CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data

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INTRODUCTION

This document presents the CGMS agency best practices (BP) in support to acquisition and processing of LEO meteorological data.

The first section of the document presents the best practices for the coordination of data acquisition from low earth orbit meteorological satellite systems, while the second section presents the best practices in support to regional processing of low earth orbit direct broadcast data.

Direct Broadcast provides continuous downlink of environmental mission data to ground users. This data is globally available to all users with an appropriate receive station. The broadcast insure the rapid delivery of data that is pre-processed and formatted in accordance with agreed upon standards.

Manufacturers and operators of direct broadcast reception stations for the polar orbiting satellites critically depend on support from the satellite operating CGMS agencies. This includes the provision of technical specification of the direct broadcast, TLE orbit information, software packages for product processing, auxiliary operational data for instrument processing as well as operational coordination.

The actual status of implementation of the CGMS best practices in support to local and regional processing of LEO direct broadcast data at the relevant CGMS agencies are available at https://www.cgms-info.org.

1. BEST PRACTICES FOR THE COORDINATION OF DATA ACQUISITION FROM LOW EARTH ORBIT METEOROLOGICAL SATELLITE SYSTEMS

BP.1. Preparation of multi-mission ground stations and sizing data communication networks

CGMS operators are encouraged to develop multi-mission ground stations and prepare agreements with partners so an operator can use its antennas to receive another agency's global data. Priorities and a process to deconflict should be included. CGMS Operators should consider conducting capacity planning and load analyses for shared/multi-mission ground networks.

Best Practice BP.1: CGMS agencies operating LEO satellites (operators) are encouraged to:

a) Make agreements so an operator can use its antennas to receive another agency's global data. Priorities and a process to deconflict should be included.
b) Consider capacity planning/load analysis for shared/multi-mission ground networks.
c) Consider cost sharing agreements for communication networks.
d) Build ground station and network redundancy for multi-mission support.
e) Select and configure Front-end Processors (FEPs) so that FEP-based downtime between contacts is minimized.
f) Design new ground systems to meet threshold data coverage/latency requirements with independent systems, while also targeting higher performance with shared systems (to reduce dependencies on external programmatic delays).

BP.2. Definition of operational concepts for satellite downlink efficiency

A CGMS operator must have an agreement in order to use its antennas to receive another agency's global data. Partnering CGMS operators should prepare and maintain Concept of Operations (CONOPS) documents that describe the data acquisition strategy. The strategy should describe how the partners will take advantage of strategically located ground stations to significantly reduce data latency and increase data availability. CGMS operators should ensure contracts with third party providers include the operational procedures approved by the partnering agencies.

Best Practice BP.2: A CGMS operator with an agreement to make its antennas available to receive another agency's global data should prepare and maintain Concept of Operations (CONOPS) documents that describe the data acquisition strategy. The CONOPS should include prioritization schemes for satellite data acquisition and consider the following:

g) Schedule ground resources and spacecraft transmissions to optimize ground resource utilization across missions.

h) Spacecraft transmissions should adhere to schedule for optimal ground station resource use. Don't transmit fill data for the sake of maintaining contact. Only transmit during the operationally scheduled time and not the full visible time.

i) Agencies review scheduling during a regular scheduling teleconference.

j) Each agency with ground resources should have a scheduling system. Consider a common schedule interchange protocol.

k) Exchange a multiple-week schedule, updated regularly. Use a scheduling tool which will take inputs (schedule requests) from the partners and schedule passes for both. The scheduling tool should use the known parameters, such as minimum pass times for each spacecraft, and will be capable of deconflicting passes (to minimize radio frequency (RF) interference), by shortening/shifting passes in the visibility window.

l) Day-to-day coordination and reservation of operational assets (satellites and ground stations) for scheduling contacts coordinated through the Schedulers/Mission Planners in both organizations and will include processes for requesting emergency support.

m) Ensure contracts with third party providers include the contact priorities established in other partner agreements.

n) Third party providers should have a scheduling system that can support and optimize cross-partner deconflictions.

o) There should be an identified chain of decision makers for deciding on spacecraft. priorities should a deconfliction be contentious.

p) Standardize ephemeris protocols.

q) Transfer ephemeris products daily between partners.

BP.3. Analysis and operational planning related to avoidance of radio frequency interference

The periods of RF interference are predictable in the sense that given the ephemerides for the spacecraft, the RF interference or other pass conflicts can be calculated. Moving a conflicting pass to another local antenna can remove the conflict if there are no RF interference issues. However, at these sites the antennas are close enough together that moving between antennas will not resolve RF interference issues. In that case, moving a pass to another location if available, might be a viable solution. Alternate sites might not see all of the passes per day for a given mission and might not be available for a specific pass. Therefore, operational planning and coordination are key activities. CGMS operators should have a process for deconfliction of spacecraft RF interference through scheduling and operational coordination. This should be included in ground station contracts/agreements.

