

PROCEEDINGS OF SPIE

Lidar Technologies, Techniques, and Measurements for Atmospheric Remote Sensing VII

**Upendra N. Singh
Gelsomina Pappalardo**
Editors

**19–20 September 2011
Prague, Czech Republic**

Sponsored by
SPIE

Cooperating Organisations
EOS— European Optical Society
Remote Sensing and Photogrammetry Society (United Kingdom)

Published by
SPIE

Volume 8182

Proceedings of SPIE, 0277-786X, v. 8182

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Lidar Technologies, Techniques, and Measurements for Atmospheric Remote Sensing VII*, edited by Upendra N. Singh, Gelsomina Pappalardo, Proceedings of SPIE Vol. 8182 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X
ISBN 9780819488091

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Copyright © 2011, Society of Photo-Optical Instrumentation Engineers

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/11/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIE 
Digital Library

SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

- vii *Conference Committee*
ix *The evolution of airborne chemical and radiological remote sensing for emergency and natural disaster response (Plenary Summary)*
P. E. Lewis, National Geospatial-Intelligence Agency (United States)

KEYNOTE SESSION

- 8182 02 **Active optical technology: recent developments (Keynote Paper)** [8182-01]
G. J. Komar, NASA (United States)

SESSION 1 SPACE-BASED LIDAR DEVELOPMENT I

- 8182 04 **Spaceflight laser development for future remote sensing applications (Invited Paper)** [8182-03]
A. W. Yu, M. A. Krainak, M. A. Stephen, J. B. Abshire, D. J. Harding, H. Riris, S. X. Li, J. R. Chen, G. R. Allan, K. Numata, S. T. Wu, J. B. Camp, NASA Goddard Space Flight Ctr. (United States)

SESSION 2 SPACE-BASED LIDAR DEVELOPMENT II

- 8182 06 **Optical parametric oscillators and amplifiers for airborne and spaceborne active remote sensing of CO₂ and CH₄** [8182-05]
A. Fix, C. Büdenbender, M. Wirth, M. Quatrevalet, A. Amediek, C. Kiemle, G. Ehret, Deutsches Zentrum für Luft- und Raumfahrt (Germany)
- 8182 07 **Development effort of the airborne lidar simulator for the lidar surface topography (LIST) mission** [8182-06]
A. W. Yu, M. A. Krainak, D. J. Harding, J. B. Abshire, X. Sun, J. Cavanaugh, S. Valett, L. Ramos-Izquierdo, T. Winkert, C. Kirchner, M. Plants, T. Filemyr, B. Kamamia, W. Hasselbrack, P. Dogoda, NASA Goddard Space Flight Ctr. (United States)
- 8182 08 **In space performance of the lunar orbiter laser altimeter (LOLA) laser transmitter** [8182-07]
A. W. Yu, G. B. Shaw, NASA Goddard Space Flight Ctr. (United States); A. M. Novo-Gradac, NASA Headquarters (United States); S. X. Li, J. Cavanaugh, NASA Goddard Space Flight Ctr. (United States)

SESSION 3 RAMAN LIDAR OBSERVATIONS

- 8182 09 **Examination of possible synergy between lidar and ceilometer for the monitoring of atmospheric aerosols (Invited Paper)** [8182-08]
I. Binietoglou, A. Amodeo, G. D'Amico, A. Giunta, F. Madonna, L. Mona, G. Pappalardo, CNR, Istituto di Metodologie per l'Analisi Ambientale (Italy)

