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| WORLD METEOROLOGICAL ORGANIZATION  COMMISSION FOR BASIC SYSTEMS  -----------------------------  THIRD MEETING OF  INTER-PROGRAMME EXPERT TEAM ON CODES MAINTENANCE  MARRAKECH, MOROCCO, 15 - 19 APRIL 2019 |  | IPET-CM-III / Doc. 2.2(5)  01.04.2019  -------------------------  ITEM 2.2  ENGLISH ONLY |

MANUAL ON CODES: TABLE-DRIVEN CODE FORMS

FM 92 GRIB

Space Weather in GRIB2

*Originally submitted and revised by Jeff Ator (U.S.A.)*

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**Summary and Purpose of Document**

The document proposes a methodology for reporting space weather in GRIB2.

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**ACTION PROPOSED**

The team is requested to approve the contents for validation and to consider the proposal for possible inclusion in November 2019 fast-track (FT2019-2).

Please note that it might be worthwhile to include the WMO IPT-SWeISS (Inter- Programme Team on Space Weather Information, System and Services) group for further review and discussions.

**DISCUSSIONS**

At the IPET-DRC II meeting in Brasilia (August 2010), the team discussed ideas for the representation of space weather in GRIB2. This was initiated by a topical paper from the U.S., and the results are documented in item 2.3.11 of the final report from the meeting.

In accordance with the guidance provided by IPET-DRC II, the NCEP Space Weather Prediction Center (SWPC) has worked closely with the UKMO and AFWA over the year 2010/2011 to develop a formal proposal for validation.

Some validations were made, but then the validation process stopped and the proposal was withdrawn at the IPET-DRMM II meeting in College Park in 2014.

Based on the increased relevance of space weather products and services in aviation and with respect to related ICAO and WMO activities in establishing global space weather centres, we propose the revision and extension of the GRIB2 data format originally initiated by Jeff Ator. The final goal is to harmonize space weather and meteorological data bases to foster inter-operability of the existing complex systems using the GRIB2 format. We hope to validate these new additions in the coming months so they can be adopted for fast-track implementation in 2019.

**PROPOSAL**

Rename Code table 3.2 as “Shape of the reference system” and add the following new entries:

**Code table 3.2** – *Shape of the reference system*

|  |  |
| --- | --- |
| **Code figure** | **Meaning** |
| 10 | Earth model assumed WGS84 with corrected geomagnetic coordinates (latitude and longitude) defined by Gustafsson et al., 1992 |
| 11 | Sun assumed spherical with radius = 695,990,000 m (Allen, C.W., 1976 Astrophysical Quantities (3rd Ed.; London: Athlone) and Stonyhurst latitude and longitude system with origin at the intersection of the solar central meridian (as seen from Earth) and the solar equator (Thompson, W, Coordinate systems for solar image data, A&A 449, 791–803 (2006)) |

Add the following new entries to Code table 4.5:

**Code table 4.5** - *Fixed surface types and units*

|  |  |  |
| --- | --- | --- |
| **Code figure** | **Meaning** | **Unit** |
| 168 | Specified radius from the center of the Sun | m |
| 169 | Solar photosphere |  |
| 170 | Ionospheric D-region level |  |
| 171 | Ionospheric E-region level |  |
| 172 | Ionospheric F1-region level |  |
| 173 | Ionospheric F2-region level |  |

In Code table 0.0, rename existing entry #3 as “Satellite remote sensing products” and add new entry #4:

**Code table 0.0** - *Discipline of processed data in the GRIB message, number of GRIB Master table*

|  |  |
| --- | --- |
| **Code figure** | **Meaning** |
| 3 | Satellite remote sensing products |
| 4 | Space weather products |

Add the following new entries to Code table 4.1:

**Code table 4.1** - *Parameter category by product discipline*

|  |  |
| --- | --- |
| **Product Discipline 4 – Space Weather Products** | |
| **Category** | **Description** |
| 0 | Temperature |
| 1 | Momentum |
| 2 | Charged particle mass and number |
| 3 | Electric and magnetic fields |
| 4 | Energetic particles |
| 5 | Waves |
| 6 | Solar electromagnetic emissions |
| 7 | Terrestrial electromagnetic emissions |
| 8 | Imagery |
| 9 | Ion-neutral coupling |
| 10 | Space Weather Indices |
| 11-191 | Reserved |
| 192-254 | Reserved for Local Use |
| 255 | Missing |

Add the following new entries to Code table 4.2:

