Community Satellite Processing Package for Geostationary Data (CSPP Geo) AIT Framework Level 2 Package Software Users’ Guide

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University of Wisconsin-Madison
Space Science and Engineering Center (SSEC)
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Section 1: Introduction

1.1 Overview

This document contains instructions for installation and operation of the CSPP Geo AIT Framework (AITF) software package.

The Community Satellite Processing Package for Geostationary Data (CSPP Geo) project is funded by the GOES-R Program and NOAA STAR.

The software is capable of processing Advanced Baseline Imager (ABI) data from GOES-R series satellites (currently GOES-16 and GOES-17), and generating derived geophysical products in real-time.

The primary input to the software is ABI Level 1B (L1B) calibrated and navigated radiance files in mission-standard format. At a direct broadcast site that is receiving data via the GOES Rebroadcast (GRB) stream, these files would be generated by the CSPP Geo GRB software package. However, the AITF software can be run on ABI L1B files obtained from any source, as long as they are in the mission-standard format.

Dynamic ancillary data is also required as input, and can be obtained over the Internet from a server maintained at the University of Wisconsin.

The software is intended to be run on CentOS7-compatible Linux. All required third-party software is bundled, other than standard Linux libraries. No compilation is required.

This package contains a mix of original software developed at different institutions, as well as bundled third-party software libraries. The core processing software was developed and is maintained by the GOES-R Algorithm Integration Team (AIT), located at the NOAA Center for Satellite Applications and Research (STAR). The algorithm code was developed by the GOES-R Science Team. Glue code and additional software modules were developed at the University of Wisconsin, Space Science and Engineering Center.

While the product algorithms share the same theoretical basis as those in the operational ground system, differences in output should be expected due to differences in implementation and algorithm versions.
Known issues affecting this software are described in Section 8: Caveats and Known Issues.

To obtain the AITF Version 2.0 software, as well as documentation, test data and other software packages, visit the CSPP Geo website (https://cimss.ssec.wisc.edu/csppgeo/).

1.2 What’s New

CSPP Geo AITF Version 2.0beta4 includes the following changes relative to Version 1.0.36:

- This is a new major release that transitions to a new and extensively rewritten version of the underlying software (AIT Framework v2).
- Product algorithms have been updated from the “baseline” to the "enterprise" versions, containing the first major science upgrades since the initial versions that were developed for GOES-16. Some enterprise products are not yet being generated in the GOES-R ground system, and should be considered preliminary and unvalidated. For information on specific improvements in each product, refer to the NOAA enterprise ATBD for that product.
- The interface has changed somewhat, though it is intended to largely be backward compatible to the 1.x releases for the default usage.
- A subset of products is available for GOES-17 ABI.
- Additional products are generated: Low Cloud and Fog (GOES-16 only) and Derived Motion Winds (GOES-16 and -17).
- Parallelism defaults (i.e. segment sizes) have been adjusted to reduce product latency on spec systems.
- A substantial re-working of the ancillary download and mirror functions has been done. This should retain default behavior expectations while allowing additional options including http/https and backup server URLs.
- A new script called aitf-update-cache has been added to be used in periodic syncing of dynamic ancillary data, replacing the script aitf-mirror, which has been deprecated.
- Default date ranges in the ancillary mirror script have been adjusted to prevent downloading of unnecessary data on initial invocation.
- Updates to PUG format conversion and Quicklook functionality to include new products, functionality, and speed improvements.
- Use of data from previous timesteps has been enabled as input to the new Derived Motion Winds and Low Cloud and Fog products. The data is maintained in a temporal cache in a user-specified location.
- Various issues affecting the Version 1 software and products have been addressed.
1.3 System Requirements

Minimum system requirements for the CSPP Geo AIT Framework software are as follows. Note that this specification allows for processing of data from a single satellite, and does not account for quicklook image generation.

- Intel Xeon E5 v2 “Ivy Bridge” or later, 20-core (2 x 10-core), 2.8GHz CPU with 64-bit instruction support,
- Minimum 192 GB RAM
- CentOS 7 or CentOS 8 64-bit Linux (or other compatible 64-bit Linux distribution),
- 14 TB disk space (does not include long-term storage)

Note that Perl is required to run the software. While Perl is included in a full install of CentOS 7 and CentOS 8, it may need to be explicitly added to a minimal install (e.g. “sudo yum install perl”).

An internet connection is required to download dynamic ancillary data. The expected volume of dynamic ancillary data is about 2.4GB per day.

Though you are free to use the command shell of your choice, the instructions and examples contained in this document assume that you are using bash. To check the command shell, run “echo $SHELL”.

1.4 Test Data

The test case consists of GOES-16 and GOES-17 ABI L1B data that was generated by the CSPP Geo GRB package, from data acquired on an antenna at the University of Wisconsin via the GRB stream. The supporting dynamic ancillary data is also included.

1.5 Copyright, Attributions and Disclaimer

Portions of the source code in this software package are copyrighted by the University of Wisconsin Regents. This software package includes binary Python runtime software licensed under the GNU General Public License and other open-source licenses; full sources for these binaries can be found at https://gitlab.ssec.wisc.edu/rayg/ShellB3/-/tree/2e426617fb3544f8ee1e1b5efcdd232c8d5ff5bd. Binary executable files and third-party source code included as part of this software package are copyrighted and licensed by their respective organizations, and distributed consistent with their licensing terms. For more information, refer to LICENSE.md, distributed with the software package.
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Section 2: CSPP Geo AIT Framework Software

2.1 Software Overview

The AIT Framework software processes a set of GOES-16 or GOES-17 Level 1B files containing ABI radiances for a single image, and generates Level 2 geophysical products.

The program is called directly at the command line for each image to be processed. Multiple CPU cores are automatically utilized for each image in order to reduce product latency, with options available to control parallelization.

Dynamic ancillary data required for product generation is downloaded from SSEC servers and maintained in a data cache. In addition, a cache is maintained for Level 1B and Level 2 product files from previous image timesteps, which are used by some of the AITF Version 2 product algorithms if available.

Quicklook images can optionally be generated from Level 2 products.

2.2 Recommended Processing Configuration

A typical processing system at a GRB receiving site consists of one or more CSPP Geo software packages running in parallel. The GRB software package processes the raw packet stream as received from an antenna / demodulator, generating data from all GOES-R series instruments in real-time. ABI L1B data can then be processed by the AIT Framework package to generate Level 2 geophysical products. Note that the CSPP Geo Geo2Grid package can also be run on ABI L1B data to generate high quality imagery and animations.

Figure 1. GRB processing chain

It is recommended that the GRB and AITF software packages be run on separate machines to avoid resource contention. While the GRB software runs as a server, continuously processing
data received over two sockets, the AITF software must be called at the command line for each image timestep being processed. The user is responsible for developing "glue" logic tying together the processing components in a way that makes sense for their site configuration and using their preferred methodology. Typically this includes monitoring L1B product generation, transferring the data as needed, and invoking the AITF software on complete sets of L1B files.

2.3 AIT Framework Software Architecture

Note that this information is provided only as background; it is not necessary that the user has an understanding of the internal architecture in order to run the software.

Internally, the AIT Framework package is composed of discrete software components connected by glue logic. The primary software components, as shown in Figure 2, are:

- the AIT Framework core module, responsible for generating all Level 2 products other than Cloud Moisture Imagery (CMI),
- a CMI generation module,
- post-processing to convert AITF-native output to near-mission-standard format and add CSPP-Geo metadata, and
- an optional quicklook image generation module.

*Figure 2. CSPP Geo AIT Framework software components*
The AIT Framework core module is a binary that was compiled from C++ and Fortran code, with some additional Perl scripting. The other modules and glue logic were written in Python with some bash.

2.4 Input Data Requirements

2.4.1 ABI Level 1B Files

The primary input is L1B files containing calibrated, navigated ABI radiances. There are 16 files that make up a single ABI image timestep, with each file containing data from a single band.

In AITF Version 2.0 processing, ABI L1B files may be used from previous timesteps if available, in addition to the files from the current timestep (i.e. the primary timestep being processed).

