GLIMPSE Legacy Science Data Products

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1 Overview

The Galactic Legacy Infrared Midplane Survey Extraordinaire (GLIMPSE), using the *Spitzer* Space Telescope (SST) (Werner et al. 2004) Infrared Array Camera (IRAC) (Fazio et al. 2004) has surveyed approximately 220 square degrees of the Galactic plane, covering a latitude range of $\pm 1^\circ$, and a longitude range of $|l| = 10^\circ - 65^\circ$. IRAC has four bands, centered at approximately 3.6, 4.5, 5.8 and 8.0 μm respectively. We will refer to them as bands 1 - 4 in this document. The observations consist of two 1.2 second integrations at each position, for a total of over 77,000 pointings and $\sim$310,000 IRAC frames in 400 hours total survey time. The survey will produce approximately 240 Giga Bytes (GB) of data in the form of a point source Catalog, a point source Archive, and mosaicked images. See Benjamin et al. (2003) and the GLIMPSE web site (www.astro.wisc.edu/glimpse/) for more description of the GLIMPSE project.

This document describes the data products from the GLIMPSE Survey. The details are subject to minor changes as both the *Spitzer* Science Center (SSC) and the GLIMPSE team continue to develop their data processing systems. This document contains numerous acronyms, a glossary of which is given at the end.

The GLIMPSE products are:

1. The GLIMPSE Catalog (GLMC, or the "Catalog"), consisting of point sources whose selection criteria (§2.2) are determined by the requirement that the reliability be ≥99.5%. The expected magnitude limit of the Catalog, based on simulations and Observation Strategy Validation (OSV) data, is given in Table 1. The photometric uncertainty is typically < 0.2 mag. For each IRAC band the Catalog provides fluxes (with uncertainties), positions (with uncertainties), the areal density of local point sources, the local sky brightness, and a flag that provides information on source quality and any anomalies present in the data. The format is ASCII, using the IPAC Tables convention (irsa.ipac.caltech.edu/applications/DDGEN/Doc/ipac_tbl.html). The Catalog occupies ∼15 GB of storage, and contains ∼ 30 million sources.

2. The GLIMPSE Archive (GLMA or the "Archive"), consisting of point sources with a signal to noise > 5 in at least one band and less stringent selection critera than the Catalog (§2.2). The photometric uncertainty is typically < 0.3 mag. The information provided is in the same format as the Catalog. The expected magnitude limit for uniform background regions of the Archive is shown in Table 1. It occupies ∼ 25 GB of storage, and contains about 48 million sources.

3. The GLIMPSE Image Atlas. Mosaicked Images for each band, each covering $1.1^\circ \times 0.8^\circ$. Approximately 1320 of these 32-bit IEEE floating point single extension FITS formatted images cover the entire survey area. These images, in units of surface brightness MJy/sr, will occupy ∼170 GB of disk space, with a pixel size of $0.6''$. Mosaics of each band will also be made for larger $3.1^\circ \times 2.4^\circ$ areas, with a pixel size of $1.2''$. There will be 152 of these $3.1^\circ \times 2.4^\circ$ mosaics, totalling ∼ 41 GB. Also included will be quicklook 3-color jpeg images of the same size as the FITS images.

4. The Web Infrared Tool Shed (WITS), a web interface to a collection of models of IR spectra of dusty envelopes and photodissociation regions (PDRs), updated for IRAC and MIPS band passes. WITS currently resides on servers at the University of Maryland.

Table 1. Estimated Magnitude Limits

Band (μm)	[3.6]	[4.5]	[5.8]	[8.0]
Catalog	14.2	14.1	11.9	9.5
Archive	14.5	14.0	13.0	11.5

All GLIMPSE products will be served by the SSC (see http://ssc.spitzer.caltech.edu/legacy/), except for the Web Infrared Tool Shed which is already served by the University of Maryland.

Numerous complementary datasets will increase the scientific impact of the GLIMPSE survey. The Two Micron All Sky Survey (2MASS) provides imaging at similar resolution to GLIMPSE, in the J (1.25 μm), H (1.65 μm), and K_s (2.17 μm) bands. The Midcourse Space Experiment (MSX) also observed the Galactic plane in several mid-IR wavebands (from 4.2 to 26 μm) with $18''$ resolution at

8 μm. The following additional datasets can be accessed by the astronomical community through links from the GLIMPSE web site (www.astro.wisc.edu/glimpse/complementary.html):

1. Arecibo and Green Bank Telescope (GBT) surveys of IR-color selected H II Regions in the GLIMPSE survey region: a dataset that resolves distance ambiguities to massive star formation regions. This dataset includes > 100 objects and can be found on the GLIMPSE web site.
2. Milky Way Galactic Ring Survey (GRS) (www.bu.edu/grs), a Boston University and Five College Radio Astronomy Observatory collaboration, is a large-scale ^{13}CO line survey of the inner Galaxy between longitudes 18° and 52°.
3. The International Galactic Plane Survey (www.ras.ucalgary.ca/IGPS) is mapping the Milky Way disk at 21-cm wavelength. This survey provides data cubes of the H I spectral line emission with resolution of $1'$ and one km/s over the entire area of the GLIMPSE survey.
4. A proposal for a Very Large Array (VLA) 6-cm continuum survey of the GLIMPSE area with a spatial resolution of $\sim1''$ was submitted to the NRAO. Proof of concept time was granted for the survey. The expected completion of the survey is the end of 2005 or later, if approved.

In addition to this document, GLIMPSE will provide three other documents for the community to aid in using and understanding the data:

- GLIMPSE Post BCD Pipeline Description (GPD; expected May 2005)
- GLIMPSE Quality Assurance (GQA; expected May 2005)
- GLIMPSE Science and Data Requirements (GSDR; v0.5 available now)

The organization of this document is as follows: §2 briefly describes the data processing; §3 discusses the validation of the source lists; §4 provides a detailed description of the data products; §5 describes the format; and §6 presents the delivery schedule for the data products and documents.

2 Brief Overview of Pipeline Processing

2.1 Image Processing, Photometry, and Bandmerging

The GLIMPSE Pipeline Description document (GPD) will describe in detail the GLIMPSE pipeline processing, including photometry and bandmerging to produce source lists. We note here some steps that are relevant to the final data products. Image processing steps for photometry include masking hot, dead, and missing data pixels (using SSC supplied flags). Pixels associated with saturated stars are masked using an algorithm generated by GLIMPSE (since the SSC saturation bits are not currently working); this algorithm finds most of the saturated stars. Pixels within a 24-pixel radius of a saturated source are flagged. We correct for column pulldown[1] in bands 1 & 2, using an algorithm written by Lexi Moustakas (GOODS team) and modified by GLIMPSE to handle variable backgrounds. We correct for banding[2] in bands 3 & 4 using an exponential

[1] Column pulldown is a reduction in intensity of the columns in which bright sources are found in Bands 1 and 2. See *Spitzer* Observer's Manual (SOM) at http://ssc.spitzer.caltech.edu/documents/som/.

