CIPS Data Overview
Last Updated February 2023

The CIPS instrument (*McClintock et al.*, 2009) consists of four wide-angle cameras that simultaneously measure 265-nm radiation scattered by the atmosphere over a wide range of scattering angles. The fundamental measurement is an albedo, which is the measured radiance divided by the input solar irradiance. From the measured albedo, the presence and structure of polar mesospheric clouds (PMCs; *Lumpe et al.*, 2013) and gravity waves (GWs; *Randall et al.*, 2017) are derived.

On each of ~15 orbits per day, ~20-30 four-camera images (referred to as "scenes") are acquired. Prior to February of 2016, these images were acquired every 43 seconds over the summer pole, between the terminator and ~40° latitude on the sunlit side, with overlapping successive scenes. In late February of 2016 CIPS began taking images throughout the orbit, with an approximately 3-minute cadence; however, geophysical quantities can only be derived from sunlit images. In November of 2018 CIPS was commanded to take all of its images over a period of ~70 minutes in order to confine imaging to sunlit latitudes while the AIM satellite orbit was experiencing high beta angles. This was modified to 60 minutes in October of 2019 and to 66 minutes in March of 2021; at this point CIPS was also commanded to turn off during the eclipse part of each orbit as a power-saving measure. All operational modes since late February of 2016 are referred to as "continuous imaging" (CI, as opposed to "summer pole imaging"), even though imaging since November of 2018 is confined to the orbit dayside.

The current version of CIPS PMC data is v05.20r05. *Lumpe et al.* (2013) described the retrieval algorithm for version 4 PMC data; a paper describing the version 5 algorithm is in preparation. As explained by *Randall et al.* (2017), GW information is derived from CIPS measurements of Rayleigh Albedo Anomaly (RAA). At the current time, CIPS RAA data for years 2016 to the present are being updated from v01.10r06 to v01.10r07, which is described by *Carstens et al.* (2023; in preparation). The current version of RAA data for years 2007-2015 is v01.10r05; this will be updated to v1.10r07 in the near future.

The PMC and RAA data products for all levels are listed below. More details can be found in documentation specific to the individual levels. CIPS data for levels 2 and above are available online at the AIM CIPS website (http://lasp.colorado.edu/aim) and at the NASA Space Physics Data Facility (SPDF; https://spdf.gsfc.nasa.gov/). Table 1 summarizes the overall date ranges of CIPS data availability since launch. Data availability for individual days within the overall time periods listed in this table can be found by visiting the AIM CIPS website Download Data page (https://lasp.colorado.edu/aim/download), selecting a data product, and then selecting the calendar icon in the date range box.

Table 1. CIPS Data Availability

Dates (yyyymmdd)	Notes
20070524-20080207	Summer pole imaging. PMC data available. RAA data available only outside the PMC seasons until v01.10r07 retrievals are complete.
20080208-20080320	Unavailable. CIPS was in safehold mode.
20080321-20100403	Summer pole imaging. PMC data available. RAA data unavailable since roll issues complicate retrievals; probably recoverable.
20100404-20160211	Summer pole imaging. PMC data available. RAA data available only outside the PMC seasons until v01.10r07 retrievals are complete.
20160212-20160805	Continuous Imaging (CI) including eclipses, but no nightside retrievals. PMC and RAA data available.
20160806-20161014	Unavailable. Various satellite operational anomalies.
20161015-20170223	CI including eclipses, but no nightside retrievals. PMC and RAA data available.
20170224-20171123	Unavailable. Transition to 1st full-sun period, unreliable calibration data while in full-sun, and exit out of full-sun; unlikely to recover.
20171124-20180206	CI including eclipses, but no nightside retrievals. PMC data unavailable due to lack of pre- and post-season calibration data. RAA data available.
20180207-20180226	Unavailable. Transition to 2nd full-sun period.
20180227-20180417	CI in full-sun. RAA data available.
20180418-20180504	Unavailable. Reaction wheel testing.
20180505-20180920	CI in full-sun. PMC and RAA data available.
20180921-20180928	Unavailable. Exit out of full-sun.
20180929-20181102	CI including eclipses, but no nightside retrievals. RAA data available.
20181103-20190717	CI dayside only. PMC and RAA data available.
20190718-20190727	Unavailable. Spacecraft battery anomaly and recovery.
20190728-20210310	CI dayside only. PMC and RAA data available.
20210310-present	CI dayside only; power cycling during eclipse. PMC and RAA data available.

Internal (not publicly released) Data Products

Level 0: Raw, uncalibrated images. Images are binned on-chip to 170×340 pixels (cross track by along track) for each camera. Effective spatial resolution varies from ~2.4 km $\times$ 2 km (nadir) to ~4.5 km $\times$ 3 km (forward & aft cameras). This is common to both PMC and RAA retrievals.

Level 1A: Calibrated and geolocated albedo. NetCDF files contain all images from a single camera over one orbit, so there are 4 files per orbit (one per camera). This is common to both PMC and RAA retrievals.

Level 1B: Map-projected albedo at 25 km^2 resolution, calculated from level 1A data. One NetCDF file per orbit. These files register all measurements of a single location into data "stacks" to facilitate level 2 retrievals. This was used only for PMC retrievals for v4.20 and earlier versions, and is considered obsolete.

Level 1P: Level 1P consists of intermediate data files that contain corrections to systematic errors in the level 1A data. These corrections are implemented during production of the Level 2 v5 PMC and v1.1 RAA data products.

