On orbit measurement of response vs. scan angle for the infrared bands on TRMM/VIRS

William L. Barnes\textsuperscript{a}, Cheng-Hsuan Lyu\textsuperscript{b}, and Robert A. Barnes\textsuperscript{c}

\textsuperscript{a}Laboratory for Hydrospheric Processes, Goddard Space Flight Center, Greenbelt, MD 20771
\textsuperscript{b}Caelum Research Corporation, Greenbelt, MD 20771
\textsuperscript{c}SAIC General Sciences Corporation, Laurel, MD 20705

ABSTRACT

The Visible and Infrared Scanner on the Tropical Rainfall Measuring Mission (TRMM/VIRS) is a whiskbroom imaging radiometer with two reflected solar bands and three emissive infrared bands. All five detectors are on a single cooled focal plane. This configuration necessitated the use of a paddlewheel scan mirror to avoid the effects of focal plane rotation that arise when using a scan mirror that is inclined to its axis of rotation. System radiometric requirements led to the need for protected silver as the mirror surface. Unfortunately, the SiO\textsubscript{x} coatings currently used to protect silver from oxidation introduce a change in reflectance with angle of incidence (AOI). This AOI dependence results in a modulation of system level response with scan angle. Measurement of system response vs. scan angle (RVS) was not difficult for the VIRS reflected solar bands, but attaining the required accuracy for the IR bands in the laboratory was not possible without a large vacuum chamber and a considerable amount of custom designed testing apparatus. Therefore, the decision was made to conduct the measurement on-orbit.

On three separate occasions, the TRMM spacecraft was rotated about its pitch axis and, after the nadir view passed over the Earth's limb, the VIRS performed several thousand scans while viewing deep space. The resulting data has been analyzed and the RVS curves generated for the three IR bands are being used in the VIRS radiometric calibration algorithm. This, to our knowledge, the first time this measurement has been made on-orbit. Similar measurements are planned for the EOS-AM and EOS-PM MODIS sensors and are being considered for several systems under development.

The VIRS on-orbit results will be compared to VIRS and MODIS system level laboratory measurements, MODIS scan mirror witness sample measurements and modeled data.

Keywords: VIRS, on-orbit calibration, spacecraft maneuvers, reflectance, infrared, imaging radiometry
The Export Control Office requests your assistance in assuring that your proposed disclosure of NASA scientific and technical information (STI) complies with the Export Administration Regulations (EAR, 15 CFR 730-774) and the International Traffic in Arms Regulations (ITAR, 22 CFR 120-130). The NASA Export Control Program requires that every domestic and international presentation/publication of GSFC STI be reviewed through the GSFC Export Control Office in accordance with the NASA Form 1676 NASA Scientific and Technical Document Availability Authorization (DAA) process. Release of NASA information into a public forum may provide countries with interests adverse to the United States with access to NASA technology. Failure to comply with the ITAR regulations and/or the Commerce Department regulations may subject you to fines of up to $1 million and/or up to ten years imprisonment per violation. Completion of this checklist should minimize delays in approving most requests for presentation/publication of NASA STI.

Generally, the export of information pertaining to the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles, i.e., space flight hardware, ground tracking systems, launch vehicles to include sounding rockets and meteorological rockets, radiation hardened hardware and associated hardware and engineering units for these items are controlled by the State Department under the ITAR. A complete listing of items covered by the ITAR can be accessed at http://gsfc-bluenun.gsfc.nasa.gov/export/regsitar.htm. The export of information with respect to ground based sensors, detectors, high-speed computers, and national security and missile technology items are controlled by the U.S. Commerce Department under the EAR. If the information intended for release falls within the above categories but otherwise fits into one or more of the following exemptions, the information may be released.

**EXEMPTION I**
If your information is already in the public domain in its entirety through a non-NASA medium and/or through NASA release previously approved by the Export Control Office, the information is exempt from further review. If the information falls into this category, you may attest that you are using this exemption by signing below.

---

**Signature**

**Date**

**EXEMPTION II**
If your information pertains exclusively to the release of scientific data, i.e. data pertaining to studies of clouds, soil, vegetation, oceans, and planets, without the disclosure of information pertaining to articles controlled by the ITAR or EAR, such as flight instruments, high speed computers, or launch vehicles, the information is exempt from further review. If the information falls into this category, you may attest that you are using this exemption by signing below.

