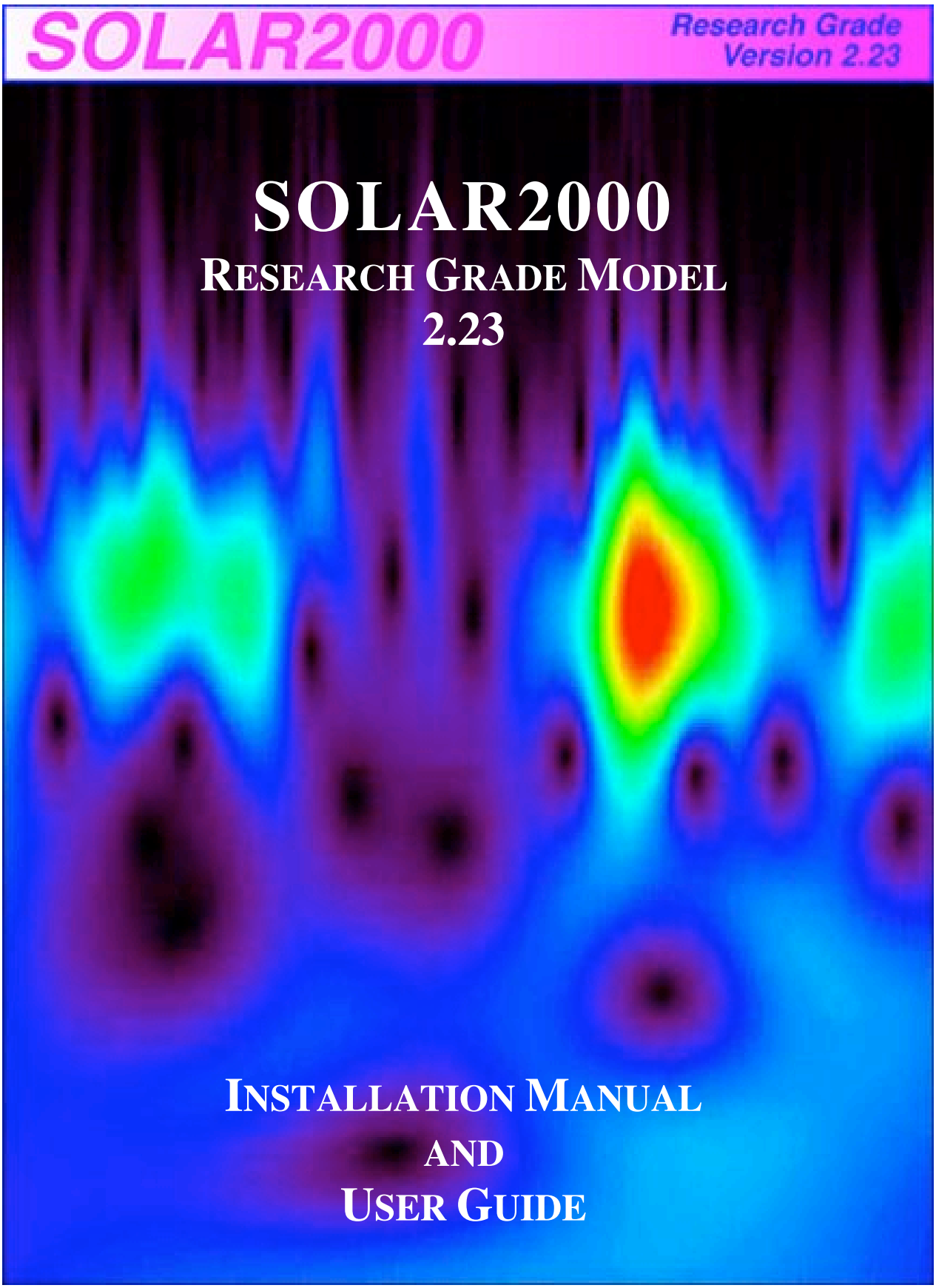

SOLAR2000

RESEARCH GRADE MODEL

2.23

INSTALLATION MANUAL

AND

USER GUIDE

RESTRICTED RIGHTS NOTICE

The SOLAR2000 Research Grade software programs and the accompanying procedures, functions, and documentation described herein are sold under license agreement. Their use, duplication, and disclosure are subject to the restrictions stated in the license agreement. Space Environment Technologies reserves the right to make changes to this document at any time and without notice.

LIMITATION OF WARRANTY

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ABOUT SPACE ENVIRONMENT TECHNOLOGIES

Space Environment Technologies provides advanced space weather Products and services. Our core expertise is the accurate specification of solar spectral irradiance variations. We link that information with empirical, physics-based, and hybrid environmental, operational, and design models that require a solar energy input. We have a wealth of experience in the process of transitioning research models into operational systems.

Along with our partners, we actively conduct research and develop applications to meet space environment user requirements by combining solar irradiances with research and operational models at a systems level. The result is improved space weather forecast products for the design, development, and operation of space and ground technological systems.

STRATEGIC VISION

Space Environment Technologies is envisioning and building the tools that enable human evolution into space in order to improve the quality of life on Earth.

MISSION STATEMENT

We will provide customers with the world's most advanced space weather information and forecasting technologies. We utilize leading-edge space physics models and aerospace applications as summarized in the National Space Weather Implementation Plan to accurately characterize the space environment. Our partners are government agencies, university researchers, and industry leaders and, together, we will create cutting-edge, applied-research solutions to reduce adverse solar-terrestrial effects. We believe that a resourceful use of our combined knowledge about the space environment's influence on technological systems will improve the quality of life for our global society.

ISO SOLAR IRRADIANCE (DRAFT) STANDARD COMPLIANCE

The SOLAR2000 Research Grade software program is compliant with the draft ISO solar irradiance standard DIS 21348.

August 2004
Manufactured by Space Environment Technologies
1676 Palisades Dr., Pacific Palisades, CA 90272, USA
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spacenvironment@spacenvironment.net; http://SpaceWx.com

TABLE OF CONTENTS

1 INTRODUCTION

Thank you for your purchase of this software that provides historical solar irradiances. Space Environment Technologies appreciates your business and makes every effort to provide the most advanced solar irradiance specification for users of space and ground systems affected by the space environment.

1.1 Contacting Space Environment Technologies (SET)

If you have problems with installation or licensing of SOLAR2000 Research Grade model, please contact SET for more assistance:

1676 Palisades Dr.
Pacific Palisades, CA 90272
USA

(phone) 1-310-573-4185
(fax) 1-310-454-9665

spacenvironment@spacenvironment.net; http://SpaceWx.com

1.2 SOLAR2000 Publication Acknowledgement

The SOLAR2000 Research Grade v2.23 empirical solar irradiance model is made available to the science and engineering communities. In all publications, please acknowledge the irradiances used from this model with the following statement:

> "SOLAR2000 Research Grade v2.23 irradiances are provided by Space Environment Technologies."

2 SYSTEM REQUIREMENTS

2.1 Hardware requirements for SOLAR2000 Research Grade model v2.23

The supported platforms and operating systems for SOLAR2000 RG v2.23 using IDL 5.6 are equivalent to the IDL 5.6 requirements (Table 1):

Table 1: Hardware Requirements for SOLAR2000 RG v2.23

Platform	Vendor	Hardware	Operating System	Supported Versions
Windows	Microsoft	Intel x86	Windows	98
	Microsoft	Intel x86	Windows NT	4.0, 2000, XP
Macintosh	Apple	PowerMac G4. G5	OS X	10.1, 10.2.x
UNIX	Compaq	Alpha 64-bit	Tru64 UNIX	5.1
	HP	PA-RISC 32-bit	HP-UX	11.0
	HP	PA-RISC 64-bit	HP-UX	11.0
	IBM	RS/6000 32-bit	AIX	5.1
	IBM	RS/6000 64-bit	AIX	5.1
	Intel	Intel x86	Linux	Red Hat 7.1
	SGI	Mips 32-bit	IRIX	6.5.1
	SGI	Mips 64-bit	IRIX	6.5.1
	SUN	SPARC 32-bit	Solaris	8
	SUN	SPARC 64-bit	Solaris	8

The supported platforms and operating systems for SOLAR2000 RG v2.23 using IDL 6.0, including the virtual machine, are equivalent to the IDL 6.0 requirements (Table 2):

Table 2: Hardware Requirements for SOLAR2000 RG v2.23

Platform	Vendor	Hardware	Operating System	Supported Versions
Windows	Microsoft	Intel x86 (32-bit)	Windows NT	4.0, 2000, XP
Macintosh	Apple	PowerMac G4 (32-bit)	Mac OS X	10.3
UNIX	Compaq	Alpha 64-bit*	Tru64 UNIX	5.1
	HP	PA-RISC 32-bit	HP-UX	11.0
	HP	PA-RISC 64-bit*	HP-UX	11.0
	IBM	RS/6000 32-bit	AIX	5.1
	IBM	RS/6000 64-bit*	AIX	5.1
	Intel	Intel x86 (32-bit)	Linux	Red Hat 7.1, 8, 9
	SGI	Mips 32-bit	IRIX	6.5.1
	SGI	Mips 64-bit*	IRIX	6.5.1
	SUN	SPARC 32-bit	Solaris 2	8, 9
	SUN	SPARC 64-bit*	Solaris 2	8, 9

*IDL can be run as a 32-bit or 64-bit application on this 64-bit platform. Both versions are installed, and the 64-bit version is the default. The 32-bit version is available via a command-line argument ('idl-32' for example).

