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Infrared Sky Imager Instrument Handbook

VR Morris

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1.0 Instrument Title

Infrared Sky Imager. More information is available at the manufacturer's website.

2.0 Mentor Contact Information

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3.0 Vendor/Developer Contact Information

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4.0 Instrument Description

The Infrared Sky Imager (IRSI) deployed at the Atmospheric Radiation Measurement (ARM) Climate Research Facility is a Solmirus Corp. All Sky Infrared Visible Analyzer. The IRSI is an automatic, continuously operating, digital imaging and software system designed to capture hemispheric sky images and provide time series retrievals of fractional sky cover during both the day and night. The instrument provides diurnal, radiometrically calibrated sky imagery in the mid-infrared atmospheric window and imagery in the visible wavelengths for cloud retrievals during daylight hours. The software automatically identifies cloudy and clear regions at user-defined intervals and calculates fractional sky cover, providing a real-time display of sky conditions.

5.0 Measurements Taken

The IRSI's primary function is to provide radiometrically calibrated imagery in the mid-infrared atmospheric window from 8-13 microns (μm). Available data products include the following:

- All-sky (180-degree field-of-view) radiometrically calibrated images

- Hemispheric cloud fraction determination
- Visible/IR image correlation
- Cloud/no cloud reporting
- Photometric quality assessment
- Sky opacity/transmission determination
- Water vapor determination
- Sky/cloud temperature (brightness and color) and emissivity measurements.

6.0 Links to Definitions and Relevant Information

See the ARM Glossary.

6.1 Data Object Description

The IRSI produces the following datastreams:

- **irsiir** –fractional sky cover, infrared
- **irsiirskyimage** –hemispheric sky image (JPEG), infrared
- ir**siircldmask** – processed fractional sky cover image (PNG), infrared
- **irsivis** –fractional sky cover, visible
- **irsivisskyimage** –hemispheric sky image (JPEG), visible
- ir**siviscldmask** – processed fractional sky cover image (PNG), visible

Table 1. Primary variables.

Variable Name	Quantity Measured	Unit
sky_cover_high_emission_narrow	High emission sky cover for narrow field of view	%
sky_cover_low_emission_narrow	Low emission sky cover for narrow field of view	%
sky_cover_high_emission_wide	High emission sky cover for wide field of view	%
sky_cover_low_emission_wide	Low emission sky cover for wide field of view	%
sky_cover_opaque_narrow	Opaque sky cover for narrow field of view	%
sky_cover_thin_narrow	Thin sky cover for narrow field of view	%
sky_cover_opaque_wide	Opaque sky cover for wide field of view	%
sky_cover_thin_wide	Thin sky cover for wide field of view	%
precipitable_water_vapor	Precipitable water vapor	mm

Table 2. Secondary variables.

Variable Name	Quantity Measured	Unit
time	Time offset from midnight	seconds
reference_bb_temperature_1	Reference black body temperature, sensor 1	C
reference_bb_temperature_2	Reference black body temperature, sensor 2	C
reference_bb_temperature_3	Reference black body temperature, sensor 3	C
external_bb_temperature_1	External black body temperature, sensor 1	C
external_bb_temperature_2	External black body temperature, sensor 2	C
external_bb_temperature_3	External black body temperature, sensor 3	C

Table 3. Diagnostic variables.

Variable Name	Quantity Measured	Unit
time_offset	Time offset from base_time	seconds
enclosure_temperature	Enclosure temperature	C
camera_temperature	Camera temperature	C
blackbody_radiance	Black body radiance	W/(m^2 sr)

Table 4. Dimension variables.

Variable Name	Quantity Measured	Unit
base_time	base time in Epoch	seconds
lat	north latitude	degrees
lon	east longitude	degrees
alt	altitude	meters above Mean Sea Level

6.2 Data Ordering

The IRSI data are available from the ARM Data Archive.

6.3 Data Plots

Available data plots and other data products.

6.4 Data Quality

Most fields contain a corresponding, sample-by-sample, automated quality check field in the b1 level datastreams. These flags are named **qc_<fieldname>**. For example, the **sky_cover_thin_wide** field also has a companion **qc_ sky_cover_thin_wide** field. Possible values for each sample of the **qc_<fieldname>** are shown in the table below.

