing correspondingly. For Swarm gravity field models, it is recommended to reprocess the months where neither GRACE nor GRACE-FO data is available. When analysing the RMS time series of the gravity field solutions, it would be interesting to compare to the local time of the ascending node. Finally, it was discovered during the DQW that the Swarm GPS receivers do not track GPS Block III satellites. Considering that there are at present only few GPS Block III satellites operational, this is not an urgent issue. However, as in the future more GPS Block III satellites will enter service, the Swarm GPS receiver will need to be patched to enable the tracking of those satellites.

2.4 Electric Field Instruments

Session 4 was dedicated to the Electric Field Instrument (EFI) status and performance. The EFI is composed of two instruments: the Thermal Ion Imager (TII) and two Langmuir Probes (LPs). It follows from SDQW presentations that both instruments are performing well.

For what concern the TII, it has been showed that the instrument performances are continuously improving. TII data processing and dissemination is performed by University of Calgary, and data are available on Swarm Dissemination Server. Nominal operations, such as scrubbing and gain map calibrations, are periodically performed in order to monitor and improve the TII imaging, together with yaw and pitch slew manoeuvres performed to calibrate the instrument. Investigations on known anomalies are ongoing, i.e. the water issue inside the dome, the occurrences of measles (red spots in the images), the peripheral anomalies (occasional halo spots that appear around the real measure).

For what concern the LPs, it has been shown that the instruments are operating nominally and delivering good quality data products.

The PLASMA product baseline 0502 (Level1BOP v03.22) is currently in operation since February 2020. The new PLASMA product baseline 0601 has been deployed on May 2021, and released to the DQW community for endorsement before the workshop.

The new baseline includes several changes respect to the one that is currently in operations. The main one is the introduction of two more parameters, Ne_error and Te_error, stored in EFIx_LP_1B and EFIxLPI_1B data, based on computation described in Lomidze et al., 2018 (https://doi.org/10.1002/2017RS006415): this study demonstrated that, comparing LP data with ISRs (Incoherent Scatter Radars) measurements at equatorial, low- and mid-latitudes, there is a systematic offset in the LP measurements of the electron density and temperature. The two newly introduced parameters include information about this offset, so that the user may choose to directly use the LP measurements or to correct them accordingly to get calibrated values.

Future improvements foreseen for the PLASMA L1B processor have also been presented, such as the renaming of the density estimate Ne into Ni, being it actually derived from the ion current, the introduction of a new Ne product which shall be estimated from the electron current, and the renaming of the calibration offset Ni_error, Ne_error, and Te_error (which may be misleading) into dNi_cal, dNe_cal, and dTe_cal.

During this session, several insights related to EFI instruments and data have been presented.

Most recent scientific publications were presented, such as the paper "Swarm Langmuir Probes' data quality and future improvements" (F. Catapano et al., 2021), describing a detailed analysis of LP products recent improvements and data quality, has been accepted for publication.

A new machine learning approach was presented, that is able to reproduce one LP parameter, using as input the others. The method aims at checking the accuracy of the model. It showed a quite good correlation, but further tests will be performed.

The SPETTRALE (Spike-trains in electron temperature measured from Swarm Langmuir probes) project has been presented. This project consists in analysing artificial Te spikes observed in LP data, performing a detailed investigation solar panel orientation with respect to the sun and HK data, and it aims at developing a new quality flag to identify these artificial Te spikes.

Several talks were focused on the most recent science updates regarding EFI data, in particular based on the comparison of LP data with ISRs measurements. Results showed a good agreement not only for Ni data but also for Ti data.

Moreover, a global survey on the electron temperature in the topside ionosphere from Swarm LP measurements, compared with ISRs data, showed that the Lomidze method correction applied on Te data is more effective at mid-latitude, suggesting that an inclusion of high latitude ISR data for Lomidze method could be advisable.

Another Cross-calibration analysis on Ni measures at LP, compared with Ne measured at ISRs and with FP, suggested a trend of the ratio on solar activity level, which open a new subject of studies.

Several talks showed that ion density measurements from FP are scientifically relevant.

It has been presented a comparison of Ni data, measured at 2 Hz rate by the LPs and at 16 Hz rate through the TII Face Plate (FP). The analysis showed a good correlation, meaning that both instruments are performing good. While the comparison between Ni and Ne measurements showed a disagreement, possibly due to instrumental issue, which suggested that more cross calibration is needed.

The outcome of these talks was the advice to plan a good strategy for the FP science acquisition in alternation to TII scientific mode. A discussion about this alternation has been opened during the workshop.

Finally, the ongoing preliminary analysis for the development of a fast-processing chain for Swarm products has been presented and discussed, obtaining a strong encouragement by the scientific community.

2.5 Swarm-based L2 data products and services

Session 5 introduced the recent advances in the areas of applications of Swarm Level 2 data products.

This session included 11 oral presentations and 25 posters. Despite the session title, most contributions use a combination of data from and other data sources, to take maximum advantage of all available data.

