Spire Level 2 Ocean Wind Derived from GNSS-R Bistatic Radar Product Summary

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Issue/Revision	*Date*	*By*	*Description*
1.0	2022-08-01	Spire	Initial version
1.1	2023-03-01	Spire	Fix missing table

Table of Contents

1. Product Summary: gbrOcn

1.1. Introduction

GNSS Reflectometry (GNSS-R) involves making measurements of the reflections from the Earth of navigation signals from the Global Navigation Satellite Systems (GNSS). Using GNSS Bistatic Radar (gbr) observations of the ocean, we retrieve sea surface roughness and near surface wind. These parameters are derived from the measured intensity of the reflected signal.

1.2. Data and Metadata

1.2.1. General Description

The Level 2 gbrOcn data includes the retrieved mean square slope (MSS) of the sea surface, wind speed, the standard deviation of the retrieved wind speed, the wind confidence flag, Normalized Radar Cross Sections (NRCS) or "sigma0" used for the retrieval, and a set of auxiliary variables copied from the Level 1B gbrNRCSm data files. The structure of a Level 2 Ocean NetCDF file repeats that of a Level 1B file; i.e., each Level 2 file is derived from a corresponding Level 1B file.

Processing of the GNSS-R ocean data from Level 1 to Level 2 uses the DDM of the reflection power as a basic input containing information about the roughness of the reflecting ocean surface. Normalized Bistatic Radar Cross-section "sigma0" is derived from the averaged DDM (DDMA) and accounts for calibrations and corrections, as it is described in [Spire GNSS-R Level 1 Product Manual]. The DDMA is estimated by averaging over 20 DDM pixels with the highest values of the effective area. This way we exclude the pixels without reflected signals and reduce DDMA noise.

In our derivation of the Level 2 wind data, we build the empirical geophysical model function (GMF) from the comparison of sigma0 with the near-surface background wind speed. MSS is derived using the algorithm described in [CYGNSS Handbook 2016 "Level 2 Mean Square Slope Retrieval"].

The processing steps are outlined as follows:

- Selecting Level 1 data based on quality control
- Space and time interpolating of the background wind speed from ECMWF analysis
- Calculating MSS
- Filtering the reflection power DDM and supporting calibration data to suppress the noise
- Calculating sigma0 from DDMA
- Derivation/updating the GMF from the filtered sigma0 and background wind
- Wind speed retrieval with the updated GMF

1.2.2. Format

The file format is NetCDF4-Classic.

The dimensions are time. There is no prescribed number of measurement points as each track length is distinct to each reflection event. gbrOcnm data are derived from gbrNRCSm data and are therefore only provided in the merged format.

The global attributes, dimensions, and variables are described in Tables 1 - 6.

1.2.2.1. Global Attributes

Attribute	Description
name	“GNSS-R L2 Ocean”
processing_center	Spire Processing Center
constellation	Receiving satellite constellation name, e.g. “spire”
product_type	GBR product name, e.g. gbrOcn(m)
processing_config	“land” or “ocean”
file_start_time	UTC file start time
file_end_time	UTC file end time
start_gpstime	File start time in GPS seconds
stop_gpstime	File end time in GPS seconds
rx_id	The flight model (FM) number of the receiving satellite
config_id	String that can be used to specify different Level 1 processing configurations.
data_level	L2
antennas	The antennas available in this file e.g. “reflect_ant_mask1, direct_ant_mask2, reflect_ant_mask4”
ddm_source_format_version	The file version of the input DDM files. E.g. “1.2.0”
format_version	The file version and the release checksum of the Level 1 processor. E.g. “0.3.14_2bbb013e44cf37d1e1330038f4c198dc9cb6d4d8”
quality_flag_info	A bit-packed integer denoting which of the quality_flags are considered for information rather than warnings.
ddma_delay_pixels	The delay size of the DDMA box used in the sigma_at_sp and sigma0_at_sp fields
ddma_doppler_pixels	The doppler size of the DDMA box used in the sigma_at_sp and sigma0_at_sp fields
ddma_delay_offset_pixels	The delay offset of the DDMA box used in the sigma_at_sp and sigma0_at_sp fields
file_created_time_utc	Data file creation time specified in UTC format.
multi_track_dataset	0: single track files 1: multi track merged files
ddma_algorithm	Algorithm name for DDMA observable

l1b_source_file	The name of the Level 1B file that was the source for this Level 2 file
l1_format_version	Level 1B processing software version, e.g. 01.01
l2_format_version	Level 2 processing software version, e.g. 02.01

1.2.2.2. Dimensions

Variable	Source	Description	Unit
sample_time	L1B	Mid-point time of measurement in UTC	sec

