Updated flag variable information for the ESA Soil Moisture Climate Change Initiative (Soil_Moisture_cci) version 08.1 data collection

Flag descriptions

The v08.1 active, passive, and combined data files each contain five flag variables: one data quality flag ('flag') and four indicative flags ('freqbandID', 'dnflag', 'mode', and 'sensor'), which contain auxiliary information corresponding to each measurement. Table 1 summarises the five flag variables, all of which are *inclusive* flag variables (i.e. zero or more flag values can be set at any one time) and are therefore represented by bitwise flags, also known as bit flags.

Table 1: Flag variables used in the v08.1 soil moisture data files.

Flag variable	Description	Flag type	Interpretation of 0 (no bits set)	Fill value	Data type	Valid range
flag	Main data quality flag	quality	good data	-9999 (missing data)	short	0 - 255
freqbandID	Frequency band identification	indicative	missing data	-	short	0 - 511
dnflag	Day/night flag	indicative	missing data	-	byte	0 - 3
mode	Satellite mode	indicative	missing data	-	byte	0 - 3
sensor	Sensor(s) used to create the soil moisture product.	indicative	missing data	-	int	0 - 131071

It should be noted that for the data quality flag variable 'flag' the value zero (i.e. no bits set) represents good data, since no quality flags have been raised, and missing data is indicated by a fill value (-9999). Conversely, the indicative flags are, by definition, only present for good data and therefore for these flags the value of zero represents missing or invalid data. As such, the indicative flags do not contain a fill value.

For each flag variable, the available bit positions, bit values, and their corresponding flag meanings are detailed in Tables 2 - 6. For NetCDF files, the CF standard variable attributes to describe inclusive bit flags are 'flag_masks', containing a list of the possible bit flag values, and 'flag_meanings', containing the corresponding bit flag descriptions. Note that for the flag 'dnflag' (Table 4) a flag value of 3 indicates that data from both daytime and nighttime measurements have been merged, and for flag 'mode' (Table 5) a flag value of 3 indicates that data from both ascending and descending nodes have been merged.

Table 2: 'flag' variable description.

Bit flag position	Decimal bit flag value (flag_masks)	Bit flag meaning (flag_meanings)
0	1	snow_coverage_or_temperature_below_zero
1	2	dense_vegetation
2	4	others_no_convergence_in_the_model_thus_no_valid_sm_estimates
3	8	soil_moisture_value_exceeds_physical_boundary
4	16	weight_of_measurement_below_threshold
5	32	all_datasets_deemed_unreliable
6	64	barren_ground_advisory_flag
7	128	not_used

Table 3: 'freqbandID' variable description.

Bit flag position	Decimal bit flag value (flag_masks)	Bit flag meaning (flag_meanings)
0	1	L14
1	2	C53
2	4	C66
3	8	C68
4	16	C69
5	32	C73
6	64	X107
7	128	K194
8	256	MODEL

Table 4: 'dnflag' variable description. Note that a flag value of 3 indicates that data from both daytime and nighttime measurements have been merged.

Bit flag position	Decimal bit flag value (flag_masks)	Bit flag meaning (flag_meanings)
0	1	day
1	2	night

Table 5: 'mode' variable description. Note that a flag value of 3 indicates that data from both ascending and descending measurements have been merged.

Bit flag position	Decimal bit flag value (flag_masks)	Bit flag meaning (flag_meanings)
0	1	ascending
1	2	descending

Table 6: 'sensor' variable description.

Bit flag position	Decimal bit flag value (flag_masks)	Bit flag meaning (flag_meanings)
0	1	SMMR
1	2	SSMI
2	4	TMI
3	8	AMSRE
4	16	WindSat
5	32	AMSR2
6	64	SMOS
7	128	AMIWS
8	256	ASCATA
9	512	ASCATB
10	1024	SMAP
11	2048	MODEL
12	4096	GPM
13	8192	FY3B
14	16384	FY3D
15	32768	ASCATC
16	65536	FY3C

Interpretation of flags

Bitwise flags represented in decimal form can be decoded using the bitwise AND (&) operation. For example, performing a bitwise AND operation of the 'flag' variable value of 88 with each of the eight possible bit values (1, 2, 4, 8, 16, 32, 64, and 128) returns 0 for the bit values *(positions)* 1 *(0)*, 2 *(1)*, 4 *(2)*, 32 *(5)*, and 128 *(7)* (indicating that bits 0, 1, 2, 5, and 7 are not set) and returns the bit value itself for bit values *(positions)* 8 *(3)*, 16 *(4)*, and 64 *(6)* (indicating that bits 3, 4, and 6 are set), corresponding to flag meanings 'soil_moisture_value_exceeds_physical_boundary', 'weight_of_measurement_below_threshold', and ' barren_ground_advisory_flag' respectively, as shown in the following Python excerpt:

```
>>> print(88 & 1)
0
>>> print(88 & 2)
0
>>> print(88 & 4)
0
>>> print(88 & 8)
8
>>> print(88 & 16)
16
>>> print(88 & 32)
0
>>> print(88 & 64)
64
>>> print(88 & 128)
0
```