CIPS Version 4 Level 3C Summary Files

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This document describes the CIPS level 3C polar mesospheric cloud (PMC) data for retrieval version 4.20 revision 6 (v4.20r06). This data version is available for PMC seasons in the northern hemisphere (NH) from 2007 through 2013 and in the southern hemisphere (SH) from 2007-2008 through 2014-2015.

The level 3C summary files provide the user with a higher-level summary of the CIPS data for each PMC season. Note that these files are distinct from the level 2 files, which each provide retrieved parameters at high resolution over only a single orbit.

To produce the level 3C summary files the CIPS level 2 data for each orbit are binned in one-degree latitude bins from 50 to 85 degrees. The ascending and descending portions of the orbit are binned separately to avoid mixing measurements made at dist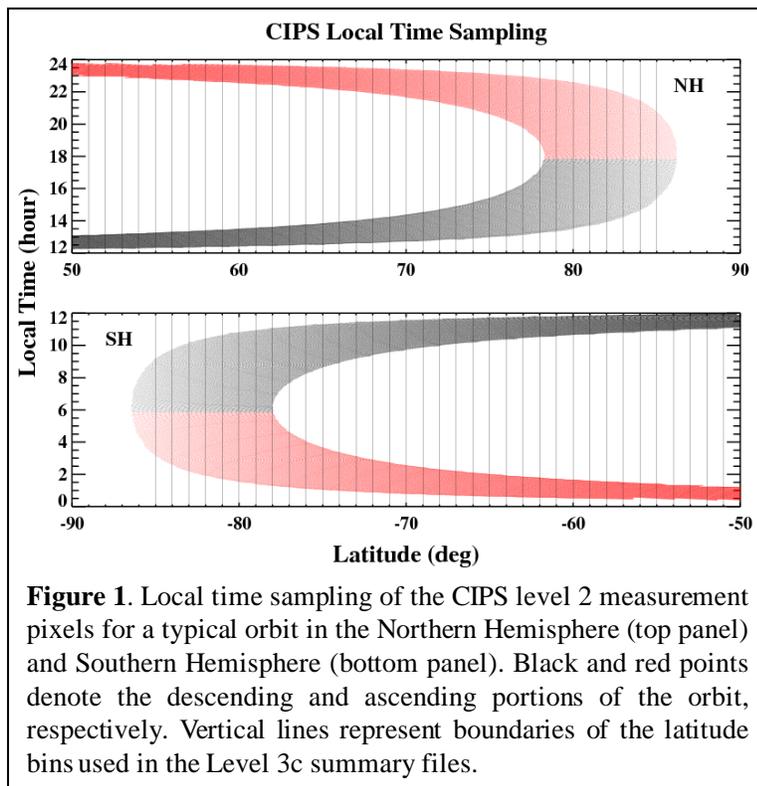inct local times (Figure 1 describes the CIPS local time sampling for seasons prior to 2015). Only observations made at solar zenith angles (SZAs) between 42° and 94°, and including at least four measurements of a single location (level 2 quality_flag ≤ 1), are included in the binning. The lower limit of 42° is currently imposed because of occasional retrieval artifacts (false cloud detections) observed in the V4.20 data at lower solar zenith angles (see level 2 data documentation). As Figure 2 demonstrates, this SZA requirement effectively limits the data to latitudes greater than ~58°, with the lowest latitude data coming from the descending node early and late in the season. In addition to the quality

Figure 1. Local time sampling of the CIPS level 2 measurement pixels for a typical orbit in the Northern Hemisphere (top panel) and Southern Hemisphere (bottom panel). Black and red points denote the descending and ascending portions of the orbit, respectively. Vertical lines represent boundaries of the latitude bins used in the Level 3c summary files.

flag and SZA screening, all measurements where the retrieved radius is less than 20 nm are omitted from calculations of the average radius and IWC values reported in the level 3C files. This is because the radius and IWC are considered very uncertain when the retrieved radius is less than 20 nm; albedo retrievals are more robust, so the albedos reported in the level 3C files do not include a screening for radius.