The topic of the session covered various aspects: The presentations by Erwan Thebault and Alexander Grayver concern the lithospheric magnetic field and mantle conductivity; Payrick Alken and Arnaud Chulliat reported on large-scale ionospheric currents (Sq and Equatorial Electrojet; and the contributions by Louis Chauvet, George Balasis, Yaqi Jin, Ivan Pakhotin and Lucas Schreiter cover small-scale ionospheric/magnetospheric currents and plasma irregularities. In addition, there have been presentations by Kevin Styp-Rekowski on "platform magnetometer calibration" and by Martin Pačes on "ViRES for Swarm".
Most of the 25 posters concern on "higher level data products", e.g., on core field modelling and secular variation, and various aspects of Swarm data processing and visualization.

2.6 Future missions

This session took place on Wednesday afternoon and was chaired by Roger Haagmans and Ilias Daras and consisted of 6 presentations which can be summarized as:

1. Daedalus: a proposed mission for the in-situ exploration of the lower thermosphere-ionosphere. Status update and results from the Daedalus Mission Simulator by Theodoros Sarris. Daedulus awaits ESA's recommendation on the way forward with international participation. Maybe an overlap with Swarm (B) can be exploited.

2. Inferring ionospheric vertical profiles from Daedalus-like measurements and complementarity with Swarm by Octav Marghitu. Daedalus provides height integrated Joule heating profiles, which can be compared to height resolved ones. The Daedalus profiles can be used to constrain/calibrate Swarm estimates whilst Swarm can be used for upper continuation.

3. Progress of CSES-02 development and the concept proposal of CSES-03 constellation by Zeren Zhima. CSES-02, in preparation, aims at a launch November 2022 with orbit complementary to CSES01 and MACAU-01. CSES-03 will complement the constellation to increase resolution and precision. Early studies are ongoing.

4. MagQuest Phase 4: Tech Demos on Three Cubesats by Mike Paniccia. MagQuest Phase 4b (2024-2025) - demonstration phase, with an independent performance assessment by NASA Goddard Space Flight Center. MagQuest Phase 4c (~2026-2027) - Launch of all cubesats with launch readiness assessed by NOAA on data quality. Beyond: A potential 20 year procurement for

magnetic data. TBD if the data will be freely available to the public, though NGA hopes that will be the case.

5. Latest news about the NanoMagsat project by Gauthier Hulot. A short overview of the mission idea was provided. The intention is to submit NanoMagsat to ESA's next scout call in 2022 (TBC).

6. MacauSat Status by Keke Zhang. A staggered approach is proposed for 4 consecutive launches. The first two satellites are launched in a staggered approach in low-inclined orbit (app. 40 degrees). The next two satellites will be launched in a staggered approach in near-polar elliptic orbits (200-5000km). Objectives are aligned with Swarm and there is a potential to offer complementary low-inclined data with faster local time sampling.

2.7 Science projects and applications

Session 7 was an opportunity to update the Swarm community with the present status of science projects and applications of Swarm products.

Part I: Several talks were given on a variety of investigations using magnetic and Langmuir probe data. The first presented evidence for short period waves in the Earth's core; the second used principal component analysis to separate magnetic sources in Geomagnetic Virtual Observatory time series; the third considered polar ionosphere currents when undertaking geomagnetic field modelling; the next three were concerned with field-aligned currents (FACs), two in conjunction with Joule heating, the third with geomagnetically-induced currents. After the break, we heard about monitoring the dynamic plasmapause; two studies of the equatorial electrojet; ionospheric plasma variability; and finally, the relationship between the ionosphere and loss-of-lock for GNSS satellites. New ionospheric and plasmapause indices were introduced. Many of the presentations showcased results from ESA-funded projects. Many different approaches were taken to probe similar physics, often taking advantage of complementary datasets (especially from other satellite missions). The studies show that separation of sources of magnetic fields is improving, based partly on the long time series available from Swarm, and partly on new and improved methods. New results derive from the good coverage Swarm provides, e.g., the spatial and local time coverage, and conjunctions.

A number of the projects presented 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. 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.

Part II: Presentations from a broad range of subjects were given. These included i) activity proxies/indices; ii) energetic particles/violent events; iii) small- and large-scale structures/ dynamics.

Numerous data sets from both Swarm (especially Swarm E), other missions (Cluster, MMS) and ground-based magnetometer data, lightning networks etc. had been used to obtain the presented results. Suggestions included to think in "science of systems" (geospace, atmosphere-ionosphere-space) and to make use of a range of different available data sets and models in order to understand the solar cycle in the heliosphere and its influence on power grids, navigation and positioning systems etc. It was suggested to hold a "Swarms ideas workshop" and to continue discussions offline.

2.8 Swarm - CSES synergies

Session 8 was an overview of Swarm - CSES synergies.

This session helps us to exchange about the recent progress of CSES payload and efforts CSES/ Swarm team made on CSES data Val/cal.

