THEMIS/ARTEMIS
L1→L2 Processing Dependencies for THEMIS Probe Data

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1. Introduction

For the purposes of this document, "L2 products" should be interpreted as referring to calibrated, coordinate-transformed L1 data, whether or not an actual L2 CDF has been officially released. For example, the online summary plots might need to be reprocessed due to a change in some L1 data type, even if that change doesn't affect any existing L2 CDFs.

Generally speaking, the THEMIS L2 products will directly depend on:

1) The corresponding L0 and/or L1 products
2) The calibration *parameters* for that instrument
3) The calibration *algorithm* for that instrument
4) The spin model parameters and V03 spin attitude and spin phase corrections from L1 STATE (except for the spectral data types, FFT and FBK, which don't participate in coordinate transforms).

> ESA, SST, MOM, and FIT also depend on L1 STATE to correct for differences between the pseudo-DSL (IDPU spin model) and true DSL coordinate systems as the IDPU freewheels through eclipse periods for which FGM spin model corrections are available.

From time to time, changes in the VC->L0 processing or L0->L1 processing tools may require a reprocessing of affected L1 products. For example, when the contact schedule for the outer probes changed as the orbits were raised, many valid L0 packets were rejected due to invalid frame versus packet timestamps. A relaxation of these constraints in the VC->L0 processing tools triggered a reprocessing of all L1 data types for the affected probes to recover and process the previously rejected packets. Therefore, all the L2 products have an indirect dependency on the L0 products, the VC->L0 processing code, and the L0->L1 processing code. Changes in any of these processing tools has the potential to trigger a reprocessing of the related L2 products.

It is worth noting that occasionally, L1 products are reprocessed to add additional "convenience" variables, or change metadata (e.g. for ISTP compliance). When deciding what needs to be reprocessed due to a change in a L1 data product, it is important to consider dependencies at the level of individual variables within a CDF, rather than the CDF as a whole.

The dependencies on L1 STATE introduce a bit of complication, because L1 STATE has a direct dependency on the calibrated FGM data, via the V03 spin attitude/spin phase corrections. The V03 corrections are derived by comparing calibrated L1 FGM data to a field model, and choosing spin axis and spin phase corrections that minimize the difference between the field model and the calibrated L1 FGM data.

This implies that any L2 products which involve coordinate transforms also have an indirect dependency on FGM data. Another implication is that special care must be taken to avoid a circular dependency in the L2 FGM processing.

2. FGM and V03 STATE Corrections

The circular dependency mentioned above is avoided by using V02 STATE, rather than V03 state, to produce calibrated FGM field measurements for comparison with a field model. The V02 state CDF does not contain the spin attitude and spin phase corrections, ensuring that previous values of those corrections

will not interfere with a V03 reprocessing. For example, if a new set of orbit-dependent FGM offsets are produced, this can trigger a recalculation of other calibration parameters, including the FGM sensor orientation with respect to the spacecraft coordinate system. The sensor orientation is closely coupled with the spin axis and spin phase corrections, so this FGM recalibration should trigger a V03 state reprocessing. But the new V03 corrections need to be calculated relative to the *uncorrected* FGM data, not the previous set of V03 corrections. Using V02 STATE rather than V03 state in this process ensures that this is the case.

3. FGM L2 Products

The L2 FGM products directly depend on the following:

L1 FGM variables thx_fgh, thx_fgl, thx_fge
FGM calibration parameters:
  Sensor orientation
  Instrument gains and offsets
  Seasonal orbit-dependent offsets
  ADC nonlinearity corrections
  Seasonal solar array currents as a function of spin phase
FGM calibration algorithm
L1 STATE spin model variables (unversioned/highest available)

The final data product is usually in geophysical coordinates (e.g. time, BxGSM, ByGSM, BzGSM, XGSM, YGSM, ZGSM). This product then also depends on L1 STATE attitude corrections (besides the already mentioned L1 STATE spin variables).

On the other hand fgm data in DSL coordinates do not depend on attitude corrections (just on spin phase angle corrections).

Furthermore, FGM data in SSL coordinates do not even depend on spin phase angle corrections.

4. SCM L2 Products

The L2 SCM products directly depend on the following:

L1 SCM (SCF, SCP, SCW) CDFs
SCM calibration parameters:
  X, Y, and Z antenna calibration tables, e.g., THEMIS_SCM1.cal
SCM calibration algorithm, and parameters:
  Size of the convolution kernel
  Despin on/off
  Number of spins to fit for antenna misalignment, dc field calculation and despin
  Spin tone and 8/32 Hz cleanup options
  Low frequency cut-off for calibration
  Min and Max frequencies fo filtering
(An explanation of the SCM calibration process and parameters can be
found in the SCM calibration document:
"ftp://apollo.ssl.berkeley.edu/pub/THEMIS/3 Ground Systems/3.2 Science
Operations/Science Operations Documents/thm_soc_129_scm_calibration.pdf")

L1 STATE spin model variables.