---

**Signature**

**Date**

**EXEMPTION III**
If your information falls into the areas of concern as referenced above, but is offered at a general purpose or high level, i.e. poster briefs and overviews, where no specific information pertaining to ITAR or EAR controlled items is offered, the information is exempt from further review. If the information falls into this category, you may attest that you are using this exemption by signing below.

---

**Signature**

**Date**
EXEMPTION IV

If your information is not satisfied by the 3 exemptions stated above, the information may be released using exemption 125.4(b)(13) of the ITAR. Use of this exemption is afforded only to agencies of the Federal Government and allows the release of ITAR controlled information into the public domain. But the GSFC Export Control Office has determined that use of this exemption will be allowed only after we receive assurance that such release is a responsible action. To this end, an internal guideline has been established pursuant to the use of this exemption: That the information does not offer specific insight into design, design methodology, or design processes of an identified ITAR controlled item in sufficient detail (by itself or in conjunction with other publications) to allow a potential adversary to replicate, exploit and/or defeat controlled U.S. technologies. All signatures of approval on NASA Form 1676 expressly indicate concurrence with the responsible use of Exemption IV when Exemption IV has been cited by the author. If you determine that you have met this criteria, you may attest your determination by signing below, and the GSFC Export Control Office will offer favorable consideration toward approving your presentation/publication request under this special exemption.

__________________________________  ______________________________
Signature                                      Date

If you do not satisfy the above exemptions, please contact the GSFC Export Control Office for further clarification on the releasability of your information under the ITAR or EAR.

1/8/1999
The EOS/SPIE Symposium on Remote Sensing

20-24 September 1999
University of Florence, Italy

Symposium Chairs:
Hatem Nasr, Baker Hughes, Houston, Texas USA
Luca Pantani, CNR-IREO, Florence, Italy

Symposium Co-Chair:
Enzo Pranzini, University of Florence, Italy

Sponsored by
University of Florence, Italy - Department of Earth Science
EO.S - The European Optical Society
SPIE - The International Society for Optical Engineering
CNR - The National Research Council of Italy
NASA - National Aeronautics and Space Administration
SIOF - Italian Society of Optics and Photonics

Invitation to Attend

A few decades ago aerial photography, photogrammetry, and radio ionospheric studies gave birth to the field of remote sensing, with some of the most dramatic developments occurring during World War II. Various national space programs helped evolve the technology into what it is today and made it a viable tool for environmental monitoring and other very practical applications. Today, remote sensing is one of the fastest growing technologies around. It is a multibillion dollar industry and remote thematic images are routinely used in an increasing number of fields. Remote sensing data has even become part of our daily lives. Weather satellites are the primary source for weather forecasting. Satellite data is being used today for crop forecasting, mining and exploration, archeological discoveries, and even real estate development, to name few. This was almost unimaginable a few decades ago. In the next millennium, as the technology continues to evolve, we will witness an even faster growth of remote sensing applications and commerce.

Today, there are very few yearly conferences on Remote Sensing that offer a comprehensive coverage of scientific topics, applications, sensors, systems and satellite platforms. The EUROPTO® Symposium is one such conference. The EUROPTO® Symposium also brings a unique blend of international participants, where over 20 countries have been represented every year. The remote sensing community has four main participants:

- Scientists, who research new sensors, data processing techniques, phenomenology, and applications;
- Industry, which develops new platforms and sensors and engages in the commerce of remote sensing technology;
- Users, who employ remote sensing products for their daily needs;
- Governments, which want to develop the technology to improve and protect their societies and promote commerce.

We invite participants from all these communities to participate in our next EUROPTO® Symposium on Remote Sensing in Florence, Italy, 20-24 September 1999. This Symposium is the sixth in this series. We continue to improve on this meeting. Last year's very successful Symposium in Barcelona attracted about 400 participants. This will be a unique forum to get informed and debate the state of the art of the technology: sensors, platforms, and applications.

Eleven conferences will be held in the framework of the Symposium. Each conference will include oral presentations and posters. We warmly invite you to participate in the EUROPTO® Symposium on Remote Sensing. We are working hard to make it a symposium of the highest quality.