The files must be in mission-standard NetCDF-4 format, as written by the CSPP Geo GRB software. Alternatively, the L1B files may be obtained from NOAA Production Distribution and Access (PDA), from the NOAA Comprehensive Large Array-data Stewardship System (CLASS) or from the cloud via the NOAA Big Data Program.

Refer to Vol. 3 of the GOES-R Series Product Definition and Users’ Guide (PUG) for the L1B file specification.

2.4.2 Dynamic Ancillary Data

The following dynamic ancillary datasets are needed to generate L2 products:

- 0.5 degree Global Forecast System (GFS) NWP data: nominally the 3, 6, 9, and 12 hour forecasts; 4 times per day (0:00, 6:00, 12:00, 18:00). The 15-hour forecast may be used as a fallback if a preferred forecast time is not available.
- Optimum Interpolation Sea Surface Temperature (OISST) data, daily.

The total volume of dynamic ancillary data downloaded per day is expected to be about 2.4 GB.

Dynamic ancillary data can be downloaded automatically as needed or periodically synced from servers maintained at the University of Wisconsin. Refer to Section 7.1 for more information on obtaining dynamic ancillary data.

Refer to Appendix A for detailed information on the use of dynamic ancillary data by the AIT framework software.
2.4.3 ABI Level 2 Files

In AITF Version 2.0 processing, Level 2 products that were generated in previous processing jobs may be used.

2.5 Quicklook Images

Quicklooks are medium-resolution images that can optionally be generated after processing to give the user an idea of what is happening in a scene, and to quickly see whether there were any obvious processing or data problems. Generation of images from all products in PNG format is supported in this version. By default, the quicklooks are generated as projected images with coastlines and geographic boundaries. Various options are available to control the appearance of the images.
Section 3: Installation

1) Download the program, static data and (optionally) test data tarballs from the CSPP Geo website (https://download.ssec.wisc.edu/files/csppgeo/)

   cspp-geo-aitf-2.0beta4.tar.gz
   cspp-geo-aitf-static-data-2.0beta4.tar.xz
   cspp-geo-aitf-test-data-20210301.tar.gz

2) Unpack the software and static data tarballs in the same location (these commands make take several minutes):

   tar xf cspp-geo-aitf-2.0beta4.tar.gz
   tar xf cspp-geo-aitf-static-data-2.0beta4.tar.xz

3) Next, set the environment variables CSPP_GEO_AITF_CACHE and CSPP_GEO_AITF_TEMPORAL_CACHE to indicate the locations where downloaded dynamic ancillary and locally generated temporal products, respectively, should be stored. The specified locations must exist when the program is executed.

   The ancillary and temporal data caches should be located on direct attached storage (i.e. local storage). Networked or distributed filesystems are currently an unsupported configuration for data caching, in part due to inconsistency in their support of file locking.

   For example:

   mkdir $HOME/aitf_2_0_cache $HOME/aitf_2_0_temporal_cache
   export CSPP_GEO_AITF_CACHE=$HOME/aitf_2_0_cache
   export CSPP_GEO_AITF_TEMPORAL_CACHE=$HOME/aitf_2_0_temporal_cache

   The second and third line above can be added to your shell login script (for example .bashrc or .bash_profile) to avoid having to set it whenever the AITF software is run.

4) Users can optionally add the AIT Framework processing scripts to their PATH by running the following commands:

   cd cspp-geo-aitf-2.0beta4
   export PATH="$PWD:$PATH"

   The AIT Framework software is now installed.
Section 4: Testing Your Installation

4.1 Running the AITF Test Case

The AITF test case consists of four Contiguous US (CONUS) sector images for GOES-16 and four CONUS sector images for GOES-17. The required dynamic ancillary data is included. All supported L2 products will be generated.

The total processing time for all images should be approximately 15 minutes for GOES-16 and 10 minutes for GOES-17, but may vary based upon computer hardware and load.

Note that the commands in this section assume you have added the main program directory to your PATH as described in Section 3 and set the CSPP Geo cache variables.

1) Unpack the test data in your preferred location:

```bash
tar xf cspp-geo-aitf-test-data-20210301.tar.gz
```

2) Run the following commands sequentially, to process a set of four GOES-16 CONUS sectors:

```bash
cd cspp-geo-aitf-test-data-20210301/
mkdir -p test-output/goes16

aitf input/goes16/*C01*s20210600001*.nc --cache-only --dynamic-data-dir \
testcase-cache --debug -vv -o test-output/goes16/0001

aitf input/goes16/*C01*s20210600006*.nc --cache-only --dynamic-data-dir \
testcase-cache --debug -vv -o test-output/goes16/0006

aitf input/goes16/*C01*s20210600011*.nc --cache-only --dynamic-data-dir \
testcase-cache --debug -vv -o test-output/goes16/0011

aitf input/goes16/*C01*s20210600016*.nc --cache-only --dynamic-data-dir \
testcase-cache --debug -vv -o test-output/goes16/0016
```

The CONUS processing will use the default maximum segment size of 1000 rows at 2km resolution, which will divide the image into two segments and will process them in parallel.

3) Run a similar set of commands sequentially, to process a set of four GOES-17 CONUS sectors:

```bash
mkdir -p test-output/goes17
```
4) Count the NetCDF-4 files in each output directory by running the following command (assumes bash):

```
for d in test-output/*/*; do printf "${d}: "; ls ${d}/*.nc | wc -l; done
```

Output from each of the GOES-16 invocations is located in a separate sub-directory of "test-output/goes16". The first three output directories (0001, 0006, 0011) should contain 30 NetCDF-4 files (*.nc) and one log file (GOES*aitf.log). The last directory (0016) should have 33 NetCDF-4 files as this timestamp had sufficient data in the temporal cache to produce Cloud Top Derived Motion Winds products.

Output from each of the GOES-17 invocations is located in a separate sub-directory of "test-output/goes17". The first three output directories (0001, 0006, 0011) should contain 22 NetCDF-4 files (*.nc) and one log file (GOES*aitf.log). The last directory (0016) should have 25 NetCDF-4 files as this timestamp had sufficient data in the temporal cache to produce Cloud Top Derived Motion Winds. The number of products for GOES-17 is smaller than the available GOES-16 products, which accounts for the reduced number of NetCDF-4 files for GOES-17.

For information on what is in each file, refer to Section 6: Output.

5) Check the log files for errors by running the following command (assumes bash):

```
for f in test-output/*/*/aitf.log; do echo "$f"; grep "ERROR" $f; done
```

Any error messages will be shown after the name of the file in which they occur. You should see a list of the log files but no error messages.

Reference output product files can be found in the “output” directory.
4.2 Creating Quicklook Images from the AITF Test Case Output

This section assumes you have added the main program directory to your PATH, as described in Section 3.

1) To create a GOES-16 CONUS quicklook image of Land Surface Temperature (LST) from the 0001Z test case using the default values, run:

```
cd test-output/goes16/0001
aitf-ql CG_ABI-L2-LSTC*.nc
```

The resulting PNG image should look similar to the one below:

![GOES-16, ABI L2+ Land Surface (Skin) Temperature from 2021-03-01 00:01:15.2Z](image)

Warning: Preliminary/Non-Operational Data.
Data created by capp-geo-aitf 2.0dev0. Plotted using C3PP ABI Quicklooks v0.7.

2) Next, create a quicklook image of the GOES-17 CONUS Cloud Top Height image from 0011Z that is 1000 pixels in width and 800 pixels in height:

```
cd ../../goes17/0011
aitf-ql --image_size 1000 800 CG_ABI-L2-ACHAC*.nc
```
The resulting output PNG should look similar to the image below:

GOES-17, ABI L2+ Cloud Top Height
from 2021-03-01 00:11:17.6Z

3) Finally, create an image of Band 8 Winds from the GOES-17 0016Z CONUS test output:

```bash
cd ../0016
aitf-ql CG_ABI-L2-DMWC-M6C08*.nc
```
The resulting output image should look similar to the one below:

GOES-17, ABI L2 Derived Motion Winds (Band 8, Cloud Targets)
from 2021-03-01 00:06:17.6Z

Warning: Preliminary/Non-Operational Data.
Data created by capp-geo-air 2.0beta4. Method using CPP ABI Quicklooks v0.7.
Section 5: Basic Usage

There are three user-callable scripts located in the main program directory: the main processing script (aitf), the ancillary cache sync script (aitf-update-cache) and the quicklook image generation script (aitf-ql).

