ASIVA

All Sky Infrared Visible Analyzer

Instrument Description

The Solmirus All Sky Infrared Visible Analyzer (ASIVA) is a multi-purpose visible and infrared sky imaging and analysis instrument designed to operate autonomously or as a component in an instrument cluster. Its utility ranges from astronomy to a variety of meteorological applications. Available data products include the following:

- Cloud/No Cloud Reporting
- Cloud Cover and Height Determination
- Photometric Quality Assessment
- Sky Opacity/Transmission Determination
- Visible/IR Image Correlation and Integration
- Water Vapor and Ozone determination
- Sky/Cloud Temperature (brightness and color) Measurements
- All-Sky (180 degree field-of-view) Radiometric Maps and Analysis

The ASIVA's primary functionality is to provide radiometrically calibrated imagery in the mid-infrared (mid-IR) atmospheric window, which stretches from 8-13 microns (µm). Figure 1 shows the clear-sky downwelling radiance as simulated using MODTRAN for a standard mid-latitude summer atmosphere pointed at the zenith for varying amounts of precipitable water vapor (PWV). The left panel demonstrates conditions (1 and 5 mm PWV) typically encountered at astronomical observatories. The right panel (22 mm PWV) demonstrates typical summertime conditions encountered at Atmospheric Radiation Measurement (ARM) Climate Research Facility sites such as the Southern Great Plains (SGP) site in Oklahoma.

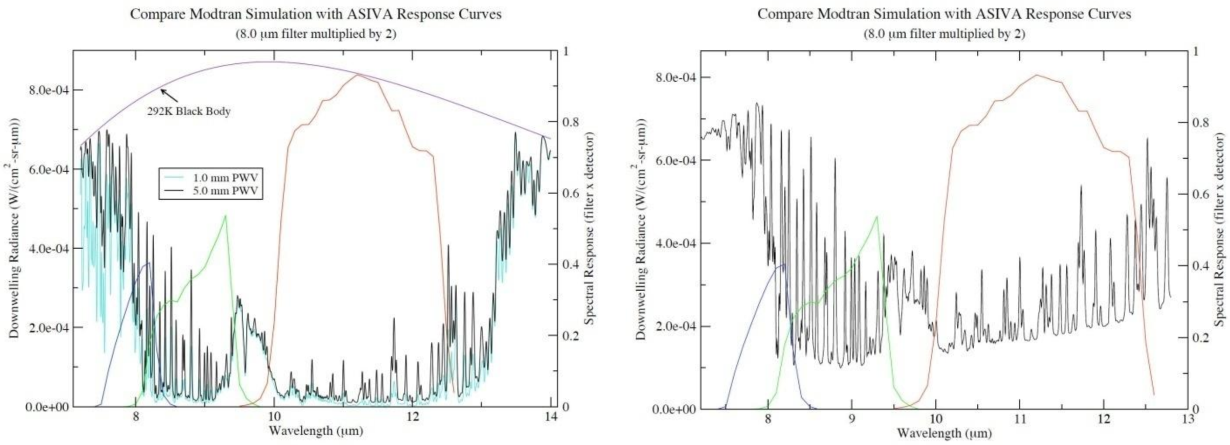

Figure 1: Simulated clear-sky downwelling radiance for 1 and 5 mm (left) and 22 mm (right) PWV and spectral response of three commonly used ASIVA filters (blue, green, red)

Absorption and therefore thermal emission is dominated by water vapor at wavelengths less than 8 µm, by carbon dioxide at wavelengths greater than 13 µm, and by ozone near 9.5 µm. Water vapor absorption lines are seen strewn throughout this spectral interval but are least prevalent in the 10.2-12.2 µm region. For this reason, Solmirus offers a custom 10.2-12.2 µm filter for optimizing clear-sky/cloud contrast. The spectral response of this filter is shown (red) in Figure 1 as well as two other filters commonly used in ASIVA instruments. The 10.2-12.2 µm filter is ASIVA's go-to filter in determining the sky's spectral radiance (and therefore brightness temperature). A calibrated spectral radiance image using this filter is shown in Figure 2.

