Plan to make SLIMED lunar calibration widely accessable

Hugh H. Kieffer File=-/slim/Plan.tex Version 2023jan06

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Abstract

The SLIM lunar calibration system was developed in IDL, a proprietary language. At least the parts used to do a lunar calibration need to be implemented in a common scientific language so that it is available to the GSICS community. A proposed way to do that is described here; first as a specification then as an implementation. To minimize the total community effort, the first step is to convert existing GIRO files into files to be input to the SLIMED calibration. All of the routines required have been generated in IDL so that most of the task is straight-forward code translation.

1 Introduction

A new model of lunar spectral irradiance has been published:
Hugh H. Kieffer, Multiple-instrument-based spectral irradiance of the Moon
Journal of Applied Remote Sensing (JARS). Vol. 16, Issue 3
https://doi.org/10.1117/1.JRS.16.038502 Open Access
This model defines and uses the SLIM methodology, designed for easy updates.

As with ROLO, all SLIM lunar model development has been done in IDL, a proprietary language, using a custom file format. To make it accessible to the lunar calibration community, the calibration software must be in a common scientific language, such as Python or some version of C (in which I am not fluent) and use common file formats. Although the instrument information needed for a SLIMED calibration is virtually identical to that for a ROLO calibration, the format for GIRO implementation is different. What is needed is a common-language and standard-format version of SLIMED calibration. It should be generic in nature so as to address sources which may be outside the GSICS domain.

The first IDL version of SLIMED calibration written using all NetCDF files, involved only 2 custom IDL routines and only about 200 lines of executable code. However, it assumes that task of converting observation time and location to photometric angles can be adopted from GIRO with little or no change. It did not address transforming band spectral response to effective wavelengths. That version was based on only what SLIM required and did not consider GIRO files. To use it, each team would have to generate calibration files in new formats.

A solution, suggested by Tom Stone, is to write a GIRO-to-SLIM converter. This routine could read any number of GIRO input files for the same instrument and write the equivalent single SLIM input file. New users would be encouraged to generate SLIM input files directly.

To ensure a full definition of widely accessible version of SLIMED calibration, the entire system, from basic user files to calibration ratios, using only NetCDF files, has been written in IDL. It can be run by anyone with and IDL version 8 or later as is. This allows testing of each stage of a new-language version.

Because few, if any, persons other than me, will run IDL:bin calibration system, the public SLIMED lunar calibration system may as well also be called SLIMED. To lessen confusion in this document, the IDL-NetCDF version will be called SLIM:N and the to-be-built version is a public language SLIM:P . The tentative name for the the GSICS to SLIM converter is GITOS (pronounced gee-toes, similar to the American orange snack food Cheetos).

In SLIM:N all file contents have been specified in a manner that separates information based upon it permanence. Everything in the specification is open to discussion, including how to group information into files. The GSICS group should come to agreement on a final specification.

The IDL versions of all routines needed were first coded to support both the SLIM native file format, −.bin5 and −.bin8, as well as NetCDF format, and the results compared. These were then simplified by removing all the .bin and debug code to make the versions to be translated, which are attached.

A few bugs remain, identified below, however these do not affect assessment of the size of the code translation task. I will continue work to eliminate the bugs.

1.1 Overview of using a lunar model for calibration

The instrument information needed to do lunar calibration has different permanence.

Spectral: S The instrument team (Team) determines the system-level relative spectral response of each band, usually pre-launch. Band spectral response is commonly stable over the life of a mission. This category can also include **S**table information about the spacecraft, instrument, institution and instrument team.

Geometry: G Time and location of lunar observations is usually static soon after each observation.

Irradiance: I The total irradiance of the Moon as derived using the same calibration coefficients as for science products. It may be computed multiple times as image processing procedures improve.

Team formats the Spectral, Geometry, and Irradiance results into standard format files. These files are input to calibration processing, which outputs a file of calibration ratios of the observation irradiance divided by the model irradiance.

The set of NetCDF files is similar to the .bin5 set. All extensions are '.nc'

_wt 'Wavetran' files containing the Relative Spectral Response (RSR) information in band-concatenated form.