Input files are specified as arguments to the scripts, and program execution parameters can be specified with command line options. Refer to the section below on each script for details.

An exit code of 0 from a user-callable script indicates that processing completed normally, while a non-zero exit code indicates that processing could not be completed due to an error.

5.1 AIT Framework Main Processing Script

The main processing script for the AIT framework package is aitf. By default, aitf will process the ABI L1B input files and create the full set of supported L2 product files.

To list the basic set of available options, run "aitf -h". The result of this command is shown below. To list a larger set of options including advanced options, run "aitf -x" (refer to Section 7 and Appendix B for more information on advanced options).

       [--debug] [--products PRODUCTS] [--skip-products SKIP_PRODUCTS]
       [--help-products]
       LEVEL_1B_FILE

Start an AIT Framework run

mandatory arguments:
   LEVEL_1B_FILE One of the level 1B input files. Additional files will be identified automatically.
   -o DIR, --output-dir DIR directory to write output into

optional arguments:
   -h, --help show this help message and exit
   --expert, -x show all help, including advanced options, and exit
   -v, --verbose increase verbosity of output; -v adds general information, -vv adds debugging information (default: progress, warnings, and errors)
   -q, --quiet only print errors and warnings
   --cache-only don't attempt to download dynamic ancillary data
Specifying input files. For each ABI image, there are 16 L1B files, each with radiance data from a single detector band. A single L1B file must be specified as the final argument to aitf, and the L1B files for other bands will be ingested automatically. The band number of the specified file does not matter, but the files for all 16 bands must be located in the same directory.

Specifying output location. The output directory must be specified with the -o or --output_dir option. If the output directory does not exist when the program is executed, it will be created. Temporary program files are written to the output directory in addition to the final output. Any output from previous program invocations should be cleared from the output directory before calling the program to avoid conflicts. Similarly, if multiple invocations of aitf are running simultaneously, output should be written to separate directories.

Selecting Level 2 products. By default, all supported L2 products will be generated. This behavior can be overridden by specifying that only certain products should be generated with the --products option, or by specifying that certain products should be omitted with the --skip-products option. These options are followed by one or more of the product abbreviations listed below, separated by commas. Note that some products are grouped because they are generated by the same algorithm.

<table>
<thead>
<tr>
<th>Product Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>acm</td>
<td>Clear sky mask</td>
</tr>
<tr>
<td>actp</td>
<td>Cloud top phase</td>
</tr>
<tr>
<td>acx</td>
<td>Cloud top height, pressure, and temperature</td>
</tr>
<tr>
<td>adp</td>
<td>Aerosol detection</td>
</tr>
<tr>
<td>amv</td>
<td>Derived motion winds</td>
</tr>
<tr>
<td>aod</td>
<td>Aerosol optical depth</td>
</tr>
<tr>
<td>cmi</td>
<td>Cloud and moisture imagery</td>
</tr>
<tr>
<td>codd</td>
<td>Day cloud optical depth and particle size</td>
</tr>
<tr>
<td>codn</td>
<td>Night cloud optical depth and particle size</td>
</tr>
</tbody>
</table>
For example, to omit the Land Surface Temperature and Aerosol Optical Depth products, specify the following option:

```
--skip-products lst,aod
```

Note that some products depend on other products, and any product that is required by a downstream product will be generated even if it is not explicitly selected by the user.

### 5.2 AIT Framework Quicklook Image Script

Quicklook images in PNG format can be created from the L2 NetCDF-4 output files by running the `aitf-ql` script, which can be found in the top level of the install directory.

```
[input_files ...]
```

Create quicklooks plots from CSPP Geo NetCDF product file.

**Positional arguments:**
- `input_files` Paths to one or more CSPP Geo NetCDF product files. If a directory is given, the program will examine all files in that directory to see if they are appropriate. This argument will also expand meta-characters understood by python's glob module (including *, ?, and +, among others). Please see the documentation for glob for specific syntax.

**Optional arguments:**
- `-h`, `--help` show this help message and exit
- `--image_size WIDTH HEIGHT` The size of the output image [*width*, *height*] in pixels. User input will be rounded to the nearest 10 pixels. [default: '[2000.0, 1600.0]'
- `-o OUTPUT_DIR`, `--output_dir OUTPUT_DIR` The directory where the generated quicklooks images will be put.
- `-O OUTPUT_FILE_PREFIX`, `--output_file_prefix OUTPUT_FILE_PREFIX` String to prepend to the automatically generated png names. [default: ]
-S STRIDE, --stride STRIDE
Sample every STRIDE rows and columns in the data, where stride is specified as a positive integer. By default or if you pass in a negative number the software will generate a stride automatically to decrease your data size to near the output image size (in pixels). If you want to plot all the data, pass in 1 for the stride. Warning: Plotting all the data can cause slow plotting and high memory usage for large data sets.

--customrange CUSTOM_DATA_RANGE
Use a custom range for plotting quicklooks. The range should be defined using the syntax min:max and will be applied to all quicklooks generated during this run.

By default the quicklooks will be plotted with a colorbar using custom range limits for some variables and the valid_range attributes for other variables. If --customrange and --rawrange are both present, the custom range will be used. If --customrange and --fileloadedrange are both present, the custom range will be used.

--rawrange
Do not pay attention to the valid range or any flag information, just display the colormap using the raw data range. By default the quicklooks will be plotted with a colorbar using custom range limits for some variables and the valid_range attributes for other variables. If --rawrange and --customrange are both present, the custom range will be used. If --rawrange and --fileloadedrange are both present, the custom range will be used.

--fileloadedrange
Use the range data in the valid_range attribute given in the attributes in the data file for plotting quicklooks. By default the quicklooks will be plotted with a colorbar using custom range limits for some variables and the valid_range attributes for other variables. If --customrange and --fileloadedrange are both present, the custom range will be used. If --rawrange and --fileloadedrange are both included in the command line call, the raw range will be used.

--no-convert
Do not convert level one radiance data to reflectances or brightness temperatures.

--onlyvar ONLY_VAR_NAME
Process only the variable name given. No other variables from the input files will be used to make quicklooks. If your variable name has spaces use single quotes around it.

--unnavigated
Do not navigate the data on a map, just display it as
--dataonly  Plot the data at full resolution and nothing else. No labeling or navigation will appear in the output images.

-v, --verbosity  each occurrence increases verbosity 1 level. If you do not include this argument the verbosity will default to INFO. -v=ERROR -vv=WARNING -vvv=INFO -vvvv=DEBUG

-V, --version  Print the CSPP FW Quicklooks package version

One or more L2 product files or a directory containing L2 product files must be specified as arguments. If files contain multiple main products (e.g. aerosol detection), plots will be generated for all products.

The default colorbar scale for each plot is set to the representable range of values based on the attributes of the variable being plotted. If the --rawrange option is specified, the colorbar scale will be based on the actual range of data in the variable, which may result in plots with a greater dynamic range.

In quicklooks for the winds products, wind vectors with quality issues (as indicated by data quality flags) are not plotted.

5.3 Ancillary Sync Script

The ancillary sync script, aitf-update-cache, can be used to sync data from the remote server to the local cache. To see a list of the standard options, run “aitf-update-cache -h”, the results of which are shown below.


Maintain a local cache of dynamic data needed by the aitf in a local cache. By default downloads files not already present going back 1 day from the current system time, and deletes files from the cache that have not been used in the last 7 days.

positional arguments:
  CACHE_DIR  Directory to maintain local mirror on (default: environment variable CSPP_GEO_AITF_CACHE)

optional arguments:
  -h, --help  show this help message and exit
  --keep-old  keep old files; do not remove them
--expiration DURATION
how long to keep unused files for (default: 7d)

--newest DATE
download data required for satellite scans through DATE (default: tomorrow)

--oldest DATE
download data required for satellite scans as far back as DATE (default: based on --download-window)

--download-window DURATION
download data required for satellite scans as far back as DURATION before --newest (default: 2d)

--verbose, -v
increase verbosity of output; -v adds a summary, -vv adds progress, -vvv adds general information, -vvvv adds debugging information (default: only warnings and errors)

--quiet, -q
only print errors

A DURATION is an integer with a unit suffix: d (days), h (hours), m (minutes), s (seconds), or w (weeks).