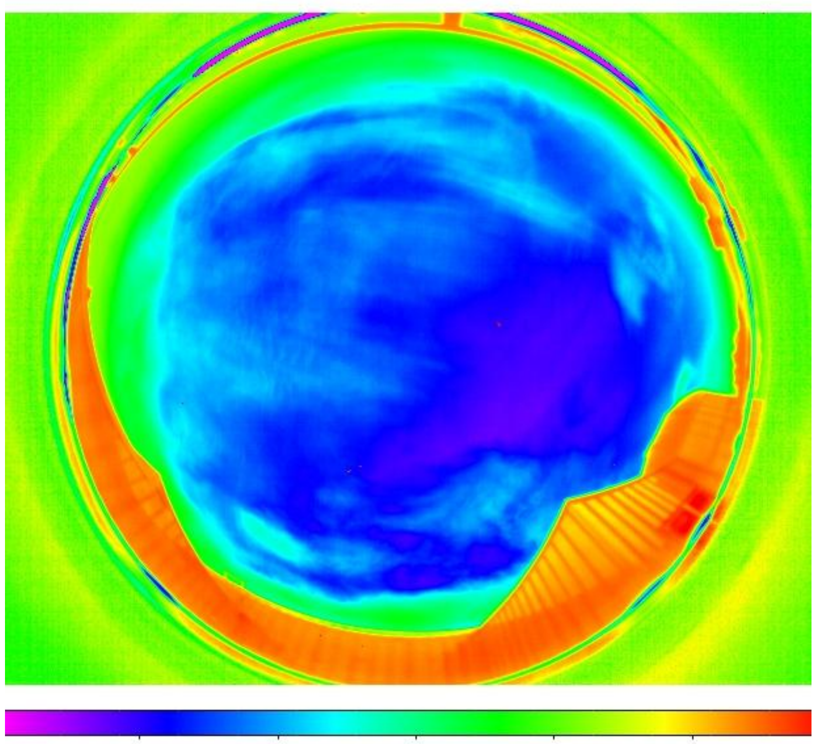

Figure 2: Spectral radiance image acquired in 10.2-12.2 µm filter (units in W/m^2-sr-µm)

Absolute radiometric accuracy has been measured in the laboratory to be ±0.2 W/m^2-µm-sr in the 10.2-12.2 µm filter for typical sky radiances. This equates to a sensitivity of ±1.4degK for temperatures near 300degK. Pixel-to-pixel sensitivity of better than ±0.01 W/m^2-sr-µm (±0.07degK) is also achieved. This performance level has allowed the ASIVA instrument to uniquely detect thin cirrus clouds. Figure 3 shows an IR sky-quality map alongside a visible image taken at the same time by ASIVA's visible camera. The sky is completely covered with thin cirrus clouds which do not readily show up in the visible image.

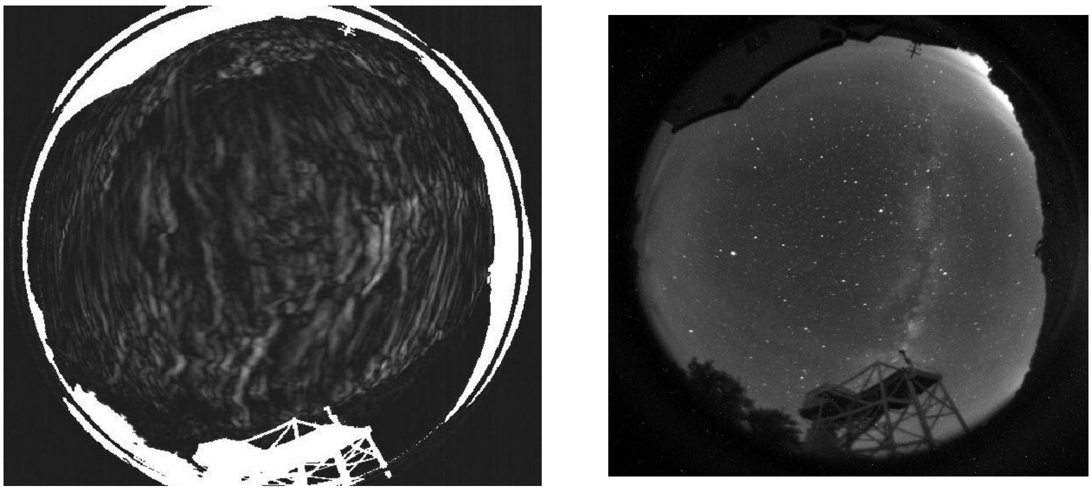

Figure 3: IR Sky Quality image (left) and Visible image (right)

The filters included in the ASIVA instrument provide a unique capability for measuring the all-sky emission in different wavebands. Analysis procedures are underway to extract water vapor, ozone, cloud temperature, cloud height, and other properties from this radiometrically calibrated data. Figure 4 shows the ASIVA's theoretical sensitivity to precipitable water vapor (PWV) in three of its commonly used filters.