Best Practice BP.3: CGMS operators should conduct analysis and operational planning to avoid Radio Frequency (RF) interference. The operational planning should include a scheduling tool and a process for deconfliction of spacecraft RF interference through scheduling and operational coordination. CGMS operators are encouraged to consider the following:

a) The scheduling tool should be able to consider RF interference events, and calculate whether there is the possibility of shortening or shifting the contacts that are conflicting within the contact windows.

b) The ground station provider should have a way to deconflict RF interference.

c) Need to have a process for deconfliction of spacecraft RF interference through scheduling and operational coordination. This should be included in ground station contracts/agreements.

BP.4. OPERATIONAL ANNOUNCEMENTS

The operation of direct broadcast reception station and/or product processing chain requires operators to receive essential announcements regarding planned operations and status changes of the spacecraft and its instruments. This should include announcements of planned spacecraft manoeuvres, planned instrument outage periods, network outages and any degradation of instrument performance.

Best Practice BP.4: Each CGMS operator should announce planned operations and status changes as well as any observed degradation of the spacecraft and its instruments via e-mail and optionally via other channels.

2. BEST PRACTICES IN SUPPORT TO REGIONAL PROCESSING OF LOW EARTH ORBIT DIRECT BROADCAST DATA

BP.5. GLOBAL SPECIFICATION FOR DIRECT BROADCAST

The document CGMS Direct Broadcast Services: LRPT/AHRPT Global Specification (Document No. CGMS 04) builds upon a set of applicable Consultative Committee for Space Data Systems (CCSDS) standards and International Telecommunication Union (ITU) regulations. It provides an architectural specification of the LRPT/AHRPT Direct Broadcast mission from a telecommunication point of view.

Best Practice BP.5: Operators should implement the agreed CGMS Direct Broadcast Services: LRPT/AHRPT Global Specification (Document No. CGMS 04).

BP.6. TIMELY PROVISION OF DIRECT BROADCAST SPACE-TO-GROUND INTERFACE CONTROL DOCUMENTS

Space-to-Ground Interface Control Documents (ICDs) are critical for direct broadcast reception station manufacturers and are therefore a long lead item for the preparation of acquisition and processing systems for DB data.

The Space-to-Ground ICD defines the radio frequency and encoding characteristics of the satellite downlink, which is essential for the design of the direct broadcast reception station antenna, feed, demodulator and bit synchroniser.

The Space-to-Ground ICD furthermore defines the layout and content of the DB data stream, which is essential for defining the interface to the processing S/W packages processing the DB data stream to level 0.

Best Practice BP.6: CGMS operators should provide up-to-date and satellite-specific Space-to-Ground Interface Control Documents in English language at least 3 years before the launch of each satellite, including at least:

a) Frequency usage
b) Polarisation
c) Encoding
d) G/T requirements
e) Data stream layout and content

f) Conformance with CCSDS.
g) Conformance with the CGMS Global Specification (see section 1)

BP.7. PROVISION OF CURRENT ORBIT INFORMATION

A direct broadcast reception station requires satellite orbit information for the following three functions:

- Prediction and planning of future satellite passes;
- Antenna pointing during the acquisition of satellite data;
- Processing and geolocation of the sensor data.

For the two first functions the Two-Line Element Set (TLE) remains the conventional format for orbit information.

For the processing and geolocation of the sensor data, TLE is also a common format for orbit information, but other mission specific formats are in use. These include the One-Line Elements used for the FY-3 product processing software as well as the NAVATT message that will be distributed via the EPS Second Generation direct broadcast signal.

Traditionally, the direct broadcast reception station community has used the TLEs generated by the NORAD radar tracking system and made available via different distribution channels. However, these TLEs are typically generated without any satellite operator information and are often inaccurate for an extended period following spacecraft manoeuvres. With most of the newest polar orbiting satellite generations performing regular orbital manoeuvres, the trend is towards the station operators retrieving the orbit information directly from the satellite operators.

Generally the orbit information from the satellite operators is based on their internal orbit determination process. However, for a period of time after a spacecraft manoeuvre until a determined orbit can be re-established, the orbit information will be based on a predicted post-manoeuvre orbit.

For a direct broadcast reception station to have the best possible orbit information available at any time, without needing information about when manoeuvres are executed, the reception station will typically be configured to retrieve the orbit information from the satellite operator every few hours.

TLE orbit information is generally provided through FTP or HTTP access via Internet. Additionally, the Metop satellites distribute TLE data via their Multi Mission Administrative Message (MMAM) contained in the satellite's direct broadcast signal.

