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ICI (INFRARED CLOUD IMAGING) SYSTEMS

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ABSTRACT

The expanding requirement for high speed information return from close Earth and profound space missions is driving an interest for the stronghold of Earthspace optical communication links. These connections will oblige an almost block free way to the correspondence stage, so there is a need to measure spatial and transient facts of clouds at potential ground-station sites. A system is depicted that uses a ground-based warm infrared imager to give nonstop day-night cloud location and grouping as indicated by the cloud optical depths and potential classification of channel weakening. The profit of recovering cloud optical depths and relating weakening is represented through estimations that distinguish overcast times at the point when optical classification may at present be conceivable through thin clouds.

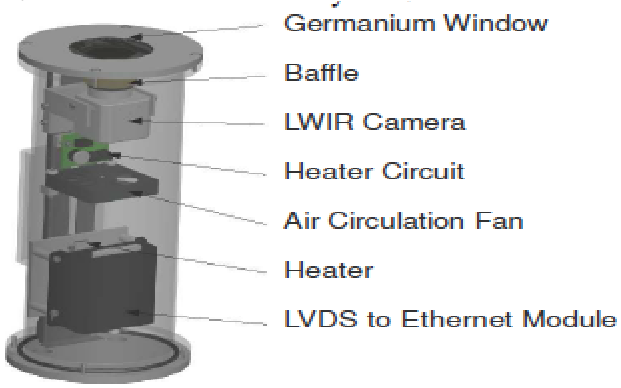
INTRODUCTION:

With the development in technology, the demand for high-data-rate communication is also increasing. Thus generating interest in Earth-spaceoptical links as an alternative to radio-based links. Various organizations are studying Optical links to both near-Earth and deep-space platforms. One major issue in Earth-space optical communication is the cloud cover at the base station on the ground. So, there is a need to characterize clouds at ground sites. It lead the researchers and scientists to develop some low cost, small sized and efficient devices to characterize cloud covers. They developed an INFRARED CLOUD IMAGING(ICI) system which helped to find out the cloud covers effect on optical communication. Then, the ICI2 built after the first-generation ICI system. It was developed formeasuring clouds in climate studies but offers much smaller size and lower cost.The ICI systems are radio metrically calibrated, ground-based, long-wave infrared imagersbased on un-cooled micro bolometer cameras that provide thermal images of the cloud base. Inthis technique, the clouds are identified by observing thermal emission in the atmospheric window(which is normally 8-13 μm), it is observed easily as the cloud emission provides good radiometric contrast compared to relatively low atmospheric emission. The ICI system has been proved reliable for cloud detection during deployments at multiple mid-latitude and Arctic sites by comparing co-located instruments, including microwave radiometers, cloud LIDAR sand radars, and visible-wavelength cloud imagers. Two ICI2 systems are discussed in this paper, one with 62° diagonal field of view and one with 110° diagonal field of view. These systems have same properties like smaller size, lower cost and larger field of view than the original ICI systems. The ICI systems identify clouds from sky radiance images after the clear-sky emission component has been estimated and removed. The ICI2systems also use enhanced algorithms for data processing to classify the detected clouds according to their optical depth and corresponding attenuation for a potential Earth-space optical communication channel.

The attenuation of an optical signal by clouds depends on the cloud'soptical properties. If the clouds are optically thick then the attenuation because of them is strong enough to break the whole communication link. On the other hand, optically thin clouds, attenuate the beam through scattering, it removes the power from the signal path and degrade signal quality. Accuratemeasurements of cloud presence and attenuation will be required to fully characterize potential or existing Earth-space optical channels. The instrument to measure cloud cover will be required to measure the following things: it should provide continuous data (24*7), it should contain both spatial and temporal data tocharacterize variation on hourly, daily, and seasonal basis, and ideally provide real-time data to allow for prediction ofavailability of communication link. Satellites can provide images of cloud tops with resolution on the order of km to tens of km per pixel, but the data may not always provide sufficiently high resolutionto characterize the atmospheric paths of optical communication channels. However, a groundbasedICI can provide spatial resolution of 50 m or less for clouds at 10 km altitude.

What is ICI2?