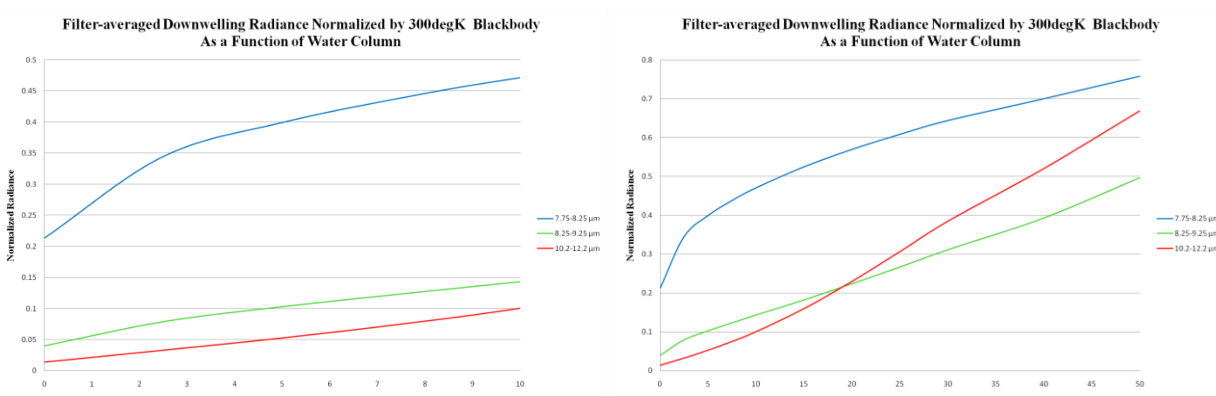

Figure 4: Sensitivity to PWV in three commonly used ASIVA filters

Absolute radiance/temperature 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 auto calibrated in the field at anytime. During a calibration procedure the blackbody reference is heated to ~350degK and then allowed to cool to near ambient temperature while acquiring image data in each of ASIVA's 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. An example of a calibration data set used to establish the instrument response coefficient for a single pixel in the IR array is shown in Figure 5.

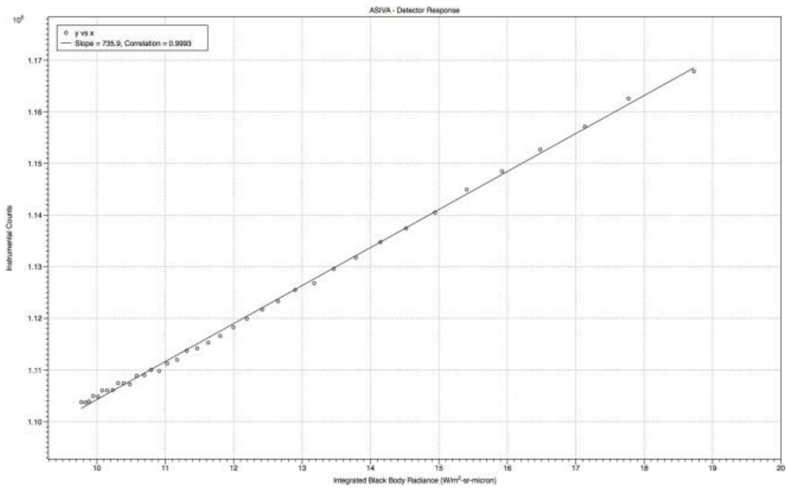

Figure 5: Instrumental counts as a function of integrated (over the 10.2-12.2 µm filter) blackbody radiance (units in W/m^2-sr-µm) for a single pixel in ASIVA's IR array

A block diagram of the ASIVA instrument and its primary functionality is shown in Figure 6.