[2] Banding refers to streaks that appear in the rows and columns radiating away from bright sources in Bands 3 and 4. See the SOM.

function. This is only an approximate correction currently. We are working on an algorithm to fit each incidence of banding individually.

We use a modified version of DAOPHOT (Stetson 1987) as our point source extractor. We iterate the photometry calculations in high background regions (referred to as "tweaking" in Table 3), which has been shown to improve the flux estimates in these regions substantially. Cosmic rays are removed from the source list based on an algorithm that operates on the residual images (images with point sources removed).

Prior to the bandmerge stage, we cull all sources with signal-to-noise less than 3. As a result, no sources in the Catalog or Archive will have signal-to-noise less than 3 in any band. We use the SSC-supplied bandmerger in two stages, first to combine detections of the same source in the same band (in-band merge), and then to cross-correlate detections in different bands (cross-band merge). Signal-to-noise and flux information is used as well as position during the in-band merge, but only position is used for the cross-band merge (to avoid any systematic effects dependent on source color).

Image processing for the mosaic image products include the column pulldown and banding corrections mentioned above. Muxbleed[3] is partly corrected by the SSC pipeline. At this time we do not apply any extra corrections for muxbleed but hope to in future data releases. Hot, dead, missing and saturated data pixels are masked. The SSC mosaicer MOPEX is run to obtain the outlier mask (rmask; generally due to cosmic rays). Both the dual outlier bit and the temporal bit of the rmask are masked during the mosaicing. Stray light from bright sources outside the field of view scatters onto the detector and can appear in the images. To remove them, we use as a first cut the SSC IRAC Stray Light Masker which uses the K magnitude from the 2MASS Point Source Catalog to predict the positions of the stray light. It creates a mask (smask) for each input IRAC frame. Not all of the stray light areas are found by the SSC Stray Light Masker. Most of the remaining stray light areas are removed by hand. Caution - most of the stray light areas and cosmic rays have been removed from the Atlas Images but not all. Artifacts that have only single-frame coverage (outside latitudes of $\pm 1°$) are left in the mosaic. See the IRAC Data Handbook at http://ssc.spitzer.caltech.edu/irac/dh/ for more information about the detector artifacts. We use the Montage package v2.0.1 to mosaic and project to Galactic coordinates.

2.2 Source Selection for Catalog and Archive

Now we describe the selection criteria for the Catalog and Archive once photometry and bandmerging have been completed.

Catalog

To satisfy the requirement that the Catalog be $\geq$99.5% reliable, it was determined from simulated data and study of the OSV data that a source must be detected at least twice in one band and at least once in an adjacent band for the general GLIMPSE observing strategy of two visits on the sky (this will be described in detail in the GQA). We call this the "2+1" criterion. To allow for the more general case of M detections out of N possible observations, we require that $M/N \geq 0.6$ in one band and $M/N \geq 0.4$ in an adjacent band. This gives $\geq$99.5% reliability down to the magnitude limits specified in Table 1.

[3] The multiplexer bleed effect is a series of bright pixels along the horizontal direction on both sides of a bright source in Bands 1 and 2

In the two bands that satisfy the 2+1 criterion, only sources with flux greater than 0.6 mJy (<14.2 mag), 0.6 mJy (<13.7 mag), 2 mJy (<11.9 mag), and 10 mJy (<9.5 mag) in bands 1 through 4, respectively, are allowed in the Catalog. We use a more conservative estimate for the limiting flux for Band 2 than the reliability plots show. This may change in future data releases. Similarly, the bright limit flux is 439 mJy (7 mag), 450 mJy (6.5 mag), 2930 mJy (4 mag) and 1590 mJy (4 mag) for the four bands, to remove sources at nonlinear response levels. The signal-to-noise in the band with the two detections satisfying the 2+1 criterion is required to be greater than 5. Sources with hot or dead pixels within 3 pixels of source center, those in wings of saturated stars, and those within 3 pixels of the frame edge are culled from the Catalog.

Once a source satisfies the 2+1 criterion, the requirements for the other 2 bands of the same source are less stringent. Flux values above the bright limit flux are nulled, but values below the low-limit flux are allowed. Signal-to-noise <5 (down to a lower limit of 3) is allowed. Bands with hot or dead pixels and in wings of saturated stars are nulled, but those within 3 pixels of the frame edge are allowed.

Archive
Requirements for source selection in the Archive are less stringent than for the Catalog. Therefore the Archive is less reliable than the Catalog but more complete. We require $M/N \geq 0.6$ in one band or $M/N \geq 0.4$ in any two bands. For a typical source observed two times, this translates to a detection twice in one band or once in two bands. We require that the signal-to-noise be greater than 5 in the band or bands used for source selection. The lower limit of the signal-to-noise for all bands is 3. There are no further culls, leaving it to the user to cull or null based on values of the fluxes and flags (described in §4.1).

3 Brief Overview of Source List Validation

We briefly summarize here analysis we use to validate the Catalog and Archive point source lists. The GQA document describes this in more detail.

Verification of our source selection criteria (§2.2) was done with a Reliability study of the OSV data. One cause of false sources in the source lists is imperfect muxbleed correction in the SSC pipeline leaving faint point-like sources every four pixels along a row from a bright source in Bands 1 and 2. Most of the muxbleed sources have signal-to-noise less than 5 and do not make it into the source lists. Very few false sources due to muxbleed are found in high background areas (e.g. in the inner Galaxy). We estimate that $< 0.4\%$ of the Catalog sources may be muxbleed. We estimate that $< 2\%$ of the Archive sources may be muxbleed due to our less stringent selection criteria. The false detections due to muxbleed will be in only Bands 1 and 2. We plan to flag and/or correct potential muxbleed sources in future data releases. Another instance of false detections in the Archive occurs in regions surrounding saturated stars where the GLIMPSE source extractor may find false sources in the wings of the PSF. These sources are culled from the Catalog but only flagged in the Archive. Our source selection criteria remove the vast majority of other potential false detections, such as cosmic rays and stray light. In addition, our photometry iteration routines reduce false source detections in variable backgrounds caused by both real sky variations as well as instrumental artifacts such as banding, stray light and column pulldown.