Best Practice BP.7: CGMS operators should ensure timely provision of accurate and up-to-date orbit information based on their operational orbit determination and knowledge of satellite manoeuvres. The orbit information should be made available to direct broadcast reception station operators:

a) In TLE format via FTP or HTTP over the Internet;
b) Additionally, if required for the processing and geolocation of the sensor data, in the relevant mission specific format via FTP or HTTP over the Internet and/or via the satellite's direct broadcast signal;
c) Additionally, if the satellite operator chose to do so, in TLE format via the satellite's direct broadcast signal.

The satellite operator shall document:

d) The details of how and where the orbit information is made available; and
e) For any mission specific format, the format definition and its application.

BP.8. PROVISION AND MAINTENANCE OF PRODUCT PROCESSING SOFTWARE PACKAGES

Product processing software packages for processing DB data to level-0 and level-1 are a prerequisite for any local processing and in particular for the DBNet regional services. Product processing packages for further processing DB data to level-2 are highly valuable.

Best Practice BP.8: Each LEO satellite operator should therefore ensure that:

a) Software packages for the relevant instruments are made available with a test version prior to launch and the operational version made available after end of commissioning of the satellite and as soon as feasible for the satellite operator;
b) To enable deployment of the software packages within organisations not permitting installation of pre-compiled software, source code should be made available;
c) Global and local product processing shall be harmonised in that brightness temperature products derived from both paths agree within tolerances that are not greater than a few tenths (goal is 10%) of the respective performance requirements for bias error at a reference brightness temperature;
d) User support and maintenance services are available for the duration of the mission;
e) Notifications for software changes are provided to the user community;
f) Complete and comprehensive user documentation and S/W release documentation is supplied in English language;
g) The software installation procedure is designed to be easily executed by an untrained user;
h) The software package is executable on a standard computer platform, typically Linux/x86-64, providing a performance compatible with the timeliness requirements defined in the Guide to DBNet (CGMS-44-WMO-WP-10);

i) For reasons of performance, it should be possible to configure the software to process only the instruments and processing levels required locally;
j) Test data for verifying the installation of the S/W packages are made available.
k) The product processing software is robust against sporadically missing data packets from the instrument or satellite in the sense that the software limits the extent of degraded or lost observations in the generated product(s) to the minimum possible.

BP.9. PROVISION OF AUXILIARY DATA FOR INSTRUMENT PRODUCT PROCESSING

Some product processing algorithms require the specifications of instruments and their performance, including instrument spectral response functions (SRFs), noise and FOV size. Some instruments (e.g. IASI) require auxiliary configuration data for the processing. Other instruments may require regular updates of instrument calibration data. See also WMO Guidelines on Best Practices for Achieving User Readiness for New Meteorological Satellites, WMO-No. 1187, https://library.wmo.int/opac/doc_num.php?explnum_id=3553 .

Best Practice BP.9: Each operator of instruments requiring auxiliary data for the product processing shall make available the necessary auxiliary data on the Internet in a user-friendly and timely manner. Announcements of the availability of new auxiliary data should be issued giving the direct broadcast reception station operators sufficient time to update their systems.

BP.10. RECCOMMENDATIONS OF CHANNEL SELECTION FOR HYPERSPECTRAL INSTRUMENTS

For hyperspectral instruments (e.g. IASI, CrIS and HIRAS) only a subset of the total information is assimilated by global NWP centres. Global distribution of the full spectral resolution data sets is also not feasible due to telecommunications constraints in many regions.

For coordinated regional processing of hyperspectral data in DBNet it is therefore imperative that a globally agreed approach for information reduction is implemented.

Best Practice BP.10: Each CGMS operator of hyperspectral instrument is responsible for defining a recommended channel selection scheme for global NWP purposes. The channel selection shall be made available to DB station operators prior to the launch of the first instrument and subsequently whenever the channel selection is modified.

BP.11. SPACECRAFT AND INSTRUMENT OPERATIONAL STATUS

When operating a direct broadcast reception station and product processing chain it is essential to have access to the current operational status and health information of the spacecraft and its instruments. This should include information such as degraded instrument channels and instrument operational/not operational, see example for NOAA POES: http://www.ospo.noaa.gov/Operations/POES/status.html. Summary information on the history of the status changes should be accessible as well.

Best Practice BP.11: Each CGMS operator should publish and maintain up to date spacecraft and instrument operational status information on the Internet. The CGMS operators should establish a scheme to review on a regular basis that the published status information is up to date.

BP.12. SATELLITE DIRECT BROADCAST AND RECEPTION STATION PERFORMANCE REQUIREMENTS

The intention of this best practice is to help satellite operators minimise the impacts on the direct broadcast reception stations and preserve the multi-mission capability of the reception stations when planning, designing, and developing satellite direct broadcast downlink capabilities.