A first presentation is given by Zhima Zeren and Chinese colleagues (National Institute of Natural Hazards, Ministry of Emergency Management of China, NINH MEMC) to introduce Cross-calibration on the electromagnetic field detection payloads onboard the CSES. It was pointed out that, due to the different hardware and software implementations of SCM and EFD, there is unavoidably a systemic sampling time difference. The cross-calibration shows that the sampling time difference between EFD and SCM is very regular and can be diminished by the linear phase method. Therefore, the corresponding synchronization tool is developed to align the timestamps of EFD and SCM's waveform data. Besides the sampling time difference, the stable periodic time deviation due to EFD's work mode switching (every 240s) can be eliminated. In the ULF band, FGM and SCM show good consistency according to their responses to the MT. In the ELF/VLF range, the SCM and EFD generally perform well; they can simultaneously respond to the ELF/VLF wave activities in an extensive L shell range.

The second presentation is from Yanyan Yang (NINH MEMC) and CSES/Swarm magnetometer team. An improvement for in-flight FGM calibration is carried out, the result shows that: (1) Now, the model parameters only need to update every 5 days; (2) There is a clear seasonal trend in residual. The investigation shows that further sensor temperature correction on the sensitivity matrix seems more reasonable. (3) The result shows that, after further temperature correction, 99% of residuals can be within 1nT. The in-flight calibration of HPM is still going.

The third presentation, by Rui Yan (NINH MEMC), presented the regular features recorded by the Langmuir probe of CSES. They found that: Sudden drop structure (SD) occurs at the terminator transition zone from 40° N to 65°N and the spike feature (SP) appears when the probe is shaded by the electric field detector boom installed in the windward panel. These two regular features are attributed to the satellite-current system adjustment to the solar illumination conditions.

The fourth presentation, by Yaxin Bi (Artificial Intelligence Research Centre at School of Computing Ulster University, UK), presents predicting Swarm observations and detecting anomalies in observations using deep learning approaches. In this work, he developed an effective method for predicting the Swarm data efficiently with the application of DL techniques, investigated the period of time for predicting the Swarm data, studied the data framing impact on predicting the Swarm data, and finally applied machine learning techniques to detect anomalies from the predicted results based on Swarm data.

The fifth presentation comes from Marchetti Dedalo (Jilin University, China), who introduces a comparison of Swarm and CSES to study ionospheric disturbances before or during the occurrence of medium/large earthquakes. He first makes a comparison of the magnetic and electron density data of Swarm and CSES and points out higher data availability by multi-mission means to have more chance to detect transient phenomena such the supposed seismo-induced ionospheric disturbances. By joint investigations of electron density latitudinal profiles of Swarm and CSES on several occasions, they identified night-time increases possibly due to the preparation of M7+ earthquakes that occurred after about one month.

The sixth presentation, by Xiachgeng Gou (NSSC) and her Chinese colleagues, introduces ionospheric Pc1 waves during a storm recovery phase observed by CSES and Swarm. In this work, both CSES and Swarm observed ionospheric Pc1 waves near the wave injection regions in conjugate hemispheres during the recovery phase of the geomagnetic storm on 27 August 2018. Further investigation suggests that the possible sources of Pc1s are EMIC waves generated near the plasmapause by the outward expansion of the plasmasphere into the ring current during the recovery phase of geomagnetic storms.

The last presentation is given by Qiao Wang (NINH MEMC). He introduces the effects on lightning whistlers analysis due to discontinuities in SCM waveform data. Two kinds of interferences from the satellite platform were confirmed: impulses due to the CSES satellite's magnetometers working near the geomagnetic equator and ~27.5 Hz and its integral or/and non-integral multiplications, which is owing to the satellite's magnetic wheels working (~1680 circle/min) in the process of satellite attitude controlling. Then, they conduct the classification of whistler morphology and pointed out that some modelling work is needed for the interpretation. Finally, the effect of discontinuity of SCM waveform in the extraction of whistler characteristics can be suppressed by the robust method.

To summarize, this session mainly shows the very recent progress we made on CSES data calibration and validation. There are also some scientific studies carried out by using CSES and Swarm.

3 Recommendations

TOPICS	RECOMMENDATIONS	STATUS	MAIN UPDATES AT DQW#11
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 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 for further validation. Soon such dataset will be made available to all the Swarm community.
	[DQW8_Rec 4.] Produce a new Swarm STR L1B "particle flux" product	**Ongoing**	Action on DTU-MI. A paper containing the description of the "Particle flux" product is currently under preparation. As soon as it is finished with be shared with ESA.
	[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.
	[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.