A DATE is a date and optional time. The form "2021-02-27T14:50:00" is recommended. The form "20210581450000" (YYYYjjjHHMMSS) is also understood.

By default, aitf-update-cache will only print screen output if a problem is encountered. Verbosity can be increased with option -v.

For information on syncing dynamic ancillary data using aitf-update-cache, refer to Section 7.

Example: Download all dynamic ancillary files that are required to process data from the past 2 days and are not already present in the cache (as specified by environment variable CSPP_GEO_AITF_CACHE).

aitf-update-cache

5.4 Ancillary Mirror Script (Deprecated)

The ancillary mirror script aitf-mirror is provided for backward compatibility with the version 1 software, but is deprecated in version 2. Users are advised to run the script aitf-update-cache instead to periodically sync ancillary data from CSPP Geo servers to the local cache. The aitf-update-cache script offers a simplified interface and more limited functionality. Specifically, downloading the ancillary data required to process a specific image time (option --required-for-scan-time) is not supported. This functionality should not be needed, since the main processing script (aitf) by default will download any ancillary files that are required for the image being
processed and not already present in the cache. However, please contact the CSPP Geo team if you rely on this functionality and would like it to be continued in future releases.
Section 6: Output

The main processing script writes output in the form of product files, a main log file and temporary files.

Output is written to the location specified with the option -o or --output-dir. By default temporary files are deleted before program termination, leaving only product files and the main log file. However, temporary files will be preserved for troubleshooting purposes if processing problems are encountered, or if option -d or --debug is specified.

Users are responsible for deleting files in the output directory in order to prevent disks from filling up. In addition, users are responsible for cleaning up the temporal cache, as described in Section 7.9, since there is no automated method to do that in this release.

6.1 Product Files

Successful processing results in a set of Level 2 product files in the output directory.

With the default set of algorithms selected, an invocation of the AIT Framework will normally generate 36 product files for GOES-16, and 29 product files for GOES-17. Each product listed in the table below is written to a separate file, but note that there is one Cloud and Moisture Imagery (CMI) file for each band (16 total), and there is one Derived Motion Winds file for each supported target type and band combination (6 total, or 7 if high-resolution Cloud Top winds is enabled).

Fewer products may be generated due to missing input data. Notably, Derived Motion Winds products will not be generated until sufficient temporal input data has accumulated.

Some product files contain more than one main product variable, as indicated below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Product ID in filename</th>
<th>Main product variables</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol Detection:</td>
<td>ADP</td>
<td>Dust</td>
<td>Dust binary mask</td>
<td>[1]</td>
</tr>
<tr>
<td>Smoke and Dust (GOES-16</td>
<td></td>
<td>Smoke</td>
<td>Smoke binary mask</td>
<td>[1]</td>
</tr>
<tr>
<td>16 only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerosol Optical Depth</td>
<td>AOD</td>
<td>AOD</td>
<td>Aerosol optical depth at 550 nm</td>
<td>[1]</td>
</tr>
<tr>
<td>(GOES-16 only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear Sky Masks</td>
<td>ACM</td>
<td>BCM</td>
<td>Cloud mask (binary)</td>
<td>[1]</td>
</tr>
<tr>
<td>Cloud and Moisture Imagery (bands 1 through 6)</td>
<td>CMIP</td>
<td>CMI</td>
<td>TOA Lambertian equivalent albedo (reflectance) multiplied by cosine solar zenith angle [1]</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------</td>
<td>-----</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Cloud and Moisture Imagery (bands 7 through 16)</td>
<td>CMIP</td>
<td>CMI</td>
<td>TOA brightness temperature K</td>
<td></td>
</tr>
<tr>
<td>Cloud Optical Depth (day, GOES-16 only)</td>
<td>CODD</td>
<td>COD</td>
<td>Cloud optical depth at 640 nm [1]</td>
<td></td>
</tr>
<tr>
<td>Cloud Optical Depth (night, GOES-16 only)</td>
<td>CODN</td>
<td>COD</td>
<td>Cloud optical depth at 640 nm [1]</td>
<td></td>
</tr>
<tr>
<td>Cloud Particle Size Distribution (day, GOES-16 only)</td>
<td>CPSD</td>
<td>PSD</td>
<td>Effective radius of cloud-condensed water particles at cloud top um</td>
<td></td>
</tr>
<tr>
<td>Cloud Particle Size Distribution (night, GOES-16 only)</td>
<td>CPSN</td>
<td>PSD</td>
<td>Effective radius of cloud-condensed water particles at cloud top um</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Height</td>
<td>ACHA</td>
<td>HT</td>
<td>Geopotential height at cloud top m</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Phase</td>
<td>ACTP</td>
<td>Phase</td>
<td>Cloud phase category [1]</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Pressure</td>
<td>CTP</td>
<td>PRES</td>
<td>Air pressure at cloud top hPa</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Temperature</td>
<td>ACHT</td>
<td>TEMP</td>
<td>Air temperature at cloud top K</td>
<td></td>
</tr>
<tr>
<td>Derived Motion Winds (cloud top target; bands 2, 7, 8, 14)</td>
<td>DMW</td>
<td></td>
<td>Wind direction measured positive clockwise from due north degree</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wind speed m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wind vector's air pressure hPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wind vector's brightness temperature [see caveat in Section 8] K</td>
<td></td>
</tr>
</tbody>
</table>
### Derived Motion Winds (clear sky target; bands 8, 9, 10)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>wind_direction</code></td>
<td>Wind direction measured positive clockwise from due north</td>
</tr>
<tr>
<td><code>wind_speed</code></td>
<td>Wind speed</td>
</tr>
<tr>
<td><code>pressure</code></td>
<td>Wind vector’s air pressure</td>
</tr>
<tr>
<td><code>temperature</code></td>
<td>Wind vector’s brightness temperature [<em>see caveat in Section 8</em>]</td>
</tr>
</tbody>
</table>

### Land Surface Temperature (GOES-16 only)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>LST</code></td>
<td>Land surface (skin) temperature K</td>
</tr>
</tbody>
</table>

### Low Cloud and Fog (GOES-16 only)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Fog_Depth</code></td>
<td>Thickness of fog/low cloud layer m</td>
</tr>
<tr>
<td><code>IFR_Fog_Prob</code></td>
<td>Probability that IFR conditions are present %</td>
</tr>
<tr>
<td><code>LIFR_Fog_Prob</code></td>
<td>Probability that LIFR conditions are present %</td>
</tr>
<tr>
<td><code>MVFR_Fog_Prob</code></td>
<td>Probability that MVFR conditions are present %</td>
</tr>
</tbody>
</table>

### Navigation (unofficial product)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Latitude</code></td>
<td>Grid Latitude ° north</td>
</tr>
<tr>
<td><code>Longitude</code></td>
<td>Grid longitude ° east</td>
</tr>
</tbody>
</table>

Refer to the Algorithm Theoretical Basis Document (ATBD) for each algorithm for information on the product contents and scientific basis of the algorithm.

In Version 2, the Derived Motion Winds and Low Cloud and Fog products have been added, and the product algorithms have been upgraded from the baseline versions to the enterprise versions, incorporating recent updates from the GOES-R Science Team.

Note that the “Aerosol” variable was removed in the enterprise version of the Aerosol Detection product.
6.1.1 Product File Formats

Level 2 product files are generated in mission standard NetCDF-4 format, except for the Low Cloud and Fog product, which is in the AITF-native NetCDF-4 format.

**Mission standard format:** For information on the mission-standard file format, including variables and attributes included in each product, refer to Volume 5 of the PUG.

The type of each mission standard product file can be identified by a unique product ID field in the filename, as shown in the table in Section 6.1. An example Cloud Top Height (“ACHA”) product filename is shown below.

```
CG_ABI-L2-ACHAM1-M6_G16_s20191471800485_e20191471800554_c20203562237180.nc
```

Mission standard product files other than CMI are created by running a post-process to convert AITF-native files to the format documented in the PUG. Known differences in format are documented in Section 6.1.3.