_rw RSR information in band-concatenated form, but interpolated onto a fixed Uniform Proportional Resolution Set (UPRS) wavelengths. SLIM uses a set starting at 300 nm with resolution $\lambda/\Delta\lambda = 1000$ with 2115 points ending at 2481.8 nm . Some other resolution or range could be used.

_ew 'Effective wave' files, converting the _rw data for each band into an effective wavelength for the nominal Sun and nominal Moon, and the in-band irradiance as well as some other values.

_tv Time and location of each observation.

_ir Observed irradiance at each time for each band. Strictly parallel to the _tv and _ew files.

_ui Uncertainty data received from teams; kept in -/src/ACRO/

_uu Full uncertainty aligned with _ir and in the same units.

_pg Photometric geometry and distance factor for each observation. Strictly parallel to the _tv file.

_mi Irradiance for each band scaled to standard distance. Strictly parallel to the _ir file. Not used in NetCDF.

_cal Calibration ratio: observed / model irradiance. Strictly parallel to the _ir file.

SlimRefSpec.nc Contains the reference Solar and Lunar spectra in UPRS form, and the solar variation arrays.

Note: The current Total Solar Irradiance (TSI) file has daily data for Nov 17, 1978 to Feb. 16, 2021, with 20 bland years added before and after. Periodically, it should be updated with recent observations.

1.2 Model generality

An important aspect of the SLIM model formulation is that it will accommodate any model that is the sum of polynomials and cross-terms of the geometric and wavelength terms described in the publication:

p signed phase angle

$g \equiv p$ the absolute value the phase angle

$q \equiv 1/g$ the inverse of the absolute phase angle

h or 'Hlon': the sub-solar selenographic longitude

z or 'Hlat': the sub-solar selenographic latitude

x or 'Vlon': the sub-viewer selenographic longitude

y or 'Vlat': the sub-viewer selenographic latitude

w or 'wave': the effective wavelength in micrometers, or its inverse or its log
Such polynomials should be adequate for all models except at very small phase angles, as $\lim \frac{\partial M}{\partial g} \to 0$ as $g \to 0$ is required because of the finite size of the Sun and is difficult to accomplish without rational functions.

2 SPECIFICATION

2.1 Information Packet concept

To accommodate the different "permanence catagories", instrument data may be divided into "packet" files, listed in Table 1 The contents of several packets could be combined into one file, as long a no item is repeated within one file, which would require renaming some items, such as 'var_desc'

Another goal is to keep files small enough that they can be exchange by email without hitting institutional size limits. For example, the total of the 6 files for SeaWiFS, 8 bands and 204 observations, is 107 kB.

3 File Specifications

Word type: Arrays are followed by an indication of dimensionality.
S: string
I: integer, generic. I1 is byte, I2 is 16-bit, I4 is 32-bit
R: real, generic. R1 is 32-bit (single precision), R2 is 64-bit (double)

Category: in order of decreasing strictness: **C** in tables below
e: essential. Required for calibration to run
c: compulsory. Required for complete identification
m: model. Good practice, but required only if data are to be used in lunar model generation
w: which. Only if needed to distinguish between similar entities
d: descriptive. Will be forwarded to calibration output if present.
o: optional. May be included, but are not forwarded to the calibration stage

The first attributes, 'title' through 'oversamp_stat', have the same names and similar content for each packet.

GSICS 'channel' is equivalent to SLIM 'band'. GITOS and SLIMED files only include VIS/NIR bands; in the range 300 to about 2500 nm.

Table 1: Instrument team Lunar Observation file contents. **M** is the number of bands, **N** is the number of dates. Leading brackets in the description column contain name used in GIRO, if different than in SLIM