2.2 Software requirements for SOLAR2000 Research Grade model v2.23

IDL: Your machine must have IDL® 5.6 or higher licensed and installed or must have IDL 6.0 Virtual Machine (VM) installed. The SOLAR2000 Research Grade model is provided for either IDL 5.6 or IDL 6.0. The IDL 6.0 VM is available as a free download from RSI. The VM does not support command line actions and only will enable the operation of the SOLAR2000 Research Grade GUI application. A licensed version of IDL is sold separately and may be purchased from Research Systems, Inc. (RSI). Technical support for assistance in installing and licensing IDL 5.6 or higher, or downloading and installing the free IDL 6.0 VM, can be obtained from Research Systems:

- E-mail: support@RSInc.com
- Phone: (303) 413-3920
- Fax: (303) 786-9909
- Web page: http://www.RSInc.com

International customers of RSI should contact their local RSI office or distributor for technical support.

IDL 6.0 VM web download link is: http://www.rsinc.com/download/index.cfm

JAVA: not required for S2KRG.

INTERNET: not required for S2KRG.

3 INSTALLING SOLAR2000 RESEARCH GRADE

3.1 Before you begin

Save to your hard disk the attached zip file you received with your ftp download delivery of SOLAR2000 Research Grade (S2KRG) model. Unzip the file to your hard drive as the folder called SOLAR2000RG_v2_23, notwithstanding "v2_22" in the figures shown in the examples.

3.2 Recommended steps for installing SOLAR2000 Research Grade with IDL VM

NOTE For IDL Virtual Machine (VM) users: starting with SOLAR2000 Research Grade v2.23 and IDL 6.0 or higher, it is now possible to run the model on any platform without an IDL license. The IDL 6.0 VM is available via download from the RSI web site:

http://www.rsinc.com/download/

Users must first download the IDL 6.0 or higher virtual machine (VM); help on downloading and installing the VM can be found at the above web links. Once the VM has been downloaded and installed, a X-terminal window must be opened on the operating system in order to issue the following command:

idl -vm=solar2000_rg_vm.sav

This will start the S2KRG GUI running on top of the IDL VM. Click on a RSI "splash screen" that closes the RSI advertisement and allows one to run S2KRG. The S2KRG version with "60" or higher in the file/folder name must be used.

3.3 Recommended steps for installing SOLAR2000 Research Grade without IDL VM

Start with a clean IDL working directory and paths relative to SOLAR2000 (see figure 1)

- start IDL through the IDLDE application
- under IDLDE File-Preferences-Paths, remove any SOLAR2000-related paths then Apply-Save-OK
- exit IDLDE completely

NOTE Windows operating systems require use of the IDLDE application while this is an optional in Unix-based systems, including Mac OSX. Under Unix-based systems, IDL can also be started in an X-terminal window environment by entering the command "idl" in the window command line. This command invokes the IDL licensed software and will display, at the start of a session, the following prompt:

IDL>

In these examples, the IDLDE window will be shown since it applies to all operating systems. However, the same commands can be alternatively submitted at the X-terminal IDL command line on Unix-based systems.

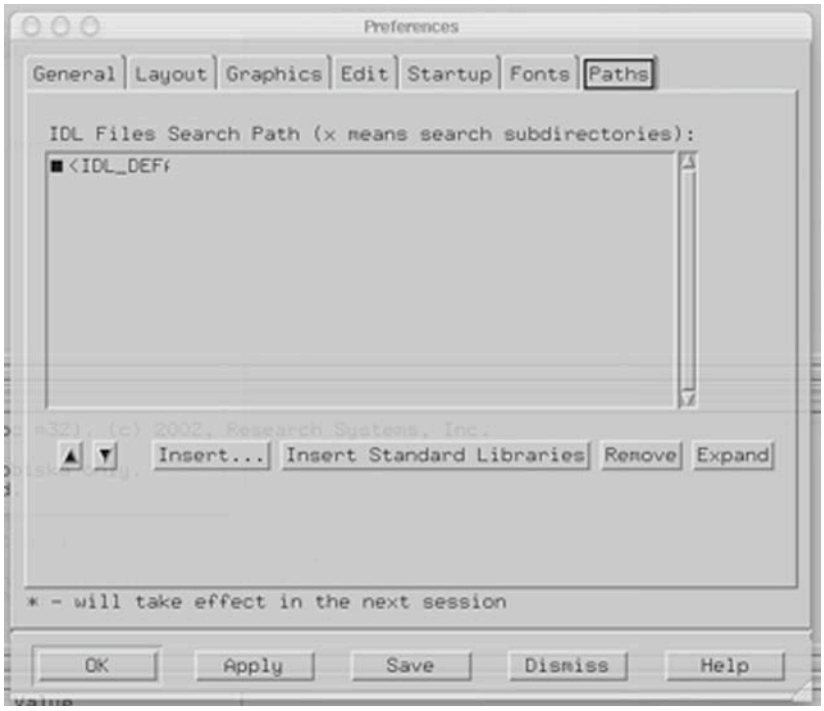

Fig. 1. IDLDE Paths window under the Preferences menu.

Set IDL working directory and paths relative to SOLAR2000 (see figure 2)

- under IDLDE File-Preferences-Startup, click Select Working Directory
- double click within the Directories side of the window to select the folder working directory of SOLAR2000RG_v2_23 on your hard drive
- click OK to exit the working directory selection window

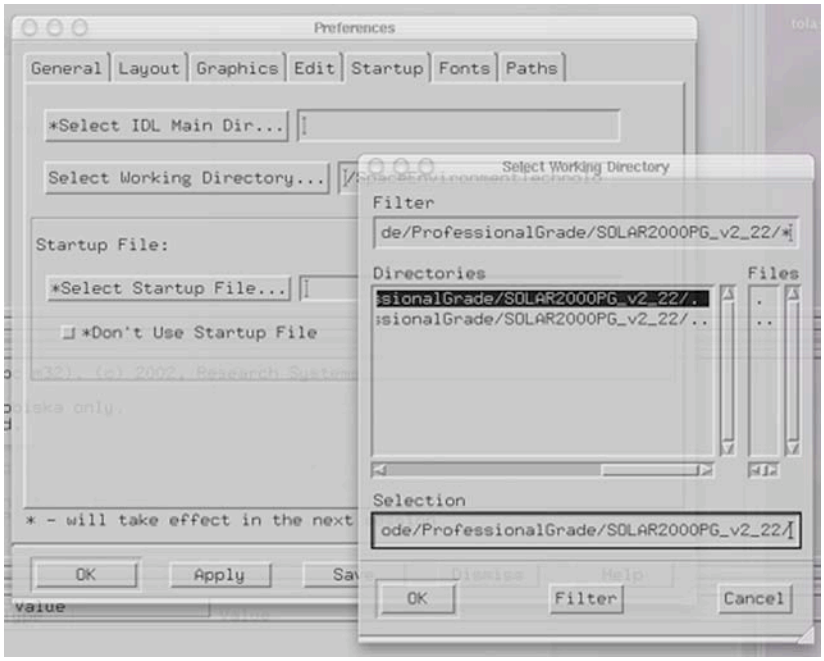

Fig. 2. IDLDE Startup window under the Preferences menu after clicking “Select Working Directory”.