Table 5. Data quality flags.

Value	Definition
0	All QC checks passed
1	Sample contained 'missing data' value
2	Sample was less than prescribed minimum value
3	Sample failed both 'missing data' and minimum value checks
4	Sample greater than prescribed maximum value
5	Sample failed both minimum and maximum value checks (highly unlikely)
7	Sample failed minimum, maximum, and missing value checks (highly unlikely)
8	Sample failed delta check (change between this sample and previous sample exceeds a prescribed value)
9	Sample failed delta and missing data checks
10	Sample failed minimum and delta checks
11	Sample failed minimum, delta, and missing value checks
12	Sample failed maximum and delta checks
14	Sample failed minimum, maximum, and delta checks
15	Sample failed minimum, maximum, delta, and missing value checks

The minimum and maximum thresholds are currently defined as follows for datastream **ceil**:

Table 6. Data quality thresholds.

Field Name	Units	Min	Max
sky_cover_high_emission_narrow	%	0	100
sky_cover_low_emission_narrow	%	0	100
sky_cover_high_emission_wide	%	0	100
sky_cover_low_emission_wide	%	0	100
sky_cover_opaque_narrow	%	0	100
sky_cover_thin_narrow	%	0	100
sky_cover_opaque_wide	%	0	100
sky_cover_thin_wide	%	0	100
reference_bb_temperature_1	C	-20	50
reference_bb_temperature_2	C	-20	50
reference_bb_temperature_3	C	-20	50
external_bb_temperature_1	C	-20	50
external_bb_temperature_2	C	-20	50
external_bb_temperature_3	C	-20	50
enclosure_temperature	C	0	40
camera_temperature	C	0	40

6.5 Instrument Mentor Monthly Summary

See the Instrument Mentor Monthly Summary (IMMS) Reporting System.

6.6 Calibration Database

See the Operations Status System Common Calibration Database (CCDB).

7.0 Technical Specification

The infrared subsystem includes a 644×512 uncooled microbolometer array sensitive to 8-14 µm radiation, a 180-degree (all sky), custom-designed, hard-carbon-coated, waterproof lens, and an eight-position filter wheel for use with 1-inch filters. The IRSI also includes a visible subsystem consisting of a 4-megapixel monochrome cooled CCD detector coupled with a 180-degree, high-quality lens. An optional eight-position filter wheel for use with 1-inch filters is also available. Both infrared (IR) and Visible imaging subsystems use automated-focusing subsystems that allow the focus position to be adjusted from one filter position to the next.

Infrared subsystem:

- Detector: Uncooled microbolometer
- Wavelength range: 8-14 µm
- Filters: 10-12 µm (sky cover, brightness temperature) and 8-9 µm (color temperature and PWV)
- Image resolution: 640 × 512 pixel, 14-bit
- Field of view: 180º

Visible subsystem:

- Detector: Interline cooled CCD (color) with electronic and mechanical shutter
- Filters: Neutral density ×10-2 and ×10-4
- Image resolution: 3296 × 2472 pixel, 16-bit per color
- Field of view: 180º

7.0 Units

See Table 1, Table 2, and Table 3.

7.1 Range

The images have a hemispheric field of view, centered on zenith.

7.2 Accuracy

Absolute radiometric accuracy has been measured in the laboratory to be ±0.2 W/m2-µm-sr for typical sky radiances.

7.3 Repeatability

Unknown.

7.4 Sensitivity

The radiometric accuracy equates to a sensitivity of ±1.4ºC for temperatures near 25ºC. Pixel-to-pixel sensitivity of <0.01 W/m2-sr-µm (<0.07ºC) is also achieved.

7.5 Uncertainty

Unknown.

7.6 Input Voltage

The power supply is 115 VAC, ±10%.

7.7 Input Current

The power consumption is 500 W maximum, with heating.

7.8 Input Values

Unknown.

7.9 Output Values

See Table 1, Table 2, and Table 3.