- 8182 0A **Preliminary measurements of tropospheric water vapor using Raman lidar system in the Great Lakes area** [8182-09]
W. Al-Basheer, K. B. Strawbridge, B. J. Firanski, Environment Canada (Canada)
- 8182 0B **Validation of COSMIC water vapor profiles using Raman lidar measurements performed at CIAO** [8182-10]
F. Madonna, CNR, Istituto di Metodologie per l'Analisi Ambientale (Italy); P. Burlizzi, Univ. of Salento (Italy); A. Giunta, I. Biniotoglou, CNR, Istituto di Metodologie per l'Analisi Ambientale (Italy); M. R. Perrone, Univ. of Salento (Italy); G. Pappalardo, CNR, Istituto di Metodologie per l'Analisi Ambientale (Italy)
- 8182 0C **One year of regular aerosol observations with a multi-wavelength Raman lidar in Portugal** [8182-12]
J. Preißler, F. Wagner, Univ. of Évora (Portugal); J. L. Guerrero-Rascado, Univ. of Évora (Portugal) and Univ. of Granada (Spain); A. M. Silva, Univ. of Évora (Portugal)

SESSION 4 CARBON DIOXIDE SENSING

- 8182 0E **Improvement of the 1.57-micron laser absorption sensor with chirp modulation to evaluate spatial averaging carbon dioxide density** [8182-14]
D. Sakaizawa, S. Kawakami, T. Tanaka, M. Nakajima, Japan Aerospace Exploration Agency (Japan)
- 8182 0G **Direct detection 1.6 μ m DIAL for measurements of CO₂ concentration profiles in the troposphere** [8182-16]
C. Nagasawa, M. Abo, Y. Shibata, Tokyo Metropolitan Univ. (Japan); T. Nagai, Meteorological Research Institute (Japan); M. Tsukamoto, Eko Instruments Corp. (Japan)
- 8182 0H **New broadband lidar for greenhouse carbon dioxide gas sensing in the Earth's atmosphere** [8182-17]
E. Georgieva, Joint Ctr. for Earth Systems Technology/UMBC (United States) and NASA Goddard Space Flight Ctr. (United States); W. S. Heaps, NASA Goddard Space Flight Ctr. (United States); W. Huang, NASA Goddard Space Flight Ctr. (United States) and Science Systems and Applications, Inc. (United States)

SESSION 5 COHERENT AND DIRECT DETECTION OF WIND

- 8182 0J **Airborne direct-detection and coherent wind lidar measurements along the east coast of Greenland in 2009 supporting ESA's Aeolus mission** [8182-18]
U. Marksteiner, O. Reitebuch, S. Rahm, Deutsches Zentrum für Luft- und Raumfahrt (Germany); I. Nikolaus, Physics Solutions (Germany); C. Lemmerz, B. Witschas, Deutsches Zentrum für Luft- und Raumfahrt (Germany)
- 8182 0K **Field programmable gate array processing of eye-safe all-fiber coherent wind Doppler lidar return signals** [8182-19]
S. Abdelazim, D. Santoro, M. Arend, F. Moshary, S. Ahmed, The City College of New York (United States)

SESSION 6 AEROSOLS AND DIAL MEASUREMENTS I

- 8182 0O **Long term observation of low altitude atmosphere by high precision polarization lidar** [8182-24]
T. Shiina, Chiba Univ. (Japan); K. Noguchi, Chiba Institute of Technology (Japan); T. Fukuchi, Central Research Institute of Electric Power Industry (Japan)
- 8182 0P **Application of active optical sensors to probe the vertical structure of the urban boundary layer and assess anomalies in air quality model PM_{2.5} forecasts** [8182-25]
C.-M. Gan, Y. Wu, L. M. Bomidi, B. Gross, F. Moshary, The City College of New York (United States)

SESSION 7 AEROSOLS AND DIAL MEASUREMENTS II

- 8182 0R **Planetary boundary layer height retrieval at UMBC in the frame of NOAA/ARL campaign** [8182-27]
S. Lolli, Leosphere (France); R. Delgado, J. Compton, R. Hoff, Univ. of Maryland, Baltimore County (United States)
- 8182 0T **Vertical resolved separation of aerosol types using CALIPSO level-2 product** [8182-29]
E. Giannakaki, D. Balis, Aristotle Univ. of Thessaloniki (Greece); V. Amiridis, National Observatory of Athens (Greece)
- 8182 0U **Indirect aerosol hygroscopic growth observations with a backscattering lidar, part II: five day breeze onset data analyses** [8182-30]
P. F. Rodrigues, E. Landulfo, IPEN-CNEN/SP (Brazil); A. W. Gandu, IAG/USP (Brazil); F. J. da Silva Lopes, R. F. da Costa, W. Nakaema, IPEN-CNEN/SP (Brazil)
- 8182 0V **Supercontinuum laser absorption spectroscopy in the mid-infrared range for identification and concentration estimation of a multi-component atmospheric gas mixture** [8182-31]
N. Cézard, A. Dobroc, G. Canat, M. Duhant, W. Renard, C. Alhenc-Gelas, S. Lefebvre, ONERA (France); J. Fade, CNRS, Institut de Physique de Rennes, Univ. de Rennes 1 (France)