	[DQW10_Rec1.] IPGP to validate the dB_Sun_ASM correction model proposed by DTU	Ongoing	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 M. Fillion at DQW11). Conclusion was that the proposed correction still had issues. Note that this did not address specifically the dB_Sun_ASM correction (but the combined VFM and ASM dB_Sun correction).
	[DQW10_Rec2.] DTU to consolidate the new dB_Sun correction model and transfer it into operations.	Ongoing	Updated model to be provided by Lars Tøffner-Clausen.
	[DQW11_Rec1.] Transfer To Operations the new L1b product baseline	**Open**	
	[DQW11_Rec2.] Release Swarm-Echo MGF dataset to the whole Swarm community	**Open**	
	[DQW11_Rec3.] IPGP to generate and distribute ASM-V data version 06	**Open**	This will be done as soon as the final dB_Sun correction for the next L1b data MAGx_LR version 06XX is known and available, for consistency with ASM-V data version 06. For the time being, ASM_V are still being produced as version 05XX, consistent with L1b data MAGx_LR version 05XX
	[DQW11_Rec4.] IPGP to process and release future burst data version 0301	**Open**	Change to version 0301 will be done as soon as the final dB_Sun correction for the next L1b data MAGx_LR and MAGx_HR version 06XX is known and available, for consistency. For the time being, ASM Burst mode data are still being produced as version 0201, consistent with L1b data MAGx_LR and MAGx_LR version 05XX.
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. The EFI engineering qualification model (EQM) has been shipped to Calgary, it is in currently in Calgary and it is possible to program it for testing new software. No progress on the revision of the onboard software to implement the TII higher-rate imagery, as the software changes will be substantial, and the priority remains the TII lab test.
	[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 collect data during conjunctions with Swarm that would allow cross-calibration of cross track plasma velocity between the two spacecraft.	Done	e-POP IRM data will be reprocessed and delivered to the EFI community for joint Cal/Val activities. A 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 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 way to have better results is to compare the EFIx_LP_1B data with the Faceplate (FP) dataset. This suggestion has been passed to the user with a note on the data quality page. Further investigations are on-going. At DQW#11 SB presented results of the comparison between Ni estimated with LP and with FP and they show a quite good correlation. But a comparison between Ni and Ne shows a disagreement, probably due to instrumental issues. Further investigation on cross-calibration is needed.
	[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.
	[DQW10_Rec3.] To include the TIICT dataset in the ViRes platform	Open	To contact the ViRes Team and check the info that they need in order to include the TIICT dataset in the ViRes platform.
	[DQW10_Rec4.] To analyse the data as outcome of the LP bias setting tests (See [DQW8_Rec9].)	Open	The dataset is currently stored in the IRFU server. Action on IRF to perform that analysis.
	[DQW11_Rec5.] Define a new quality flag for artificial Te spikes observed in LP data	Open	the LP electron current suffers from "spike trains" affecting the estimates of Te and Vs. Issue analyzed within the SPETTRALE (Spike-trains in electron temperature measured from Swarm Langmuir probes) project. Preliminary results show a possible correlation with specific orientation of solar panels with respect to the sun elevation angle. A detailed investigation on HK data from solar panels is ongoing.The aim of this project is to define a new algorithm to define a new quality flag for these artificial Te spikes.
	[DQW11_Rec6.] Open discussion on how to operate between TII science acquisition vs Faceplate science acquisition	Open	the LP 16 Hz ion density estimates are only reliable if the faceplate bias < -2.5 V, while for the TII in active or ready states a bias ≥ - 1 V gives best results. An EFI science meeting should be held to discuss how the setting of the faceplate bias could be scheduled for overall the best science output. An EFI science meeting should be held to discuss how the setting of the faceplate bias could be scheduled for overall the best science output. Discussion started during EFI Science Discussion Group meetings. The focus of the discussion is the planning of FP mode in SwC during the constellation configuration (temporarily conjunction of SwA and SwC), 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.
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 13.] Improve the flagging and daily quality index of the ACCxCAL data products.	**Ongoing**	Some improvements were implemented after the discussions at DQW#8. However, this should be considered a standing recommendation.
		[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.
GPS and ACC		[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.
		[DQW10_Rec6.] Investigate dependency of density observations on errors in the concentration of Helium in thermosphere models.	**Ongoing**	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).
	A/B/C GPS	[DQW8_Rec 15.] Exploit integer ambiguity fixing when determining the non-gravitational acceleration from GPS receiver data.	**Ongoing**	Reprocessing of orbit in progress
		[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.	**Ongoing**	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	**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

		density observations product, to be distributed also in near real-time.		need to be made available in near real-time. A near real-time mass density product needs to be developed.
	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 performing precise orbit determination for Swarm E.	**Done**	Work completed by O. Montenbruck, A. Hauschild, and R. Langley. Submitted a paper recently to GPS Solutions.
		[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 24.] Develop new data processing/ modelling approaches using Swarm data to get better	**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"

	mantle conductivity models and understanding of core dynamics on sub-decadal timescale.		was opened. This recommendation was extended into DQW9_Rec 12.
	[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.
	[DQW10_Rec9.] Investigate annual signals in GVO series	Open	
	[DQW10_Rec10.] Explore more realistic prior information for external fields, to be used in field modelling for example in the MCM model of Lesur and co-workers	Open	
	[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	
	[DQW10_Rec12.] Clarify difference between ground and satellite Q-matrix in induction studies for mantle conductivity	Open	
	[DQW10_Rec13.] Continue efforts to calibrate platform magnetometers, using housekeeping data, if possible (e.g., GRACE), to aid induction studies	Open	
	[DQW10_Rec14.] VRE-based dashboards for exploring ground observatory data and magnetic field models	Open	
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.
	[DQW8_Rec 28.] Develop a well-documented toolbox to facilitate wider usage of innovative methods for Swarm-based FAC determinations.	Ongoing	Python jupyter notebook version swarmpyfac of Swarm L2 FAC single processor developed by DISC. Available on github (https://github.com/Swarm-DISC/SwarmPyFAC) and on Swarm VRE Another Python package for FAC calculation is under development by ISS, in the context of SIFACIT project. The first toolbox for computing the FAC with three s/c method is completed, and the team is now working on