**AITF-native file format:** The Low Cloud and Fog product is provided in the AITF-native NetCDF-4 format, without conversion to the mission standard format. This is similar to the operational fog product that is available from NOAA CLASS, but there are some differences as noted in Section 6.1.3, including a different file naming convention. The operational fog product is not documented in the PUG, but will be documented in the NOAA Fog External Users’ Manual, planned for release by NOAA NESDIS by February 2022.

An example Low Cloud and Fog product filename is shown below.

```
GOES16_ABI_2KM_FD_2022012_0800_20_AVIATION_FOG_EN.nc
```

6.1.2 Quality Flags

Quality flags are available in all product files on a per-observation level. It is recommended that users check quality flags before using product data. Data that otherwise looks reasonable may have defects that were flagged during processing and can only be detected using quality flags. For some products, a significant percentage of observations may be flagged with defects.

In all mission standard format product files, the name of the quality flag variable is “DQF”. In the Low Cloud and Fog product, the name of the quality flag variable is “Fog_Qf”. The remainder of this section describes interpretation of the DQF variables in the mission standard format products. For interpretation of the Low Cloud and Fog quality flags, refer to the Low Cloud and Fog Enterprise ATBD.
A value of 0 in a DQF variable indicates that no defects were found for that observation, while positive values indicate defects are present. The meanings of the different values are indicated by the variable attributes “flag_values” and “flag_meanings”.

If a quality variable is intended to be interpreted as a bit-mask variable, it will also have the attribute “flag_masks”. Currently only the DQF variable in the Cloud Top Pressure product falls in that category.

Refer to the CF Standard for information on using the “flag_*” attributes to interpret the values of quality variables.

6.1.3 Differences Compared to Operational Products

Please note that differences exist in both the format and contents of products compared to the mission documentation and operational product. These differences include:

- Filenames of mission-standard format products are prefixed with “CG” instead of “OR”, to distinguish from products that were generated by the GOES-R Ground System.
- Quantitative differences in products due to differences in algorithm implementations and versions.
- For some products, DQF values are specified differently in the ATBD and the PUG. In these cases, CSPP Geo products follow the specification in the ATBD and the operational products follow the PUG. Note that CSPP Geo DQF variables contain CF-compliant attributes describing the meaning of the individual bits or overall values.
- Some secondary statistical and summary variables are omitted from CSPP Geo product files. While data quality flags (DQFs) are included in CSPP Geo products, the more detailed product quality information is not.
- The values of variable attributes specifying fill values, scaling, valid ranges and signedness may not match the operational product (or the PUG). However they should be consistent with the data, so they should be used to interpret the data. Note that the values of these attributes may change in a future release.
- The _Unsigned attribute is not used in CSPP Geo products. However note that products follow CF conventions for specifying packed data (using scale_factor and add_offset attributes).
- Cloudy and space pixels in the Aerosol Detection product are set to the fill value in the operational product, and to 0.0 in the CSPP Geo product.
- There are separate daytime and nighttime files for the Cloud Optical Depth and Cloud Particle Size Distribution products generated by CSPP Geo, consistent with the ATBDs for those algorithms. In the operational products there is a single file that includes merged daytime and nighttime products. Note that daytime files may contain no data if the image time is at night, and vice versa.
- Data types differences exist between CSPP Geo and operational ADP products. This may be due to an issue in the operational products.
• All CSPP Geo products are written at 2-km resolution, other than CMI for bands 1, 2, 3 and 5, and the Derived Motion Winds product.
• Band 9 and band 10 clear sky winds filenames contain the identifier “DMWV” in CSPP Geo products, and “DMW” in the operational products (as of December 2021).
• The Low Cloud and Fog product follows a different file naming convention, compared to the operational product. This may be addressed in a future release.
• The Low Cloud and Fog product contains added projection information (as is found in PUG-format products), compared to the operational product

6.1.4 Derived Motion Winds Product

The Derived Motion Winds product is an outlier, in that it requires input ABI Level 1B data from bracketing timesteps, in addition to the timestep being processed. Consequently, the Winds product requires a “ramp-up” period after the initial program invocation to accumulate Level 1B context, and in general will not be generated if sufficient Level 1B context is not available. In addition, for a given aif invocation, the winds product times will be earlier than the time of the other products and the primary Level 1B input file. Refer to Section 7.8 for more information on temporal dependencies.

As described in the PUG Volume 5, the Derived Motion Winds product is derived by tracking environmental features, specifically clouds and clear sky water vapor, over multiple ABI observations. For each combination of tracking types and ABI bands that is used as input, algorithm processing occurs independently and a separate product file is generated, as described in the table below.

Nominally six Derived Motion Winds product files are generated for each ABI image timestep, with the product sub-type indicated by a token in the filename. Note that the band 2 (high-resolution Cloud Top) product is disabled by default in the Version 2 beta release, but can be enabled by specifying option --ct-winds-hr.

<table>
<thead>
<tr>
<th>ABI band</th>
<th>tracking type</th>
<th>filename token (Full disk, Mode 6)</th>
<th>resolution</th>
<th>day/night</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Cloud Top</td>
<td>DMWF-M6C02</td>
<td>500m</td>
<td>day</td>
</tr>
<tr>
<td>7</td>
<td>Cloud Top</td>
<td>DMWF-M6C07</td>
<td>2km</td>
<td>night</td>
</tr>
<tr>
<td>8</td>
<td>Cloud Top</td>
<td>DMWF-M6C08</td>
<td>2km</td>
<td>day/night</td>
</tr>
<tr>
<td>8</td>
<td>Clear Sky WV</td>
<td>DMWVF-M6C08</td>
<td>2km</td>
<td>day/night</td>
</tr>
<tr>
<td>9</td>
<td>Clear Sky WV</td>
<td>DMWVF-M6C09</td>
<td>2km</td>
<td>day/night</td>
</tr>
<tr>
<td>10</td>
<td>Clear Sky WV</td>
<td>DMWVF-M6C10</td>
<td>2km</td>
<td>day/night</td>
</tr>
</tbody>
</table>
Below is an example set of Derived Motion Winds filenames, for a single CONUS timestep:

CG_ABI-L2-DMWC-M6C07_G16_s20213611546171_e20213611548555_c20220090050430.nc
CG_ABI-L2-DMWC-M6C08_G16_s20213611546171_e20213611548555_c20220090050430.nc
CG_ABI-L2-DMWC-M6C14_G16_s20213611546171_e20213611548555_c20220090050430.nc
CG_ABI-L2-DMWVC-M6C08_G16_s20213611526171_e20213611528555_c20220090051020.nc
CG_ABI-L2-DMWVC-M6C09_G16_s20213611526171_e20213611528555_c20220090051020.nc
CG_ABI-L2-DMWVC-M6C10_G16_s20213611526171_e20213611528555_c20220090051020.nc

6.1.5 Navigation Files

In addition to the L2 product files, the AITF generates a navigation file (*NAV*.nc) that contains pixel latitudes and longitudes at 2-km resolution. This is provided as an alternative to the projection information that is contained in the L2 product files, but it is not an official product and is not described in the PUG.

An example navigation filename is shown below. The format and contents of the navigation file are shown in Appendix C.

CG_ABI-L2-NAVM1-M6_G16_s20191471800485_e20191471800554_c20203562237180.nc

6.2 Log Files

Each time the program is invoked, a main log file is created in the output directory. The log file contains informational messages, warnings and errors, as well as timestamps indicating the time the message was logged.

An example log file name is:

GOES16_ABI_2KM_MESO_2019147_1800_48_aift.log

To see a list of any errors encountered while processing, type:

```bash
grep 'CRITICAL\|ERROR' *aift.log
```

Normally, you will see no output, indicating no errors occurred.
6.3 Temporary Files

Temporary files are written to a subdirectory of the output directory called “work”. This directory is automatically deleted after processing is completed, unless an error occurred or option --debug was specified. Generally these temporary files are not useful, however they may help with troubleshooting in some situations.
Section 7: Advanced Usage

Refer to Appendix B for a list of `aitf` advanced usage options.