4 RUNNING SOLAR2000 RESEARCH GRADE

4.1 Start SOLAR2000 Research Grade

- at the IDL command line (bottom of the IDLDE window or at the "IDL>" command line of an X-terminal) type "solar2000_rg". The SOLAR2000 Research Grade v2.23 GUI will start and the IDLDE message window will show the following:

```
% Compiled module: SOLAR2000_RG.
% Loaded DLM: TIFF.
% XMANAGER: Error handling is now off
```

- the SOLAR2000 Research Grade model application is now running and a new window will pop up called "SOLAR2000 Research Grade Version 2.23" (see figure 3); you are now ready to begin the process of obtaining operational solar irradiance proxies that drive the model and produce spectral irradiances and integrated irradiance proxies.
- The model can be left running in the background of your computer desktop. In the background state, the program is inactive but does use internal memory resources. No actions are taken by the program until the user submits a manual input.
-

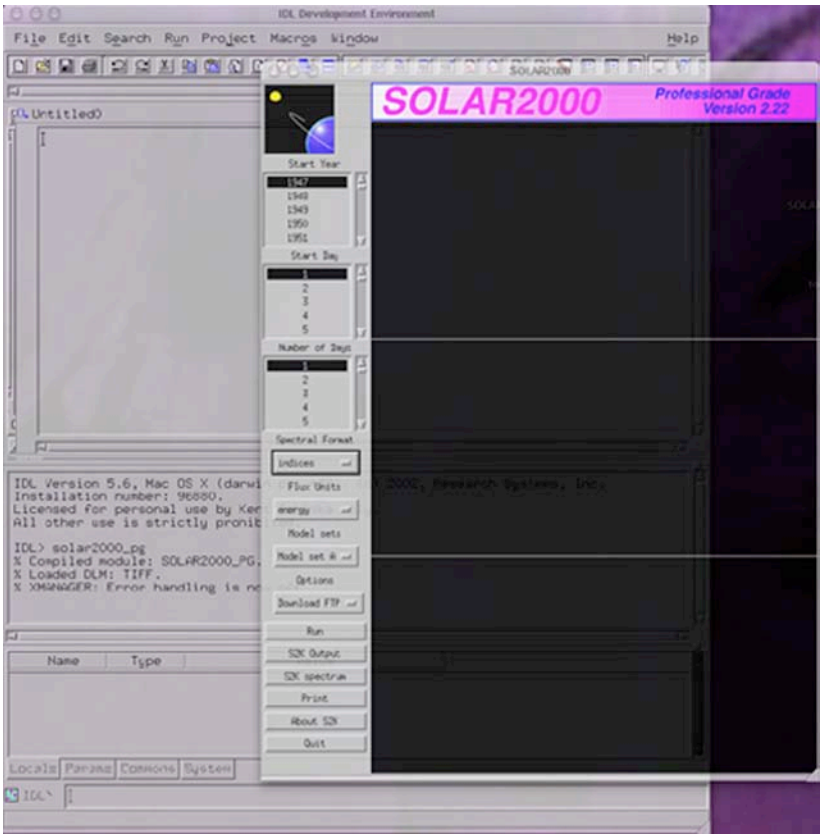

Fig. 3. SOLAR2000 Research Grade GUI window at startup. Use drop down lists and option buttons for selections.

- go to the SOLAR2000 Research Grade model GUI window and select the options you would like to run, click “Run”. The program may print informational messages in the IDLDE message window (see figure 4):

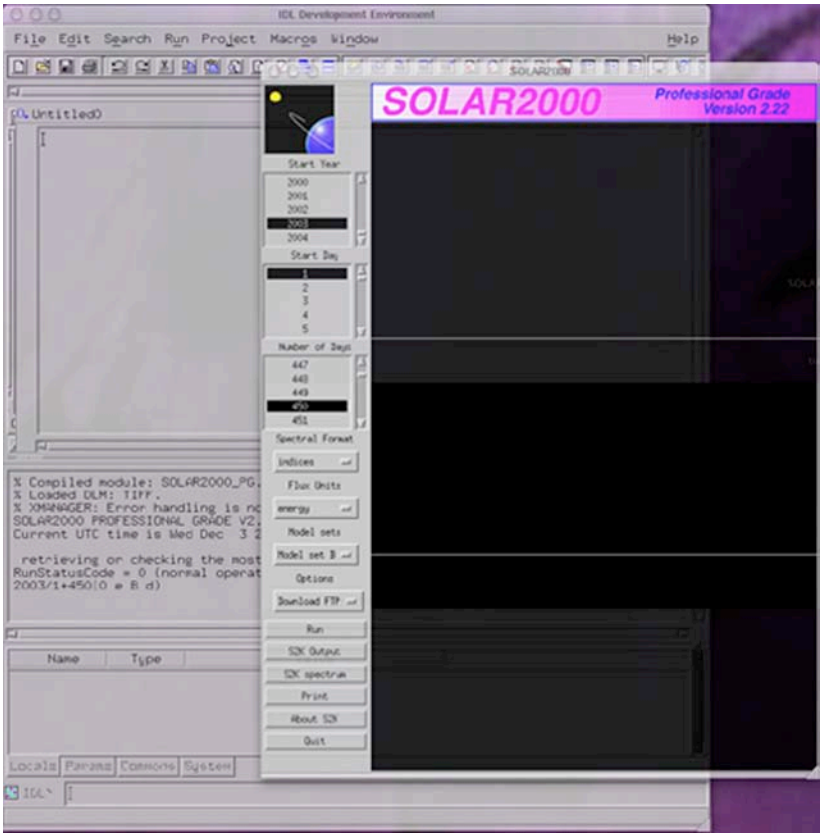

Fig. 4. IDLDE message window in the background.

SOLAR2000 RESEARCH GRADE V2.23

- a pop-up window will appear and request the name of a file you would like to save the output data into for this particular run (see figure 5). Type a file name, then click “OK”. For example, if you are making multiple runs and want to retain the irradiances values from separate runs, provide a unique filename. The file created is ASCII and it is appropriate on most systems to attach the suffix “.txt” to this file name.
- The program will show an “hourglass” while the model calculates the solar irradiances and will show a “crosshair” when finished (see figure 6). The three black panels, showing at startup, will fill with figures that provide an overview of the data run. The program is running properly and it can be left inactive in the background. The program will not automatically update and a manual click on the “Run” button is required to produce new data.
- click S2K Output to view the s2k_output.txt file (see figure 7). These values will be identical in format to the file that you saved.
- All SOLAR2000 Research Grade model output windows can close by selecting “Close” from the File menu button in the upper left corner.

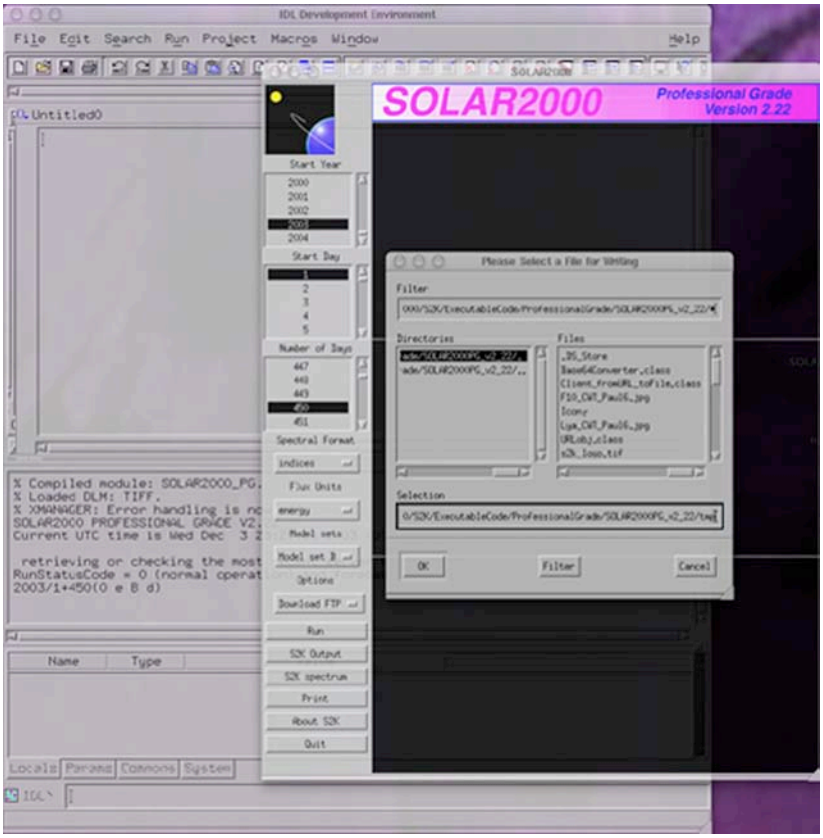

Fig. 5. Pop-up window requesting the user to provide a unique filename for this model run. Click “OK” after typing a file name.