			the second package to automatically identify the conjunctions at auroral latitude among the three s/c.
	[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	
Space physics and weather applications	[DQW9_Rec 13.] Further analyse and investigate LP based Te and Ne features potentially impacted by instrumental issues.	Ongoing	Discussed in DQW#9 session7. But this recommendation is more related to the E-field instrument (i.e. DQW#9 session 3). Status at DQW#11: see [DQW9_Rec7.] and **[DQW11_Rec6.]**
	[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.
	[DQW10_Rec16.] Investigate the potential of Swarm for Space Weather research and application	Open	
	[DQW10_Rec17.] Evaluate the potential of fast access of Swarm data with respect to reduced processing time and/or more frequent download	Ongoing	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 L1B 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"	Open	
	[DQW11_Rec10.] Process and distribute "Fast-track" L2 data (where it makes sense)	Open	
	[DQW11_Rec11.] Identify new "Space-weather–related" higher level data products	Open	
	[DQW11_Rec12.] More long-term: Investigate possibility of more frequent data downlink ideally using stations in N and S 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	Open	Suggestions to think in "science of systems" (geospace, atmosphere-ionosphere-space) and to make use of a range of different available data sets and models in order to understand the solar cycle in the heliosphere

	models to understand the solar cycle		and its influence on power grids, navigation and positioning systems etc.
Swarm - CSES Synergies	[DQW8_Rec 29.] Foster collaboration between CSES and Swarm experts' team for cross-calibration and validation activities.	**Ongoing**	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.
	[DQW8_Rec 30.] Make available appropriate level of CSES data to Swarm experts for starting such activities to as soon as possible.	**Ongoing**	Two sides initially shared specific level data according to specific calibration tasks and scientific interests for Swarm-CSES synergies. Efforts have recently (after SQW#10) resumed and is ongoing to ensure transfer of all CSES HPM Level-2 data files currently available to an ESA ftp site easily accessible to the ESA partners.
	[DQW9_Rec 15.] Organise a joint CSES-Swarm Data Quality or Science workshop	**Ongoing**	As stated above, several sessions have been organized, and an ISSI-BJ science team set-up. 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 cross-visits for spending significant joint working time in same location, for allowing quick exchange of practical (hence critical) information.	**Open**	
	[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 auxiliary 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.	**Ongoing**	Some CSES data available at ESA CSES ftp site (restricted access), as original H5 data files and reformatted to "Swarm-like" daily CDF files.
	[DQW10_Rec20.] CSES data: Produce and provide high-latitude	**Open**	

	(above 65° latitudes) HPM scalar data (at least).		
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	**Ongoing**	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.
	[DQW11_Rec14.] Release Swarm-Echo MGF dataset to the whole Swarm community	**Ongoing**	
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.
	[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) currently developed in DISC TIRO. New DISC call open for generation of thermospheric data of GRACE or similar missions. GOCE TEC data is openly published 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 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**	
	[DQW9_Rec 19.] Prepare and provide calibrated data of (platform) satellite magnetometers in support for Swarm. These data may include	**Ongoing**	Fully calibrated Cryosat-2 magnetic data for August 2010 to December 2018 available as daily CDF files at Swarm PDGS (ftp://swarm-diss.eo.esa.int/%23CryoSat-2)

	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.		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 "Multimission 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
	[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
	[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	
	[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	
	[DQW#10_Rec22.] Express strong support for exciting contribution Daedalus mission can make to lithospheric studies	Open	
Swarm SPACE4.0I, Data Visualization and Analysis	[DQW8_Rec 36.] Provide lessons learned from the Swarm community to the Daedalus MAG	Ongoing	
	[DQW8_Rec 37.] Investigate whether the science objectives of Daedalus could be broadened to Swarm areas of science	Ongoing	
	[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	Ongoing	Initial version of Swarm VRE will be open at Swarm QWG #9
	[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 working in close collaboration with ESA EO web team on the design and content of the new ESA EO website (will be updated for all missions). The launch of the new website occurred in April 2020. However, many other changes/updates will be introduced later in time, as already agreed with the ESA EO team.
Future Missions	**[DQW11_Rec15.] 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, B & C or Swarm B
	[DQW11_Rec16.] 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_Rec17.] 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_Rec18.] Ensure that data from complementary missions are open and free	**Open**	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_Rec19.] Explore the possibility for a workshop to align existing and future missions	**Open**	
	[DQW11_Rec20.] Swarm and beyond: Swarm is the backbone of "Geomagnetism and Geospace Satellite Fleet" … … synergy with other existing and future satellite missions	**Open**	
	[DQW11_Rec21.] 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_Rec22.] Create a series of "Swarms ideas workshop"	**Open**	A number of projects presented during SDQW#11 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.

