# UCalgary SKYMAP

Georeferencing All-Sky-Imager (ASI) data is a calibration process that specifies the coordinate transformation between CCD coordinates (pixel X & Y) and geographic latitude and longitude at an assumed altitude. The output of this calibration process is a 'skymap', a file that contains the geographic latitudes and longitudes of the CCD pixel corners (at three altitudes), as well as local observer coordinates (azimuth and elevation).

To convert CCD pixel coordinates to an earth-centered coordinate system, the ASI optics (assumed symmetric about an optical axis) and physical orientation (pitch, roll, tilt) are used to define local AIM coordinates (East, North, Zenith Angle). Images are then converted into a celestial reference frame (GEI coordinates), and stars within the images can be compared to known celestial bodies. If the orientation and projection parameters are accurately defined, a sequence of images (in time) viewed in GEI coordinates will contain static stars. Comparing the locations of stars in the GEI images with those from the Yale Bright Star Catalogue defines the CCD to GEI coordinate transformation and confirms the optical projection and physical orientation parameters for a specified time. The transformation from GEI coordinates to a geodetic Earth model is then completed at three altitudes, and the information is saved in a skymap file.

Note: Cameras installed at remote sites may shift due to camera maintenance or changes in the building (freeze-thaw cycle). Skymaps are therefore completed at least once per imaging season, preferably at the beginning of the season.

Skymaps are currently available for UCalgary operated (and archived) ASI networks:	**TREx-RGB, TREx-NIR, REGO, THEMIS-ASI, Rainbow, NASCAM**
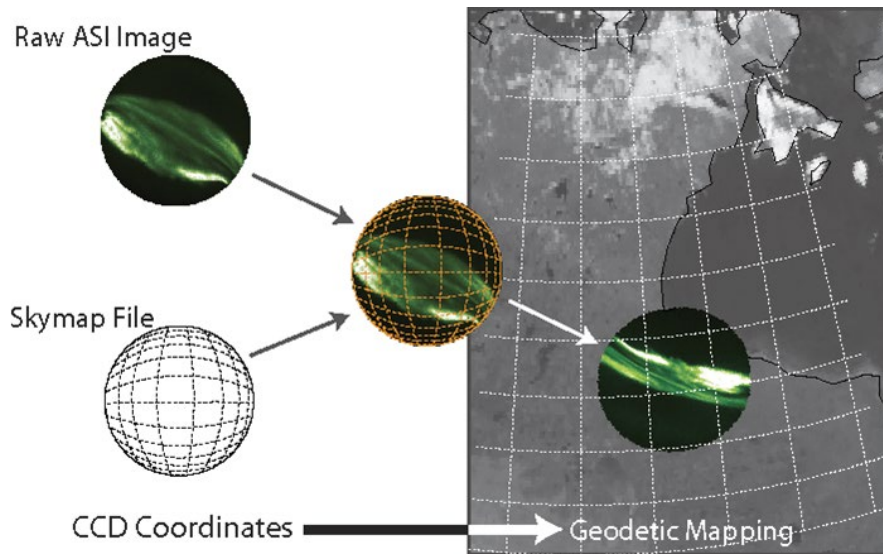
Our instrumentation and processes are constantly evolving to enhance the information available from our data. This document will be updated as required.

LAST UPDATED: 2024-01-30

Skymap File Description

1. **Finding skymap calibration files (directory tree and file naming convention).**

   Skymap files are archived alongside imager data. Within each imager data tree there is a directory called 'skymaps'. For example, the THEMIS-ASI skymaps can be found here,

   https://data.phys.ucalgary.ca/sort_by_project/THEMIS/asi/skymaps/.

   TREx-RGB skymaps can be found here,

   https://data.phys.ucalgary.ca/sort_by_project/TREx/RGB/skymaps/,

   and so on. Each type of imager has skymaps tailored to their respective data size (CCD size).

   Within the skymap directory there are directories for all available sites, and within the site directory are folders that have a **date included in the folder name** (see below).