Photometric accuracy was verified with simulated images consisting of known point source fluxes placed on residual images (GLIMPSE images with point sources removed giving realistic back-

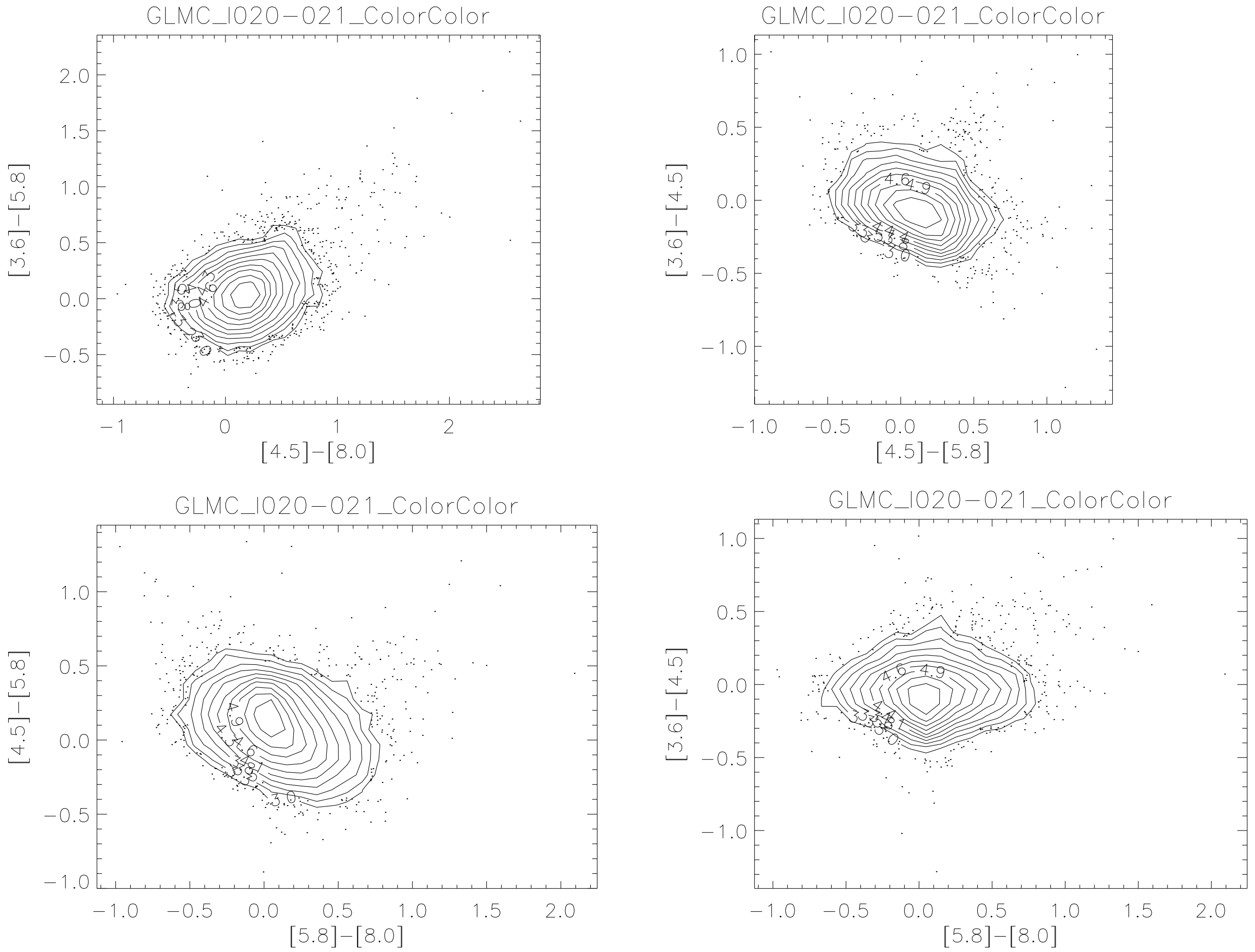

Figure 1: Color-color plots of the region $l = 20 - 21°$ and $|b| < 1.15°$. The contours are labelled with the log of the number of sources per square magnitude.

grounds). The point source accuracy depends on background level. A table of photometric accuracy as a function of background level is given in the GQA document. For average background levels, the photometric accuracy is $\leq 0.2^m$ at magnitudes brighter than $\sim 14, \sim 12, \sim 10.5, \sim 9.0$ for bands 1 - 4 respectively.

Photometric accuracy was further verified by comparison with $\sim$ 200 flux calibrators supplied by Martin Cohen and distributed throughout the GLIMPSE survey region. These span a wide range of fluxes in each IRAC band. The comparison of GLIMPSE to predicted fluxes also provides further confirmation of the chosen non-linear/saturation limits used in the Catalog (§2.2). The average deviation between GLIMPSE and Cohen fluxes are about 5% in flux density.

Color-color and color-magnitude plots were made of each Catalog and Archive table (approximately $1° \times 2°$ regions). These source lists were culled using the in-band and cross-band confusion flags (§4.1 and Table 3). An example set of color-color plots is shown in Figure 1. These generally show a peak near 0 color due to main sequence and giant stars, and a red tail corresponding to the large variety of stars with circumstellar dust.

Spot checks include inspection of residual images to verify proper point source extraction; overplotting the positions of the sources in the Catalogs and Archives on mosaic images; and plotting SEDs of several sources.

4 Data Products Description

4.1 Catalog and Archive Fields and Flags

Each entry in the GLIMPSE Catalog and Archive has the following information:

designation	SSTGLMC GLLL.llll±BB.bbbb, SSTGLMA GLLL.llll±BB.bbbb
position	l, b, l_err, b_err, ra, dec, ra_err, dec_err
flux	mag$i$, mag$i$_err, Fi, Fi_err, Fi_rms
diagnostic	sky$i$, SNi, srcdens$i$, # detections Mi out of Ni possible
flags	confusion flag, source quality flag (i), flux calculation method flag (i)

where i is the IRAC band number, ranging from 1-4. Details of the fields are as follows:

Designation
This is the object designation or "name" as specified by the IAU recommendations on source nomenclature. It is derived from the coordinates of the source, where G denotes Galactic coordinates, LLL.llll is the degrees of Galactic longitude, and ±BB.bbbb is the degrees of Galactic latitude. The coordinates are preceded by the acronym SSTGLMC (GLIMPSE Catalog) or SSTGLMA (GLIMPSE Archive).