Appendix I: SDQW#11 AGENDA

		Swarm 11th DQW Agenda	
		11 - 15 October 2021, Athens, Greece	
Day 1	**Monday 11/10/2021**		
All the talks and events are scheduled in Greek Local Time (CEST+1hour)			
09:00	10:45	**Registration**	
10:45	11:00	**Welcome by** **Professor Athanasios Kyriazis, Secretary General for Research and Innovation** **Dr. Spyros Basilakos, Director of IAASARS & Vice President of the National Observatory of Athens** **Dr. George Balasis, Local Organising Committee**	
		Session 1: Mission overview	**Chairs:Anja Stromme & Jerome Bouffard**
11:00	11:15	Swarm mission status	Anja Stromme
11:15	11:30	Swarm and beyond - exploring Earth's magnetic field from Space using ESA's satellite trio and a fleet of other satellites	Nils Olsen
11:30	11:45	Flight Operations Segment Status	Ignacio Clerigo
11:45	12:00	Constellation status of the Swarm mission	Detlef Sieg
12:00	12:15	Swarm-E Operations Status and New Data Products	Andrew Howarth*
12:15	**12:45**	**Swarm Constellation Evolution - Discussion**	
12:45	**14:30**	**Lunch**	
		Session 2: Magnetic field measurements	**Chairs: Nicola Comparetti / Jan Miedzik**
14:30	14:45	Magnetic package instruments and processors	Nicola Comparetti
14:45	15:00	New correction scheme for dB_Sun in Level 1b	Lars Tøffner-Clausen
15:00	15:15	Investigations of Swarm Euler Angles Using the CHAOS field model	Chris Finlay
15:15	15:30	A tiny -almost imperceptible- error in satellite magnetic field at magnetic equator? Real or artifact?	Angelo De Santis*
15:30	16:00	Coffee break	
16:00	16:15	Swarm ASM Burst mode L1b data	Pierre Vigneron*
16:15	16:30	On the improved experimental ASM vector mode data	Gauthier Hulot
16:30	16:45	The New Swarm-Echo Magnetic Field Data Product	David Miles
16:45	17:00	In-situ calibration of the Magnetic Field Instrument on Swarm-Echo	Robert Broadfoot*
17:00	**17:30**	**Discussion and Recommendations**	
17:30	**19:00**	**Ice Breaker**	
*remote participant			

Day 2	**Tuesday 12/10/2021**		
All the talks and events are scheduled in Greek Local Time (CEST+1hour)			
		Session 3: GPSR and accelerometer	**Chair: Christian Siemes / Elisabetta Iorfida**
09:00	09:15	GPS and Accelerometer instruments and processors	Christian Siemes*
09:15	09:30	Advances in Swarm accelerometers data processing	Sergiy Svitlov
09:30	09:45	Analysis of Swarm A & C accelerometers' data - do we see signal or noise?	Elisabetta Iorfida
09:45	10:15	Coffee break	
10:15	10:30	Swarm total mass densities compared with models: how to interpret the results?	Sean Bruinsma*
10:30	10:45	Swarm precise orbit and density products	Jose van den Ijssel*
10:45	11:00	Combined gravity field models from Swarm GPS data	Joao Encarnacao*
11:00	**11:30**	**Discussion and Recommendations**	
11:30	**14:00**	**Lunch**	
		Session 4: Electric field measurements	**Chairs: Roberta Forte / Lorenzo Trenchi**
14:00	14:15	Electric field instrument and processors	Roberta Forte
14:15	14:30	The Swarm LPs, status and results	Stephan Buchert
14:30	14:45	Spike-trains in electron temperature measured from Swarm Langmuir probes (SPETTRALE project)	Matthias Foerster
14:45	15:00	Revalidation of plasma density measured by the Swarm Langmuir probe	Chao Xiong*
15:00	15:30	Coffee break	
15:30	15:45	Swarm EFI Science Update	David Knudsen*
15:45	16:00	A global survey on the electron temperature in the topside ionosphere through in-situ Swarm satellites observations and comparison with the International Reference Ionosphere model and Incoherent Scatter Radars data	Alessio Pignalberi*
16:00	16:15	Inference of Swarm Langmuir probe measurements with machine learning techniques	Akinola Olowookere*
16:15	16:30	Swarm EFI TII instrument status and data quality	Johnathan Burchill*
16:30	**17:00**	**Discussion and Recommendations**	
17:00	**18:15**	**Poster session 1**	
*remote participant			
18:30/19:30 2 groups		**Visit to National Observatory of Athens (NOA)**	

