Sentinel-6 Michael Freilich GNSS-RO Near-Real-Time Science Data Product Release

Initial Version

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EPDM Electronic Signatures

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1.0 INTRODUCTION

1.1 Purpose and Scope

This document provides information related to the public release of Sentinel-6/Jason-CS GNSS radio occultation levels 1B and 2 science data products in the Binary Universal Format for the Representation of meteorological data (BUFR).

1.2 Applicable and Reference Documents

“Applicable” documents levy requirements on the areas addressed in this document. “Reference” documents are identified in the text of this document only to provide additional information to readers.

1.2.1 Applicable Documents

[AD.1] Sentinel-6 Program Level Requirements Appendix (PLRA), Sentinel6-NASA-002, v1.9a [NASA Level 1 Requirements]

[AD.2] Sentinel-6 End User Requirements Document (EURD), EUM/LEO-JASCS/REQ/12/0013

1.2.2 Reference Documents

[RD.1] Sentinel-6 Project GNSS-RO Levels 1B and 2 BUFR Science Data Product Description, D-103439, Initial Release

[RD.2] Sentinel-6 Project Radio Occultation Processor Algorithm Theoretical Basis Document, D-71564, Initial Release

2.0 BACKGROUND

The Sentinel-6/Jason-CS mission provides continuity of ocean topography measurements beyond TOPEX/POSEIDON, Jason-1, OSTM/Jason-2, and Jason-3 for determining ocean circulation, climate change, and sea-level rise. The Sentinel-6 mission was developed and is operated as a four-partner international collaboration among NASA, NOAA, ESA, and EUMETSAT. Two identical spacecraft will be launched five years apart. The first spacecraft, named Michael Freilich (MF), was successfully launched on November 21, 2020.

In addition to traditional measurements related to sea surface height, the Sentinel-6 spacecraft carry the advanced NASA/JPL TriG GNSS receiver with fore- and aft-looking antennas that collect radio occultation (RO) data by tracking radio signals transmitted from Global Navigation Satellite System (GNSS) (in this case, GPS and GLONASS) satellites as they rise or set over the horizon. GNSS-RO measurements provide global, high vertical-resolution profiles sensitive to temperature and water vapor useful for a number of weather and climate applications.

NASA/JPL is responsible for providing near-real-time (NRT) RO products for numerical weather prediction (NWP) applications that are covered in this release. EUMETSAT is responsible for non-time-critical (NTC) RO products that will be released at a later date.

3.0 DATASET DESCRIPTION

The Sentinel-6/Jason-CS Mission has planned to release the JPL-produced NRT GNSS-RO Level 1B and 2 BUFR products for distribution on the World Meteorological Organization's (WMO) Global Telecommunication Service (GTS) in August 2021. This product contains neutral atmosphere, L1, and L2 bending angle profiles with impact height and neutral atmosphere refractivity profiles with mean-sea-level altitude. One BUFR file is approximately 17.5 kB in size and is generated for each retrieved occultation. The BUFR products are produced every orbit, which is nominally about 113 minutes in duration. See [RD.1] for the full Sentinel-6 BUFR product description.

3.1 WMO Routing Headers

The BUFR product files are provided from NASA/JPL to NOAA to make available on the GTS. The WMO routing headers for products generated from the Sentinel-6 MF (formerly, Sentinel-6A) satellite are as follows:

Abbreviated WMO header	Source
IPXA01 KWBC	Sentinel-6 MF BUFR product generated from NASA/JPL's RO primary processor near Denver, CO
IPXA02 KWBC	Sentinel-6 MF BUFR product generated from NASA/JPL's RO backup processor near Los Angeles, CA

The second satellite, Sentinel-6B, is planned to launch in 2025. The WMO headers for the corresponding NRT BUFR products are as follows:

Abbreviated WMO header	Source
IPXB01 KWBC	Sentinel-6B BUFR product generated from NASA/JPL's RO primary processor near Denver, CO
IPXB02 KWBC	Sentinel-6B BUFR product generated from NASA/JPL's RO backup processor near Los Angeles, CA

3.2 File Naming Convention

The BUFR product files have the following naming convention:

RO-TriG-<LEO>-<GNSS>_L1bL2_NRT_v<VERSION>_<STARTTIME>.bfr

where <STARTTIME> is the UTC time at which the occultation begins, <LEO> is "S6A" or "S6B", <GNSS> is the identifier for the occulting GNSS transmitter, and <VERSION> is the integer product version number, which for this release is "1". An example file name for an occultation of the GPS satellite with PRN 23 received by Sentinel-6 MF at UTC time 2021-07-01T03:14:15 is

RO-TriG-S6A-G23_L1bL2_NRT_v1_20210701T031415.bfr .

The contents of the NRT BUFR products will be captured also in netCDF format and archived at NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) for 60 days. The NRT netCDF products will also contain Level 1A data (including excess phase data), Level1B bending angle profiles at higher sampling rates and vertical resolutions than reported in the BUFR product, and Level 2 atmospheric profiles. Public accessibility of the NRT netCDF products will be provided at a later date.

3.3 Validation

The GNSS-RO instrument has been working nominally with antenna beam-forming enabled, producing high SNRs comparable to COSMIC-2 for setting occultations. (Rising occultations have lower SNRs than COSMIC-2 due to the smaller fore-looking RO antenna.) As of this writing, the average number of NRT BUFR products generated per day is about 860. Bending angle precision at high altitudes has been estimated to be less than 1 micro-rad on average, which is well below the mission requirement of 2 micro-rad. Comparison of the retrieved bending angle and refractivity profiles at the core region (5-25 km) shows performance characteristics that are similar to other validated GNSS-RO missions including COSMIC-2 and TerraSAR-X.

These products have also been assessed by partner NWP centers (UK Met Office, ECMWF, JCSDA, and NOAA) and deemed to be of sufficient quality for weather forecasting purposes. Data assimilation impact experiments are in progress but preliminary results have shown improvements from assimilating one month of data.

3.4 Caveats

Minor issues were identified during validation, which are expected to be resolved in the near future:

- A small bending angle mean bias at high impact heights between rising and setting occultations
- A positive bending angle mean bias near the Earth's surface
- Time-dependent bending angle bias between rising and setting occultations

In addition, it is currently not recommended to assimilate refractivity profiles above 40 km due to large uncertainties specific to JPL's refractivity retrieval algorithms [RD.2].

Updates to the BUFR product resulting in improvements to the minor issues noted above will be provided here when available along with the new version number.

3.5 Processing Configuration

The products in this release have been generated with the Sentinel-6 RO Processor release version 1.3.0. The processor version will be updated as needed in future releases of this document.

4.0 ACRONYMS

BUFR	Binary Universal Format for the Representation of meteorological data
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
CS	Continuing Service
GES DISC	Goddard Earth Sciences Data and Information Services Center
ECMWF	European Centre for Medium-range Weather Forecasts
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GTS	Global Telecommunication System
JCSDA	Joint Center for Satellite Data Assimilation
JPL	Jet Propulsion Laboratory
MF	Michael Freilich
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NRT	Near-Real-Time
NTC	Non-Time-Critical
NWP	Numerical Weather Prediction
RO	Radio occultation

SNR	Signal-to-Noise Ratio
UK	United Kingdom
UTC	Coordinated Universal Time
WMO	World Meteorological Organization