Index of /sort_by_project/THEMIS/asi/skymaps/gill/

```
../
gill_20071218/                    17-Sep-2012 19:13         -
gill_20081029/                    15-Mar-2010 19:32         -
gill_20090916/                    18-Sep-2009 18:20         -
gill_20100903/                    19-Jan-2018 18:05         -
gill_20110202/                    17-Sep-2012 19:13         -
gill_20120219/                    17-Sep-2012 19:13         -
gill_20130103/                    28-Jan-2014 20:29         -
gill_20151121/                    30-May-2018 20:01         -
gill_20170914/                    30-May-2018 20:01         -
gill_20190324/                    05-Oct-2019 18:37         -
gill_20190325/                    20-Feb-2020 21:43         -
gill_20200315/                    09-Jan-2023 16:43         -
gill_20200911/                    09-Jan-2023 16:43         -
gill_20210308/                    09-Jan-2023 16:43         -
gill_20220301/                    09-Jan-2023 16:43         -
gill_20230220/                    22-Jan-2024 15:05         -
```

The date on the folder is the **date from which the skymap is valid. A skymap is valid from the time it was created until there is another calibration file that supersedes it.** ***Note: if you suspect the georeferencing calibration is not correct, please contact us and we will verify accuracy and, if necessary, calibrate the georeferencing for the appropriate timeframe. ***

Within the file folders are the associated skymap files (see below). We note that each date referenced skymap directory contains all working files for that specific georeference calibration, including files used for real-time binning and a visual record of the skymap process intended to support verification.

Index of /sort_by_project/THEMIS/asi/skymaps/gill/gill_20151121/

```
../
gill_skymap_interface.png                              11-Dec-2015 20:11        214475
reshape_full_vec1024.themis_gill_20151121.pgm          11-Dec-2015 20:11        403812
reshape_vec1024_pacegrid.themis_gill_20151121.pgm      11-Dec-2015 20:11         13096
themis_skymap_gill_20151121-+_vXX.sav                  11-Dec-2015 20:11       3539328
themis_skymap_gill_20151121-20170914_vXX.sav           30-May-2018 20:01       3539328
```

The files of relevance for scientific use of the data are those named (in this case) '*themis_skymap_gill_20151121020170914_vXX.sav*'.

2. Variables inside the skymap files

Skymap files are IDLsav files. They contain a single anonymous structure called 'skymap', which holds all information relevant to the calibration process.

```
IDL> help,skymap,/str
** Structure <2e4151b0>, 26 tags, length=3006888, data length=3006878, refs=1:
   GENERATION_INFO STRUCT    -> <Anonymous> Array[1]
   SITE_UID          STRING   'gill'
   IMAGER_UID        STRING   'themis19'
   PROJECT_UID       STRING   'themis'
   IMAGER_UNIX_TIME
                     LONG                0
   SITE_MAP_LATITUDE
                     FLOAT          56.3800
   SITE_MAP_LONGITUDE
                     FLOAT          265.360
   SITE_MAP_ALTITUDE
                     FLOAT          108.000
   FULL_ROW          UINT     Array[256, 256]
   FULL_COLUMN       UINT     Array[256, 256]
   FULL_IGNORE       BYTE     Array[256, 256]
   FULL_SUBTRACT     UINT     Array[256, 256]
   FULL_MULTIPLY     FLOAT    Array[256, 256]
   FULL_ELEVATION    FLOAT    Array[256, 256]
   FULL_AZIMUTH      FLOAT    Array[256, 256]
   FULL_MAP_ALTITUDE
                     FLOAT    Array[3]
   FULL_MAP_LATITUDE
                     FLOAT    Array[257, 257, 3]
   FULL_MAP_LONGITUDE
                     FLOAT    Array[257, 257, 3]
   FULL_BIN          UINT     Array[256, 256]
   BIN_ROW           UINT     Array[1024]
   BIN_COLUMN        UINT     Array[1024]
   BIN_ELEVATION     FLOAT    Array[1024]
   BIN_AZIMUTH       FLOAT    Array[1024]
   BIN_MAP_ALTITUDE
                     FLOAT          110000.
   BIN_MAP_LATITUDE
                     FLOAT    Array[1024, 4]
   BIN_MAP_LONGITUDE
                     FLOAT    Array[1024, 4]
```