NAME	C	TYPE	———— Attributes ———— Packet S:/ Spectral and Source File _wt
title	d	S	Brief name for what is in this file
summary	d	S	Summary of file, describing contents of each variable.
institution	c	S	Name of organization generating this file
insti_url	d	S	url of the institution
license	d	S	Any legal limits or disclaimers
platform	c	S	Name of spacecraft or observatory
instrument	e	S	Name of instrument. Should not repeat 'platform'
serial	w	S	Serial number within virtually identical instruments. May be null. See note
acronym	c	S	Short word that is unique within GSICS. Registered upon first submission
data_source	d	S	Source of the data, and any version number or date
creator_name	d	S	Name of Individual or group that generated this file
creator_email	c	S	How to contact the above person
date_created	d	S	Time when this file was generated, UTC in yyyymonddThh:mm:ss format
history	d	S	Processing history, e.g., software & version, special processing, ... See note
id	d	S	File names(s) that institution would normally associate with these data. Commonly ridgedly formatted and long.
model	c	S	[reference_model] Name of the lunar spectral irradiance model
reference	d	S	List of materials describing the instrument, observations or processing
oversamp__stat	c	S	Status of over-sample factor. Valid values are: 'none, 'team','calib'
- - -	-	-	- - - End of standard ID set - - - -
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables ————
band_id	c	S(M)	[channel_name] Name normally associated with the band, each unique
nom_wav	e	I2(M)	[effective_wavelength] Nominal wavelength in nm, each unique
srf	e	R1(x,2)	System-level Relative Spectral Response, bands concatenated. [*,0] is Wavelength in nm. [*,1] is the System-level relative spectral response. See note
nin_band	e	I2(M)	Number of points in each band in 'srf'
NAME	C	TYPE	———— Attributes ———— Packet G: Geometry File _tv
ditto	"	"	Similar to standard set in Packet S
view_type	e	I	Allowed values: 1: observatory (fixed to the ground)
–	–	–	2: airplane or balloon (in the atmosphere)
–	–	–	3: spacecraft (beyond the atmosphere)
num_date	e	I2	[date] Number of observation times.
——	–	—-	———— Variables ————
date	e	R2(N)	Observation time of center of the Moons disk, seconds since 1970-01-01T00:00:00Z See note.
sat_pos	e	R1(N,3)	Viewer location. XYZ of Earth-Centered Inertial position or N=1 Observatory location. See note.
tele_loc	e	R1(3)	Fixed telescope location. latitude, Longitude E, elevation. See note.
obs_qual	m	R1(N)	Relative uncertainty of the irradiance determination of each observation. Median value of 1.
oversamp_fa	d	R1[N]	Optional. Factor already applied to "irr_obs"
NAME	C	TYPE	———— Attributes ———— Packet I: Irradiance File _ir
ditto	"	"	Similar to standard set in Packet S
——	–	—-	————Variables ————
irr_obs	e	R1(N,M)	Measured lunar spectral irradiance. Units: micro-Watt m^{-2} nm^{-1}. See note
obs_unc	m	R1(N,M)	One-sigma uncertainty of the measurement, same units. Independent of 'obs_qual'

3.1 Table 1 Notes

The following attributes MUST agree between packets: 'platform', 'instrument', 'acronym' and 'serial'.

date The SLIM system was developed using days from 2000 Jan 01 noon UTC, with the conversion to JPL ephemeris time (ET, now defined by the IAU to be identical to TDB) within the lunar geometry routine. In late 2022, a change was made to allow ingest into the SLIM system using either UTC as days after 2000 jan 1 00:00 Zulu or the GIRO standard of seconds after 1970 jan 1 00:00 often called Terrestrial Time, or TT. The conversion to ET is done in a separate routine (which ignores the periodic terms under 2 millisecond) prior to interrogating the ephemeris. The conversion between TT and ET is simple: ET = TT/86400 -10957.5. The conversion between UTC and ET involves leap seconds and some fixed offsets.

history Human readable set of 4 to 6 items in order, appended for each process
- Entry separator, " [=> ". Omitted before the first entry
- Date of running the process as yyyymonddThh:mm
- Process name
- Process software date as yyyymondd; Thh:mm optional
- Optional: Email address of the person who ran the process
- Optional: Notes: any additional description.

irr_obs SLIM system uses micro-Watt m^{-2} nm^{-1}, as does ROLO; values are on the order of 1. GIRO units of W $m^{-}2$ $\mu m^{-}1$ are smaller by a factor of 1000.