7.1 Obtaining Dynamic Ancillary Data

Dynamic ancillary data is required as an input to generate Level 2 products. The dynamic ancillary data is pre-processed and staged on servers located at the University of Wisconsin-Madison. Note that ancillary files are only retained on the servers for a limited period of time; processing of old or archived data is not supported.

Ancillary data can be downloaded by either of two methods:

1) On-the-fly, as needed when the `aitf` script is executed, or
2) Periodically synced from the server to the processing machine, for example via a cron job.

The “on-the-fly” download method is enabled by default. Users do not need to configure ancillary downloading if this method is satisfactory. Refer to the sections below for more information.

7.2 Downloading Dynamic Ancillary Data “On-the-Fly”

By default, each time the `aitf` script is executed, the required dynamic ancillary files are automatically downloaded (“on-the-fly”) to the ancillary data cache if they are not already present. This method has the advantage of simplicity from a user perspective, but note that whenever a new ancillary file is needed, the processing job will be delayed while that data is downloaded. In addition, a reliable internet connection is needed at runtime to ensure successful processing. See Section 2.4.2 for ancillary data volume and frequency.

These problems can potentially be avoided by periodically syncing ancillary data using `aitf-update-cache` as described in Section 7.3.

“On-the-fly” downloading can be disabled by specifying option `--cache-only` when calling `aitf`.
7.3 Syncing Dynamic Ancillary Data

The script `aitf-update-cache` can be used to periodically sync dynamic ancillary data from the remote server to the cache. By downloading ancillary data before it is needed, users can avoid the occasional product latency impacts (or in the worst case processing failures) associated with on-the-fly downloading. Users who are processing data on “air-gapped” machines without internet access can sync ancillary data to another machine and transfer it over manually.

To maintain sync between the remote server and the cache, it is recommended to run `aitf-update-cache` every 30 minutes. Feel free to optimize this frequency for your local conditions and needs, but please do not check more often than every 30 minutes to avoid over-taxing the CSPP Geo ancillary data servers.

The location of the cache is specified by an argument to `aitf-update-cache`, or by the environment variable `CSPP_GEO_AITF_CACHE` if the argument is not specified.

A simple way to automatically call `aitf-update-cache` at fixed time intervals is to use `cron`. For example, the following crontab entry will call `aitf-update-cache` every 30 minutes. Note that the full path to the cache location should be explicitly specified as an argument when calling `aitf-update-cache` via `cron`.

```
0,30 */ * * * /opt/cspp-geo-aitf-2.0/aitf-update-cache --quiet /var/cache/cspp-geo-aitf
```

The first time `aitf-update-cache` is called, by default it will download ancillary files sufficient to process data going back 2 days from the current system time. Subsequent calls will download only new files, if any are available. Command line options exist to override this behavior, for example to specify that only the ancillary data needed for a specific date range of input data should be downloaded.

If `aitf-update-cache` is used to sync ancillary data, “on-the-fly” downloading can still be used as a back-up method, in case syncing fails for some reason.

7.4 Ancillary Data Cache

The location of the ancillary data cache is specified by the environment variable `CSPP_GEO_AITF_CACHE`. Ancillary data downloaded by either method will land in that location, and the main processing script `aitf` will check for ancillary data in that location. Generally the user can set the environment variable to a suitable location and not worry about the cache thereafter.
Note that both the aitf and aitf-update-cache script offer methods to override the location of the cache as specified by CSPP_GEO_AITF_CACHE.

By default, each time the aitf or aitf-update-cache script is called, files older than 7 days are deleted from the cache, based on the most recent usage by the AITF software (as indicated by Linux mtime). Therefore the user is not required to manually remove old files from the cache provided sufficient disk space is available.

The default cache cleanup behavior can be overridden with option --cache-only in the aitf script, and options --keep-old and --expiration in the aitf-update-cache script.

The software uses file locking in the ancillary data cache to prevent multiple downloads of the same ancillary file, and to ensure that processing jobs wait until the required ancillary files are present before proceeding. Users do not need to worry about conflicts between multiple aitf-update-cache or aitf instances regarding ancillary data.

The ancillary data cache should be located on direct attached storage (i.e. local storage). Networked or distributed filesystems are currently an unsupported configuration for ancillary data caching, in part due to inconsistency in their support of file locking.

7.5 Parallel Processing

Parallel processing is required in Level 2 product generation in order to keep up with the high data rate of the GRB stream and reduce overall product latency.

At a typical GRB receive site, AIT Framework Level 2 processing is initiated by user-developed automation scripting as complete sets of Level 1B files arrive on the system. At any given time, multiple aitf instances will be running on the same machine, processing different ABI image timesteps simultaneously.

Further parallelization is employed within each instance by dividing up each image spatially into "segments", which may then be processed in parallel. This reduces product latency at the cost of increased CPU and memory usage due to the added overhead to divide, process each segment, and recombine.

The default parallel processing behavior has been optimized to run on the recommended hardware. However, various options are available to the user to control spatial parallelization. These options are discussed in the following sections.

While in Version 1 parallel processing was accomplished using logic that was developed external to the core AIT Framework software, in Version 2 it is accomplished using internal parallelization functionality that has been added to the core software. This is expected to improve overall
performance, and simplifies the user interface. Most significantly, options related to “chunking” and “padding” have been eliminated.

7.6 Segmentation

*Segmentation* describes the process by which an input data image is divided into two or more sections, which are then processed in parallel. After processing has completed for all segments, the results are stitched back together to form the final product.

The segment size is controlled with the `--max-segment-rows` and `--max-segment-cols` command line options, and is specified in rows and columns at 2-km resolution. Note that these options specify the maximum size of a segment; for a given maximum size the actual size will be calculated based on the image size so that each segment is approximately the same size. The default maximum segment size is 1,000 rows at 2-km resolution, 2,000 rows at 1-km resolution and 4,000 rows at 0.5-km resolution, with an unlimited number of columns.

Increasing the number of segments will allow more processing to be done in parallel, potentially reducing product latency and helping to ensure that temporal dependencies are met (Section 7.8). However, those gains may be offset by increased overhead related to segmentation and stitching, as well as resource limitations on the processing machine such as CPU and memory availability. In addition, artifacts may occur in some products along segment boundaries.

While the default segment sizes have been found to work well on the recommended hardware, users may be able to obtain better performance by optimizing the segment sizes for their processing systems.

7.7 Simultaneous Jobs

Parallel work is done as "jobs", or simultaneous tasks.

The number of AIT Framework processing tasks done simultaneously is controlled by the `--jobs` command line option. It defaults to 10, which has been found to be a reasonable default. Generally it is recommended to leave this setting at the default value. However, if the number of segments is increased with the options `--max-segment-rows` and `--max-segment-cols`, to avoid unnecessary latency it may help to set `--jobs` to the maximum number of segments in any image.
7.8 Use of Temporal Data

The Low Cloud and Fog and the Derived Motion Winds product algorithms use ABI products from other image timesteps as input if they are available. This is sometimes referred to as “temporal data” or a “temporal dependency”.

In general the user does not need to worry about use of temporal data since it is managed automatically in CSPP Geo scripting; the information in this section is provided mainly as background. However, it is advisable to consider use of temporal data when configuring a reduced product schedule, as described in Appendix D. In addition, users may wish to check logs to ensure that the optimal temporal dependencies are being met on a given processing system. In order to be used, the temporal context data must be available when the program is invoked; therefore it is important that product latencies are not excessive.

Products are maintained in the temporal data cache and will be automatically used as temporal context when needed; thus temporal context is not explicitly specified as inputs in program invocation.

When running the software for the first time, or when processing has been interrupted, users should expect a “ramp-up period”, where for several invocations products are generated without the optimal temporal context (in the case of Low Cloud and Fog) or are not produced (in the case of Derived Motion Winds). This will continue until sufficient temporal context is accumulated.

The table below shows the time offset of the generated product, relative to the input product time, as well as the optimal and acceptable temporal context for the products that use them, relative to the output product time. Note that for Derived Motion Winds the temporal requirements are different for the Cloud Top (CT) and Clear Sky (CS) product types, and the current and context timesteps must be evenly spaced.