POSTER SESSION

- 8182 0W **Six-channel polychromator design and implementation for the UPC elastic/Raman lidar** [8182-11]
D. Kumar, F. Rocadenbosch, M. Sicard, A. Comerón, C. Muñoz, D. Lange, S. Tomás, Univ. Politècnica de Catalunya (Spain); E. Gregorio, Univ. de Lleida (Spain)
- 8182 0X **Development of white light polarization lidar system** [8182-34]
T. Somekawa, Institute for Laser Technology (Japan); K. Oka, Hokkaido Univ. (Japan); M. Fujita, Institute for Laser Technology (Japan) and Osaka Univ. (Japan)
- 8182 0Y **Real-time mapping of an industrial flare using lidar** [8182-35]
R. F. da Costa, IPEN-CLA (Brazil); J. Steffens, Univ. de São Paulo (Brazil); E. Landulfo, IPEN-CLA (Brazil); R. Guardani, Univ. de São Paulo (Brazil); W. M. Nakaema, IPEN-CLA (Brazil); P. F. Moreira, Jr., Univ. de São Paulo (Brazil); F. J. S. da Silva Lopes, P. Ferrini, IPEN-CLA (Brazil)

- 8182 07 **Remote sensing detection of atmospheric pollutants using lidar, sodar and correlation with air quality data in an industrial area** [8182-36]
J. Steffens, Univ. de São Paulo (Brazil); R. F. da Costa, E. Landulfo, Instituto de Pesquisas Energéticas e Nucleares (Brazil); R. Guardani, P. F. Moreira, Jr., Univ. de São Paulo (Brazil); G. Held, IPMet/UNESP (Brazil)
- 8182 10 **Experimental evaluation of a model for the influence of coherent wind lidars on their remote measurements of atmospheric boundary-layer turbulence** [8182-37]
M. Sjöholm, Technical Univ. of Denmark (Denmark); S. Kapp, Robert Bosch GmbH (Germany); L. Kristensen, T. Mikkelsen, Technical Univ. of Denmark (Denmark)
- 8182 13 **First open field measurements with a portable CO₂ lidar/dial system for early forest fires detection** [8182-40]
P. Gaudio, M. Gelfusa, I. Lupelli, A. Malizia, A. Moretti, M. Richetta, C. Serafini, Univ. of Rome, Tor Vergata (Italy); C. Bellecci, CRATI S.c.r.l. (Italy)
- 8182 14 **Initial analysis from a lidar observation campaign of sugar cane fires in the central and western portion of the São Paulo State, Brazil** [8182-41]
F. J. da Silva Lopes, IPEN-CNEN/SP (Brazil); G. Held, IPMet-UNESP (Brazil); W. M. Nakaema, P. F. Rodrigues, IPEN-CNEN/SP (Brazil); J. M. Bassan, IPMet-UNESP (Brazil); E. Landulfo, IPEN-CNEN/SP (Brazil)
- 8182 15 **Validation of CALIPSO level-2 products using a ground based lidar in Thessaloniki, Greece** [8182-42]
E. Giannakaki, E. Vraimaki, D. Balis, Aristotle Univ. of Thessaloniki (Greece)
- 8182 16 **Multiwavelength micropulse lidar in atmospheric aerosol study: signal processing** [8182-43]
M. Posyniak, S. P. Malinowski, T. Stacewicz, K. M. Markowicz, Univ. of Warsaw (Poland); T. Zielinski, T. Petelski, P. Makuch, Institute of Oceanology (Poland)
- 8182 17 **Estimating the relationship between aerosol optical thickness and PM₁₀ using lidar and meteorological data in Limassol, Cyprus** [8182-44]
N. Argyro, H. G. Diofantos, A. Dimitrios, Cyprus Univ. of Technology (Cyprus)