oversamp_fa, oversamp_stat Determination of any oversample-factor (oversamp_fa) is done by the instrument team. It is commonly the same for all bands, but may be 2-D:[N,M]. 'oversamp_stat' records its status: "none" if there is none. If it is applied before reporting "irr_obs", then 'oversamp_stat' should be 'team'; else 'oversamp_stat' should be 'calib' and the factor will be applied in the calibration stage.

sat_pos N points of Cartesian Earth-Centered Inertial position; e.g., Earth-centered ICRF in km. (as used in the JPL ephemeris) or some other ECI system different by less than 0.5 km.

serial If not null, will be appended to the acronym name for identification in file names.

srf Bands must be in the same order as in 'band_id' and 'nom_wav'

tele_loc Ground-fixed instrument location. Only if view_type=1, required if sat_pos not supplied. In WGS-84: fractional degrees N and E plus altitude in meters.

4 SLIMED lunar calibration output files

Items in **eff_wave**: only 0,3 and 7 are used in calibration
- 0] Nominal wavelength in nm, an integral unique within the instrument
- 1] effective wavelength for the Sun in nm
- 2] mean in-band solar irradiance in lunar units; micro-Watt m^{-2} nm^{-1}.
- 3] effective wavelength for the Moon in nm
- 4] mean wavelength in nm
- 5] equivalent width in nm
- 6] Mean albedo
- 7] mean in-band lunar irradiance in lunar units

Items in **pg_desc**:
- 0] sphase: signed phase angle
- 1] Hlon: Sub-Sun selenographic longitude, degrees
- 2] Hlat: Sub-Sun selenographic latitude, degrees
- 3] Vlon: Sub-Viewer (spacecraft) selenographic longitude, degrees
- 4] Vlat: Sub-Viewer (spacecraft) selenographic latitude, degrees
- 5] distFac: Distance factor; multiplier to adjust observed irradiance to standard distance
- 6] Hdist: Center-of-Moon heliocentric distance in Astronomical Units

Table 2: Lunar Calibration output file contents

NAME	C	TYPE	———— Attributes ————- File _ew: Effective wave
ditto	"	"	Similar to standard set in Packet S
vardesc	c	S	brief description of the 2nd dimension of 'eff_wave'
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables ————
eff_wave	e	R1(M,8)	Effective wavelength array [band,item]
NAME	C	TYPE	———— Attributes ————- File _pg: Photometric Geometry
ditto	"	"	Similar to standard set in Packet S
vardesc	c	S	brief description of the 2nd dimension of 'pgeom'
num_date	e	I2	[date] Number of observation times.
——	–	—-	———— Variables ————
eday	e	R2(N)	Observation time of center of the Moon's disk, ephemeris time as days since epoch J2000 . See note.
pgeom	e	R1(N,7)	Photometric geometry and distances
NAME	C	TYPE	———— Attributes ————- File _cal: Calibration
ditto	"	"	Similar to standard set in Packet S
reference_model	e	S	Name of the reference model and its version
vardesc	c	S	brief description of the 2nd dimension of 'calib_rat'
num_date	e	I2	[date] Number of observation times.
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables ————
calib_ratio	e	R1(N,M)	Calibration ratio: Observed / model irradiance [date,band]

NAME	C	TYPE	———— Attributes ————- File _tr: Trends UNDER CONSTRUCTION
ditto	"	"	Similar to standard set in Packet S
reference_model	e	S	Name of the reference model and its version
trend_form	C	I	Trend form number
vardesc	c	S	brief description of 'trend' and 'T_coef'the 2nd dimension of 'TBD'
——	–	—-	———— Variables ————
trend	e	R1(N,M)	Normalized trend
t_coef	e	R1(k,M)	Coefficients for each band

5 IMPLEMENTATION

This system currently checks for existing output files and creates unique names as needed so files are always written. Other methods may be decided later.