Day 3	**Wednesday 13/10/2021**		
All the talks and events are scheduled in Greek Local Time (CEST+1hour)			
		Session 5: Swarm-based L2 data products and services	**Chair: Nils Olsen**
09:00	09:15	A Spherical Harmonic model of Earth's lithospheric magnetic field up to degree 1050	Erwan Thebault
09:15	09:30	A new approach of estimating electromagnetic induction transfer functions from satellite and ground data	Alexander Grayver
09:30	09:45	Updates to the equatorial electrojet and electric field product	Patrick Alken*
09:45	10:00	Swarm Whistler L2 data	Louis Chauvet
10:00	10:15	Extended climatological model of non-polar geomagnetic daily variations	Arnaud Chulliat
10:15	10:30	Swarm ULF wave indices using Convolutional Neural Networks	George Balasis
10:30	11:00	Coffee break	
11:00	11:15	Validating electron density fluctuations at mid and low latitudes using GPS TEC data	Yaqi Jin*
11:15	11:30	The Swarm Langmuir Probe Ion Drift and Effective Mass: Validation Status	Ivan Pakhotin*
11:30	11:45	Calibration of GRACE-FO and GOCE platform magnetometers using machine learning	Kevin Styp-Rekowski
11:45	12:00	Topside Ionosphere Radio Observations (TIRO) from CHAMP, GRACE and GRACE-FO	Lucas Schreiter
12:00	12:15	VirES for Swarm - evolution of the VirES and VRE services	Martin Pačes
12:15	**12:45**	**Discussion and Recommendations**	
12:45	**14:00**	**Lunch**	
		Session 6: Future missions	**Chair: Roger Haagmans**
14:00	14:15	Daedalus: a proposed mission for the in-situ exploration of the lower thermosphere-ionosphere. Status update and results from the Daedalus Mission Simulator.	Theodoros Sarris
14:15	14:30	Inferring ionospheric vertical profiles from Daedalus-like measurements and complementarity with Swarm	Octav Marghitu*
14:30	14:45	Progress of CSES-02 development and the concept proposal of CSES-03 constellation	Xuhui Shen*
14:45	15:00	MagQuest Phase 4: Tech Demos on Three Cubesats	Mike Paniccia*
15:00	15:15	Latest news about the NanoMagsat project	Gauthier Hulot
15:15	15:30	A high-precision and highly-elliptical-orbit geomagnetic constellation	Keke Zhang*
15:30	**16:00**	**Discussion and Recommendations**	
16:00	16:30	Coffee break	
16:30	**18:00**	**Poster session 2 + VirES DEMO**	
Dinner			
*remote participant			

Day 4	Thursday 14/10/2021		
All the talks and events are scheduled in Greek Local Time (CEST+1hour)			
		Session 7: Science projects and applications **Sub-session A**	**Chair: Kathy Whaler**
09:00	09:15	Satellite magnetic data reveal interannual modes in Earth's core	Nicolas Gillet*
09:15	09:30	Separating signals in Geomagnetic Virtual Observatory time series using Principle Component Analysis	Will Brown*
09:30	09:45	Geomagnetic field modelling and polar ionospheric currents	Clemens Kloss
09:45	10:00	Overview of SIFACIT results	Octav Marghitu*
10:00	10:15	Dissipation of field-aligned currents via Joule heating in the topside ionosphere at high latitudes	Fabio Giannattasio*
10:15	10:30	Comparison of field-aligned currents and GIC variations	Malcolm Dunlop
10:30	11:00	Coffee break	
11:00	11:15	Monitoring the dynamic plasmasphere at low-Earth orbit	Balázs Heilig
11:15	11:30	Understanding the daily to monthly equatorial electrojet variability	Gabriel Brando Soares*
11:30	11:45	Comparison of Swarm equatorial electrojet with ICON/MIGHTI thermospheric winds	Yosuke Yamazaki
11:45	12:00	Swarm-VIP project - developing a global model for ionospheric plasma variability based on Swarm data	Wojciech Miloch*
12:00	12:15	Occurrence of GPS Loss of Lock Based on a Swarm Half-Solar Cycle Dataset and Its Relation to the Background Ionosphere	Michael Pezzopane*
12:15	**12:45**	**Sub-session A: Discussion and Recommendations**	
12:45	**14:00**	**Lunch**	
		Session 7: Sub-session B	**Chair: Stephan Buchert**
14:00	14:15	ROTEI: a new ionospheric index to investigate electron temperature small-scale variations in the topside ionosphere	Alessio Pignalberi*
14:15	14:30	Swarm-derived indices of geomagnetic activity	Constantinos Papadimitriou
14:30	14:45	The use of IPIR L2 data product in global studies of ionospheric plasma	Wojciech Miloch*
14:45	15:00	Global distribution of TLE (Transient Luminous Events) derived from Swarm data	Ewa Slominska
15:00	15:15	Characteristics of Whistlers in the ELF as observed during ASM burst sessions	Pierdavide Coïsson
15:15	15:30	Mapping High Energy Particle Population in Earth's Magnetosphere using Swarm and MMS	Christina Toldbo
15:30	16:00	Coffee break	
16:00	16:15	Small-scale (sub-kilometer) plasma density structures using high-cadence Swarm-E plasma current data	Andrew Yau*
16:15	16:30	Swarm-E Time of Flight Analysis of Ion Upflow and Downflow Velocities	Victoria Foss*
16:30	16:45	Swarm-E GAP data for observing ionospheric electron content and multi-scale plasma structures	Chris Watson*
16:45	17:00	Effects of Atmospheric and Spacecraft-generated Photoelectrons on Spacecraft Charging in Topside Ionosphere	Andrew Yau*
17:00	17:15	Investigating the impact of the new data calibration on F-region current density estimates	Martin Fillion
17:15	**17:45**	**Sub-session B: Discussion and Recommendations**	
*remote participant			