Hatem Nasr
Baker Hughes, Houston, Texas

Luca Pantani
CNR-IROE "Nello Carrara", Florence, Italy
The major interest of this conference is focused on Satellite / Lunar Laser Ranging (S/LLR) and Atmospheric Lidar. SLR contributed a lot to the earth sciences over the last two decades, enhancing the resolution of the measured ranges continuously. Nowadays the domain below one centimetre has been reached. Therefore, the structure of the targets and the rapidly changing propagation properties of the atmosphere and a high level of system stability have become relevant. Multiple sensor models, near real-time data consistency checks in clustered stations and in situ measurements of atmospheric parameters via remote sensing techniques are becoming keywords of a mm-level SLR community.

There are a lot of similarities between SLR and lidar, beginning from the laser radar technique and ending in the application for atmospheric monitoring or correction. Tomography is a new technique that can be applied from ground stations using retro-reflectors in space or from space using hard targets on the ground. There are lidars or laser radars in orbit. Results of these sensors and discussions of planned missions are the goal of the second part of the conference.

The conference will be the continuation of the Europto® London conference in 1997 and is aimed to be a market for ideas. The session chairs are advised to stimulate the discussion. Therefore the number of accepted papers is limited to relevant new material and one or two invited papers. It is planned to provide time for discussions of planned missions and their interpretation.

Papers are solicited on the following and related topics:

- Imaging (band, spectral and hyperspectral) of ground-based and airborne objects from space and vice versa;
- Techniques for mitigation of atmospheric effects on imaging: adaptive optics, deconvolution, sensor fusion, post processing etc;
- Propagation and imaging through inhomogeneous dense media; multiple scattering effects on LIDAR and imager performance;
- Propagation and imaging through optical turbulence, including strong turbulence regimes;
- Propagation models and correction methods for atmospheric effects in remote sensing;
- Statistics of propagation parameters, statistics of cloud free line of sights, etc. Effects of depolarisation, pulse stretching, loss of coherence for active (laser) systems;
- Characterisation of the propagation environment: profiles of temperature, humidity, extinction, refractivity, radiance (also non-LTE), optical turbulence; updates of transmission and radiance codes.

A special session is planned to combine this conference with the conference on Laser Radar Techniques. The session will be dedicated to multiple scattering effects with respect to laser propagation and backscattering.
Papers are solicited on the following and related example topics:

- planned and proposed photonics and fiber optics nuclear reactor and space experiments.
- Quantification and qualification of photonic systems, materials and component responses in radiation environments.
- modeling of radiation environments-photonic responses
- MEMS-MOEMS system and component radiation effects studies
- optical interconnects and optical bus architectures for space systems
- advances in photonic materials suitable for radiation applications
- research emphasizing FO components and systems.
Satellite remote sensing has become a common tool of the investigation in the different fields of Earth science. The progress of the performance capabilities of the optoelectronic devices mounted on-board space platforms have further improved the capability of instruments to explore inside the structure of the lithosphere and related resources, and to achieve the necessary information for a land-use global assessment, allowing us to make expanded and more detailed use of the electromagnetic spectrum. Satellite imagery is also an important complementary support in the description of spatial distribution of urban areas and archaeological sites, being largely dependent on environmental characteristics such as landform, soil fertility, rock type, water proximity, climatic conditions.

The present conference will be an occasion to outline how scientists involved in the Earth studies can take advantage of new remote sensing techniques, what their needs are, and what perspectives are just around the corner for tomorrow.

Particular subjects are:
- Imaging spectrometry and its hyperspectral dimension
- Image texture and spatial analysis and the 3-D computer vision
- Radar interferometric techniques to detect small displacements in relation to geodynamic events
- GIS for retrieval of land resource information
- Integration between remote sensing and geophysical prospecting

This announcement is an invitation to present new research results in these fields of satellite remote sensing applications in the following and related topics:
- Structural geology and tectonics
- Mineral and petroleum exploration
- Hydrogeology in arid and semi-arid zones
- Landform analysis and Quaternary geology
- Lithological classification and mapping
- Geological hazard and land degradation
- Soil properties and land-use classification
- Archaeological site identification
- Paleo-environmental reconstruction
- Infrastructures and urban areas