5.1 SLIM NetCDF directory and file names

The input argument for all routines is an array of 16 words the specify directory and file names. The same array, with the same values, is used for all the routines to get from the GITOS output to calibration results. 9 of the 16 values are normally null. The 7 '_xx" fields allow a unique value to be inserted. For 9 of the values, indicated by an '*' in the description, if the field includes a '/' at any location, the field must contain the full path name. Otherwise, use the standard name construction; e.g., directories + acronym + entry + standard last part and '.nc'. Below is how it can appear:

```
I      Description              Value
0 Instrument acronym          = SeaW
1  " serial number            =
2  Unique run version         =
3 Top directory               = /work2/slimnet/
4 Sub-dir for input files     = S/
5 _wt version *               =
```

Figure 1: Leading numbers are the SLIM processing steps. See chart 4 of CRWG22Dec01.pdf

```
--------------------------------------------------------------------------

                            [GIRO file 1][file 2]... [file N]
                                                   V
 New Teams: Generate GIRO files /\                GITOS converter
               or SLIM packets \/              NetCDF formatting only

 - - - - - - - - - - - - - SLIM NetCDF system  - - - - - - - - - - - - -

                    [SLIM input file(s): 1-to-3 packets]
   [Spectral data: _wt]+ [Irradiance data: _ir] +[Time & Location data: _tv]
                    V                 |                   V
   1: RSR's to Effective Wave         |     2: Location to angles & distance
      Run once for an instrument      |      correction. Same as GIRO:SPICE
                    |                 |          |
                    V                 |          V
 [Sun & Moon]  [_ew file]            V     [_pg file]  [Model file]

                  3. SLIM Calibration: SLIMCAL_NC

                     [ Instrument CalibRatio file. _cal ]
--------------------------------------------------------------------------
```

```
  6 _tv version *              =
  7 _ir version *              =
  8 Sub-dir for output files   = L/
  9 _rw version                =
 10 _ew version *              =
 11 _pg version *              =
 12 _cal version *             =
 13 Sub-dir for reference files = refer/
 14 Sun & Moon file name *     = SlimRefSpec
 15 Model file name (dhm) *    = 22Apr16T1827
```

6 Remaining bugs

- slim2pg_nc: Rotation of observatory to inertial coordinates . Error in longitude. This is a new capability not yet being used.
- slimcal_nc: Calibration ratios have offsets associated with sign of phase angle. Serious, in work.

7 Files needed

The subsections here list all routines needed to run the SLIMED:N calibration system. Most or all of the Utility category can probably be found in existing libraries for the target language.

SLIMNTOP is simply a pipeline of the full process. It main purpose is to enable my automatic system of listing all required routines.

A draft version of GITOS is provided; it reads .bin file to produce valid NetCDF files.

The software to convert the instrument time and location to photometric angle must exist in the current GIRO system and would replace nearly all the vector algebra routines in SLIM2PG_NC

7.1 If use GIRO geometry

22 routines. Total executable lines= 2040.

```
Primary
 SLIMNTOP     Main program to run SLIMED calibration on GIRO files. Test version
 GITOS        Write SLIM _wt _tv _ir  [_tr] NetCDF files for one instrument
 SID2BIJ      Convert term symbols to their values (coef*BF) for each date
 SLIM2EW_NC   Convert relative spectral response to effective wavelengths
 SLIM2PGFAKE  SKELETON Convert time and location(_tv) to photometric angles. NetCDF
 SLIMCAL_NC   Calibration of 1 instrument against SLIM model. .nc only

Substantial
 DINTERP    Interpolation of integrated values using double precision
 EPHEMDAY   Convert between times: UTC as days fomr 200 Jan 1 00:00, TT seconds & Ephemeris
 RWAVE      Generate wave-set for the RW uniform log spacing wavelength
 SLIMFAME   Construct names for the NetCDF system from parts.
 SLIMSATT   Read or write SLIM-system NetCDF standard attibutes to files

Utility
 BIN5       Write/Read numeric binary files with 'standard' header
 BIN8       Write/Read files with standard header, 3 numeric and 1 string arrays
 DELAST0    Delete trailing 0's past the decimal point
 FILEMASK1  Select one file from all matching a mask. Can sort 1951 to 2050
 FILEUNIQ   Ensure file name generated is unique; does not yet exist
 GETPSN     Interactive input any elements of a string array, with prompt
 LOCATE     Find lower index of interval in ordered xx containing x
 MONTH      Converts 3-character month to/from integer 1:12
 READTXTCOL Read a columnar file of ASCII [space,comma,tab]-delimited text
 STO        Make minimal string for numbers, or string arrays
 STRUMS     Separate or concatonate strings into one using separator.
```