<table>
<thead>
<tr>
<th>Product</th>
<th>Image type</th>
<th>Output product time offset</th>
<th>Optimal temporal context (Mode 6)</th>
<th>Acceptable temporal context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derived Motion Winds (CT)</td>
<td>Full Disk</td>
<td>-20m</td>
<td>+10m, -10m</td>
<td>two other evenly spaced</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>-10m</td>
<td>+5m, -5m</td>
<td>bracketing timesteps,</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>-5m</td>
<td>+5m, -5m</td>
<td>with spacing from 5 to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 min</td>
</tr>
<tr>
<td>Derived Motion Winds (CS)</td>
<td>Full Disk</td>
<td>-30m</td>
<td>+30m, -30m</td>
<td>two other evenly spaced</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td></td>
<td></td>
<td>bracketing timesteps,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with spacing from 20 to</td>
</tr>
</tbody>
</table>
The Low Cloud and Fog algorithm uses Level 1B, Cloud Phase and Low Cloud and Fog products from previous timesteps, if available, in order to maintain product quality in the terminator region (solar zenith angle 70° to 90°). If present, the previous two consecutive timesteps are preferred. Otherwise the algorithm will fall back to using context data from the first two available timesteps within the last 60 minutes. As long as context data is available, any product degradation in the terminator region will be minimal. If no context is available, the product will still be generated but should be considered degraded in the terminator region.

The following commands can be run on logs to show what temporal data was used in Low Cloud and Fog processing. If no temporal data was used, the command will not print any output.

```
grep "tm[12]\[AVIATION_FOG_ENV"]" GOES*aitf.log
grep "tm[12]\[CLOUD_PHASE_ENV"]" GOES*aitf.log
```

The Derived Motion Winds algorithm requires ABI Level 1B data from temporally bracketing “before” and “after” timesteps in order to generate a product, in addition to L1B and L2 products from the middle (output) timestep. Since the AIT Framework software is intended to be run in forward processing on a live data stream, the output time must be earlier than the user-specified input time to ensure that the required input data is available. The times of the resulting Derived Motion Winds products are thus earlier than the time of the primary ABI file specified by the user, as well as the time of any other products that were generated by that program invocation.

The optimal temporal context, as indicated in the table above, will be used if available. Otherwise, the algorithm will fall back to using substitute context if available within the acceptable range. If no acceptable context is available, the Derived Motions Winds products will not be generated.

The product can be considered degraded if context spacing was used that is greater than the optimal spacing. The variable “seconds_between_images” in the Derived Motion Winds product indicates the spacing between the three input image times.

<table>
<thead>
<tr>
<th></th>
<th>Mesoscale</th>
<th></th>
<th>45 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Cloud &amp; Fog</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Disk</td>
<td>no offset (same as the input time)</td>
<td>-10m, -20m</td>
<td>one or two other previous timesteps from the last 60 min, or no context</td>
</tr>
<tr>
<td>CONUS</td>
<td>-5m, -10m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesoscale</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
7.9 Temporal Data Cache

The location of the temporal data cache is specified by the environment variable `CSPP_GEO_AITF_TEMPORAL_CACHE`. Any Level 1B and Level 2 products that can be used as temporal context are automatically cached by the main processing script, and are then loaded as needed by future processing jobs.

Note that the `aitf` script offers a method to override the location of the cache as specified by `CSPP_GEO_AITF_TEMPORAL_CACHE`.

Automated cleanup of the temporal cache has not been implemented for this beta release, therefore the user is responsible for cleanup of old files. It is recommended that files should be preserved in the temporal cache for at least 2 hours.

Below is an example of a cron tab entry that runs every 20 minutes and cleans out files that are older than 2 hours. Note that the full path must be specified in the cron tab entry rather than referencing an environment variable.

`*/20 * * * * /usr/bin/tmpwatch 2h /path/to/temporal-cache`

The temporal data cache should be located on direct attached storage (i.e. local storage). Networked or distributed filesystems are currently an unsupported configuration for data caching, in part due to inconsistency in their support of file locking.
1. End times in L2 product filenames may differ slightly from end times in product files generated on the ground system. (#222)

2. Under significantly degraded network conditions dynamic ancillary data may not download fully and can result in invalid or failed processing. This will be addressed in a future software update. (#235)

3. Warnings like the following may be generated by aiit-update-cache. These can happen routinely due to the timing of data arrival on the ancillary data server, and in general can safely be ignored. Tolerances will be increased in a future software version to eliminate these messages. (#82)

```
WARNING:root:Failed to download final or preliminary data from https://geodb.ssec.wisc.edu/ancillary/2019_07_14_195/avhrr-only-v2.20190714.nc and
https://geodb.ssec.wisc.edu/ancillary/2019_07_14_195/avhrr-only-v2.20190714_preliminary.nc
WARNING:root: Final data error: HTTP Error 404: Not Found
WARNING:root: Preliminary data error: HTTP Error 404: Not Found
```

4. In the Cloud Top Phase product, space pixels are set to the value indicating “unknown” instead of missing values as is done with other products, and there is a narrow band of pixels near the edge of the disk with values indicating “mixed phase”. This will be addressed in a future update to the science code. (#134)

5. The “temperature” variables in the Winds (AMV) products are incorrectly described as air temperature in attributes, when in fact they represent brightness temperature. This issue also affects the operational winds products. (fw2pug#24)

6. The software has not been tested on ABI Mode 3 and Mode 4 data, including GOES-17 data acquired during the cooling timeline. In particular it is expected that the different L1B cadence relative to Mode 6 may impact the products that use temporal data (Winds and Fog). (#251)

7. The latencies of CONUS and Full Disk Cloud Top Winds products may be improved in a future release, through performance optimizations that will allow a reduction in the offset of the output product times relative to the input product times. (#339)

8. Mesoscale Clear Sky Winds products are currently not generated, and Mesoscale Cloud Top Winds products have not been fully tested. (#340)
9. Band 2 (high resolution) Clear Sky winds has not been tested in forward processing, and is disabled by default in this release. A command line option is provided to enable it. (#341)

10. The intervals of temporal data (i.e. the spacing of the “before” and “after” timesteps) in winds processing should be equal, however use of asymmetric temporal intervals has been observed in offline processing, and rarely in forward processing in the mesoscale domain. (#338)

11. Missing Full Disk Winds products have been observed in GOES-16 forward processing, occurring in a regular pattern every ~12 hours. (#342)

12. Automated cleanup of the temporal cache has not yet been implemented, therefore the user is responsible for cleanup of old files. (#330)

13. The –required-for-scan-time option for aitf-mirror is currently broken. (#322)

14. Downloading and usage of RAP NWP data has not yet been implemented. The quality of the Low Cloud and Fog product over North America can be improved by use of RAP data. (#333)

15. The operational product uses IMS-SSMI snow mask while the current processing configuration is using NWP-derived snow mask, which has minor product impacts in comparison to the operational implementation. This will be addressed in a future release, with IMS as preferred and NWP as fallback option. (#291, #293, #295)

16. The file naming convention and file format followed by the Low Cloud and Fog product may be changed in a future release to more closely match the operational product. (#326)

17. The validity of Mesoscale Low Cloud and Fog products is unknown. Support for Mesoscale Low Cloud and Fog products may be removed in a future release. (#343)
Section 9: References

1. GOES-R Series Product Definition and Users’ Guide (PUG), Rev 2.2
   https://www.goes-r.gov/resources/docs.html

2. GOES-R Product Algorithm Theoretical Basis Documents (ATBDs)
   https://www.star.nesdis.noaa.gov/goesr/documentation_ATBDs.php

3. Climate and Forecast (CF) Metadata Convention
   https://cfconventions.org/
Appendix A: Use of Dynamic Ancillary Data

This section describes the use of dynamic ancillary data by the CSPP Geo AIT Framework software. This information is provided as background and to help with troubleshooting.

Dynamic ancillary files are acquired, converted and staged on CSPP Geo servers soon after they are made available by the data providers. However, it should be noted that outages on the data provider side may occasionally occur, resulting in failed AIT Framework processing.