Author Index

Conference Committee

Symposium Chair

Karin Stein, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Symposium Cochair

Charles R. Bostater, Florida Institute of Technology (United States)

Conference Chairs

Upendra N. Singh, NASA Langley Research Center (United States)
Gelsomina Pappalardo, Consiglio Nazionale delle Ricerche (Italy)

Programme Committee

Arnoud Apituley, Rijksinstituut voor Volksgezondheid en Milieu (Netherlands)

Andreas Behrendt, Universität Hohenheim (Germany)

Alain M. Dabas, Meteo-France CNRM (France)

Gerhard Ehret, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

Martin Endemann, European Space Research and Technology Center (Netherlands)

Pierre H. Flamant, Laboratoire de Météorologie Dynamique (France)

Barry Gross, The City College of New York (United States)

Philippe L. Keckhut, Université de Versailles Saint-Quentin-en Yvelines (France)

Eduardo Landulfo, Instituto de Pesquisas Energéticas e Nucleares (Brazil)

Gennadii G. Matvienko, V.E. Zuev Institute of Atmospheric Optics (Russian Federation)

Doina N. Nicolae, National Institute of Research & Development for Optoelectronics (Romania)

Alexandros D. Papayannis, National Technical University of Athens (Greece)

Vincenzo Rizi, Università degli Studi dell'Aquila (Italy)

Laurent Sauvage, Leosphere France (France)

Valentin B. Simeonov, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

Ulla Wandinger, Leibniz Institut für Troposphärenforschung (Germany)

David M. Winker, NASA Langley Research Center (United States)

Session Chairs

- 1 Space-based Lidar Development I
Upendra N. Singh, NASA Langley Research Center (United States)
- 2 Space-based Lidar Development II
Upendra N. Singh, NASA Langley Research Center (United States)
- 3 Raman Lidar Observations
Doina N. Nicolae, National Institute of Research & Development for Optoelectronics (Romania)
Eduardo Landulfo, Instituto de Pesquisas Energéticas e Nucleares (Brazil)
- 4 Carbon Dioxide Sensing
George Komar, NASA Earth Science Technology Office (United States)
Stephen P. Sandford, NASA Langley Research Center (United States)
- 5 Coherent and Direct Detection of Wind
Stephen P. Sandford, NASA Langley Research Center (United States)
George J. Komar, NASA Goddard Space Flight Center (United States)
- 6 Aerosols and DIAL Measurements I
Chikao Nagasawa, Tokyo Metropolitan University (Japan)
Graham R. Allan, Sigma Space Corporation (United States)
- 7 Aerosols and DIAL Measurements II
Anthony W. Yu, NASA Goddard Space Flight Center (United States)
Ioannis Binietoglou, Istituto di Metodologie per l'Analisi Ambientale (Italy)

Plenary Summary

The Evolution of Airborne Chemical and Radiological Remote Sensing For Emergency and Natural Disaster Response

Summary of the September 19, 2011 SPIE Remote Sensing Plenary Session Presentation by

Paul E. Lewis

National Geospatial-Intelligence Agency, United States of America

First responders, joint operations centers, and recovery and remediation personnel consider timely and affordable airborne chemical, radiological, imagery analysis, and related mapping products essential in the formulation of a complete understanding of an incident and its potential impact on adjacent communities, and for recovery and remediation. Airborne remote sensing provides the flexibility to produce incident specific products and conduct over-flights at the frequencies needed to provide timely and relevant information for recovery and remediation operations, optimization of resources during an event, and for the safety of emergency response personnel.