7.2 Additional, with all geometry

20 routines. Total executable lines= 435

```
Primary
 SLIM2PG_nc  Convert time and location(_tv) to photometric angles. NetCDF

Substantial
 MOONGEOM     Photometric geometry of vehicle, Earth, Moon, Sun
 MOON_ORIENT  Compute Moon spin axis and prime meridian orientation

Utility
 COCEMC     Coordinate conversion: elliptical mapping to Cartesian
 COCOCE     Coordinate conversion: cartesian to latitude & East Long.
 COCOCS     Coordinate conversion: Cartesian to spherical.
 EUL2M      Euler angles to rotation matrix
 PM180      Brings angles into half-circle range [-180,+180)
 ROTAX      Change coordinate transform to include additional rotation 'R'
 ROTDIA     Form diagonal 9-vector form of 3x3 matrix of magnitude  R.
 ROTMATA2E  Rotation matrix from J2000 to ecliptic, or reverse
 ROTMAT     Construct a rotation matrix from pointing triple.
 ROTROW     Extract  N'th  row [or column] from a 9-vector rotation matrix.
 ROTVEC     Rotate a vector         !  U =  B *  V
 ROTZXM     Make rotation matrix from vectors along Z-axis, and in X-Z plane
 TRANS3     Transpose a 3x3 matrix stored as 9-element vector
 VCROSS     cross-product of 2 vectors
 VDOT       Dot product of two vectors of same length
```

```
VMAG       return magnitude of a vector
VNORM      Normalize a vector to magnitude 1.
ZERO360    Brings angles into 0:360 degree range
```

8 Spectral scheme and Effective wavelength

A practical approach is to move all spectra onto a common set of wavelengths, then spectral operations are simple. For the SLIM system, a set with uniform resolution $\lambda/\Delta\lambda = 1000$ and starting at 300 nm was chosen; the last of the 2115 points is at 2481.8 nm

The effective wavelength of a band k with RSR $R_k(\lambda)$ to a spectral irradiance of $E(\lambda)$, for example the Sun at 1 A.U., is:

$$\lambda_{S_k} = \frac{\int_{\lambda_1}^{\lambda_2} \lambda \cdot E(\lambda) R_k(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} E(\lambda) R_k(\lambda) d\lambda} \tag{1}$$

The wavelengths limits are in theory zero and infinity but realistically are the wavelengths over which the spectral response is measured. In practice, summations are used:

$$\lambda_{S_k} = \frac{\sum_{i_1}^{i_2} \lambda_i E_i R_{ki} \Delta\lambda_i}{\sum_{i_1}^{i_2} E_i R_{ki} \Delta\lambda_i} \tag{2}$$

Effective wavelength for the Moon, where M_i is the lunar disk reflectance:

$$\lambda_{M_k} = \frac{\sum_{i_1}^{i_2} \lambda_i M_i E_i R_{ki} \Delta\lambda_i}{\sum_{i_1}^{i_2} M_i E_i R_{ki} \Delta\lambda_i} \tag{3}$$

The nominal lunar irradiance for each band is calculated using:

$$E_k = \frac{\sum_{i_1}^{i_2} E_i M_i R_{ki} \Delta\lambda_i}{\sum_{i_1}^{i_2} R_{ki} \Delta\lambda_i} \tag{4}$$

In practice the summation is done over the the full point set as R_{ki} is zero outside the RSR range of a band.