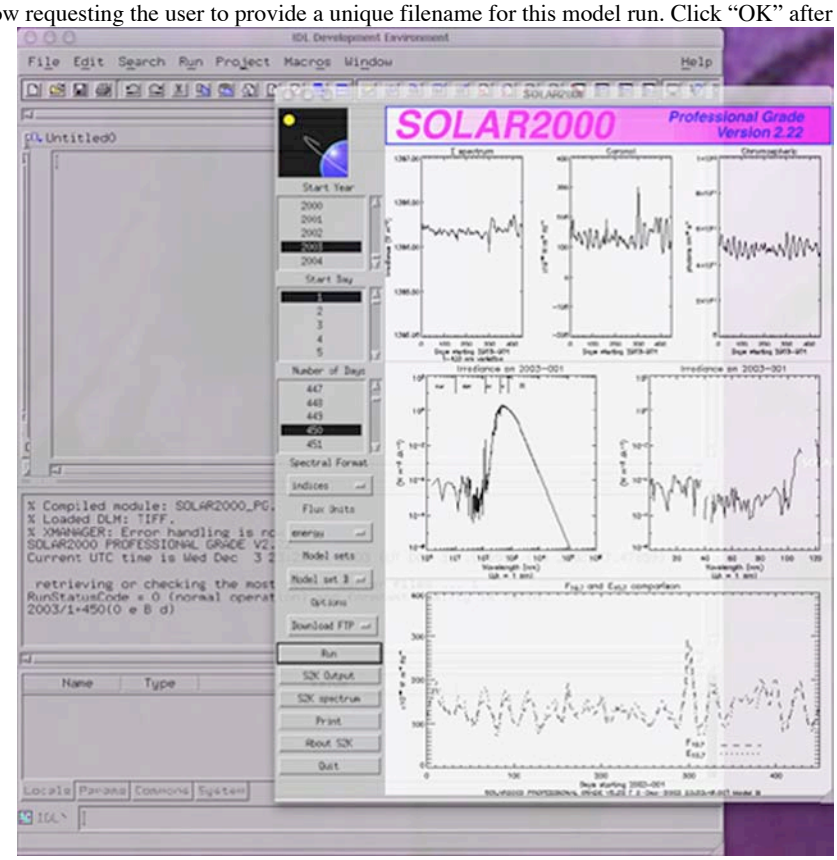

Fig. 6. SOLAR2000 Research Grade GUI window showing a successful model run.

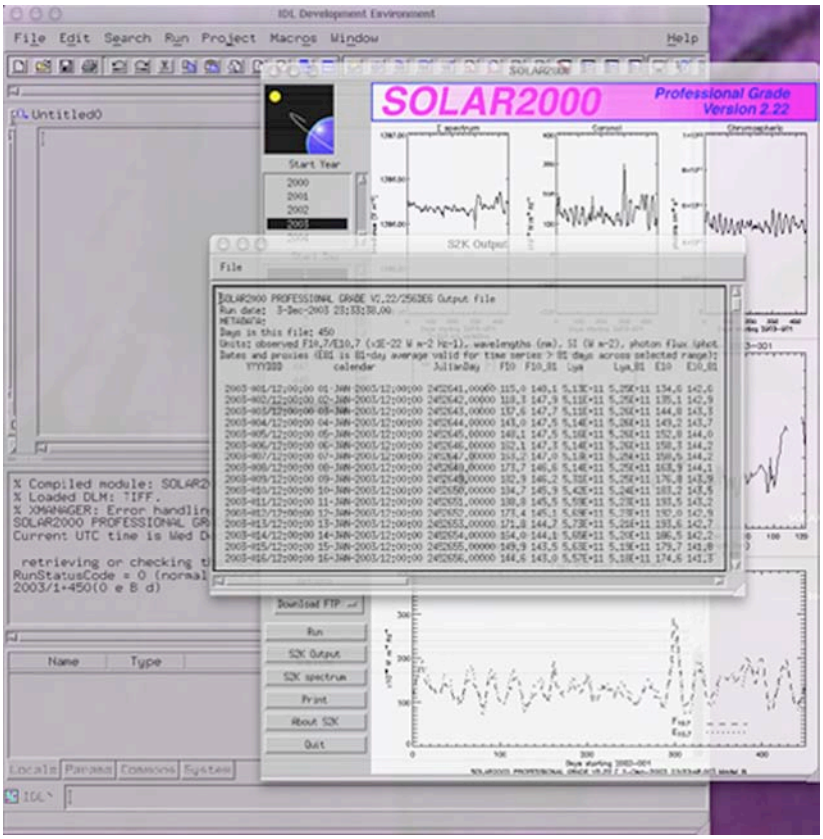

Fig. 7. SOLAR2000 Research Grade GUI window showing the contents of the s2k_output.txt (ASCII) file run for the case of 450 days, starting on January 1, 2003, with the selections of "indices", "energy", and model B ("S2K+VUV2002").

4.2 SOLAR2000 Research Grade options

There are several options available for a model run. In addition to date selection (Start Year, Start Day, and Number of Days), the Spectral Format, Flux Units, Model sets, and other Options can be changed. Many systems are capable of printing EPS files from the GUI and background information about Space Environment Technologies as well as the derivation of SOLAR2000 can be viewed.

4.2.1 Date selection

Date selection is made by the drop list menus for Start Year, Start Day, and Number of Days.

Valid start years are listed in the Start Year menu and the Research Grade program will generate the next new year on each January 1. The list starts at 1947.

Valid start days are listed in the Start Day menu and range from 1 through 366 using the Day-Of-Year (DOY) numbering system. Day 366 as a start day is an invalid entry for years other than

leap years. The program is Leap Year and Year 2000 compliant. If invalid dates or date ranges are entered, the IDLDE message window will indicate that an invalid date or range has been found and will return the program to the last valid run.

Valid number of days are listed in the Number of Days menu and range from 1 through 4018. The latter number is one full solar cycle. Some machines may run into memory problems with the selection of a large number of days and may cause IDL to crash. In this case, simply restart the program with a new IDLDE session and select a smaller number of days.

4.2.2 Spectral Format

Spectral format selection is made by the pull down menu for Spectral Format.

Valid spectral formats are “indices”, “1 nm bins”, “39 W/L bins”, and “867 W/L bin”.

indices: generates a listing in the s2k_output.txt file of only input and derived integrated solar irradiance proxies along with the date in three time formats; there is one line listing per calendar day.

1 nm bins: generates a listing in the s2k_output.txt file of the indices line followed by 1 nm binned solar irradiance data ranging from 0.5 to 1,000,000 nm for each day selected in the number of days; the output file lists wavelength, flux value, and 1-sigma uncertainty and this file can grow very rapidly if a large number of days are selected; wavelengths less than 630 nm are in 1 nm bins centered in the middle of the bin; a value of 1.0 for the uncertainty indicates a placeholder value only.

39 W/L bins: generates a listing in the s2k_output.txt file of the indices line followed by 39 wavelength groups and lines that are in common use in the aeronomy community; the output file lists the start wavelength, end wavelength, flux value, and 1-sigma uncertainty and this file can grow very rapidly if a large number of days are selected.

867 W/L bin: generates a listing in the s2k_output.txt file of the indices line followed by 867 line or continua emissions in the extreme ultraviolet (EUV) part of the spectrum; the output file lists wavelength, flux value, and 1-sigma uncertainty and this file can grow very rapidly if a large number of days are selected; the 1-sigma values are not placeholders but the formally calculated uncertainty based upon reported measurement and regression fit uncertainties at each wavelength.

4.2.3 Flux Units

There are three types of flux units that can be selected (energy, photon, SI). The values are the integrated irradiances values reported for the “1 nm bins”, “39 W/L bins”, and “867 W/L bin” spectral formats over the appropriate bin size, line, or continua emission.

energy: flux units of ergs cm^{-2} s^{-1}

photon: flux units of photons cm^{-2} s^{-1}

SI: flux units of W m^{-2}

4.2.4 Model sets

This version of the SOLAR2000 Research Grade model supports three options for models that can be run for any spectral format or flux unit format. The options are designated "S2K+ASTM490", "S2K+VUV2002", and "VUV2002" with the following differences:

Button value	EUV	FUV UV	VIS IR
S2K+ASTM490	S2K EUV	ASTME490--	ASTM E490-- (0,1,39,867)
S2K+VUV2002	S2K EUV	VUV2002---	ASTM E490-- (0,1,39,867)
VUV2002	VUV2002	VUV2002---	ASTM E490-- (1)

S2K+ASTM490: for all spectral formats and flux units the SOLAR2000 extreme ultraviolet (EUV) algorithm is used and described in the release notes under "About S2K". Longwards of Lyman-alpha through the far ultraviolet (FUV), ultraviolet (UV), visible (VIS), and infrared (IR) spectral regions, the ASTM E490 static reference spectrum is used, i.e., no daily variability. The integrated total spectral irradiance, S (row 1, first panel), will show only modest variability due to EUV variations.

S2K+VUV2002: for all spectral formats and flux units the SOLAR2000 EUV algorithm is used while in the FUV and UV spectral regions the Woods VUV2002 model is used. In the VIS and IR spectral regions, the ASTM E490 reference spectrum is used. The integrated total spectral irradiance, S, will show moderate variability due to EUV, FUV, and UV variations.