The ICI2 instruments are much smaller, lower-cost versions of the original ICI. The Original ICI achieves higher sensitivity and stability through the use of a large-area blackbodyreference source, but the smaller ICI2 is simpler to deploy and costs less. Data reported in thispaper are from two compact ICI2 systems, one with a 50° × 38° (62° diagonal) field of view (fov), the other with a 86° × 67° (110° diagonal) fov. The 110° fov is close to the optimalvalue for comparing cloud fraction derived from ground-based and satellite sensors.The Photon320 camera core, from Indigo Systems of FLIR Systems, Inc., was selected asthe thermal imaging camera to be used in the ICI2 systems. This is a small, low-cost, thermalinfraredcamera employing an uncooled microbolometer detector array that operates without athermoelectric cooler (i.e., a TEC-less, camera). The detector has 324 × 256 pixels.The compact ICI2 systems use an environmentally sealed enclosure tohouse the camera, a heater and associated control circuitry, a fan to circulate the internal air, amodule to convert the Low Voltage Digital Signaling (LVDS) data to Ethernet signals for dataacquisition and camera control, a hard carbon-coated germanium window through which thecamera views the scene, and a baffle around the lens to shield the window from variablereflections of emission emanating from within the housing. The baffle improves the spatialuniformity of the window-dependent signal, but does not entirely remove the effects of thewindow. The algorithms developed to correct for these effects are described in a paper that issubmitted but pending review at the time of this writing. Since the window-correctionalgorithms were not yet complete during early ICI2 measurements, the data presented herewere taken with the window removed from the system.



An environmental enclosure houses the ICI2 system.

The ICI2 systems are calibrated (radio metrically) to measure the radiance. It permitsremoving the radiance arising fromatmospheric emission, resulting in isolation of the cloud signature. Since the TEC-lessmicrobolometer camera response changes with temperature, software routines were developed toread the focal plane array temperature and giving out real-time correction ofresponse of the camera. Each different set of routines is used for each camera by making it operate in a thermalchamber with varying temperature while viewing a blackbody source of constant-radiance. Thischaracterization provides a stable radiometric calibration that can be maintained withoutphysical temperature stabilization.

HOW THE DATA IS PROCESSED?

The data received by ICI systems is processed in the two steps, these are:

1. Atmospheric emission removal
2. Cloud detection and classification

These two steps are explained in details as follows:

1. *Atmospheric emission removal*

The measurements (which are radiometrically calibrated) of down-welling sky radiance are processed intwo steps. These are:

- The first step is removing of the clear-sky atmospheric emission component, after which only a residual radiance(cloud-onlyemission) is left.
- In second step, one or more thresholds are applied to the residual radiance

todetermine cloud presence and cloud optical depth.

The routines used to remove the atmospheric emission rely on measurements of PWV andsurface air temperature. The data is then used to calculate theemission expected from a clear sky. The resulting valueis subtracted from each pixel of the calibrated images to give a residual radiance that isolatescloud emission. The atmospheric emission removal algorithm also employs an angularcorrection that increases the PWV by the secant of the zenith angle for each pixel.The required air temperature is readily available from surface meteorological stations andPWV measurements can be made with several sensors, including microwave radiometers,radiosondes, solar radiometers, and global positioning systems. Alternately, the PWV can beestimated through the Reitan Relationship using surface readings of dew-point and airtemperature, but this inevitably increases the cloud-detection uncertainty.

2. Cloud detection and classification

Clouds are detected by applying a threshold-based algorithm to the residual radiance data afterthe background atmospheric emission is removed. This threshold is based on the combineduncertainty of the atmospheric correction and the camera calibrations, including a sufficientmargin to prevent detecting spatial variations of water vapor as clouds.The ICI2 systems use a multi-threshold algorithm to classify the detected clouds accordingto their optical depth (OD) or the resulting optical-link attenuation. Without additionalinformation, these algorithms actually provide an upper estimate of the cloud OD and only doso for the relatively thin clouds.

ATMOSPHERIC EFFECTS IN THE LONGWAVE INFRARED WINDOW

The long-wave infrared window (8 µm to 13 µm), is well suited to observeclouds with an upward-viewing system. It has relatively low absorption and emission.Here, the two major sources of absorption or emission are ozone centered at 9.6 µmand water vapor throughout. Thick clouds can be detected easily in long-wave thermal infraredimages because the cloud emission provides significant contrast as compared to the generally lowatmospheric emission. However, the radiometric contrast is much smaller for thin cirrusdetection, which requires the atmospheric emission to be determined and removed forconsistent detection with varying water vapor content.

CONCLUSION:

in this paper, we have discussed about the applications of compact, ground-based, infrared cloud imagers formeasuring spatial and temporal statistics of clouds and their optical effects on Earth-spaceoptical communication links. The ICI2 systems are relatively small and lowcostthermal infrared cloud imagers that can be used easily at multiple locations and can be reproduced with comparably low cost. But also, these imagers need careful radiometriccalibration.

Researchers are trying to find new methods to improve the atmospheric emission removal algorithms and to refine thecloud optical depth calculations by incorporating external data streams from sensors, reduce sensitivity to atmospheric emission by using narrower spectralfilters, and to perform long-term testing of the weatherproof system and its associated infraredwindow correction algorithms. These refinements will further reduce the calibrationuncertainty of these systems and result in more accurate cloud detection, especially moresensitive detection of thin cirrus. The possibility of using a dual-band technique to moreuniquely identify thin liquid and ice clouds has also being proposed.

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