Remote Sensing and Estimation

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1. NPOESS Aircraft Sounder Testbed (NAST) Passive Microwave Sensor

Sponsor
MIT Lincoln Laboratory, Agreement BX-7601

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The NPOESS Aircraft Sounder Testbed (NAST) incorporates a microwave sounder built by RLE which flies together with other instruments on high altitude aircraft to explore technical issues related to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS). [1] This year considerable progress was made in adding a 7-channel passive microwave spectrometer operating between 166 and 194 GHz near a strong water vapor absorption line at 183.31 GHz. Progress was also made in developing a 7-channel microwave spectrometer operating within 3.5 GHz of the strong 424.76-GHz resonance of oxygen. These two new scanning spectrometers will sound tropospheric temperature and humidity profiles, and supplement the two existing NAST spectrometers operating at 50-56 GHz (8 channels) and within 4 GHZ of the 118.75-GHz oxygen resonance (7 channels). These two existing spectrometers sound tropospheric temperature profiles and image precipitation.

During 2001 NAST flew on the Proteus aircraft as part of the TRACE-P mission to Hawaii, Alaska, and Japan, and in the CLAMS experiment at Wallops Island. These and prior aircraft missions have provided unique data sets which enable comparison of the 14-channel NAST microwave data with 9000-channel infrared imagery from the NAST-I infrared spectrometer and the MAMS multi-channel high-spatial-resolution imager. These instruments and the data they provide are collectively the most advanced available for exploring the future potential of hyperspectral environmental sensing of tropospheric weather. The principal scientific issues addressed this year concern the ability of such suites of instruments to compensate atmospheric temperature and humidity profile retrievals for the effects of clouds, and to respond to precipitation and cloud characteristics.

2. Earth Observing System: Advanced Microwave Sounding Unit

Sponsor
National Aeronautics and Space Administration/Goddard Space Flight Center
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The AIRS/AMSU/HSB facility instrument is currently scheduled to be launched in April 2002 on the Aqua satellite in polar orbit as part of NASA's Earth Observing System (EOS). AMSU will image the earth in a wide swath with 50-km resolution at nadir at 15 different millimeter-wave frequencies sensitive to: water vapor over ocean, precipitation rate, and the temperature profile from the surface to ~40 km. HSB will image 4 frequencies near the water vapor resonance at 183 GHz with 15-km horizontal resolution.

An iterated minimum-variance algorithm was developed that retrieves atmospheric temperature and humidity profiles from NOAA-15 AMSU data [2]. This instrument carries all AMSU/HSB channels plus an 89-GHz channel with 15-km resolution. Important issues addressed included the modeling of the surface and clouds. General agreement between these profile retrievals and test radiosondes was obtained and waves were identified at 5-20 hPa at the edge of the South Polar vortex. Others have attributed such waves to amplification of weak background gravity waves by the temperature structure of the winter polar stratosphere. AMSU currently maps all polar regions four times daily, so such waves can now be studied more readily.

Significant improvements were also made this year in retrieval algorithms used for estimating precipitation rates. Particularly effective is a new method for utilizing the 50-km resolution data to infer precipitation rates at 15-km resolution. Preliminary comparisons with NEXRAD radar data over the eastern United States show good agreement and suggest the declining accuracy of NEXRAD at distances beyond 110km.

Progress was also made during the year in methods for utilizing passive microwave data to estimate and remove the effects of clouds in AIRS hyperspectral infrared images.

3. Passive Microwave Spectral Imaging of Atmospheric Structure

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Jay B. Hancock retrieved profiles of relative humidity by combining the NAST infrared and microwave data [4]. The 9000 infrared and microwave spectral bands were first reduced in dimensionality using principal components analysis and were then processed in a neural network to produce retrievals with significant horizontal and vertical resolution. These retrievals exhibited humidity features evident in nearby radiosonde records.

William J. Blackwell has been improving methods for cloud clearing infrared radiances using microwave data, and in utilizing NAST data to validate those concepts. Initial results suggest that few infrared pixels of 15-km size will be truly cloud free, and that the simulated impact of simple two-layer opaque clouds with partial coverage matches the NAST-observed statistical distribution of cloud effects rather well despite the simplicity of these physical models. This work is being extended to explore the additional degrees of freedom introduced by real clouds.

Herbert E. M. Viggh completed his PhD thesis on methods for estimating changes in terrestrial surface emissivity using hyperspectral and near infrared images [5]. These techniques utilize prior information about the spatial and spectral statistics of the region of interest. Tests of these methods using HYDICE visible and infrared spectral data collected from aircraft flying over rural terrain with roads and parking lots suggest that these spectral emissivity estimates improve subsequent pattern classification experiments relative to physics-based methods using in-situ calibration panels.

Gil Alterovitz completed his SM thesis: "Temporal Characterization of Patient State with Applications to Prediction of Tachycardia in Anesthesia via Induction of Inhaled Desflurane" [6]. This work helped illustrate the applicability of our Iterated Order Noise (ION) algorithm [3] (used for remote sensing) to limited sets of medical data for purposes of improving principal component analyses. The data consisted of hour-long 32-variable records of pulmonary and cardiac data (20-second sampling) provided by Dr. James H. Philip for 46 patients who were under anesthesia. The noise in the data set was estimated and normalized using ION before principal component analysis; five significant principal components resulted. Using these five principal components tachycardia was then predicted 2.3 minutes in advance with 70-percent detection efficiency and 3-percent false-alarm rate. Such advance warning of tachycardia can be useful to an anesthesiologist. Without ION only two principal components were significant in the variance-normalized data set, and the tachycardia predictions were then less successful.

Publications

Journal Articles, Published

1. Blackwell, W.J, J.W. Barrett, F.W. Chen, R.V. Leslie, P.W. Rosenkranz, M.J. Schwartz, and D.H. Staelin. "NPOESS Aircraft Sounder Testbed-Microwave (NAST-M): Instrument Description and Initial Flight Results." *IEEE Trans. Geosci. and Remote Sensing.* 39(11): 2444-2453 (2001)

2. P.W. Rosenkranz. "Retrieval of Temperature and Moisture Profiles From AMSU-A and AMSU-B Measurements." *IEEE Trans. Geosci. and Remote Sensing.* 39(11): 2429-2435 (2001).

3. Lee, J. and D.H. Staelin. "Iterative Signal-Order and Noise Estimation." *Electronics Letters*. 37(2): 134-135, January 18 (2001).

Theses

4. Hancock, J.B. "Passive Microwave and Hyperspectral Infrared Retrievals of Atmospheric Water Vapor Profiles." SM Thesis, Department of Electrical Engineering and Computer Science, MIT, May 2001.

5. Viggh, H.E.M. "Surface Prior Information Reflectance Estimation (SPIRE) Algorithms." PhD Thesis, Department of Electrical Engineering and Computer Science, MIT, August 2001.

6. Alterovitz, G. "Temporal characterization of patient state with applications to prediction of tachycardia in anesthesia with induction of inhaled desflurane." S.M. Thesis, Department of Electrical Engineering and Computer Science, MIT, February 2001.