Day 5	**Friday 15/10/2021**		
All the talks and events are scheduled in Greek Local Time (CEST+1hour)			
		Session 8: Swarm - CSES synergies	**Chair: Gauthier Hulot/ Zeren Zhima**
09:00	09:15	Cross-calibration on the electromagnetic field detection payloads onboard CSES.	Zeren Zhima*
09:15	09:30	In-flight calibration of CSES HPM data	Yanyan Yang*
09:30	09:45	The regular interferences recorded by Langmuir probe on-board low Earth polar orbit satellite CSES	Rui Yan*
09:45	10:00	Predicting Swarm Observations and Detecting Anomalies within the Observations by Deep Learning Approaches	Yaxin Bi
10:00	10:15	Comparison of Swarm and CSES to study ionospheric disturbances before or during the occurrence of medium / large earthquakes	Dedalo Marchetti*
10:15	10:30	Ionospheric Pc1 waves during a storm recovery phase observed by the China Seismo-Electromagnetic Satellite	Xiaochen Gou*
10:30	10:45	The effects on lightning whistlers analysis due to discontinuities in SCM waveform data	Qiao Wang*
10:45	**11:00**	**Discussion and Recommendations**	
11:00	11:30	Coffee break	
		Session 9: Summaries , Recommendations & Future	**Chair: Jerome Bouffard**
11:30	11:40	Summary & Recommendation session 2	Nicola Comparetti / Jan Miedzik
11:40	11:50	Summary & Recommendations session 3	Christian Siemes/Elisabetta Iorfida
11:50	12:00	Summary & Recommendations session 4	Roberta Forte / Lorenzo Trenchi
12:00	12:10	Summary & Recommendations session 5	Nils Olsen
12:10	12:20	Summary & Recommendations session 6	Roger Haagmans
12:20	12:30	Summary & Recommendations session 7	Kathy Whaler / Stephan Buchert
12:30	12:40	Summary & Recommendations session 8	Gauthier Hulot/ Zeren Zhima
		Open discussion	
DQW #11 Closure			
Lunch			
		NanoMagSat Meeting	**Organized by IPGP**
14:00	16:00	NanoMagSat Consortium presentations	**Chair: Gauthier Hulot**
16:00	16:30	Coffee break	
16:30	18:30	**Open discussion** **to be potentially continued on Saturday morning**	
*remote participant			

Posters

1	Swarm PDGS Status & Evolution	Antonio de la Fuente
2	Swarm data products delivered by GFZ to the ESA's Payload Data Ground Segment (PDGS)	Guram Kervalishvili
3	Core surface flow changes associated with the 2016 Pacific jerk deduced from GVO secular variation gradients	Kathy Whaler
4	Swarm L2: Comprehensive Inversion using 7½ years of Swarm Data	Lars Tøffner-Clausen
5	Sequential modelling of the core magnetic field and associated flow	Vincent Lesur*
6	Secular Variation Signals in Magnetic Field Gradient Tensor Elements derived from Swarm-based Geomagnetic Virtual Observatories	Magnus Danel Hammer
7	Observatory quality magnetic data from ground and space	Eija Tanskanen*
8	Estimating the properties of the magnetic lithosphere from satellite and aeromagnetic data	Jörg Ebbing*
9	Inversion of the satellite-observed tidal magnetic fields in terms of three-dimensional upper-mantle electrical conductivity	Jakub Velímský
10	Direct Sequential Simulation for spherical linear inverse problems	Mikkel Otzen
11	Comparison of SWARM and GRACE time-variable gravity field at low degree spherical harmonics	Hugo Lecomte
12	Equatorial Spread F-related electromagnetic energy flux	Juan Rodriguez-Zuluaga
13	Dynamical complexity in Swarm time series using entropy analysis	George Balasis
14	The effective ion mass estimated from Swarm Langmuir probe and faceplate data (SLIDEM project)	Matthias Foerster
15	Different typical disturbances in Swarm LP and POD data detected by spectral analysis.	Wojciech Jarmołowski
16	Quality Assessment and Features of the ePOP MGF 1 Hz Swarm L1b CDF lookalike product	Martin Rother*
17	VirES and beyond: Data visualisation and a Python ecosystem for Swarm	Ashley Smith*
18	Electron temperature across equatorial plasma density depletions	Juan Rodriguez-Zuluaga
19	Time dependent Comsol simulations of the ASM/VFM magnetic field disturbance	Gabriela Blaga*
20	Comparative Anomaly Detection for Swarm and CSES Data by Deep Learning-based Data Analytics	Yaxin Bi
21	Combination of Swarm and COSMIC-2 ionospheric observations for plasma irregularities specification.	Iurii Cherniak
22	Use of Swarm ionospheric products for COSMIC-2 Calibration/Validation campaign	Irina Zakharenkova
23	First results from the Swarm DISC TOLEOS project: GRACE and GRACE-FO accelerometer data quality and radiation pressure modelling	Christian Siemes*
24	The multi observations around strong Yutian Earthquakes in China during 2008-2020	Xuemin Zhang*
25	Altitude distribution of equatorial ionospheric irregularities sampled from an elliptical low-earth orbit	Ali Mohandesi*

*remote participant