Particular subjects are:
- Operational monitoring
- Detection of deep water formation
- Water-quality monitoring
- Sea ice classification and sea ice dynamics
- Studies and modelling of microwaves and optical signatures of sea and ice
- Studies of shore-fast ice with interferometry
- Multi-satellite, sensor integration, and sensor studies
- Data fusion
- Regional and global sea ice monitoring in climate change research
- Operational monitoring systems and their requirements

The Conference on remote sensing of the ocean and sea ice should address the following issues of application of data from a variety of sensors, combined with meteorological, physical, biological, chemical, and geological data:
- Ocean currents and fronts
- Detection of deep water formation
- Water-quality monitoring
- Sea ice classification and sea ice dynamics
- Studies and modelling of microwaves and optical signatures of sea and ice
- Studies of shore-fast ice with interferometry
- Multi-satellite, sensor integration, and sensor studies
- Data fusion
- Regional and global sea ice monitoring in climate change research
- Operational monitoring systems and their requirements
Many new remote sensing programs are under way throughout the world, specifically by U.S., European countries and Japan. NASA’s office of Earth Science Enterprise (ESE) is developing plans for a series of programs including EOS, Landsat, Earth System Science Pathfinder (ESSP), and New Millennium Earth Orbiting Flight. Japanese NASDA has a series of ADEOS and ALOS programs. ESA has ENVISAT and METOP programs. Each of these programs is developing a set of remote sensing systems to address their science objectives.

Papers are solicited on the following and related topics:

- Sensors being developed.
- Satellites being developed.
- Technologies required to enable these sensors and satellites.
- New design concepts of sensors, systems and satellites.
- Hyper spectral sensors in space.
- Sensor calibration techniques.
- Modeling and simulation techniques for sensor concept development.
- Focal plane assemblies including detectors and spectral filters.
- Space cryogenics.
- System precursors including test beds and airborne simulators.
- Data system being developed.
- New data processing techniques.

Sessions on the following topics are being planned:
- ADEOS/ALOS mission and technologies.
- ENVISAT/METOP mission and technologies.
- ESE mission and technology.
- New satellite technologies (navigation, on-board data processing, cooling system, etc.).
- Calibration.
- Hyper spectral sensors (mission analysis, design, performance, technologies, airborne sensors, etc.).
INSTRUCTIONS FOR SUBMITTING ABSTRACTS
Please choose only one of the following options and send by the due date:
• E-mail each abstract separately to: europto@associationhq.com in ASCII text (not encoded). IMPORTANT: to ensure receipt and proper processing of your abstract, the Subject line must include only the following: Example: SUBJECT: rs01 (or code listed after the conference title). Attachments in Word only.
• or mail three copies of your abstract to: Remote Sensing Boulevard St. Michel 15 B-1040 Brussels Belgium or fax one copy to +32-2-743 15 50 (send each abstract separately).
PUBLISHING POLICY
Manuscript due dates must be strictly observed. Whether the conference volume will be published before or after the meeting, late manuscripts run the risk of not being published in the Proceedings. The objective of this policy is to better serve the conference participants and the technical community at large. Your cooperation in supporting this objective will be appreciated by all.
PROCEEDINGS
These meetings will result in published Proceedings available for order through the Advance Programme. Manuscripts are required of all accepted applicants and must be submitted in English by 23 August 1999. Copyright to the manuscript is expected to be released for publication in the conference Proceedings. Note: If an author does not attend the meeting and make a presentation, the chair may choose not to publish the author's manuscript in the conference volume. Papers published are indexed in leading scientific databases including INSPEC, Compendex Plus, Physics Abstracts, Chemical Abstracts, International Aerospace Abstracts and Index to Scientific and Technical Proceedings.

ORAL PRESENTATION
Each author is generally allowed 15 minutes plus a five-minute discussion period. The following media equipment is provided free of charge: 35 mm slide projectors, overhead projectors, and flipcharts. Video and other equipment may be provided upon request.

AUTHOR BENEFITS
Authors and co-authors are expected to pay a reduced registration fee. Included with a fee payment is a copy of the Proceedings volume in which the participant's role or paper appears.