VUV2002: for only the 1 nm spectral format and all flux units the Woods VUV2002 model is used for the spectral regions of EUV, FUV, and UV spectral regions. The ASTM E490 reference spectrum is used in the VIS and IR. The integrated total spectral irradiance, S, will show moderate variability due to EUV, FUV, and UV variations.

4.2.5 Options (available only with Professional Grade model)

There are four options available in this release of the model (DownloadFTP, Standalone, Morlet6 CWT, and Paul6 CWT).

DownloadFTP: selection of this option will cause the program to activate the Java classes and retrieve a new set of proxy files from the SET server each run. Depending on internet access bandwidth, the length of time to complete this operation may vary significantly from machine to machine. Ethernet connections (T1 or greater) are extremely fast, DSL connections are moderately fast, and modem dial-up (56K baud minimum) can be quite slow. There is no need to select this option, even during the first run, unless the user specifically wants to download a new set of proxy files. Proxy files are updated hourly on the SET server.

Standalone: selection of the option will cause the program to run the model with the existing proxy files in the folder. If this is the first run after activating the SOLAR2000 GUI, or if an hour has passed since the last model run, then the standalone option is ignored and the program automatically goes to the SET server to retrieve a new proxy file.

Morlet6 CWT: creates the Morlet continuous wavelet transforms (order 6) of F10.7, Lyman-alpha, and E10.7 for the selected dates; the data sets are first globally detrended and the magnitude is plotted on an x-axis of days and a y-axis of frequency (in days).

Paul6 CWT: creates the Paul continuous wavelet transforms (order 6) of F10.7, Lyman-alpha, and E10.7 for the selected dates; the data sets are first globally detrended and the magnitude is plotted on an x-axis of days and a y-axis of frequency (in days).

4.2.6 Run

Clicking the "Run" button will start a new model run based on the selected parameters in the drop lists and pull down menus described above. As a general rule, runs with greater number of days selected will proportionately lengthen the time it takes to execute the model run. Execution times will vary based on machine bus speeds and memory.

4.2.7 S2K Output

Selection of this button will bring a pop-up window on top of the GUI and will show the values of the selected parameters. The s2k_output.txt file is shown and each file has a common meta-data section that lists the following:

```
SOLAR2000 RESEARCH GRADE V2.23/256E36 Output file
Run date:  4-Dec-2003 02:08:28.00
METADATA:
Days in this file: 1
Units:  F10.7/E10.7 (x1E-22 W m-2 Hz-1) ...
Dates and proxies (E81 is 81-day average valid for ...
     YYYYDDD          calendar           JulianDay    F10  ...
```

4.2.8 S2K Spectrum

Clicking this button will display a pop-up window in front of the GUI and the content is the s2k_tsi.txt file. The full solar spectrum is shown for the last day of the selected run in three columns of wavelength (microns), bin energy (flux of W $m^{-2}$$micron^{-1}$), and accumulated energy (W m^{-2}) (see figure 8). The third column number at the end of the file equals the value of S in the 1-line indices listing in the s2k_output.txt file.

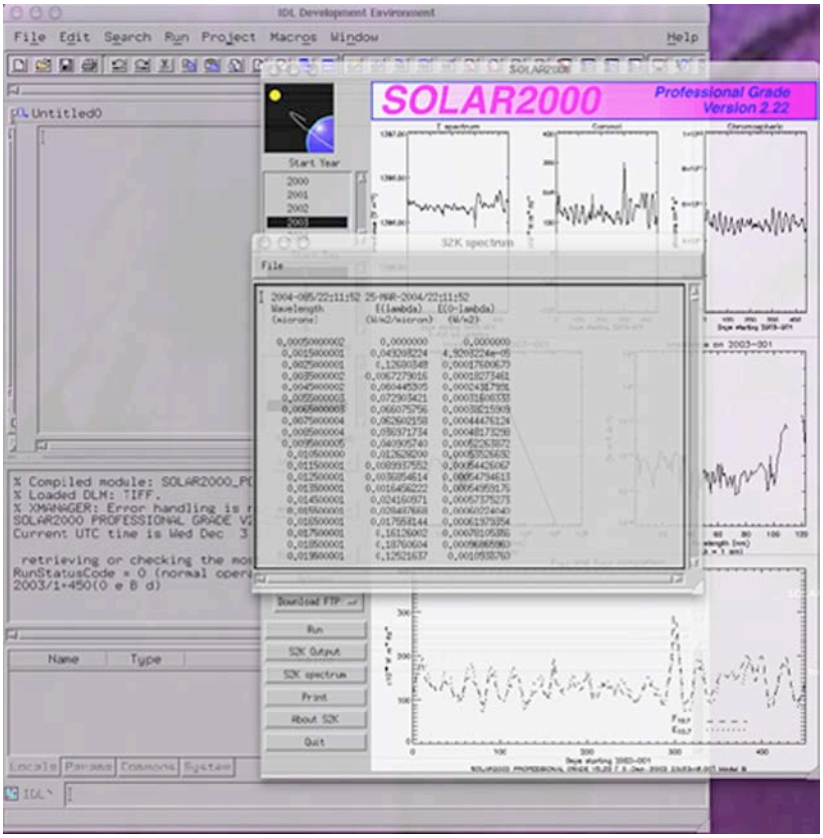

Fig. 8. SOLAR2000 Research Grade GUI window showing the "S2K spectrum" window.

4.2.9 Print

Operating systems are often capable of printing EPS files through the GUI. The Print button feature may not work on some platforms.

If a print of the GUI window is desired, there is a s2k_plot.tif produced for each model run that contains the GUI window figures. Each model run overwrites the previous s2k_plot.tif file. Separate applications outside of IDL can open this file and print it.

All other run-time files created in the SOLAR2000RG_v2_22 folder are either ASCII text files or TIFF files and can be opened and printed in non-IDL applications.

4.2.10 About S2K

By clicking on the "About S2K" button, the license agreement, publication acknowledgement notice, SOLAR2000 release notes, and SOLAR2000 user guide for the Research Grade version of the model can be viewed (see figure 9). Included in the user guide is a section on Frequently Asked Questions that is also reproduced in section 5.1 of this manual.

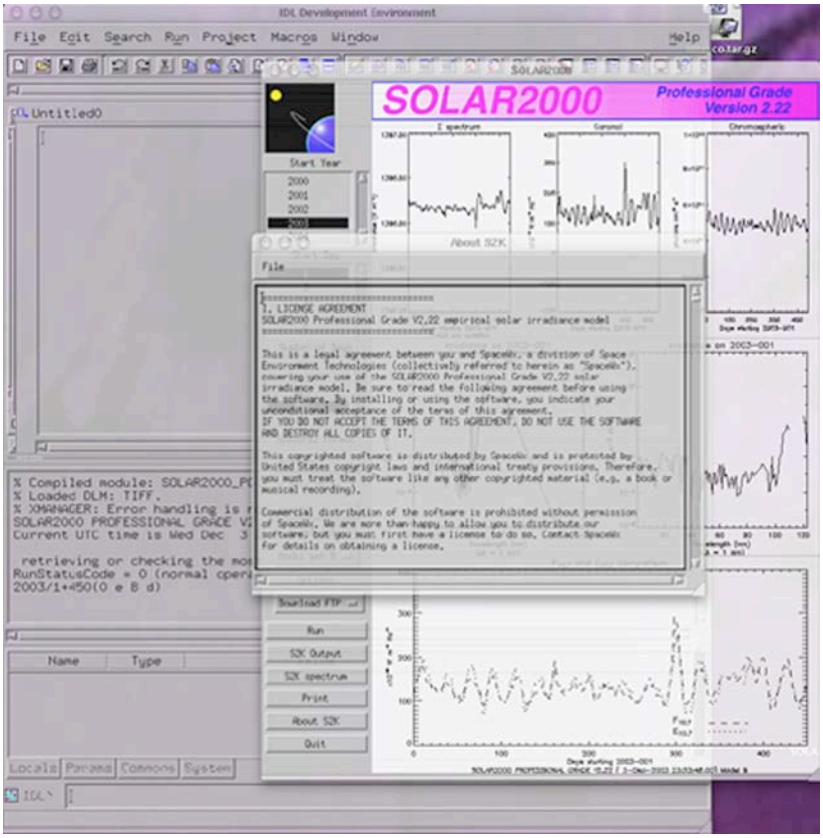

Fig. 9. SOLAR2000 Research Grade GUI window showing the “About S2K” window.

4.2.11 Open File (available only with Professional Grade model)

By clicking on the “Open File” button, any file on the user’s hard disk can be viewed that is either ASCII or PDF format. In the SOLAR2000 Research Grade folder, for example, the following files can be viewed within the GUI application. This function is useful for quick comparisons between the S2K Output window and other files that may be archived on the computer hard disk, for example.