8.0 Instrument System Functional Diagram

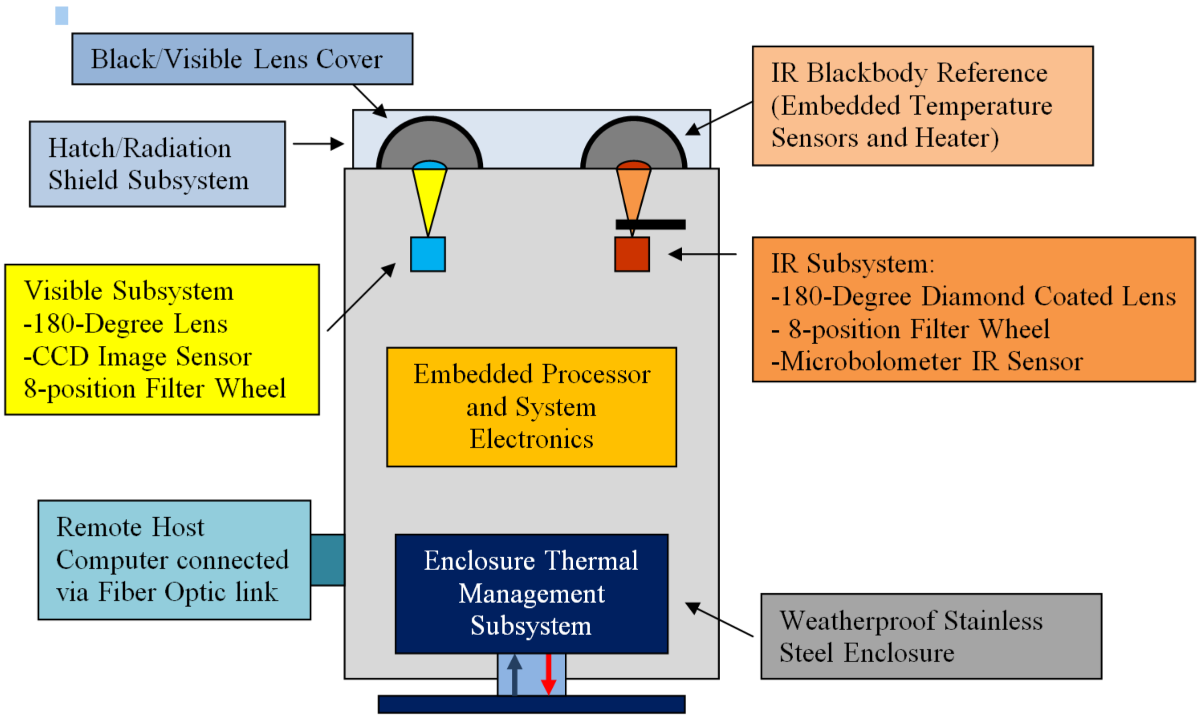

Figure 1. A block diagram of the IRSI and its primary components.

9.0 Instrument/Measurement Theory

The IRSI's primary function is to provide radiometrically calibrated imagery in the mid-infrared atmospheric window from 8-13 µm. Solmirus offers two custom filters for the IRSI that operate in this spectral interval. The 10.2-12.2 µm filter optimizes cloud/clear-sky contrast and is the primary filter used to determine fractional sky cover. The 8.1-9.2 µm filter is used in conjunction with the 10.2-12.2 µm filter to provide color temperature information as well as addition information in determining precipitable water vapor (PWV). The instrument response is the product of the filter transmission, lens transmission, and the nominal detector response. This data is used in image analysis and calibration procedures. The ARM IRSI was configured with the following IR filter set:

- Filter 1: Solmirus' custom 10.2-12.2 micron filter
- Filter 2: Solmirus' custom 8-9.5 micron filter
- Filter 3: Blocked
- Filter 4-8: Open

The visible color CCD detector was configured with the following filters:

- Filter 1: Open
- Filter 2: Neutral density filter with attenuation of 100

- Filter 3: Neutral density filter with attenuation of 10,000
- Filter 4: Blocked
- Filter 5-8: Open

The infrared and visible imagers use automated focusing systems that allow the focal position to be adjusted from one filter position to the next.