5. EFI L2 Products

The EFI L2 products directly depend on the following:

L1 EFI (EFF, EFP, EFW, VAF, VAP, VAW, VBF, VBP, VBW) CDFs
EFI calibration parameters:
  Instrument gains and offsets
  Boom length and boom shorting factors
EFI calibration algorithm
L1 STATE spin model variables

6. ESA L2 Products

The ESA L2 products directly depend on the following:
L0 apids 454, 455,456,457,458,459
(future: depends on L1 ESA CDF)
ESA calibration parameters:
  Instrument gains and offsets
ESA calibration algorithm
L1 FIT (for spin-fit magnetic field (FGS) data, and raw spacecraft potential)
L1 MOM (for raw spacecraft potential, and the determination of the presence of solar wind plasma.)
EFI L1 data, and gains/offsets (to calibrate spacecraft potential)

The ESA particle distributions and moments are produced in pseudo-DSL coordinates, so do not require a despin operation. However, during an eclipse, pseudo-DSL differs from true DSL as the IDPU freewheels through the eclipse with a constant spin period. So for those time intervals where FGM is used to augment the BAU sunpulse spin model, ESA L2 products depend on the L1 STATE eclipse spin model variables.

7. SST L2 Products

The SST L2 products directly depend on the following:

L1 SST CDF
SST calibration parameters
  Instrument gains and offsets
SST calibration algorithm
L1 FIT (for raw spacecraft potential)
L1 MOM (for raw spacecraft potential)
EFI gains/offsets (to calibrate spacecraft potential)
L1 FGS data (for magnetic field aligned temperature magt3)
FGM calibration parameters (for magnetic field aligned temperature magt3)

The SST particle distributions and moments are produced in pseudo-DSL coordinates, so do not require a despin operation. However, during an eclipse, pseudo-DSL differs from true DSL as the IDPU freewheels

through the eclipse with a constant spin period. So for those time intervals where FGM is used to augment the BAU sunpulse spin model, SST L2 products depend on the L1 STATE eclipse spin model variables.

It should be noted that the SST L1 CDF includes some ESA configuration data (the sweep mode, and solar wind mode flags). So the L2 SST products do not depend directly on L1 ESA data; however, a change in the ESA L0 or L1 data may trigger reprocessing of L1 SST to update the ESA configuration.

At this writing, the L2 SST CDF does not include the magt3 quantity, representing magnetic field aligned temperatures. This quantity depends on calibrated fgs (FGM spin fit) data, and therfore on the L1 FGS data and FGM calibration parameters. If the magt3data is ever added to the SST L2 CDF, the same dependencies will apply.

8. MOM L2 Products

The MOM L2 products directly depend on:

L1 MOM CDF
ESA calibration parameters
  Instrument gains and offsets
SST calibration parameters
ETC table configuration
EFI gains/offsets (to calibrate raw spacecraft potential)

Note that the L1 MOM CDF also includes some SST and ESA configuration data: SST attenuator status, ESA sweep mode, and ESA solar wind flags. So changes to the L1 SST, L0 ESA, or L1 ESA products may trigger a reprocessing of L1 MOM to pick up any changes in ESA or SST configuration.

Some of the MOM data quantities represent vector data (e.g. velocities) which are subject to coordinate transforms. Since MOM is calculated onboard, from ESA and SST particle distributions in pseudo-DSL coordinates, no despin operation is required. However, during an eclipse, pseudo-DSL differs from true DSL as the IDPU freewheels through the eclipse with a constant spin period. So for those time intervals where FGM is used to augment the BAU sunpulse spin model, MOM L2 products depend on the L1 STATE eclipse spin model variables.

9. FIT L2 Products

The FIT L2 products directly depend on:

L1 FIT CDF
EFS calibration parameters
  Instrument gains and offsets
EFS calibration algorithm
FGS calibration parameters
  Instrument gains and offsets
FGS calibration algorithm

The FGS and EFS spin fits are produced onboard, in pseudo-DSL coordinates, so do not require a despin operation. However, during an eclipse, pseudo-DSL differs from true DSL as the IDPU freewheels through

the eclipse with a constant spin period. So for those time intervals where FGM is used to augment the BAU sunpulse spin model, FIT L2 products depend on the L1 STATE eclipse spin model variables.

The L1 FIT CDFs now include some spacecraft potential measurements, which may be used for calibrating ESA, SST, and MOM. Therefore these data types may need an L2 reprocessing if the L1 FIT EFI-Z quantity (which can contain spacecraft potential) is changed due to a L1 FIT reprocessing.

10. FBK L2 Products

The FBK L2 products directly depend on:

FBK L1 CDF
FBK calibration parameters
  Instrument gains and offsets
FBK calibration algorithm

FBK is a spectral data type that does not participate in coordinate transforms, therefore there is no dependency on L1 STATE.

11. FFT L2 Products

The FFT L2 products directly depend on:

FFT (FFF, FFP, FFW) L1 CDFs
FFT calibration parameters
  Instrument gains and offsets
FFT calibration algorithm

FFT is a spectral data type that does not participate in coordinate transforms, therefore there is no dependency on L1 STATE.