Position
The position is given in both Galactic (l, b) and equatorial (α, δ) J2000 coordinates, along with estimated uncertainties. The pointing accuracy is $1''$ (Werner et al. 2004). The SSC pipeline does pointing refinement of the images based on comparison with the 2MASS Point Source Catalog, whose absolute accuracy is typically $< 0.2''$ (Cutri & Skrutskie 2000). After applying the SSC geometric distortion corrections and updating to the 2MASS positions, the GLIMPSE point source accuracy is typically $\sim 0.3''$ absolute accuracy, limited by undersampling of the point-spread function. The position uncertainties are calculated by the bandmerger based on the uncertainties of individual detections, propagated through the calculation of the weighted mean position.

Flux
For each IRAC band $i = 1-4$, the fluxes are expressed in magnitudes (mag$i$) and in mJy, Fi. Each flux is the error-weighted average of all independent detections of a source. The zeropoints for converting from flux to magnitude are from Martin Cohen for the IRAC bands and Cohen et al. 2003 for 2MASS and given in Table 2.

Table 2. Zeropoints for Flux to Magnitude Conversion

Band	J	H	K	[3.6]	[4.5]	[5.8]	[8.0]
Zeropoints (Jy)	1594	1024	666.7	277.5	179.5	116.5	63.13

Naturally, the reliability of brighter sources is higher. The statistical reliability and photometric uncertainty of GLIMPSE sources as a function of magnitude will be provided in the GQA.

The flux/magnitude uncertainties (Fi_err; mag$i$_err) are computed during the photometry stage and take into account photon noise, readnoise, goodness of flat fielding, and PSF fitting (Stetson 1987). Magnitude uncertainties are estimated to be <0.2 mag for the Catalog and < 0.3 mag for the Archive. The uncertainties are smaller in Bands 1 and 2 than Bands 3 and 4 due to lower backgrounds.

The rms deviation (Fi_rms) of the individual detections from the final flux of each source is provided.

Diagnostics

The associated flux diagnostics are a local background level (sky$i$) ($i = 1, 4$) in MJy/sr, a Signal/Noise (SNi), a local source density (srcdens$i$) (number of sources per square arcmin), and number of times (Mi) a source was detected out of a possible number (Ni). The local background, an output of DAOPHOT, is provided because high backgrounds were shown to affect the reliability of IRAS sources, and for IRAC as well (especially Bands 3 and 4) (see the GQA document). However, the effects may not be easily characterizable in the quoted error. The Signal/Noise is the flux (Fi) divided by the flux error (Fi_err). The local source density is measured as follows: The individual IRAC frame is divided into a 3×3 grid, each section being $1.71'$ x $1.71'$. A source density is calculated for each section (number of sources per arcmin^2), and is assigned to each source in that section. The local source density can be used to assess the confusion in a given region, along with the internal reliability. Mi and Ni can be used to estimate reliability. Ni is calculated based on the areal coverage of each observed frame; due to overlaps some areas are observed more than twice per band.

Flags

There are three types of flags: the confusion flag, the source quality flag and the flux calculation method flag. The confusion flag will be set for sources that are within $1''$ of each other. The source quality flag provides a measure of the quality of the point source extraction. The flux calculation method flag describes how the final Catalog/Archive flux was determined.

• The Confusion Flag will be set when another source is within one arcsecond of the current source. Preliminary results show approximately 0.25% of the sources in the Archive will have this flag set. Note: the confusion flag is not yet set in the April 12, 2005 data release.

• The Source Quality Flag (SQF) is generated from SSC-provided masks and the GLIMPSE post-processing pipeline, after point source extraction on individual IRAC frames. Each source quality flag is a binary number allowing combinations of flags (bits) in the same number. Flags are set if an artifact (e.g., a hot or dead pixel) occurs near the core of a source - i.e. within ∼3 pixels. A non-zero SQF will in most cases decrease the reliability of the source. Some of the bits, such as the DAOPHOT tweaks, will not compromise the source's reliability, but will likely increase the error assigned to the source flux. Since the current data release does not include a confusion flag, users may wish to make use of two bits in the source quality flag, bits 13 and 14, set during the bandmerge step of data processing. These are set when the bandmerger has more than one possible candidate to merge with a given source. Bit 13 is set during the merge within a given band, and bit 14 is set during merges across bands. About 20% of the sources have bit 14 (cross-band) set, and less than 1% have bit 13 (in-band) set.

Table 3 shows the SQF sequence for the April 12, 2005 data release. Some of the flags have not been implemented, but will be in future data releases. For example, SSC and the GLIMPSE team are working on an algorithm for stray light masking. We have determined that false sources from these regions do not make it into the Catalog due to our 2+1 source selection criterion (§2.2).

In addition, our photometry algorithm has been modified substantially to find sources in high background regions that gives it the ability to find sources in stray light and banded regions as well, increasing the photometric uncertainties accordingly. Details such as these will be discussed more in the GPD and GQA documents.

The value of the SQF is $\sum 2^{(bit-1)}$. For example, bit 1 corresponds to $2^0 = 1$. If the SQF is 0, the source has no detected problems. More information about these flags can be found in the *Spitzer* Observer's Manual (SOM) and the GLIMPSE Pipeline Description (GPD).

Table 3. Source Quality Flag (SQF) Bits

SQF bit	Description	Ref	Source	Status
1	poor pixels in dark current	SOM	SSC pmask	OK
2	flat field questionable	SOM	SSC dmask	not working[a]
3	latent image	SOM	SSC dmask	OK[b]
7	recorrected muxbleed	GPD	SSC,GLIMPSE	not done[c]
8	hot, dead or otherwise unacceptable pixel	SOM	SSC pmask	OK
9	MUX bleed uncertain or incomplete	SOM	SSC dmask	not working[a]
10	DAOPHOT tweak positive	GPD	GLIMPSE	OK
11	DAOPHOT tweak negative	GPD	GLIMPSE	OK
13	confusion in in-band merge	GPD	GLIMPSE	OK
14	confusion in cross-band merge	GPD	GLIMPSE	OK
15	column pulldown corrected	GPD	GLIMPSE	OK
16	banding corrected	GPD	GLIMPSE	OK
17	stray light	SOM	SSC,GLIMPSE	not done[c]
19	nonlinear correction not applied	SOM	SSC dmask	not sure
20	saturated star wing region	GPD	GLIMPSE	OK
30	within three pixels of edge of frame	GPD	GLIMPSE	OK

[a] According to SSC.

[b] Due to the high sky backgrounds in the GLIMPSE fields, we have not seen evidence for latent sources in the images, even though they are flagged.

[c] We plan to have these implemented in a future data release.

• Flux calculation Method Flag (MF). This is a flag for each band indicating how the final averaged flux was determined by weighting individual flux measurements. The procedure is especially important when the individual measurements have different SQFs or significantly discrepant values.