9 Example steps from RSR and lunar observation to calibration

1. Do: famm=slimfame(parf,/edit)   to create the string array `parf` of file name parts

2. (SLIM computer only) Do: GITOS,ACRO,['/work2/slim/','/work2/slimnet/S/','0'],'22Apr16T1827'
   to create SLIM _wt _tv _ir [_tr] NetCDF files for one instrument
   Replaces the next 3 steps

3. Create the ACRO_wt.nc file containing the RSR's for each band.
   Each team should here check and modify the entire cdeval array.
   Thereafter, each routine generating a NetCDF file should read this array using the SLIMSATT routine to get the static descriptions
   Open _wt or a later file containing the full cdeval array. Then do:
   cdename='q' & cdeval='q' & SLIMSATT,cdename,cdeval,fid,0,/show

4. Create the ACRO_tv.nc file containing the time and location of each lunar observation.

5. Create the ACRO_ir.nc file containing the observed irradiance in all bands for each lunar observation date.

6. Do: slim2ew_nc,parf   to create the ACRO_rw.nc and _ew.nc spectral files.
   Need this only once unless the RSR's change (e.g., Suomi VIIRS)

7. Do: slim2pg_nc,parf   to create the ACRO_pg.nc geometry file

8. Do: slimcal_nc,parf   to create the ACRO_cal.nc calibration file

10 Coding Task, from IDL to public

GITOS: New code reformatting GIRO NetCDF files, attributes and variables. No calculations.

Relative-Spectral-Response to Effective-Wavelength-File: [_wt to _ew]
Currently slim2ew_nc.pro
May exist somewhere in the GIRO system
Requires two functions:
1) Interpolation of the RSR's onto the uniform proportional resolution system (UPRS): $\lambda/\Delta\lambda = 1000 \Longrightarrow$ *ACRO_rw.nc*
2) Spectral multiplies to form effective wavelength and in-band nominal lunar irradiance.

Time+location to angles (+ Distance Factor). Requires JPL ephemeris [_tv to _pg]
Currently slim2pg_nc.pro, reads the JPL ephemeris
Other possible methods:
Use the JPL SPICE software system. Already exists in the GIRO system?
Use the JPL Horizons system. https://ssd.jpl.nasa.gov/horizons/

Calibration
Currently slimcal_nc.pro
One major subroutine (generic basis function generator): sid2bij.pro

10.1 File overwrite

For .nc output files, the function FILEUNIQ checks if the named file already exists. If so, the user is first asked if they want to over-write the existing file and unless they choose to, the output name is modified by inserting a single character before the file type.

10.2 Treatment of uncertainties

Uncertainties may be expressed as fractional or in the same units as irradiance. Uncertainties are not used in calibration, but are essential for developing a model. Ideally, each team would generate uncertainties along with irradiance and express them in the same units. If they are not provided, some estimate must be made before incorporating the irradiance data in a fit.

The system here also allows for "obs_qual" observation relative uncertainty factor that would multiply the the uncertainties of all bands for the corresponding date. The median value for this factor should be near unity.

10.2.1 DINTERP: exact-weight interpolation

Given a spectrum Y_i at a set of X_i (monotonic increasing) points. Consider $Y(x)$ to be the piece-wise linear function that connects the (X_i, Y_i) points.

Find the equivalent spectrum Z_j at a set of N X_j monotonic increasing points where the domain of each j point, j_- to j_+, extends midway to the point below or above it. I.e. $x_{j\pm-} = [x_j + x_{j\pm1}]/2$ and for the end points the exterior part of their domain is the same size as the interior part.

$Z_j = \int_a^b y\ dx / \int_a^b\ dx \Leftrightarrow (x_b - x_a)$

Each Z_j is the average value of Y over the range $\Delta X_j = X_{j-}$ to X_{j+}

The j set may be either sparser or denser than the i set. If on the average denser, uses linear interpolation between input points.

End conditions:

Outside of the X_i range, Y may be considered to be either zero or constant at its end value. The wavelength range of source Sun and Moon spectra for lunar calibration is adequate that condition is not needed. However, for band RSR's, exterior i points are assigned $Y_i = 0$

DINTERP impliments this. Method: Makes cumulative sum of $Y_i \Delta X_i$, linear interpolation at X_j midpoints. Takes Δ of this interpolation and divides by ΔX_j .

To make Z in this way, the lowest useful i is last point before first j- midpoint and last useful i is first after the last j+ midpoint.

11 Changes to charts

GSICS may chose to combine the S,G and I files. I would discourage this.