10.0 Setup and Operation of Instrument

10.0 Installation

Installation of the IRSI instrument is a simple procedure. The instrument should be mounted on a level 24-inch x 24-inch platform using four ½-inch bolts positioned at the corners of the IRSI base on 22-inch centers. It is recommended that the enclosure access door be directed to the south (for Northern Hemisphere installations) so that the external blackbody reference is situated to the north. This is not critical because the infrared and visible cameras can be rotated internally, accommodating any orientation on the sky. A more important criterion is to minimize any unwanted obstructions in the IRSI's 180-degree field of view.

The IRSI requires only two external connections: power (115V-230V) and fiber optic (Multi-mode SC-connector) that connects the onboard system computer to the external network.

10.1 Operations:

Boot the onboard system computer by switching the main power breaker located inside the IRSI enclosure to the "on" position. Allow several minutes for the system to boot. IRSI automatically enters its default mode of operations and remains on indefinitely.

To access control of the IRSI instrument, simply launch a web browser user interface (web-UI) by going to IP address (http://198.124.98.50/) of the instrument.

11.0 Software

11.0 Onboard System Computer and System Electronics

The system control computer is the data collection and data processing subsystem that resides within the IRSI instrument, retrieves data from the imaging subsystems, and performs on-the-fly data product analysis. It serves as the primary control mechanism for the IRSI instrument (i.e., imaging subsystems and other subsystems such as the hatch motor, filter wheels, focuser, and temperature meters and sensors) and provides data display and interfacing functions.

11.1 User Interface

The web-UI is accessed by going to the IP address http://198.124.98.50/ in a browser window that has access to the local network.

11.2 Data Acquisition and Analysis Architecture

Images are acquired in batches, which comprise a user-defined data acquisition sequence. The following list describes the acquisition sequence of the ARM IRSI.

1) Each data acquisition sequence is 30 seconds in length and begins with the hatch closed.
2) An IR blackbody reference image is acquired in each of the two infrared filters as well as visible dark reference image taken at the user-defined exposure time for the visible filter.
3) The hatch is then opened wherein IR sky images are acquired in each of the two IR filters.
4) A visible sky image is acquired in each at the selected exposure time.
5) When all sky images have been acquired, the hatch is closed and the system waits for the start of the next 30-second interval.

All quantitative image data are ultimately stored in Flexible Image Transport System (FITS) format; a lossless image format that also incorporates a header in which all pertinent metadata associated with the image is stored.

11.3 Data Processing and Analysis

Data products are then constructed from the acquired data using a Process Program written in Interactive Data Language (IDL) running on the IRSI's system computer. These data products are archived to the hard drive.

12.0 Calibration

Absolute radiance calibration is attained using Solmirus' innovative hatch design, which incorporates a blackbody reference with embedded temperature sensors and a heater. This allows the instrument to be automatically calibrated in the field. During a calibration procedure, the blackbody reference is heated to ~80ºC and then allowed to cool to near ambient temperature while acquiring image data in each of IR filters. This calibration procedure takes about an hour and is used to determine instrument response as a function of blackbody radiance. Calibration images mapping the instrument response are created in the calibration process and are subsequently used to provide on-the-fly calibrated images during normal operation. Further refinements to the calibration images are made after the system is operational.

13.0 Maintenance

The infrared lens and visible glass dome should be periodically cleaned with a lens-cleaning solution and a micro-fiber cloth.

The hatch subsystem requires no maintenance but should be inspected periodically to insure that it is moving freely. This can be done by moving the hatch up and down by hand while it is in the open position. There is some backlash in the gearbox that allows motion through an angle of ~10º. The hatch should move with little resistance within this extent.

14.0 Safety

- Electrical: EN 60950
- Electromagnetic: Class B, EN 61326
- Environmental: ISO 10109-11
- Vibration: IEC 60086-2-6

15.0 Citable References

Klebe D, RD Blatherwick, and VR Morris. 2014. "Ground-based all-sky mid-infrared and visible imagery for purposes of characterizing cloud properties." *Atmospheric Measurement Techniques* 7:637-645, doi:10.5194/amtd-7-637-2014.

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