Table 4. Method Flag (MF)

MF	Description
0	all fluxes in agreement within errors
1	some discrepant fluxes discarded
2	all fluxes were discrepant; use this source with caution

4.2 GLIMPSE Image Atlas

The IRAC images are mosaicked using the Montage package (montage.ipac.caltech.edu) into rectangular tiles that cover the surveyed region. The units are MJy/sr and the coordinates are Galactic.

The mosaic images conserve surface brightness. The angular size of each tile is currently set at $1.1° \times 0.8°$. Three tiles span the latitude range of the survey ($\pm 1.15°$) and $\sim$110 span the longitude range, giving a total of $\sim$330 mosaic images in each band to cover the survey region. The pixel size is $0.6''$, smaller than the native IRAC pixel size of $1.2''$. World Coordinate System (WCS) keywords are standard (CTYPE, CRPIX, CRVAL, CD matrix keywords) with a Galactic projection (GLON-CAR, GLAT-CAR; Calabretta and Greisen 2002). See (§5.2) for an example of a FITS header. The mosaicked images will be 32-bit IEEE floating point single-extension FITS formatted images and require about 170 GB. We will also provide $3.1° \times 2.4°$ FITS files with a pixel size of $1.2''$ for an overview look that covers the full latitude range of GLIMPSE. There will be 152 of these $3.1° \times 2.4°$ mosaics, totalling $\sim$ 41 GB. For a quick-look of the mosaics, we will provide 3-color jpeg files (bands 1,3 and 4) for each area covered by the FITS files. These are rebinned to much lower resolution to make the files small. Note that outside the latitudes of $\pm 1°$ we do not necessarily have full coverage in all four IRAC bands. This can be seen in the jpeg files.

4.3 Web Infrared Tool Shed

The Web Infrared Tool Shed (WITS) (dustem.astro.umd.edu) contains two toolboxes: the Dust Infrared Toolbox (DIRT) and the PhotoDissociation Region Toolbox (PDRT). The toolboxes provide extensive databases of circumstellar shell emission models and PDR emission models. Users input data and retrieve best fit models. DIRT output includes central source and dust shell parameters. PDRT output consists of gas density, temperature, incident UV field and IR line intensities.

Legacy Tools include, for DIRT, a retrievable database of SEDs convolved with IRAC bands, an IRAC specific input GUI (Graphic User Interface), and an extended model base containing embedded brown dwarfs and embedded low luminosity protostars with and without accretion luminosity. It will also include models with alternate grain models. *Spitzer* enhancements to PDRT will consist of PDR lines (Si II, Fe II) useful for Infrared Spectrograph (IRS) observations and interpretation of IRAC PDR emission.

DIRT is based on the radiation transfer code of Wolfire and Cassinelli (1986) that calculates the passage of stellar radiation through a spherical dust envelope. The web interface to DIRT is a JAVA applet which accesses a catalog of pre-run spectral energy distributions. There are currently about 400,000 models on-line. Users can display models with various properties including:

Table 5. Ranges of the DIRT Tool

Parameters	Current values	*Spitzer* enhancements
The gas density power law:	0, -0.5, -1.0, -1.5, -2.0	
Stellar Luminosity (L_0):	10,30,50,100,....5×10^5	1e-5,3e-5,5e-5,....1
Effective temperature (K):	3e3,5e3,1e4,3e4,4e4	1e3,1.5e3,2e3,2.5e3,3e3
Outer Shell Radius (cm):	1e14,3e14,5e14,....5e18	1e11,3e11,5e11....5e15
Inner Shell Radius (cm):	1e13 to Outer Radius/10	1e11 to Outer Radius/10
A_V through Shell:	1,3,5,10,....5e3	1,3,5,10,....5e2

The models are displayed in an interactive plot window showing flux versus frequency for a series of models with increasing A_V. Users can change scale, color code models, axes, etc. Users can input observations with error bars and beam sizes and run a χ^2 fit to find the best model. The best fit is overlayed with observations and error bars. Additional details are displayed including the run of gas density and gas temperature, the run of grain temperatures, emitted intensity across model source at various wavelengths, and flux versus beam size for a beam centered on the source at various wavelengths. Flux and source size are scaled to input distance. There will be a *Spitzer* specific interface to accept IRAC data input. Models will be retrievable and displayed in IRAC band integrated quantities. Model space will be searched for the best fit from the input IRAC observations. For each band, plots will show model flux versus wavelength (μm) and model surface brightness versus source size ($''$).

PDRT is based on the photodissociation region code of Tielens and Hollenbach 1985 and updated by Wolfire, Tielens, and Hollenbach 1990, and Kaufman et al. 1999. The interface to PDRT allows users to input three or more spectral line observations, with errors, and χ^2 contour plots are generated showing the best fit model parameters to their data set. The output model parameters are the incident ultraviolet radiation field, the gas density, and the gas temperature. In addition, several predicted line intensities are given that match the best fit model. Current lines include the dominant coolants of PDRs including [C II] 158 μm, [O I] 63 μm, and CO (J=1-0), plus several weaker lines that are also observable e.g., [O I] 145 μm, and [C I] 370 μm and 610 μm. Updates to the on-line models will include [Si II] 35 μm and [Fe II] 26 μm, both observable by *Spitzer* IRS. These emission lines along with IRAC maps of PDRs may be used to constrain the PDR properties including the distribution and abundance of poly aromatic hydrocarbons (PAHs), as well as the efficiency of grain photoelectric heating.

4.4 Complementary Datasets

Arecibo/GBT: More than 100 IR-color selected H II regions have been observed with the Arecibo 300m and NRAO Green Bank Telescope in the H110α and H_2CO ($1_{10}-1_{11}$) lines to resolve distance ambiguities. The H110α line determines the kinematic distance and the H_2CO ($1_{10}-1_{11}$) absorption line resolves the near-far distance ambiguity. In 2001 this technique was applied as a pilot project at Arecibo to 20 Ultra-Compact (UC) H II regions. Distances were successfully determined for 19 sources (Araya et al. 2002). In 2002 H110α was detected toward 45 UC H II regions and the near-far distance ambiguity resolved for 35 objects; ten were found to lie near the tangent point (Watson et al. 2003). H110α and H_2CO ($1_{10} - 1_{11}$) data have been obtained for an additional 72 compact HII regions using the NRAO GBT telescope. Results of all these observations are available on the GLIMPSE web page (www.astro.wisc.edu/glimpse/glimpsepubs.html).