Two routines for handling file names and the descriptions (attributes) in NetCDF files are used. SLIMFAME and SLIMSATT; the intention is to ensure consistency.

A Programming language notes

IDL uses zero-based indices and many of the descriptions put into NetCDF files assume this.

Within SLIM:development, the band name (string), nominal wavelengths (unique integer) and nominal proportional uncertainties are assigned in a text command file, *-/WT/ACRO_unc.tab*. This file sets the band order; e.g., it can be made monotonic increasing wavelength or bands may be omitted. The NetCDF version does not have this flexibility, band order remains as submitted.

A.1 File locations on SLIM home computer

On the SLIM home computer, "H4", all .bin5[8] and IDL save files, and all text control files, are under /work2/slim/

Files from teams go in -slim/src/ACRO/... and are not modified.
NetCDF files that are only modified to SLIM format go in -/slimnet/S/
NetCDF files that result from SLIM calculations go in -/slimnet/L/

A.2 SLIMFAME and the parf array

```
The 'parf' array of strings is an attempt to deal with several objectives:
-) Have a simple and consistent argument pointing to files for several routines
-) Allow each Team will have its own directory structure for lunar calibration
-) Anticipate that there will be cases when a team wants to run alternate versions of files.

Normal use is:
   famm=slimfame(parf,/edit)
This should produce:
------------------------------
Input item # and its new value. [-1 1 for current list, -2 2 for quit].
No quotes.  First space deleted, so <space><CR> yields the null string
 -1 9 will show blanks or null
File names: parf
  0 Instrument acronym          = AerN
  1  " serial number            =
  2  Unique run version         =
  3 Top directory               = /work2/slimnet/
  4 Sub-dir for input files     = S/
  5 _wt version *               =
  6 _tv version *               =
  7 _ir version *               =
  8 Sub-dir for output files    = L/
  9 _rw version *               =
 10 _ew version *               =
 11 _pg version *               =
```

```
 12 _cal version *              =
 13 Sub-dir for reference files = refer/
 14 Sun & Moon file name *      = SlimRefSpec
 15 Model file name (dhm) *     = 22Apr16T1827
Enter index and new value>
---------------------------------
The top 4 lines are instructions. E.g., enter: 3 /home/lunar/
                                   will replace: /work2/slimnet/
At any time,  -1 x  (any character for x)  will display the current set
At any time,  -2 x  (any character for x) will save the current values and return

The extension for all files defaults to '.nc'

Items 0+1+2 make up the name of the instrument as used in files.
Items 3+4 make up the directory for instrument input file
Items 3+8 make up the directory for output files
Items 3+13 make up the directory for items 14 and 15.

Each installation will almost certainly want to change the defaults in
slimfame.pro for at least items 0 and 3.

Full names are constructed as
  <top-dir>+<sub-dir>+<inst.name>+<type>+<value>+'.nc'
  where <type> is the first word in items 5:7 and 9:12
Thus, different versions can be made by setting the value for these.
*:  If the entered value for any of 5:7, 9:12, 14:15 contains a slash,
  then that value is treated as the full pathname for the file.
This allows complete flexability in naming files.

The returned argument, 'famm' is aligned with parf and the same size.
It contains the full path name for each file in 5:7, 9:12 and 14:15.
This is meant as a convenience.
'famm' is used in many SLIM routines for reading files.
```

A.3 SLIM system to-do list

Add prenumbral angle to the _pg file. Use fixed atm of 8.5 km. 2022Nov07
If not calculated, set to 179 degrees, which is impossible.

B Building the distribution

```
under ~/gong    mkdir dist

cd dist
 mkdir idl

In IDL
Run mycalltree on slimntop with each version of slim2pg_nc
Ehould get two different files in ~/gong/dist/
cd ~/gong/dist
Make them executable: chmod +x  <file>
  slimfake.lnk
 lt  ./idl       should have only set of links
 grep -i ';_Titl' *.pro > ti1
     if any have othercase of _Titl , then fix  that file
     if any capitals name does not agree with files name, fix that
```

```
  sed "s/^[^ ]* //" ti1 > ti2     Will remove the first 'field'
Spread ti2 into Files Needed section,
```