Given a defined reception station performance in combination with a defined set of link budget conditions, the best practice achieves this by requiring the performance of the satellite direct broadcast to be sufficient for ensuring a nominal data reception at the reception station.

In this respect, the best practice complements the Global Specification for Direct Broadcast covered by Best Practice BP.01 and is intended to be applicable to future satellites that have not yet been designed.

A reception station operator may be required to establish a reception station with a performance better than the one defined in this best practice. This could be required in response to local climate conditions beyond the allocation in the best practice for rain and atmospheric losses, to mitigate the effect of local radio frequency interference or to account for the impact of an antenna radome. A typical X-Band radome loss is 1 dB to 1.5 dB.

The current scope of the best practice is the satellite direct broadcast downlink in X-Band in the ITU MetSat Band around 7.8 GHz.

Best Practice BP.11: When planning, designing, and developing satellite direct broadcast (DB) downlink capabilities, the CGMS agencies will strive to minimise, when possible, negative impacts on the DB community by communicating with manufacturers and users; coordinating with the other CGMS agencies; and considering these potential impacts during the CGMS agency’s decision-making process.

The performance of the satellite's DB X-Band (7.8 GHz, ITU MetSat Band) downlink should be sufficient for nominal data reception at any reception station within the satellite's footprint at elevations above 5 degrees and a G/T value of at least 22.7 dB/K. The calculation of the satellite DB performance shall include an allocation of at least 8.55 dB for reception station losses, rain and atmospheric losses, and link budget margin. The G/T is defined at the input of the receiver interface, at 5 degree antenna elevation and clear sky conditions.

A reception station operator may be required to establish a reception station with additional performance margin to account for local conditions, including climate, RF interference or the impact of an antenna radome.

BP.13. Monitoring of the direct broadcast downlink

Operators of satellites with direct broadcast (DB) should ensure that the downlink is functioning as specified and that application packets generated on the spacecraft are arriving in good condition at the ground system monitoring point(s).

Monitored signal quality parameters should include receive signal strength, signal to noise ratio, spectral power distribution, and carrier, bit and frame lock statistics.

Monitored data quality parameters should include discarded frames and packets, missing frames and packets, and frames and packets with bad length or sequence errors.

For an operator of a DB reception system it is relevant to know if a degradation in data quality is attributable to frames or packets discarded or degraded on the spacecraft, prior to transmission to the ground. The satellite operator should monitor such effects by looking for identical patterns of degradation in data streams acquired by geographically separated DB reception systems. If supported by the spacecraft, spacecraft monitoring telemetry may complement this monitoring.

The ground system monitoring point(s) may not be representative of a typical DB user's ground receiving station. Therefore, operators are encouraged to consider installing and operating a reference station. A reference DB reception station can be equipped with monitoring equipment to provide the operator situational awareness. For example, a spectrum analyser can be installed in-line with the RF input to the demodulator. The reference station would have the hardware (reflector, feed, downconverter, demodulator, etc.) corresponding to the minimum requirements of BP.09. The reference station should include RF signal logging, packet inspection and logging, and higher level processing with product generation software.

Once for each satellite, the satellite operator should validate that nominal reception is possible for a DB reception station anywhere within the footprint of the satellite DB antenna. Practically, acquiring all visible passes from a single DB reception station throughout a full satellite ground track repeat cycle provides an even coverage of the full satellite DB antenna footprint.

Best Practice BP.13: Operators of satellites with DB should routinely monitor the quality of the DB downlink and address any anomalies in accordance with each organisation's established procedures, and notify users of degraded performance. Monitoring should include:

a) For each satellite, during the six months following DB signal activation, a validation that nominal reception is possible for a DB reception station anywhere within the footprint of the satellite DB antenna by acquiring all passes at an elevation of 5 degrees or more above the local horizon throughout a full satellite ground track repeat cycle. Nominal reception implies a positive link budget margin as well as the signal and data quality parameters defined under d) and e) below, being in their nominal range for a reception station corresponding to the minimum requirements of BP.09;
b) During at least one pass per day for each satellite, monitoring of the signal quality parameters and the data quality parameters, as defined under d) and e) below respectively, for the part of the pass which is at an elevation of 5 degrees or more above the local horizon;
c) During at least one pass per day for each satellite, monitoring of the data quality parameter degradation, attributable to frames or packets discarded or degraded on the spacecraft, prior to transmission to the ground;

where

d) Signal quality parameters should include receive signal strength, signal to noise ratio, spectral power distribution, and carrier, bit and frame lock statistics; and
e) Data quality parameters should include discarded frames and packets (failing error free decoding/reconstruction), missing frames and packets (calculated from measured frame and packet sequence counters), bad lengths (frame or packet out of tolerance length), and sequence errors (frame or packet detected gaps/sequence error) per Virtual Channel Identifier (VCID) for frames and Application Process Identifier (APID) for packets.