PDF	ASCII
AIAA-2004.pdf	s2k_output.txt
ASR_2004.pdf	s2k_tsi.txt
JASTP_2000.pdf	s2k_v2_23_license.txt
JSR_2003.pdf	s2k_v2_23_readme.txt
SOLAR2000_RG_MANUAL.pdf	s2k_v2_23.txt
	s2krg_proxies.txt
	s2krg_v2_4monForecast.txt
	s2krg_v2_hist_proxies.txt
	solar2000_rg.pro
	spacewx.txt
	swdsNowcast.txt

4.2.12 Quit

Clicking the “Quit” button will exit the SOLAR2000 Research Grade v2.23 model GUI and return the user to the IDLDE application or the X-terminal window, if the user has a licensed version of IDL. If one is using the IDL VM, the IDL VM application will return the user to the X-terminal window command line.

4.2.13 SET Sun-Earth logo

By clicking on the SET Sun-Earth logo at the top left of the GUI, background information about Space Environment Technologies can be viewed.

5 TROUBLESHOOTING

5.1 Frequently Asked Questions (FAQ)

QUESTION:	ANSWER:
1. If the SOLAR2000 Research Grade V2.23 GUI application is run with a number of days to model that extends past the last valid date (see item 7.b above), the program will ungraciously stop. Why?	The GUI is being asked to display invalid dates and/or indices and the program must be restarted. In this case, simply exit IDL, start a new IDL session, and restart the GUI, taking care to not run the model past the last valid date.
2. If the "Print" button on the GUI is used for printing the plot file the right-hand border of the displayed plot may not be reproduced. Is there another solution for this?	The file "s2k_plot.tif" is the default plot file and is fully displayed with graphic software. Other print options include using the cursor to click and highlight one of the three plot panels then print that panel from IDL. Another alternative is to highlight a panel, copy the plot panel contents into the computer's internal buffer or 'clipboard', then paste, print, and/or save the graphic within a graphics program.
3. The September 1, 2000 release of SOLAR2000 RG did not properly display the irradiances in the output file for NT platforms. Can you fix this?	The display was fixed in the September 25, 2000 release (1.05a).
4. The combined selection of "energy flux" and "1 nm" in the GUI does not produce a tabular listing of energy flux on a 1 nm grid. Only the indices are displayed. How do I produce this combination?	The combination was provided in the February 10, 2001 release (1.15).
5. The program takes considerably longer to run on a DEC alpha workstation. The symptom is that the user clicks. the "Run" button and an hourglass cursor icon comes up on the GUI. window. After some time, the proper files are created and the session run is completed. Is this normal?	As of March 9, 2001 the reason for this is not yet understood and is being investigated. One possible source of latency could be a large number of files in the directory that the GUI is located within. However, there may be IDL-DEC compatibility issues that are not yet understood.
6. On some Unix systems (DEC alpha), clicking the "Print" button brings	One can manually print the "s2k_plot.tif" file that is located

up a printer manager window that does not easily allow printing of the s2k_plot.tif file with Unix-based commands such as "lp -P <printer> s2k_plot.tif". How can I print the tif files?	in the SOLAR2000 directory directly from a separate window using the appropriate Unix printer command ("lp -P <printer> s2k_plot.tif").
7. IDL, in this GUI application, does not properly display colors if the monitor is set to 16-bit color. Why?	Set the monitor to 8-bit or, as an alternative, 24-bit color.
8. I would like to have the capability of using a callable IDL subroutine module rather than a GUI. This would serve better in an IDL or Fortran routine that needs solar irradiances updated in by a time step. Can you provide this?	This capability is being developed. It will be possible to use this as a special subroutine in the future.
9. I would like to have the model extended to shorter wavelengths and higher energies in the X-rays (0.05 - 1.8 nm). When will this be available?	This capability is planned for a future upgrade of SOLAR2000.
10. There is a discontinuity for E81 values between the beginning of one time frame run and the end of a previous run. How do I remove this?	This artifact was minimized in v1.16 by using an 81-day convolution. However, a user is advised to create a data set of desired length and to use his or her own smooth algorithm.
11. Some of the highest resolution wavelengths in the 809 template are not uniform in grid-spacing and are repeated. Is this correct?	The SC21REFW format is used for the 809 wavelength bin format and this format does not have uniform spacing between the lines. In addition, some values may appear to be repeated, e.g., 6.63 nm, but is a result of truncation of finer resolution lines (6.630 Fe XII and 6.637 Fe XVI). The v1.21 upgrade changed the lines to be reported with 3 decimal places to avoid this truncation confusion.
12. How do I find the uncertainty in the irradiances and how is it calculated?	The 1 sigma error of reported instrument measurement error plus linear regression uncertainty can be found as a fraction (1.0 = 100%) in the 809 wavelength (highest resolution) listing. In the other listings, there are placeholders right now. However, since they are all coarser resolution than the 809 listing, a simple wavelength bin-average would be acceptable. A

	future version will incorporate the 1 sigma error for all formats.
13. Is it possible to get irradiances closer to the current epoch, nowcast, or forecast irradiances in addition to the Research grade version?	Yes, there are system, operational, and Professional grade SOLAR2000 versions that produce all these irradiances. For more information, including high time resolution data, please contact SpaceWx or visit the products and services link at http://SpaceWx.com. Additionally, NOAA/SEC hosts the daily nowcast SOLAR2000 irradiances on their server at http://sec.noaa.gov.
14. Can I retrieve SOLAR2000 products without using IDL?	E10.7 and Lyman-alpha are available for 5 solar cycles at the products links at http://SpaceWx.com. These are daily historical data for Research use. Current epoch, daily irradiance products are also provided at that web site location. In the second half of 2003, SET plans to release historical 3-hourly data sets as well as forecast data sets, both of which will be provided for a fee. It may be possible to run SOLAR2000 from a web browser in the future and we are researching this capability.
15. Why doesn't the S(t) value of the SOLAR2000 output match the variability in the total solar irradiance (TSI)?	The solar integrated spectrum (often referred to as S(t) in SOLAR2000 literature) is only variable between 1-122 nm in versions 1.yz. It is the integrated spectrum and will increasingly become the same as the variable TSI in versions 2.yz, 3.yz, and 4.yz. In version 2.yz, the spectrum is variable between 1-420 nm but does not include irradiance deficit due to sunspots.
16. Why are there double entries for some of the wavelengths longwards of Lyman-alpha?	The ASTM-E490 placeholder spectrum was used in earlier versions and had a problem of double entries. That placeholder spectrum was upgraded to the officially released version of the reference spectrum starting with SOLAR2000 version 1.24.
17. Why is the value of E10.7 in older model versions different from the v2.21 release?	As the accuracy and precision of the EUV wavelengths are improved in Model releases, the value of E10.7

	will change since it is the integrated 1-105 nm EUV energy flux and the latter changes. As measurements improve through time, the value of E10.7, though changing, will more and more approach a fixed level for given solar conditions. For example, the 1-sigma E10 v1.15:v1.24 ratio is 6.15% while v1.20:v1.24 is 0.38%. See the discussion in version 2.21 release related to "Known differences..." items 3 and 4. We have identified a process to create a "standard" by which to judge E10.7 and all other integrated irradiance proxies and work is progressing to create this standard. Our AFRL colleagues will create a several solar cycle derived F10.7 from an ensemble of satellite drag data and this independent measure of what the general level of solar flux should have been will be used to evaluate future E10.7.
18. Is there a Fortran version of SOLAR2000 available?	A Fortran version of the model is not under development since most of our efforts are going into improvement in various spectral ranges. However, current and selected historical data files are available at the http://www.SpaceWx.com web site. Also, the http://SpaceWx.com web site points to links with older EUV models that are written in Fortran.
19. Are the plotted values correct in the v2.21 GUI window, row 2, panel (e) (EUV spectrum)?	No, the units are high by a factor of 1E3. A typo in the v2.21 plot module uses the energy flux rather than SI units as in row 2, panel (d). This has been corrected in v1.24a, v1.25, and versions after v2.21.
20. Which exospheric temperatures are being shown in the Tinf column of the S2K_output.txt file?	In all versions except for v2.21 these are the daytime average exospheric temperature. They are not the subsolar point temperature as has been reported earlier since a cos(72) (72 deg is the angle between local atmosphere normal vector and the Sun-line vector) is used in the physics-based 1DTD model. This angle was selected because the 1DTD temp-

	eratures and neutral densities for 1976-200 (SC21REFW) and 1979-050 were very close to the MSIS-86 output for those dates. In addition, this angle provides an average daytime exospheric temperature for 6 years (Jan 1 1996 - Dec 31 2001) that is 1.3 times the J70 nighttime minimum exospheric temperature for the same period. The 1-sigma variation about this average temperature is +/-6.4%. Altogether, these point to a self-consistent exospheric temperature for input spectral solar flux. 1DTD does not use the E10.7 integrated irradiance proxy but uses the 39 wavelength groups and lines that are common in aeronomy. In v2.21, a conversion was applied to the temperatures to produce an absolute value very close to J70 nighttime minimum exospheric temperatures. We have decided not to use this conversion in all other releases of this Tinf parameter.
21. Is there a SC21REFW type of template for wavelengths between 121.5 and 199.5 nm?	We plan to extend the current SC21REFW type of wavelength template into this spectral region in an upcoming release of the model.
22. Why are there slight differences in the output numbers between the RG and PG model versions?	The S2K PG proxy file is generated on an operational server and will have slightly different values for either the F10 or Ly-a and/or their 81-day smoothed values. This will translate to small output differences in the integrated irradiance proxies since the data on the server is continually being updated and may also be running with a different version of S2K.
23. Why do v2.21 and 2.23 have the same results for the integrated irradiance proxies and some wavelength formats for models B and C?	Model C uses the VUV2002 model and it's results are currently provided only through the 1 nm spectral resolution formats. A future upgrade will include VUV2002 values through all formats and will change the integrated irradiance proxies to reflect calculations with that model.