**Code table 4.2** - *Parameter number by product discipline and parameter category*

**Product discipline 4 – Space weather products, parameter category 0: Temperature**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Temperature | K |  |
| 1 | Electron temperature | K |  |
| 2 | Proton temperature | K |  |
| 3 | Ion temperature | K |  |
| 4 | Parallel temperature | K |  |
| 5 | Perpendicular temperature | K |  |
| 6-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 1: Momentum**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Velocity magnitude (Speed) | m s-1 |  |
| 1 | 1st vector component of velocity (coordinate system dependent) | m s-1 |  |
| 2 | 2nd vector component of velocity (coordinate system dependent) | m s-1 |  |
| 3 | 3rd vector component of velocity (coordinate system dependent) | m s-1 |  |
| 4-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 2: Charged particle mass and number**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Particle number density | m-3 |  |
| 1 | Electron density | m-3 |  |
| 2 | Proton density | m-3 |  |
| 3 | Ion density | m-3 |  |
| 4 | Vertical total electron content | TECU |  |
| 5 | HF absorption frequency | Hz |  |
| 6 | HF absorption | dB |  |
| 9 | Spread F | m |  |
| 10 | h’ | m |  |
| 11 | Critical frequency | Hz |  |
| 12 | Maximal usable frequency (MUF) | Hz | The maximal usable Frequency (MUF) can be derived from the critical frequency and is commonly used in the space weather community. |
| 13 | Peak height (hm) | m |  |
| 14 | Peak density (Nm) | m-3 |  |
| 15 | Equivalent slab thickness (τ) | km |  |
| 16-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 3: Electric and magnetic fields**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Magnetic field magnitude | T |  |
| 1 | 1st vector component of magnetic field | T |  |
| 2 | 2nd vector component of magnetic field | T |  |
| 3 | 3rd vector component of magnetic field | T |  |
| 4 | Electric field magnitude | V m-1 |  |
| 5 | 1st vector component of electric field | V m-1 |  |
| 6 | 2nd vector component of electric field | V m-1 |  |
| 7 | 3rd vector component of electric field | V m-1 |  |
| 8-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 4: Energetic particles**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Proton flux (differential) | (m2 s sr eV)-1 |  |
| 1 | Proton flux (integral) | (m2 s sr )-1 |  |
| 2 | Electron flux (differential) | (m2 s sr eV)-1 |  |
| 3 | Electron flux (integral) | (m2 s sr)-1 |  |
| 4 | Heavy ion flux (differential) | (m2 s sr eV/nuc)-1 |  |
| 5 | Heavy ion flux (integral) | (m2 s sr)-1 |  |
| 6 | Cosmic ray neutron flux | h-1 |  |
| 7-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 5: Waves**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** |  |
| 0 | Amplitude | dB |  |
| 1 | Phase | rad |  |
| 2 | Frequency | Hz | Needed to couple observables with used frequency. (For example scintillation index S4 for L1 GNSS frequency). |
| 3 | Wave length | m |  |
| 4-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 6: Solar electromagnetic emissions**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Integrated Solar Irradiance | W m-2 |  |
| 1 | Solar X-ray Flux (XRS Long) | W m-2 |  |
| 2 | Solar X-ray Flux (XRS Short) | W m-2 |  |
| 3 | Solar EUV Irradiance | W m-2 |  |
| 5 | Solar Spectral Irradiance | W m-2 nm-1 |  |
| 6 | F10.7 | W m-2 Hz-1 |  |
| 7 | Solar radio emissions | W m-2 Hz-1 |  |
| 8-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 7: Terrestrial electromagnetic emissions**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Limb intensity | J m-2 s-1 |  |
| 1 | Disk intensity | J m-2 s-1 |  |
| 2 | Disk intensity day | J m-2 s-1 |  |
| 3 | Disk intensity night | J m-2 s-1 |  |
| 4-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 8: Imagery**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** |  |
| 0 | X-ray radiance | W sr-1 m-2 |  |
| 1 | EUV radiance | W sr-1 m-2 |  |
| 2 | H-alpha radiance | W sr-1 m-2 |  |
| 3 | White light radiance | W sr-1 m-2 |  |
| 4 | CaII-K radiance | W sr-1 m-2 |  |
| 5 | White light coronagraph radiance | W sr-1 m-2 |  |
| 6 | Heliospheric radiance | W sr-1 m-2 |  |
| 7 | Thematic mask | Numeric |  |
| 8-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 9: Ion-neutral coupling**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** |  |
| 0 | Pedersen conductivity | S m-1 |  |
| 1 | Hall conductivity | S m-1 |  |
| 2 | Parallel conductivity | S m-1 |  |
| 3-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

**Product discipline 4 – Space weather products, parameter category 10: Space Weather Indices**

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Parameter** | **Units** | **Description** |
| 0 | Scintillation index σϕ | rad |  |
| 1 | Scintillation index S4 | Numeric |  |
| 2 | Rate of change of TEC Index (ROTI) | TECU/min |  |
| 3 | Disturbance Ionosphere Index Spatial Gradient (DIXSG) | Numeric |  |
| 4 | Along Arc TEC Rate (AATR) | TECU/min |  |
| 5 | Kp | Numeric |  |
| 6 | Equatorial disturbance stormtime index (Dst) | nT |  |
| 7 | Auroral Electrojet (AE) | nT |  |
| 8-191 | Reserved |  |  |
| 192-254 | Reserved for Local Use |  |  |
| 255 | Missing |  |  |

TEC units (TECU) are used in the Space Weather community (and also in the ICAO context).

**Add in Common Code Table C-6: List of units for TDCFs**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Code  figure |  | Conventional  abbreviation | Abbreviation in  IA5/ASCII | Abbreviation  in ITA2 | Definition in  base units |
| 844 | Total Electron Content Unit | TECU | TECU | TECU | 1016 Electrons m-² |