**OISST:** The software uses the best single OISST file that is available, based on the following criteria:

1. The most recent OISST file with a model date (in the filename) preceding or matching the date of the image being processed will be used.
2. If both preliminary and non-preliminary files are available for the same model time, the non-preliminary file will be used. However, note that non-preliminary files are generally not available in time during forward processing.
3. OISST files with dates up to 7 days before the image time will be used. If no such file is available, processing will fail.

**GFS:** As mentioned in Section 2.4.2, the 3, 6, 9 and 12-hour GFS forecasts are normally used, and the 15-hour forecast may be used as a fallback if a preferred forecast time is not available. GFS forecasts are generated on the 00, 06, 12 and 18 model hours, so there are a total of 16 GFS files which may be used in a given day under nominal conditions.

For each processing job, a pair of GFS files is needed with forecast times that bracket the image time, in order to interpolate temporally to the image time.

1. Depending on the image time, either the 3 and 6-hour or the 6 and 9-hour forecast times will be used, if they are available for the appropriate model time.
2. The fallback if the 3 and 6-hour files are not available is to use the 9 and 12-hour files from the previous model run. This has been observed to happen routinely, even with a fast internet connection.
3. The fallback if the 6 and 9-hour files are not available is to use the 12 and 15-hour files from the previous model run. This should not happen routinely, but can happen in certain situations, for example if GFS data from a newer model run is delayed or unavailable.
4. If neither the preferred nor fallback pair of files is available, processing will fail.
Appendix B: Advanced aitf Options

A full help message including advanced options can be obtained by running aitf -x. The result of this command is shown below. The basic options are described in Section 5.1, and some of the more useful advanced options are described in Section 7.

Most options have reasonable defaults and should not need to be specified by the user. For example, options related to segmentation and parallel processing should be optimized by default for the recommended hardware.


Start an AIT Framework run

mandatory arguments:
LEVEL_1B_FILE One of the level 1B input files. Additional files will be identified automatically.
-o DIR, --output-dir DIR directory to write output into

optional arguments:
-h, --help show help message for basic options and exit
--expert, -x show all help, including advanced options, and exit
-v, --verbose increase verbosity of output; -v adds general information, -vv adds debugging information (default: progress, warnings, and errors)
-q, --quiet only print errors and warnings
--instrument-dir DIR directory holding instrument specific files (default: /data/users/graemem/workspace/aitf_2_0_beta4/cspp-geo-aitf-2.0beta3/lib/instruments/<instrument>)
--dynamic-data-dir DIR location of dynamic ancillary data; overrides $CSPP_GEO_AITF_CACHE environment variable
--cache-only don’t attempt to download dynamic ancillary data
--temporal-cache-dir DIR location of temporal cache directory; overrides $CSPP_GEO_AITF_TEMPORAL_CACHE environment variable
--max-segment-rows # maximum number of rows in each segment, specified at 2km resolution (default: 1000)
--max-segment-cols # maximum number of columns in each segment, specified at 2km resolution (default: all)
-j #, --jobs # maximum simultaneous jobs (default: 10)
-cmip-args ARGUMENTS

arguments to pass to aitf-cmip; run "libexec/aitf-cmip --help" to see options (default: --cmi --environment CG)

--force, -f Run despite warnings. NOT RECOMMENDED

--version print version and exit

--setup-only prepare directory and write scripts but do not run them

--debug, -d preserve temporary files (default: delete them unless an error occurs)

--stages STAGES comma separated list of stages to run; skipping stages may cause problems; choose from: setup process pug cmipgen clean (default: setup,process,pug,cmipgen,cmipgen,cmipgen)

--products PRODUCTS comma separated list of products to generate for ABI (default depends on satellite; see --help-products)

--ct-winds-hr Generate the high-resolution cloud top winds product. Only in effect if the Winds is already in the list of desired products (default: False)

--skip-products SKIP_PRODUCTS comma separated list of products to not generate, overrides --products

--help-products list available products and exit

--sequential Do primary processing sequentially (default: parallel)

@filename - A file specified this way will be read as additional command line arguments, one per line.
Appendix C: Navigation File Format

Below is an example showing the format of the navigation file that is created by the AITF software.

```netcdf
CG_ABI-L2-NAVC-M6_G17_s20210600016176_e20210600018560_c20220122050320 {
  dimensions:
    x = 2500 ;
    y = 1500 ;
    number_of_image_bounds = 2 ;
    number_of_time_bounds = 2 ;
  variables:
    double t ;
      t:long_name = "J2000 epoch mid-point between the start and end image scan in seconds" ;
      t:standard_name = "time" ;
      t:units = "seconds since 2000-01-01 12:00:00" ;
      t:axis = "T" ;
      t:bounds = "time_bounds" ;
    double time_bounds(number_of_time_bounds) ;
      time_bounds:long_name = "Scan start and end times in seconds since epoch (2000-01-01 12:00:00)" ;
    float Latitude(y, x) ;
      Latitude:_FillValue = -999.f ;
      Latitude:valid_range = -90.f, 90.f ;
      Latitude:long_name = "Latitude" ;
      Latitude:standard_name = "grid_latitude" ;
      Latitude:units = "degree_north" ;
    float Longitude(y, x) ;
      Longitude:_FillValue = -999.f ;
      Longitude:valid_range = -180.f, 180.f ;
      Longitude:long_name = "Longitude" ;
      Longitude:standard_name = "grid_longitude" ;
      Longitude:units = "degree_east" ;

  // global attributes:
    :time_coverage_start = "2021-03-01T00:16:17.6Z" ;
    :time_coverage_end = "2021-03-01T00:18:56.0Z" ;
    :scene_id = "CONUS" ;
    :instrument_ID = "FM2" ;
    :instrument_type = "GOES R Series Advanced Baseline Imager" ;
    :spatial_resolution = "2km at nadir" ;
    :platform_ID = "G17" ;
    :naming_authority = "gov.nesdis.noaa" ;
    :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
    :standard_name_vocabulary = "CF Standard Name Table (v35, 20 July 2016)" ;
    :cdm_data_type = "Image" ;
    :orbital_slot = "GOES-West" ;
    :timeline_id = "ABI Mode 6" ;
    :project = "GOES" ;
}
```
Appendix D: Reduced Product Schedules

The processing load on a system can be reduced by implementing a reduced product schedule. For example, certain products, image times or domains can be skipped, depending on the user’s needs.

Currently it is left to the user to implement such a scheduling mechanism, if needed. However this capability may be added in a future release if it is identified as a high priority to users.

For users who are generating the Low Cloud and Fog or Derived Motions Winds product, it is important that the temporal requirements of those products are satisfied by the product refresh schedule. Failure to do so may result in missing or degraded products.

A suggested product schedule is shown below. This is based on the schedule followed by the GOES-R Ground System as found in the PUG, Volume 5, Appendix B, but with the following changes:

- Low Cloud and Fog added, for every image timestep, Full Disk and CONUS domains only. This is the schedule followed by the NOAA ASSIST group.
- Derived Motions Winds produced for every Full Disk and CONUS timestep, and every 5 minutes for Mesoscale. This is more frequent than the refresh rate of the operational product, but is recommended to optimally satisfy the temporal dependencies of that product.

As of the AITF Version 2 beta release, this schedule has not been tested in forward processing.

<table>
<thead>
<tr>
<th>Product &amp; Imagery</th>
<th>Image Type</th>
<th>ABI Mode 3</th>
<th>ABI Mode 4</th>
<th>ABI Mode 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud &amp; Moisture Imagery</td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerosol Detection</td>
<td>Full Disk</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>5</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Aerosol Optical Depth</td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mesoscale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cloud Optical Depth</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Cloud Particle Size Distribution</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Cloud Top Phase</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Cloud Top Height</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Cloud Top Pressure</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cloud Top Temperature</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Clear Sky Masks</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Derived Motion Winds</strong></td>
<td>Full Disk</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mesoscale</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Land Surface (Skin) Temperature</strong></td>
<td>Full Disk</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>CONUS</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Low Cloud &amp; Fog</td>
<td>Mesoscale</td>
<td>60</td>
<td>60</td>
<td></td>
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