Publicly Available PMC Data Products

Level 2: Retrieved cloud parameters at 25 km^2 resolution for v4 and earlier versions, and at 56.25 km^2 resolution for v5 and later versions. Four NetCDF files per orbit containing, respectively:

> (1) Geolocation ("catalog") data (e.g., latitude, longitude, time, etc.). The file name is *cat.nc.

> (2) Cloud properties, including albedo, particle radius, and ice water content. The file name is *cld.nc.

> (3) Cloud phase function (cloud albedo vs. scattering angle). The file name is *psf.nc.

> (4) Retrieved ozone parameters; only experimental at this time.

Cloud albedo in file #2 is normalized to 90° scattering angle and nadir view. Most users of level 2 data will only require files #1 and #2. File #4 is experimental and not publicly available at this time. Images (png files) of cloud albedo, particle radius and ice water content for each orbit are also available.

Level 3A: Quicklook data product of daily cloud albedo maps, produced by combining level 2 data from all individual orbits on a given day. Where pixels from different orbits overlap, the brightest pixel (not the average) is used. Same resolution as level 2. One NetCDF and one png file per day. Each individual png file uses a color scale appropriate for that day.

Level 3B: Movies of daily cloud albedo maps for an entire PMC season. One MP4 file per season. Same resolution as level 3A. Each individual MP4 file uses a single color scale appropriate for that season.

Level 3C: Season-long files of level 2 data. Retrievals of cloud albedo, particle size, and ice water content from each orbit are binned in one-degree latitude bins and output for an entire PMC season. Files are available in NetCDF and IDL save formats.

Level 3D: Season-long files of level 2 data in the "common volume" (CV) viewed by both CIPS and SOFIE. The CIPS Level 3D data are pulled directly from the Level 2 data files, and consist of the subset of pixels that are co-located with the SOFIE line-of-sight. Because of changes in the AIM orbit with time, CIPS and SOFIE viewed a common volume only from 2007 to February 2010. Therefore the CIPS Level 3D data are only available for the first three PMC seasons in each hemisphere. The CIPS level 3D file contains the primary CIPS level 2 retrieval products and associated auxiliary data, in the CV, for each orbit over an entire PMC season. The file format is ASCII text.

Level 3E: Analogous to Level 3D; but these files contain data that are coincident with a selected group of ground stations, and are available throughout the AIM mission.

Publicly Available Rayleigh Albedo Anomaly (RAA) Data Products

Level 2A: Retrieved CIPS RAA and RAA Variance for each scene, as well as wave properties (wavelength, amplitude, phase speed direction); the variance and wave property information is available only in version 01.10r06 and later. A CIPS scene contains simultaneous images from the four CIPS cameras, with a footprint of approximately 2000 km by 900 km (*Lumpe et al.* 2013) and horizontal resolution of ~56.25 km^2. For v01.10r06 and later, three level 2A NetCDF data files for each orbit are provided, with each file containing data for all scenes individually in a given orbit (items 1-3 below). In addition, one png file for each scene is provided separately (~20-25 png files per orbit).

> (1) Geolocation: Includes variables such as date, time, latitude, longitude, solar zenith angle, etc. The file name is *cat.nc ("cat" is short for "catalog").

> (2) Rayleigh Albedo Anomaly (RAA): Includes Rayleigh Albedo, Rayleigh Albedo Anomaly (RAA), RAA uncertainty, FFT-filtered RAA, FFT-filtered RAA variance, and FFT-filtered RAA variance uncertainty. These files also include the 2D FFT wave amplitudes vs. wavenumber (1/wavelength) and wave orientation. The file name is *alb.nc.

> (3) Measurement geometry: Includes satellite view angles and scattering angles for each scene. The file name is *ang.nc.

> (4) Plots of RAA, FFT filtered RAA, and RAA variance for each scene (one png file per scene). Regions of significant wave detections are indicated. *As of February 2023, the level 2A plotting code is being updated to correct formatting issues that appear in some seasons in v1.10r06.*

Level 2B: Retrieved RAA in an orbit-by-orbit format. All scenes from an orbit are merged together by averaging overlapping pixels from different cameras. Two NetCDF files and one png file are provided for each orbit.

> (1) Geolocation: Includes variables such as date, time, latitude, longitude, solar zenith angle, etc. File content is similar to the Level 2A geolocation file. The file name is *cat.nc.

> (2) RAA: Includes Rayleigh Albedo, Rayleigh Albedo Anomaly (RAA), RAA uncertainty, FFT-filtered RAA, FFT-filtered RAA variance, and FFT-filtered RAA variance uncertainty. The file name is *alb.nc.

> (3) Plots of RAA and RAA variance for each orbit. File name is *.png.

Level 2C: Daily, global maps of RAA and of RAA variance, produced by over-plotting level 2B RAA and RAA variance data for all orbits each day. Maps are made for each day, but are blank if data is missing. File format is png.

Level 3A: Daily, global maps of gridded (0.5° × 0.5°; lat x lon) RAA variance. Both one-day and five-day maps are provided in a single file for each day, in numerical (NetCDF) and graphical (png) formats. The 5-day map corresponding to day "x" contains mean variances in each grid cell from

days "x-4" to day "x". Maps are made for each day, with whatever data are available for days x-4 to day x; maps are blank if all 5 days are missing.

References

Lumpe, J. D., et al. (2013). Retrieval of polar mesospheric cloud properties from CIPS: algorithm description, error analysis and cloud detection sensitivity, *J. Atmos. Solar-Terr. Phys*., doi:10.1016/j.jastp.2013.06.007.

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Randall, C. E., et al. (2017). New AIM/CIPS global observations of gravity waves near 50-55 km, *Geophys. Res. Lett*., 44, 7044–7052, doi:10.1002/2017GL073943.