Table 1 describes the data contained in the summary files, which are available in both ASCII text and binary IDLSAVE formats. Each file contains the latitude-binned data, by orbit, for one complete PMC season. The data include the primary CIPS cloud retrieval products – cloud albedo, particle mode radius and ice water content – as well as auxiliary data such as date, UT and local time, longitude and solar zenith angle. Also included are the total number of valid measurements in each bin and the number of cloud detections (NUM_OBS and NUM_CLD, respectively), from which cloud frequencies can be calculated as described below.
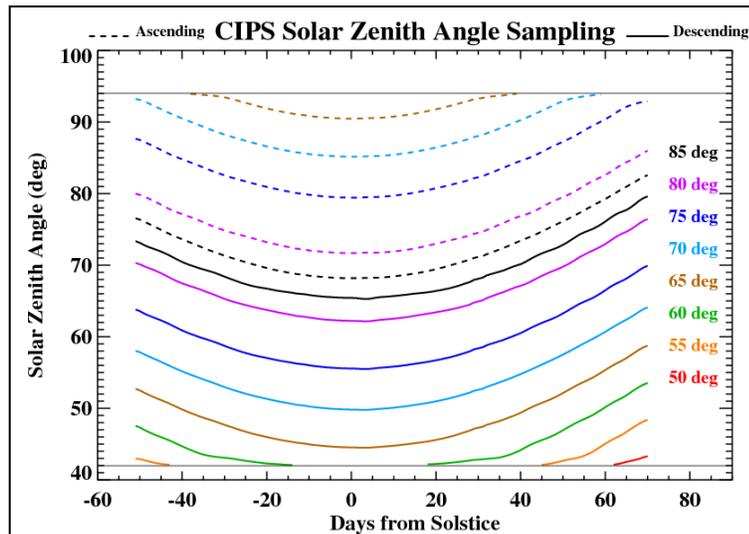

Figure 2. Mean solar zenith angle sampled by CIPS during the PMC season in representative latitude bins. Solid (dashed) curves correspond to the descending (ascending) part of the orbit. Horizontal lines represent the 42° and 94° limits used to screen the summary data. Results are representative of both hemispheres.

To make the summary files more useful for scientific analysis, a process of selective data screening and binning has been implemented. The data are first screened using three different cloud albedo thresholds: 1×10^{-6}, 2×10^{-6} and 5×10^{-6} sr^{-1}. As described in the level 2 data documentation each level 2 data pixel is assigned a CLD_PRESENCE value. A value of 1 means the algorithm detected a cloud and successfully retrieved cloud parameters; a 0 indicates no cloud was detected. For the purpose of 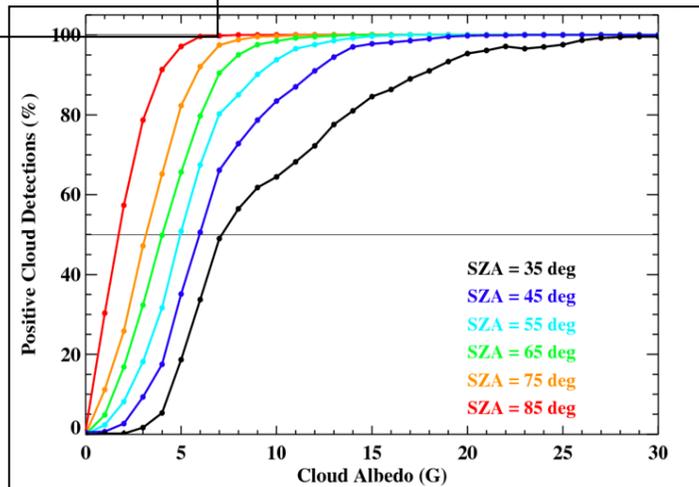latitude binning a cloud point is defined by a CLD_PRESENCE value of 1 and a retrieved cloud albedo greater than the threshold. Similarly, a measurement having a CLD_PRESENCE value of 1 but an albedo below the threshold is interpreted as a non-cloud point (obviously a CLD_PRESENCE value of 0 indicates a non-cloud point also).

These three thresholds provide the user with a full range of options for interpretation based on increasing levels of confidence in the cloud detection. The CIPS cloud detection sensitivity varies with solar zenith angle for two reasons: as the solar zenith angle increases the

Figure 3. Estimated CIPS cloud detection sensitivity. Each curve corresponds to CIPS measurements at a fixed solar zenith angle (SZA), from 35° to 85°. For a given cloud albedo (x-axis, in units of 1G = 10^{-6} sr^{-1}) the curve shows the probability of detection (in %). For example, a 5 G cloud will be detected 50% of the time at 55° SZA and 97% of the time at 85° SZA.

Rayleigh background signal decreases, while at the same time the CIPS sunward (PX) camera samples more forward-peaked scattering angles. Both of these factors enhance the discrimination between cloud and background contributions in the measured scattering profile, and hence increase detection sensitivity. Figure 3 shows the estimated CIPS cloud detection sensitivity based on retrieval simulations. These results show that clouds with an albedo equal to the three threshold values used will have a detection probability of approximately 0, 3 and 30% at 42 deg SZA, increasing to 50, 95 and 100% at 94 deg. Thus the lowest threshold value will obviously give the highest frequencies, but will also contain more false detections. On the other hand, by using the highest threshold case the user is guaranteed to be using only the most robust CIPS cloud measurements.