For scientific use, the variables of interest are the **full_map_altitude, full_map_latitude, and full_map_longitude**. These are the georeference variables for the full CCD readout. Other information in the file is relevant to data products that rely on pointing information (such as the THEMIS real-time mosaics, etc.).

Georeferencing is done for the corners of the pixels. This allows for a more accurate representation of pixel size and warping when the ASI image is mapped at lower elevation angles. For this reason, the full_map_longitude and full_map_latitude arrays are larger (by 1) than the CCD size. A pixel located at $[i, j]$ on the CCD has four corresponding latitudes and longitudes that define the area of the pixel in geographic coordinates.
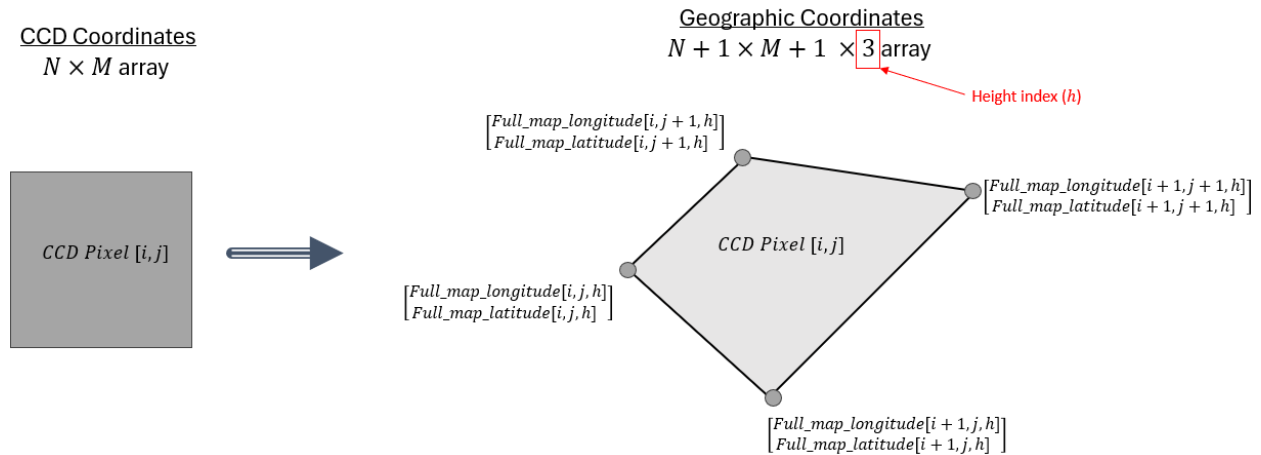
Latitudes and longitudes are available at three heights and can be found by specifying a height index of 0,1, or 2. The corresponding altitudes (in meters) are contained in the full_map_altitude array. For THEMIS, TREx-RGB, and TREx-Blueline, the mapped heights are 90, 110, and 150 km. For REGO and TREx-NIR the mapped altitudes are 110, 150, and 230 km.

Note: Mapping is done using a geodetic model of the Earth. If using the UCalgary mapping crib sheets, the altitude of the image can be adjusted to an arbitrary height within the range of the georeferenced calibration. If you require other altitudes, please contact the UCalgary technical team.

3. Using skymaps to plot data in geographic coordinates

Crib sheets are available in Python and IDL to guide users through our recommended use of the skymaps for plotting the data. Please refer to https://data.phys.ucalgary.ca. (available 2024-03)

4. Contact information

Please email the technical team with any requests, questions, or concerns about the skymaps.

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