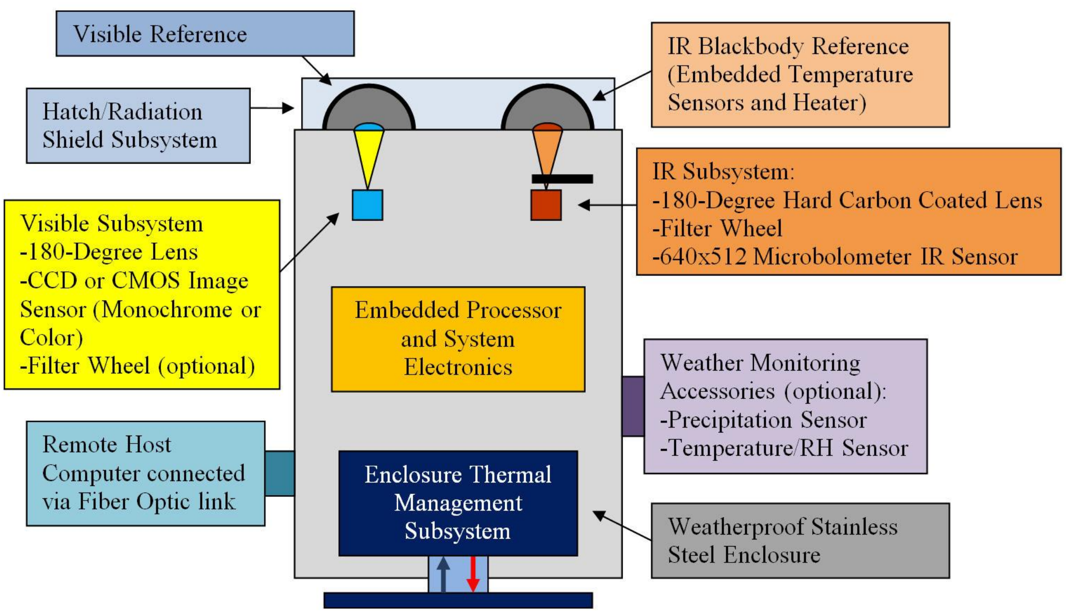

Figure 6: Block diagram of ASIVA functionality

The ASIVA instrument sits on a rugged 20” x 20’ stainless steel pedestal standing 37” off the ground. Weighing ~160 lbs the instrument is easily transported and set up at different locations. Pictures of the ASIVA instrument with the hatch in the closed position are shown in Figure 7.

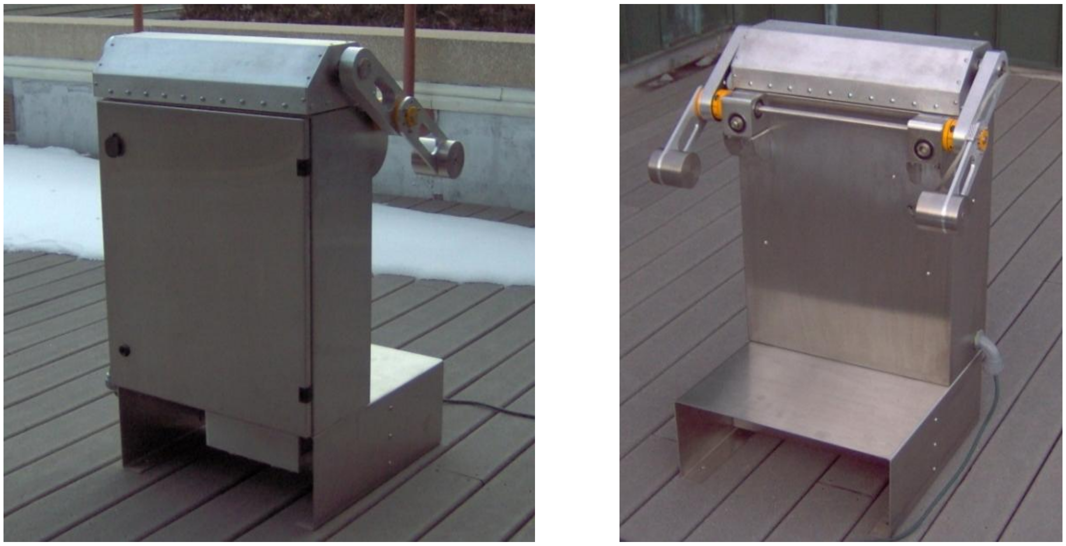

Figure 7: ASIVA instrument with hatch in closed position

At the heart of the ASIVA instrument lays the Infrared and Visible imaging subsystems. The infrared subsystem includes a 640×512 uncooled microbolometer array sensitive to 8-14 micron radiation, a 180-degree (all sky) custom designed hard carbon coated waterproof lens, and a six-position filter wheel for use with 1-inch filters. As standard issue, Solmirus offers its custom 10.2-12.2 µm filter. The visible subsystem consists of a monochrome/color CCD or CMOS detector coupled with a 180-degree off-the-shelf lens. The visible lens has undergone a slight modification to improve water tightness. For monochrome systems, an optional six-position filter wheel for use with 1-inch filters is also available. In general, CMOS detectors offer better daytime performance and CCD detectors offer better nighttime performance.

The ASIVA instrument features a unique Hatch/Radiation Shield subsystem shown in Figure 8.