1.2.2.3. Variables (Time)

Variable	Source	Description	Unit
sample_time	L1B	Mid-point time of measurement in UTC	sec
gpstime	L1B	Mid-point time of measurement in seconds since the GPS epoch	sec

1.2.2.4. Variables (Track meta-data)

Variable	Source	Description	Unit
l1b_index	L1B	The data copied from Lev1b files are indexed like lev2_antenna_mask = lev1b_antenna_mask[lev1b_index]	
quality_pass	L1B	Flag whether the data quality is considered acceptable. This is the master quality flag that can be used instead of decoding the detailed quality_flags field. This helps specify which of the flags is considered informational vs. a quality failure.	
quality_flags	L1B	Quality flags bit-packed A word containing the bit-packed combination of quality flags. A'1 in any bit indicates the presence of that state. QualityFlagsEnum: 1=warn_unavailable_tx_antenna_pattern, 2=warn_calibration_invalid, 4=warn_comms_s_band_active, 8=warn_comms_uhf_band_active, 16=warn_attitude_changing, 32=warn_attitude_offset, 64=error_compute_specular_point, 128=rx_ant_gain_correction_invalid, 256=warn_low_snr, 512=warn_possible_rfi, 1024=warn_direct_signal_in_ddm, 2048=warn_low_rcg, 4096=warn_inconsistent_pseudorange, 8192=warn_unstable_direct_obs, 16384=warn_unstable_cal_direct, 32768=warn_unstable_cal_reflect	
track_id_hash	Derived	Uniquely identifies the observation track. This is an ID equivalent to track_id but unique across files. A single track that crosses L1 files will share the same track_id_hash. This track_id_hash allows linking back to the Level 0 DDM file and should not change, even if the Level 1 data is reprocessed. This makes it	

		suitable for use in publications. The adopted display convention is to use base64 encoding e.g track_id_hash=1035645046200408516 should be displayed as "TID=xBkrtK5ZXw4"	
tx_system	L1B	Transmitter GNSS constellation 0=GPS,1=GALILEO,2=GLONASS,3=SBAS,4=BDS,5=QZSS,6=IRNSS	-
tx_prn	L1B	Transmitter PRN The transmitted PRN code	-
tx_svn	Derived	Transmitter SVN The unique identification number (that is unique per GNSS system and not transferred between space-vehicles. Unknown = 0.	-
tx_signal	Derived	Transmitter signal SignalType: 0=GPS_L1_CA, 1=GPS_L2_CL, 2=GPS_L2_PY, 3=QZS_L1_CA, 4=QZS_L2_CL, 5=GLO_L1_CA, 6=GLO_L2_CA, 7=GAL_E1_BA, 8=GAL_E1_CA, 9=GAL_E5B_Q, 10=BDS_B1C_D, 11=BDS_B1C_P, 12=BDS_B2A_D, 13=BDS_B2A_P, 14=BDS_B2B_I, 15=BDS_B2B_Q	-
antenna_mask	L1B	Which antennas were used for the measurement: Binary field made of setting bits to 1 for when that antenna is utilised. Multiple bits are set for beamforming multiple antennas. Bit 0 corresponds to radio frontend 0, Bit 1 to radio frontend 1 etc.	-
reflect_snr_at_sp	L!B	The signal to noise ratio around the specular point using power_reflect_at_sp Land: using peak. Ocean: using DDMA.This is calculated as the unbiased SNR: 10 * log10(power_reflect / power_noise_reflect - 1).	

1.2.2.5. Variables (Derived observations)

Variable	Source	Description	Unit
sigma0_dB	L1B	The normalised Bistatic Radar Cross-Section (NRCS) measured at the specular point.	dB
mss	Derived	The mean square slope estimated from sigma0 and Fresnel reflection coefficient.	1
wind	Derived	The wind speed retrieved from the empirical relation between Sigma0 and background ECMWF 10m wind.	m/s
wind_std	Derived	The standard deviation of the wind speed estimated from the empirical relation between Sigma0 and background ECMWF 10m wind.	m/s
wind_confidence	Derived	Confidence flag is set to 0 for the sigma0 values outside the limits of 14-30 dB.	0 or 1

1.2.2.6. Variables (Geometry)

Variable	Source	Description	Unit

sp_lat	Derived	Specular point latitude The specular point location in geodetic coordinates	degrees_north
sp_lon	Derived	Specular point longitude The specular point location in geodetic coordinates	degrees_east
sp_incidence_angle	Derived	Specular point incidence angle The angle between the ellipsoid surface normal and the incident ray	degrees
sp_coast_distance	Derived	Distance to the nearest coast for specular point location. Values >0 are in the land, <0 are in the ocean. This is quantised to 5 km steps and saturated at +/-635 km.	km