GRS: Astronomers from Boston University and Five College Radio Astronomy Observatory are collaborating on a ^{13}CO Galactic Ring Survey (Simon et al. 2001)(www.bu.edu/grs). This survey will catalog molecular clouds and cloud cores, establish kinematic distances to many clouds and Young Stellar Objects (YSO), determine their sizes, luminosities, and distributions, and determine the distribution of molecular gas in the inner Milky Way, especially that of the 5 kpc ring. Compared with previous molecular line surveys of the inner Galaxy, the GRS offers excellent sensitivity (<0.4 K), higher spectral resolution (0.2 km s^{-1}), comparable or better angular resolution ($46''$) and sampling ($22''$), and the use of ^{13}CO (1-0), a better column density tracer than the commonly observed ^{12}CO (1-0) line.

IGPS: The GLIMPSE survey will be complemented by data from the International Galactic Plane Survey, a collaboration of radio astronomers in the US, Canada, and Australia to map the Milky Way disk in the HI 21-cm line (www.ras.ucalgary.ca/IGPS). This survey provides data cubes of the H I spectral line emission with resolution of $1'$ and one km/s over the entire area of the GLIMPSE survey. It also provides continuum maps of the Stokes *I, Q, U*, and *V* emission. The radio data will be valuable for measuring unreddened emission measures from H II regions, and the H I absorption spectra will help resolve distance ambiguities to many of our sources.

VLA: A proposal for a VLA 6-cm survey of the GLIMPSE region was submitted to the NRAO and time was granted for a pilot survey. The half-power-beam-width will be $\sim 1.2''$, comparable to the IRAC resolution. This survey will cover the GLIMPSE survey region reachable from the VLA ($66^\circ \geq l \geq -20^\circ$), and will image supernova remnants, H II regions, planetary nebulae, extended H II emission, and galaxies. The sensitivity will be ∼1 mJy.

These products will not be delivered to the SSC. The GLIMPSE website will serve as a portal to the user community for accessing these data (www.astro.wisc.edu/glimpse/complementary.html).

5 Product Formats

5.1 Catalog and Archive

• The Catalog and Archive are broken into 1° (longitude) x 2.3° (latitude) areas for the GLIMPSE Survey. 115 Catalog files and 115 Archive files will be delivered for the entire survey region. Each Catalog 1°x 2.3° Area has about a third of a million sources and each Archive Area has around a half million sources. The Catalog and Archive files are in IPAC Table Format. Filenames are GLMC_llmin.tbl and GLMA_llmin.tbl, for the Catalog and Archive respectively (e.g. GLMC_l306.tbl, GLMC_l307.tbl, GLMA_l306.tbl, GLMA_l307.tbl, etc.) The entries are sorted by increasing Galactic longitude within each file. Due to the nature of the survey mapping, there are areas outside of the nominal GLIMPSE survey region that were observed. There is a small amount of IRAC coverage from l=9.8 to 10°, l=65-65.3°, l=294.8-295°, and l=350-350.3°. Also we provide whatever sources that were detected from $|b|$ =1.0 to 1.15°.

• Each source in both the Catalog and Archive has the entries given below.

Table 6. Fields in the Catalog and Archive

Column	Name	Description	Units	Data Type	Format	Nulls OK? or Value
1	designation	Catalog (SSTGLMC GLLL.llll±BB.bbbb) Archive (SSTGLMA GLLL.llll±BB.bbbb)	-	ASCII	A26	No
2	l	Galactic longitude	deg	R*8	F11.6	No
3	b	Galactic latitude	deg	R*8	F11.6	No
4	l_err	Error in Gal. longitude	arcsec	R*8	F7.1	No
5	b_err	Error in Gal. latitude	arcsec	R*8	F7.1	No
6	ra	Right ascension (J2000)	deg	R*8	F11.6	No
7	dec	Declination (J2000)	deg	R*8	F11.6	No
8	ra_err	Error in right ascension	arcsec	R*8	F7.1	No
9	dec_err	Error in declination	arcsec	R*8	F7.1	No
10	conf	Confusion flag	-	I*2	I4	-9
11–18	mag$i$,mag$i$_err	Magnitudes & 1σ error in IRAC bands i=1-4	mag	R*4	8F7.3	99.999,99.999
19–26	Fi,Fi_err	Fluxes & 1σ error in IRAC bands i=1-4	mJy	R*4	8E11.3	-999.9,-999.9
27–30	Fi_rms	RMS dev. of individual detections from Fi	mJy	R*4	4E11.3	-999.9
31–34	sky$i$	Local sky bkg. for band i flux	MJy/sr	R*4	4E11.3	-999.9
35–38	SNi	Signal/Noise for band i flux	-	R*4	4F7.2	-9.99
39–42	srcdens$i$	Local source density for band i object	no./sq ′	R*4	4F9.1	-9.9
43–46	Mi	Number of detections for band i	-	I*2	4I6	-9
47–50	Ni	Possible number of detections for band i	-	I*2	4I6	-9
51–54	SQFi	Source Quality Flag for band i flux	-	I*4	4I11	-9
55–58	MFi	Flux calc method flag for band i flux	-	I*2	4I6	-9

- Example of GLMC entry:

SSTGLMC G318.7007-00.2028 318.700745 -0.202847 0.3 0.3 224.813900 -59.104278 0.3 0.3 -9
99.999 99.999 6.901 0.044 6.799 0.031 6.658 0.036 -9.999E+02 -9.999E+02 3.116E+02 1.269E+01
2.222E+02 6.325E+00 1.371E+02 4.493E+00 -9.999E+02 1.233E-02 8.317E-04 2.710E-03
2.002E+00 1.575E+00 1.432E+01 3.863E+01 -9.99 24.55 35.13 30.52 61.5 51.4 17.8 9.1
2 3 2 2 2 4 2 3 24834 24834 8194 32770 0 0 0 0

Table 7. Example of Catalog/Archive Entry

desig	SSTGLMC G318.7007-00.2028	Name
l,b	318.700745 -0.202847	Galactic Coordinates
dl,db	0.3 0.3	Error in Galactic Coordinates
ra,dec	224.813900 -59.104278	RA and Dec (J2000.0)
dra,ddec	0.3 0.3	Error in RA and Dec
conf	-9	Confusion/nearby source flag
mag,dmag	99.999 6.901 6.799 6.658	Magnitudes (bands 1-4)
	99.999 0.044 0.031 0.036	Uncertainties in bands 1-4
f,df	-9.999E+02 3.116E+02 2.222E+02 1.371E+02	Fluxes (mJy)
	-9.999E+02 1.269E+01 6.325E+00 4.493E+00	Uncertainties in fluxes (mJy)
f_rms	-9.999E+02 1.233E-02 8.317E-04 2.710E-03	rms_flux (mJy)
sky	2.002E+00 1.575E+00 1.432E+01 3.863E+01	Sky Bkg (MJy/sr)
sn	-9.99 24.55 35.13 30.52	Signal to Noise
srcdens	61.5 51.4 17.8 9.1	Local Source Density
m	2 3 2 2	Number of detections
n	2 4 2 3	Number of possible detections
sqf	24834 24834 8194 32770	Source Quality Flag
mf	0 0 0 0	Flux Calculation Method Flag

5.2 GLIMPSE Image Atlas

The mosaicked images for each IRAC band are standard 32-bit IEEE floating point single-extension FITS files in Galactic coordinates. Pixels that have no flux estimate have the value NaN. The FITS headers contain relevant information from both the SSC pipeline processing and the GLIMPSE processing: e.g., IRAC frames included in the mosaicked image and coordinate information.