5.2 Unknown errors

It is possible that some error conditions exist in running the SOLAR2000 Research Grade v2.23 model that are not caught. All messages and errors that occur while running SOLAR2000 will appear in the IDLDE message window. While we have done our utmost to provide a robust, validated, and rigorously tested product, WE ARE VERY INTERESTED TO LEARN ABOUT ANY UNDOCUMENTED ERRORS THAT MAY OCCUR WHEN RUNNING THIS APPLICATION. We realize that users are often under time constraints and are working to deadlines. Therefore, we will do our utmost to fix any significant problems that you bring to our attention and we will notify you of the fix in a timely way. General concerns that are of interest to a broad community of users will be posted in the FAQ section of in future upgrades.

If unreported errors occur, please email the "session.txt" file (Professional Grade only), with the subject line message "S2KRG v2.23 error", to Space Environment Technologies at the email address of spacenvironment@spacenvironment.net. We will immediately investigate the problem and contact you with a method for resolving it or will provide a fix to the code.

5.3 Upgrades to SOLAR2000

Regular and continuous upgrades to SOLAR2000 are occurring during the first half of the decade starting in 2000. These upgrades include additional spectral range variability (FUV, UV, VIS, IR), enhanced accuracy of the data with the inclusion of new datasets and improved algorithms, specification of the uncertainty in the irradiances, the development of nowcast and forecast irradiances, and the development of new proxies for new user communities. Historical irradiances are upgraded to near the current epoch on a scheduled of approximately every three months starting in October 2000. Current epoch and forecast irradiances are updated hourly by Space Environment Technologies and can be downloaded through the SOLAR2000 Research Grade model from the SET server (Professional Grade only). Your registration of the SOLAR2000 Research Grade v2.23 model automatically places you on the notification list for these upgrades.

5.4 Licensing SOLAR2000 Research Grade

The SOLAR2000 Research Grade model is a licensed product (see section 8) provided by Space Environment Technologies. For Professional Grade users, your unique user license can be viewed within the GUI application by clicking the "Open File" button and selecting the file called s2k_v2_23_license.txt. The top line of the file is your unique license number.

6 GLOSSARY

6.1.1 Generalized definitions

6.1.1.1 Space weather

The shorter-term variable impact of the Sun's photons, solar wind particles, and interplanetary magnetic field upon the Earth's environment that can adversely affect our technological systems is colloquially known as space weather. It includes, for example, the effects of solar coronal mass ejections, solar flares, solar and galactic energetic particles, as well as the solar wind, all of which affect Earth's magnetospheric particles and fields, geomagnetic and electrodynamical conditions, radiation belts, aurorae, ionosphere, and the neutral thermosphere and mesosphere.

6.1.1.2 National Space Weather Program

The National Space Weather Program (NSWP) Implementation Plan (IP), second edition (FCM-P31-2000) published in July 2000 and accessible at http://www.ofcm.gov/, describes the goal to improve our understanding of space weather effects upon terrestrial systems. Operationally characterizing space weather as a coupled, seamless system from the Sun to Earth is one achievement of this goal. Among the areas of interest for improved understanding are the space weather processes affecting the thermosphere and ionosphere.

6.1.1.3 AU

AU designates an Astronomical Unit (AU) and is a unit of length equal to the mean distance between the Sun and Earth. The accepted value is 149,597,870,660(20) meters. Distances between objects within the solar system are frequently expressed in terms of AU.

6.1.1.4 Solar irradiance

Solar irradiance is the Sun's radiation integrated over the full disk of the Sun expressed as a unit of power (Watts) through a unit of area (per meter squared) centered at a specified wavelength and integrated across a wavelength interval.

6.1.2 SOLAR2000 definitions

6.1.2.1 Input proxy definitions

6.1.2.1.1 F10

F10.7 is the daily value of the 10.7-cm solar radio emission measured by the Canadian National Research Council Dominion Radio Astrophysical Observatory at Penticton, BC, Canada. The "observed" value is the number measured by the solar radio telescope at the observatory, is modulated the level of solar activity and the changing distance between the Earth and Sun, and is the quantity to use when terrestrial phenomena are being studied. When the Sun is being studied, it is useful to remove the annual modulation of F10 by the changing Earth-Sun distance and the "1 AU adjusted" value is corrected for variations in the Earth-Sun distance, giving the average distance. Penticton measures the F10, NOAA/SEC reports the F10, and numerous organizations, including SET, forecast the F10. Its units are solar flux units (sfu) or x10-22 Watts per meter squared per Hertz. Normal practice is to refer to the value as "F10.7" but F10 is used here as an abbreviation.

6.1.2.1.2 F81

F81 is the daily value of the 81-day running average of the F10 centered at the current epoch (date) and in the F10 units.

6.1.2.1.3 Lya

Lya is the daily value of the solar hydrogen atom emission of Lyman-alpha irradiance at 121.67 nm measured from outside the atmosphere and reported in photon flux of x10+09 photons per centimeter squared per second.

6.1.2.1.4 L81

L81 is the daily value of the 81-day running average of the Lya centered at the current epoch (date) and in the Lya units.

6.1.2.2 SOLAR2000 irradiance products

6.1.2.2.1 Integrated solar irradiance proxies

With the release of SOLAR2000 v2.21, there are a total of seven integrated flux irradiance proxies that are produced for the benefit of specific user communities. These proxies are provided in addition to the three spectral irradiance wavelength formats of 1 nm bins for the full spectrum from 1–1,000,000 nm, 39 EUV wavelength groups/lines from 1–105 nm, and 867 EUV lines from 1–122 nm. Each wavelength format is reported in three flux formats of energy (ergs per centimeter squared per second), photon (photons per centimeter squared per second), and SI units (Watts per meter squared). The seven proxies are described in more detail below.

6.1.2.2.2 E10

E10 is the daily value of the integrated solar extreme ultraviolet (EUV) energy flux from1–105 nm at the top of the atmosphere and reported in F10 units. It represents the spectral solar energy available for photoabsorption and photoionization that is separately input into numerical models. Normal practice is to refer to the value as “E10.7” but E10 is used here as an abbreviation.

6.1.2.2.3 E81

E81 is the daily value of the 81-day running average of the E10 centered at the current epoch (date) and in the E10 units.

6.1.2.2.4 S(t)

S(t) or S_C is the daily value of the integrated solar spectrum in units of Watts per meter squared and is provided to users who require the integrated spectrum variability. In early versions of the SOLAR2000 model (v1.yz), the variability comes from the solar spectrum between 1–122 nm (EUV variability). Longwards of 122 nm in the v1.yz model, the ASTM E490 solar reference spectrum is used. Hence, the current variability in S is not the same as the total solar irradiance (TSI). In upgrades beyond v1.yz of SOLAR2000, time-varying spectral models are included to represent the ultraviolet, visible/infrared, and theoretical spectral variability in versions 2.yz, 3.yz, and 4.yz, respectively. In v3.yz, this spectrum will be extremely useful for space systems’ users who require an operational, variable integrated solar spectrum for solar radiation pressure calculations on spacecraft. In v4.yz, a high spectral resolution of the Sun’s irradiances will be provided for use in satellite imagery calibration.

6.1.2.2.5 Qeuv

Qeuv is the daily value of the thermospheric heating rate derived from an analysis of the time-dependent solar heating of the thermosphere as a function of EUV energy by wavelength, altitudinal heating efficiency, unit optical depth, absorption cross section of each neutral species, and density of each species. These combined quantities are the constituent volume-heating rate in the thermosphere and are integrated across all species, wavelengths, and altitudes for a unit of time to become the derived total thermospheric heating rate in ergs per centimeter squared per second. A third degree polynomial fit is made between the total heating rate and E10.7 for several years over a solar cycle and this is the Qeuv.