Figure 8: ASIVA instrument with hatch in open position

This subsystem provides the following features:

- Integrates the IR blackbody reference and visible reference in one mechanism
- IR blackbody reference and the visible reference remain in the same protected orientation (pointed downward) as the hatch mechanism is opened and closed
- Hatch drive motor, position encoder, and magnetic limit switches are housed within the enclosure for better protection and durability
- Temperature sensors and a heater are embedded in the IR blackbody reference for accurate in situ radiometric image calibration
- Custom silicon gasket allows for complete protection of the IR and visible lenses when the hatch is closed
- Radiation shield allows the blackbody reference to equilibrate with the ambient air

For meteorological research requiring operations in inclement weather, Solmirus offers an optional feature wherein filtered air is blown over the surface of each optic to keep them dry during rainy or snowy conditions. This feature, however, does sacrifice some of the instrument's usable field of view but this obscuration is low on the horizon and of minimal angular extent.

The ASIVA instrument incorporates a thermal management subsystem consisting of an internal temperature meter/controller, temperature sensor, and Peltier thermoelectric heater/cooler. This subsystem operates autonomously and is designed to maintain a reasonable and constant temperature within the stainless steel enclosure. In addition to providing a stable environment for system electronics, this temperature regulation helps to improve absolute radiometric image calibration.

The brain of the ASIVA instrument is the embedded processor that communicates with and controls the imaging subsystems and other subsystems such as the hatch motor, filter wheel, temperature meters, and weather monitoring subsystems. Data (both raw and preliminarily processed) is passed over a fiber optic link to the host computer where it is further analyzed, archived, and displayed. Operational control of the ASIVA instrument, on-the-fly image processing, and off-site control through the Internet is done via the host computer.

Solmirus offers a complete end-to-end software solution for instrument control and operation, data acquisition and analysis, and data archival. All user-selected data products are processed on-the-fly and quick-look images and all metadata are stored in an easily accessible web database. Quantitative data is archived as FITS formatted images; a lossless image format that also incorporates an image header in which all pertinent metadata associated with the image can be stored. Examples of Solmirus' highly customizable web database are shown in Figure 9. This web interface also allows easy access to ASIVA configuration settings as well as a coordinate modeling tool that allows for accurate registration of ASIVA IR and visible images on the sky.

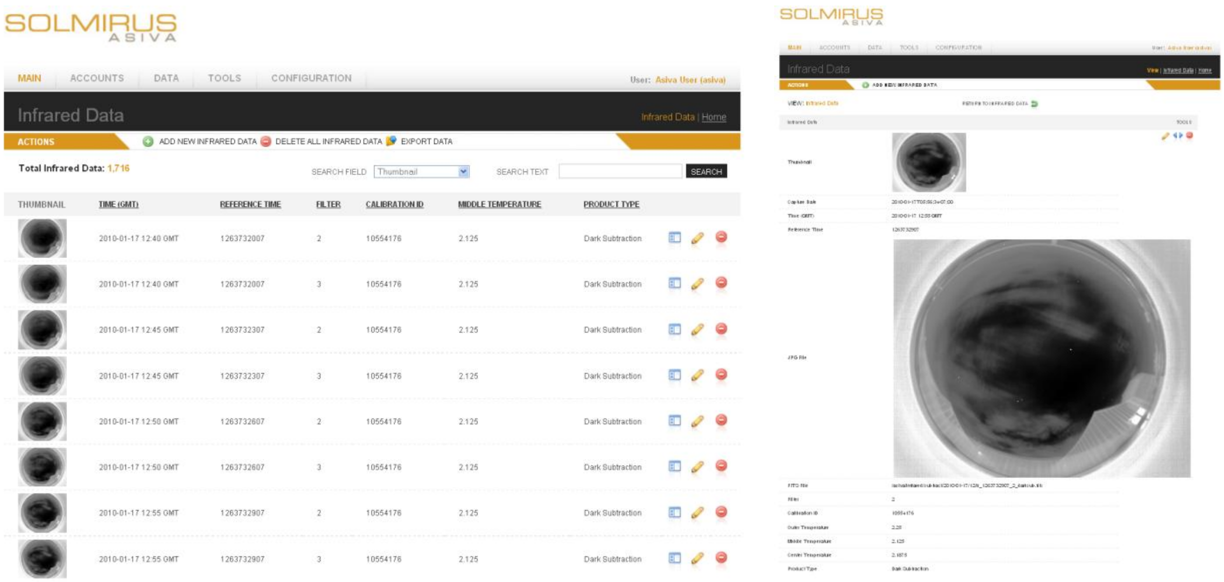

Figure 9: Experts from ASIVA's web database system

Solmirus has completed three production ASIVA instruments. These instruments have been delivered to the Institute for Astronomy (IfA) for operation on Mauna Kea, Hawaii, to the Astrophysikalisches Institut Potsdam (AIP) for operation on the island of Tenerife, Spain, and to the National Optical Astronomy Observatory (NOAO) for operation on Cerro Pachón, Chili. For more information visit our website at www.solmirus.com.