The mosaic images are each 1.1°x 0.8° (6640 x 4840 0.6″ pixels). Each file is about 128 Megabytes in size. There are three mosaics per one degree galactic latitude interval with 0.05° overlap between mosaics. For example, for the Galactic longitude of 308°, the centers of the three mosaics will be (308.5°, +0.75°), (308.5°, 0.0°), and (308.5°, -0.75°). The longitude range is 307.95° to 309.05° for each of the three mosaics. The latitude ranges are 0.35° to 1.15°, -0.40° to +0.40°, and -1.15° to -0.35°. Filenames are GLM_*lcbc*_mosaic_I*ch*.fits, where *lc* and *bc* are the Galactic longitude and latitude of the center of the mosaic image, I denotes IRAC, and *ch* is the IRAC channel number. For example, GLM_30850+075_mosaic_I1.fits is a 1.1°x 0.8° IRAC channel 1 mosaic centered on l=308.50°, b=0.75°. We will provide low-resolution 3-color jpeg images for each 1.1°x 0.8° area, combining bands 1,3, and 4 to be used for quick-look purposes. The filename for this jpeg file is similar to the mosaic FITS file: e.g. GLM_30850+075.jpg We will also provide 3.1°x 2.4° mosaic FITS files (9320 x 7220 1.2″ pixels) for each band, along with low resolution 3-color jpegs. Each mosaic is about 270 Megabytes in size. The filenames are similar to the other FITS and jpeg images: e.g. GLM_02650+000_mosaic_I1.fits, GLM_02650+000_3x2.jpg.

Here is an example of the FITS header for the 1.1°x 0.8° GLM_30850+000_mosaic_I1.fits:

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 6640 / length of data axis 1
NAXIS2  =                 4840 / length of data axis 2
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
TELESCOP= 'SPITZER '           / Telescope
INSTRUME= 'IRAC    '           / Instrument ID
ORIGIN  = 'UW Astronomy Dept'  / Installation where FITS file written
CREATOR = 'GLIMPSE Pipeline'   / SW that created this FITS file
CREATOR1= 'S9.5.0  '           / SSC pipeline that created the BCD
PIPEVERS= '1v03    '           / GLIMPSE pipeline version
MOSAICER= 'Montage V2.0.1'     / SW that originally created the Mosaic Image
FILENAME= 'GLM_30850+000_mosaic_I1.fits' / Name of this file
PROJECT = 'SURVEY  '           / Project ID
SEGNAME = '3050-3220'          / Segment Name (lmin*10-lmax*10)
FILETYPE= 'mosaic  '           / Calibrated image(mosaic)/residual image(resid)
CHNLNUM =                    1 / 1 digit Instrument Channel Number
DATE    = '2005-01-11T07:12:10' / file creation date (YYYY-MM-DDThh:mm:ss UTC)
COMMENT --------------------
COMMENT Proposal Information
COMMENT --------------------
OBSRVR  = 'Ed Churchwell'      / Observer Name
```

```
OBSRVRID=                   90 / Observer ID of Principal Investigator
PROCYCLE=                    2 / Proposal Cycle
PROGID  =                  190 / Program ID
PROTITLE= 'GLIMPSE-Galactic Plane Survey' / Program Title
PROGCAT =                   27 / Program Category
COMMENT ----------------------------
COMMENT Time and Exposure Information
COMMENT ----------------------------
SAMPTIME=                  0.2 / [sec] Sample integration time
FRAMTIME=                  2.0 / [sec] Time spent integrating (whole array)
EXPTIME =                  1.2 / [sec] Effective integration time per pixel
COMMENT DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME
AFOWLNUM=                    4 / Fowler number
COMMENT --------------------
COMMENT Pointing Information
COMMENT --------------------
CRPIX1  =            3320.5000 / Reference pixel for x-position
CRPIX2  =            2420.5000 / Reference pixel for y-position
CTYPE1  = 'GLON-CAR'           / Projection Type
CTYPE2  = 'GLAT-CAR'           / Projection Type
CRVAL1  =         308.50000000 / [Deg] Galactic Longtitude at reference pixel
CRVAL2  =           0.00000000 / [Deg] Galactic Latitude at reference pixel
BORDER  =           0.00333333 / [Deg] GLIMPSE mosaic grid border
CD1_1   =      -1.66666665E-04
CD1_2   =       0.00000000E+00
CD2_1   =       0.00000000E+00
CD2_2   =       1.66666665E-04
PIXSCAL1=                0.600 / [arcsec/pixel] pixel scale for axis 1
PIXSCAL2=                0.600 / [arcsec/pixel] pixel scale for axis 2
OLDPIXSC=                1.221 / [arcsec/pixel] pixel scale of single IRAC frame
RA      =         204.92752075 / [Deg] Right ascension at reference pixel
DEC     =         -62.34874344 / [Deg] Declination at reference pixel
COMMENT ----------------------
COMMENT Photometry Information
COMMENT ----------------------
BUNIT   = 'MJy/sr  '           / Units of image data
GAIN    =                  3.3 / e/DN conversion
JY2DN   =           308515.656 / Average Jy to DN Conversion
ETIMEAVE=               1.2000 / [sec] Average exposure time
COMMENT Flux conversion (FLUXCONV) for this mosaic =
COMMENT Average of FLXC from each frame*(old pixel scale/new pixel scale)**2
FLUXCONV=          0.459675938 / Average MJy/sr to DN/s Conversion
COMMENT ----------------------------
COMMENT AORKEYS/ADS Ident Information
COMMENT ----------------------------
AOR001  = '0009233664'         / AORKEYS used in this mosaic
AOR002  = '0009228544'         / AORKEYS used in this mosaic
AOR003  = '0009235200'         / AORKEYS used in this mosaic
```