6.1.2.2.6 Rsn

Rsn is the daily value of the derived sunspot number for use in ray-trace algorithms that historically use the Wolf sunspot number, Rz. Rsn is dimensionless and is derived from a third degree polynomial fit between Rz and E10.7 for several years over a solar cycle. Rsn differs from Rz during solar maximum conditions and does not reach the highest values of Rz. We believe it provides a capability for more accurately representing the variations in the ionosphere that come directly from solar EUV photoionization.

6.1.2.2.7 Tinf

Tinf is the daily value of the Earth exospheric temperature at 450 km in units of Kelvin (K). It was developed using a first-principles thermospheric model and is useful for long-term studies to investigate potential anthropogenic climate change effects (cooling) in the thermosphere and subsequent changes to the ionospheric E and F2 layer heights. Tinf is derived from a third degree polynomial fit between the first principles derived exospheric temperature and E10.7 for several years over a solar cycle.

6.1.2.2.8 Peuv

Peuv is the daily value of the EUV hemispheric power in units of Watts and is complementary to the auroral hemispheric power index. It is designed for science research and operations use. It is derived from the solar EUV energy flux summed across all wavelengths from 1–105 nm. This value is approximately 6 ergs per centimeter squared per second for an average level of solar activity. This solar energy is assumed to be input across the disk of Earth and is reported in units of gigaWatts (GW). The Peuv heating is greater than auroral hemispheric power except during storm periods.

6.1.2.2.9 E1_40

E1_40 is the daily value of the integrated EUV energy flux between 1-40 nm in units of ergs per centimeter squared per second.

6.1.2.2.10 E3h

E3h is the MFD bulletin 3-hour average value of the E10 forecast to 72 hours in E10 units.

6.1.2.2.11 B3h

B3h is the MFD bulletin 3-hour average value of the E81 forecast to 72 hours in E10 units.

6.1.2.2.12 a3h

a3h is the MFD bulletin 3-hour average value of the Ap forecast to 72 hours in Ap units.

6.1.2.2.13 E1s

E1s is the MFD bulletin 1-sigma uncertainty of E3h in E10 units.

6.1.2.2.14 SRC

SRC is the MFD bulletin data source designation (Issued, Nowcast, Predicted).

6.1.2.2.15 Ap

Ap is the daily mean value of the planetary geomagnetic index in units of 2 nanoTesla (nT).

6.1.2.2.16 a1s

a1s is the MFD bulletin 1-sigma uncertainty of a3h in Ap units.

6.1.2.3 Time domain definitions

6.1.2.3.1 Historical

SOLAR2000 daily irradiances and integrated irradiance proxies are provided for all applications from research to operational systems starting from February 14, 1947 through the current date.

6.1.2.3.2 Nowcast

SOLAR2000 nowcast irradiances and integrated irradiance proxies, using the operational NOAA 16 SBUV Mg II data for the chromospheric proxy and the 20 UT observed F10 for the coronal proxy, are provided hourly by the SOLAR2000 Operational Grade model located at NOAA Space Environment Center (SEC) in Boulder, Colorado (http://sec.noaa.gov/spacewx/) and by the SET proprietary server (http://SpaceWx.com/). The model is run independently and hourly at both sites. Although the information content changes only twice per day in 2003 using the daily 20 UT F10 and the daily Mg II (NOAA 16), or a few times per day (NOAA 16 combined with NOAA 17 starting in late 2003), the cadence will significantly increase with the inclusion of 5-minute data using the GOES-N EUV broadband detector data after 2005. After that time, the F10 and Mg II will be retained as redundant input proxy data to ensure a capability of calculating the irradiances. At that time, the GOES-N data, absolutely calibrated to the TIMED/SEE instrument data, will become the primary data set for the EUV part of the spectrum. The Mg II will still remain the primary data set for calculating the FUV irradiances after 2005. In addition to graphical representations of the irradiances located at the web sites above, nowcast data files are located and updated with the same hourly cadence at SEC's anonymous FTP server:

http://sec.noaa.gov/ftpmenu/lists/spacewx.html

The files located at that site of "E10.7 nowcast data," "Solar spectral data," and "Validation of today's E10.7 data" provide the nowcast E10 with ±1-sigma values, the full solar spectrum at 1 nm resolution, and comparative nowcast data of F10, F81, Lya, L81, E10, E81, and S.

The definition of nowcast has evolved in current operations to indicate the period of time between –24 hours to the current epoch (time). Starting 24 hours in the past, the input parameters required for model runs, i.e., the F10 and Mg II data, are already operationally issued and will not change. However, at the current epoch, or "0" hour, the solar conditions will have changed slightly and new information has not yet been received to precisely define what the new proxy values are. Hence, an estimate made of the current conditions and the interpolation from known

to unknown conditions during the past 24-hours constitutes a nowcast.

6.1.2.3.3 Forecast

Forecast irradiances and integrated irradiance proxies are provided for government and commercial customers. The SOLAR2000 PG, OP, and SY models current (and first) generation forecast algorithm is denoted FGen 1x and relies on linear predictive techniques. The fundamental assumption of persistence in solar irradiances at time scales of interest (3-days, 14-days, 28-days, 4-months, 1 solar cycle, and 5 solar cycles) is the basis for these techniques. FGen 2 will provide forecast irradiances on the same timescales based on physics, measurements, and mathematical tools.

6.1.2.3.4 High time resolution

In FGen 1x, the forecasts for next 72-hours are produced on a 3-hour cadence and synchronized with the release of the NOAA/SEC and U.S. Air Force Kp and ap geomagnetic indices.

6.1.2.4 Model Upgrade, Release Convention

Regular and continuous upgrades to SOLAR2000 are occurring during the first half of the decade starting in 2000. These upgrades include additional spectral range variability (FUV, UV, VIS, IR), enhanced accuracy with the inclusion of new datasets and improved proxy regression algorithms, improved specification of the uncertainty in the irradiances, the development of nowcast and forecast irradiances along with the historical representations, and the development of new integrated irradiance proxies for user communities. The model has been upgraded 18 times between October 7, 1999 (v0.10) and May 2, 2003 (v2.21) through the publicly released SOLAR2000 Research Grade model. The convention for the model Grade designation is explained in detail above and in briefly summarized here:

6.1.2.4.1 RG

Research Grade provides daily historical to current epoch data through a platform-independent IDL GUI application;

6.1.2.4.2 PG

Professional Grade provides daily historical through current epoch to forecast data in addition to analysis tools through a platform-independent IDL application;

6.1.2.4.3 OP

Operational Grade provides daily historical, hourly nowcast, 72-hour (3-hour interval) forecast, and daily forecast data from the SET proprietary operational server; and

6.1.2.4.4 SY

System Grade provides historical, nowcast, forecast data in all time resolutions as a turn-key system on at a user-specified location.

SOLAR2000 v2.23 is variable in the XUV/EUV/FUV/UV part of the spectrum. Upgrades in progress include v3.00 VIS/IR variability and v4.00 physics-based model variability. The versioning convention of x.yz for SOLAR2000 upgrade releases is:

x: variability of the model's spectral range

1: empirical XUV/EUV (1–122 nm);
2: empirical XUV–UV (1–420 nm);
3: empirical XUV–IR (1–2000 nm);
4: hybrid empirical and physics-based (1 – 1,000,000 nm);

y: data improvement

0: original 12 rocket observations (AFGL f74113, sc21refw, f79050n, f79226, f79314; USC 82222, 83228, 88298, SERTS_96; LASP nov_1988, 1992, 1993, 1994), 1 reference spectrum (ASTM E-490), 4 satellite datasets (SOLRAD, AEE monochromators, YOHKOH/SXT, SOHO/CDS), and 3 theoretical spectra (Avrett);
1: SOHO (SUMER, SEM, CDS accuracy in solar minimum short wavelengths);
2: SNOE, TIMED (SEE) and SDO (EVE) (accuracy in all spectra <200);
3: UARS, TIM, and SIM (UV, VIS, IR accuracy);
4: ISS (SOL-ACES, SOLSPEC, TSI) (solar cycle upgrade to full spectrum);
5: GOES EUV and POES UV/VIS data (minutely time resolution); and

z: code improvement and bug fixes

0-9: new features, algorithm, and code improvements;
a: minor bug fixes; and
b: internal beta test version.

7 REFERENCES

An up-to-date journal reference list for the derivation and validation of SOLAR2000 can be found at the SET web site http://SpaceWx.com. Many of the articles below are available in PDF format as preprints or reprints from SpaceWx at the publications link. The following citations are relevant to SOLAR2000:

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8 LICENSE AGREEMENT

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