For each of the three albedo threshold values the data are then binned separately to produce files containing information on non-cloud data only, cloud data only, and combined cloud and non-cloud (all) data. The binning methodology and primary purpose of each file are as follows:

Non-cloud ("nocld" file): This file includes only non-cloud points, so all data fields pertaining to cloud parameters are set to fill values. NUM_OBS is the number of non-cloud points in the bin and NUM_CLD is set to zero. This file is provided so that users have information regarding the locations and times of the cloud-free measurements. (Note: this file is generated for each cloud threshold value, despite containing no "cloud" data, because the non-cloud definition includes all points with albedo less than the threshold, as described above.)

Cloud-only ("cld" file). These files include only cloud points for each threshold value, as defined above. In addition to providing the locations and times of the CIPS cloud measurements, this file quantifies directly the mean and standard deviation of the retrieved cloud parameters (albedo, particle radius and ice water content) in each bin, without "contamination" by non-cloud points. Note that this file cannot be used to calculate cloud frequencies, since NUM_OBS = NUM_CLD by definition.

Cloud+non-cloud ("all" file). This file includes both cloud and non-cloud points in the binning. The PMC frequency can be calculated directly by dividing the number of clouds, NUM_CLD, by the total number of points, NUM_OBS. Besides providing cloud frequencies, these files are useful for users who wish to know the cloud parameters averaged over all space, rather than just over the cloudy areas (i.e., to give a true area-weighted average). Note that it only makes sense physically to average cloud and non-cloud areas to yield an effective albedo and ice water content; this average is meaningless for the particle radius, which is thus set to the fill value. This same argument applies to the standard deviation arrays for all cloud parameters.

The end result of this analysis is 9 independent files for each PMC season ("nocld", "cld" and "all" files for each of the three albedo thresholds). These files all contain identical data fields and, in the case of the ASCII files, have identical formats. A fill value of -999 is used when a particular data field is meaningless (see explanations above), or if no valid data points exist in a given bin. The user will note that some of the lower latitude bins are never populated. This is primarily due to the

solar zenith angle screening applied to the data, since the lowest latitudes are never sampled at 42º < SZA < 94º (see Figure 2). Rather than eliminating these bins from the files they have been retained as placeholders because we expect that future CIPS data versions will significantly improve our data reliability at low solar zenith angles.

Cautions regarding data usage are described in the CIPS Level 2 documentation. In addition, with regard to the summary files described here, users should exercise caution when average parameters are based on only a few clouds.

IDL code is provided to read the ASCII files. This code should be sufficiently simple and well documented for users who do not use IDL to translate it into FORTRAN or another language.

Table 1. Definition of variables in CIPS Level 3C summary file.

Variable Name	Units	Type/Dimension	Description
NBIN	NA	INTEGER/SCALAR	Number of latitude bins (fixed at 70).
NREV	NA	INTEGER/SCALAR	Total number of orbits in the season.
LATLO	Degrees	INTEGER(NBIN)	Lower latitude of bin
LATHI	Degrees	INTEGER(NBIN)	Upper latitude of bin
REV	NA	INTEGER(NREV)	AIM orbit number
DATE	NA	LONG(NREV)	Date in YYYYMMDD format
UT	Hours	REAL(NREV,NBIN)	Mean UT time in bin.
LTIME	Hours	REAL(NREV,NBIN)	Mean local time in bin.
LON	Degrees	REAL (NREV,NBIN)	Mean longitude in bin.
SZA	Degrees	REAL(NREV,NBIN)	Mean solar zenith angle in bin.
NUM_CLD	NA	INTEGER(NREV,NBIN)	Number of pixels in bin containing clouds.
NUM_OBS	NA	INTEGER(NREV,NBIN)	Total number of data points in bin.
RAD	nm	REAL(NREV,NBIN)	Mean particle radius.
RAD_STD	nm	REAL(NREV,NBIN)	Particle radius standard deviation.
ALB	10^{-6} sr^{-1}	REAL(NREV,NBIN)	Mean cloud albedo.
ALB_STD	10^{-6} sr^{-1}	REAL(NREV,NBIN)	Cloud albedo standard deviation.
IWC	$\mu g/m^2$	REAL(NREV,NBIN)	Mean ice water content.
IWC_STD	$\mu g/m^2$	REAL(NREV,NBIN)	Ice water content standard deviation.