```
AOR004  = '0009229056'         / AORKEYS used in this mosaic
AOR005  = '0009230848'         / AORKEYS used in this mosaic
DSID001 = 'ads/sa.spitzer#0009233664' / Data Set Identification for ADS/journals
DSID002 = 'ads/sa.spitzer#0009228544' / Data Set Identification for ADS/journals
DSID003 = 'ads/sa.spitzer#0009235200' / Data Set Identification for ADS/journals
DSID004 = 'ads/sa.spitzer#0009229056' / Data Set Identification for ADS/journals
DSID005 = 'ads/sa.spitzer#0009230848' / Data Set Identification for ADS/journals
COMMENT ----------------------------------------
COMMENT Info on Individual Frames in Mosaic
COMMENT ----------------------------------------
NIMAGES =                  341 / Number of Frames in Mosaic
IRFR0001= 'SPITZER_I1_0009233664_0164_0000_02_levbflx.fits' / IRAC BCD frame
DOBS0001= '2004-03-10T05:50:52.205' / Date & time at frame start
MOBS0001=      53074.242187500 / MJD (days) at frame start
ZODY0001=              0.05600 / [MJy/sr] Zodiacal light for this image
FLXC0001=              0.11100 / Flux conversion for this image
IRFR0002= 'SPITZER_I1_0009233664_0082_0000_02_levbflx.fits' / IRAC BCD frame
DOBS0002= '2004-03-10T05:27:07.019' / Date & time at frame start
MOBS0002=      53074.226562500 / MJD (days) at frame start
ZODY0002=              0.05600 / [MJy/sr] Zodiacal light for this image
FLXC0002=              0.11100 / Flux conversion for this image
.
.
.
IRFR0340= 'SPITZER_I1_0009235200_0224_0000_02_levbflx.fits' / IRAC BCD frame
DOBS0340= '2004-03-10T09:50:10.417' / Date & time at frame start
MOBS0340=      53074.410156250 / MJD (days) at frame start
ZODY0340=              0.05600 / [MJy/sr] Zodiacal light for this image
FLXC0340=              0.11100 / Flux conversion for this image
IRFR0341= 'SPITZER_I1_0009235200_0226_0000_02_levbflx.fits' / IRAC BCD frame
DOBS0341= '2004-03-10T09:50:45.217' / Date & time at frame start
MOBS0341=      53074.410156250 / MJD (days) at frame start
ZODY0341=              0.05600 / [MJy/sr] Zodiacal light for this image
FLXC0341=              0.11100 / Flux conversion for this image
END
```

5.3 Web Infrared Tool Shed

The output from PDRT is in the form of contour plots in FITS, postscript, or GIF format. Pregenerated diagnostic plots as well as plots with observation overlays can be downloaded directly from the web interface. The model output from DIRT can be downloaded as ASCII tables directly from the web interface.

6 Delivery Schedules

The GLIMPSE products will be delivered to the SSC on the schedule outlined in the tables below. The first increment of the Catalog was delivered to the SSC at L+12 (= Launch + 12 months)- *Spitzer* was launched August 25, 2003. The first set of mosaicked images was delivered at L+16. Subsequent releases of the Catalog, Archive and mosaicked images will occur at L+18, L+24 and L+30. The final delivery of the products is at L+36. After delivery of GLIMPSE data to the SSC, there will be a period of about 4 weeks duration devoted to verifying data quality before release by the SSC to the community.

The Web Infrared Tool Shed was delivered for community use at L+12 months and the final version will be available at L+24 months.

Approximate GLIMPSE data acquisition and product delivery schedules are given below, with L meaning date of launch (∼ September 2003) and numbers counting months:

Table 8. Product Delivery Dates

Products	Date	
(start of GLIMPSE SURVEY data taking)	*L+6*	*March 2004*
Catalog - initial	L+12	Sept 2004
IR Tool Shed with online documentation - initial	L+12	Sept 2004
(end of GLIMPSE data taking)	*L+14*	*Nov 2004*
Mosaicked Images - initial	L+16	Jan 2005
Catalog, Archive, Mosaicked Images - initial and intermediate	L+18	March 2005
IR Tool Shed with online documentation - final	L+24	Sept 2005
Catalog, Archive, Mosaicked Images - intermediate	L+24	Sept 2005
Catalog, Archive, Mosaicked Images - intermediate	L+30	March 2006
Catalog, Archive, Mosaicked Images - final	L+36	Sept 2006

Table 9. Document Delivery Dates

Documents	Date	
Science and Data Requirements - v0.5	L+3	Nov 2003
Data Products - v0.5	L+3	Nov 2003
(start of GLIMPSE SURVEY data taking)	*L+6*	*March 2004*
Data Products - v1.0	L+12	Sept 2004
(end of GLIMPSE data taking)	*L+14*	*Nov 2004*
Data Products - v1.1	L+16	Jan 2005
Data Products - v1.3	L+18	Mar 2005
Science and Data Requirements - v1.0	L+18	Mar 2005
Post BCD Pipeline - v1.0	L+18	Mar 2005
Quality Assurance - v1.0	L+18	Mar 2005
All documents - v2.0	L+24	Sept 2005
All documents - v3.0	L+30	March 2006
All documents - v4.0 (final)	L+36	Sept 2006

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GLOSSARY

2MASS	Two Micron All Sky Survey
BCD	Basic Calibrated Data, released by the SSC
DIRT	Dust Infrared Toolbox, for data analysis
dmask	A data quality mask supplied by the SSC for the BCD
GBT	Green Bank Telescope (100 m)
GLIMPSE	Galactic Legacy Infrared Midplane Survey Extraordinaire
GLMC	GLIMPSE Point Source Catalog
GLMA	GLIMPSE Point Source Archive
GPD	GLIMPSE Pipeline Description
GQA	GLIMPSE Quality Assurance
GRS	Galactic Ring Survey (^{13}CO)
GSDR	GLIMPSE Science and Data Requirements
IPAC	Infrared Processing and Analysis Center
IRAC	*Spitzer* Infrared Array Camera
IRS	*Spitzer* Infrared Spectrometer
MF	Method Flag used to indicate method of weighting fluxes
MIPS	*Spitzer* Multiband Imaging Photometer
MSX	Midcourse Space Experiment
NRAO	National Radio Astronomy Observatory
OSV	Observation Strategy Validation
PDR	Photodissociation Region
PDRT	PhotoDissociation Region Toolbox, for data analysis
pmask	A bad pixel mask supplied by the SSC for the BCD
PSF	Point Spread Function
rmask	Outlier (radiation hit) mask
SOM	*Spitzer* Observer's Manual
SSC	*Spitzer* Science Center
SED	Spectral energy distribution
SQF	Source Quality Flag
SST	*Spitzer* Space Telescope
smask	Stray light mask
TBD	To Be Determined
VLA	Very Large Array
WITS	Web Infrared Tool Shed, for data analysis