The utility of airborne chemical remote sensing became apparent to the EPA during a chemical plant explosion, which occurred in Sioux City, Iowa in December of 1994. The facility produced ammonium nitrate fertilizer, and also produced its own ammonia for use in the process. In late December an explosion occurred rupturing the main storage tank and spilling three million gallons of ammonia. This resulted in lethal vapor levels in and around the plant and created a plume of ammonia vapors estimated to be 35 miles long. Approximately 3,500 people were evacuated over a 50 square mile area. The EPA sent in vehicles with ground sampling crews dressed in Level A hazmat suits with 30 minute air packs to monitor the site. Due to heavy snow coverage on the ground and saturated soil conditions underneath the snow, all of the EPA vehicles became stuck. Ground sampling crews had to be rescued before air supplies ran out. Consequently, no monitoring of vapor levels was accomplished.

The lessons learned from responding to the chemical explosion in Sioux City, Iowa in 1994 prompted the EPA to begin evaluating the application of airborne remote sensing infrared and gamma ray spectroscopy for emergency responses involving chemical and radiological incidents. Concurrently, with the evaluation process to determine the performance and feasibility of implementing infrared and gamma ray spectroscopy in an airborne platform came the evolution of a set of core requirements for an airborne operational capability: Standoff chemical and gamma ray detection and identification with low false alarm rates; High resolution ortho-rectified day-night imagery; Airborne data collection under cloud ceilings; Rapid dispatch-wheels up in under one hour after activation; Automated data processing –real or near-real-time chemical data analysis; Direct integration of data and information to local incident commanders-local and federal joint operations centers; Data telemetry to and from the aircraft.

According to the EPA, in the United States there are approximately 123 facilities where a release of chemicals could threaten more than one million people. There are approximately 750 additional facilities where a chemical release could threaten more than a hundred thousand people.

In 2001, the EPA implemented the United States only civilian operational airborne chemical detection and identification capability called the **A**irborne **S**pectral **P**hotometric **E**nvironmental **C**ollection **T**echnology (**ASPECT**) Program. Subsequently in 2003, the EPA and NGA agreed to collaborate in a cooperative research and development program focused on evolving the capabilities of the ASPECT Program to produce near-real-time state of the art chemical, radiological and imagery mapping emergency response products.

Plenary Summary

Airborne Spectral Photometric Environmental Collection Technology (ASPECT) Program
The United States Only Airborne
24/7 Operational CIVIL Emergency Response Chemical, Radiological, & Imaging Mapping Capability



The ASPECT model of operation combines an airborne operational remote sensing suite with a research and development support team to insure that analysis and products are validated and verified scientifically and are reviewed and checked before release. The research and development support team collaboration between the EPA and NGA to evolve the capabilities of the ASPECT Program has resulted in the following significant accomplishments: Near-real-time automated onboard chemical detection and identification of 78 chemical compounds with low false alarm rates; Near-real-time information on plume direction and concentrations; Automated software producing day/night ortho-rectified imagery rapid response maps; Automated software producing gamma ray survey information maps onboard the aircraft; Data and information telemetry to and from the aircraft facilitating turn-around times and seamless integration of vital situational awareness information from the aircraft to first responders or joint operation centers in 5 to 15 minutes.

Since 2001 the ASPECT Program has provided essential information during 115 emergency, disaster, and homeland security related incidents ranging from chemical plant explosions and train derailments to fires, floods, hurricanes, and special events. The ASPECT Program played key roles in providing essential information to first responders and joint operations centers in response to the following historical events: The Shuttle Columbia break up during re-entry over Texas in February of 2003; Hurricane Katrina in August of 2005; The Deepwater Horizon Oil Spill disaster in the Gulf of Mexico from April-August 2010.

Over the past decade in over 115 responses, the ASPECT program has demonstrated the utility of having timely, cost-effective operational airborne chemical and radiological remote sensing information integrated seamlessly into the local, state and federal emergency response and disaster recovery and remediation communities. What is needed next is the implementation of multiple aircraft strategically located throughout the United States so that ASPECT capabilities can be on the scene of a disaster or event in less than three hours.