Remote Sensing and Estimation

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Self-Organizing Spectrum Allocation

Sponsor
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This new research program seeks to determine: 1) approximate limits to the average total wireless communications bit rate per Hz per user that can be exchanged between mobile users randomly distributed over a two-dimensional plane, as a function of link length relative to user density, 2) the dependencies of those limits upon coding and decoding complexity, number of antennas employed, and multipath characteristics, and 3) the relations between protocol definition and achievable performance assuming there are no designated organizing agents. Preliminary results have been obtained for questions (1) and (2), and work has begun on question (3).

Blind Multivariate Source Separation

Sponsor
MIT Lincoln Laboratory
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Development of the algorithm for Order, Noise, and A (ONA) estimation was continued and documented in the MEng. thesis of Amy Mueller. The algorithm accepts as input m vectors x of dimension n >~3k, where $x = \mathbf{A}p + \mathbf{G}w$; k is the unknown order of the unity-variance white Gaussian process characterized by the k-element vector p. $\mathbf{A}$ is the unknown mixing matrix, w is unknown Gaussian white noise of unity variance, and $\mathbf{G}$ is the unknown diagonal noise gain matrix. ONA can estimate all unknowns with useful accuracy if m is sufficiently large and $\mathbf{G}$ is sufficiently small. Previous successful tests using simulated data and actual factory data (over 500 variables) were followed by successful analysis of a 224-channel infrared image. ONA yielded more useful independent components than did traditional principal components analysis (PCA). The main advantages of ONA relative to PCA include iterative determination of $\mathbf{G}$ and k,

which is important if the elements of **G** vary widely, and use of horizontal correlations in the raw data when estimating **G**, so as to produce more accurate values. ONA also estimates **A**, *p*, and *w*, which PCA does not.

ONA is now being tested for its abilities to identify independent transmitters based on antenna array data. This is one part of a new NSF-sponsored wireless telecommunications research program that sprang directly from the work on ONA; this program was summarized above.

Theses

A. Mueller, *Iterative Blind Separation of Gaussian Data of Unknown Order*, MEng thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2003.

Earth Observing System: Advanced Microwave Sounding Unit

Sponsor

National Aeronautics and Space Administration/Goddard Space Flight Center
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The Aqua satellite of NASA's Earth Observing System was launched May 4, 2002. Its instrument complement includes AIRS, AMSU-A, and HSB, which are treated as a single facility for the purpose of retrieving profiles of atmospheric parameters such as temperature and moisture. We have supplied algorithms for the purpose of retrieving precipitation, cloud liquid water content, microwave surface emissivity, and first-guess profiles of temperature and water vapor from the microwave channels [1,2,4]. The latter two profiles are used to initialize the cloud-clearing of infrared channels, and also constitute the product in overcast fields of view.

Significant improvements were made this year in the surface emissivity model, which now adapts to eight different surface types and to the scattering of downwelling atmospheric emission by the wind-roughened ocean. A stochastic cloud-clearing algorithm is being developed for the infrared channels, and shows potential for improved results. Intense Arctic snowstorms have been noted in the Aqua data [3], an atmospheric phenomenon difficult to observe with other means.

Journal Articles

1. Rosenkranz, P.W., "Rapid radiative transfer models for AMSU/HSB channels," *IEEE Trans. Geoscience and Remote Sensing*, **41**(2), pp. 362-368, 2003.

2. Chen, F.W. and D.H. Staelin, "AIRS/AMSU/HSB Precipitation Estimates," *IEEE Trans. on Geoscience and Remote Sensing*, **41**(2), pp. 410-417, 2003.

Conference Papers Presented

3. Chen, F.W., A.M Leckmann, and D.H. Staelin, "Passive microwave signatures of arctic snowstorms observed from satellites," *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

4. Rosenkranz, P.W, "Cloud liquid water retrievals from Aqua/AMSU/HSB," *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

5. Chen, F.W., A.M. Leckman, and D.H. Staelin, "Satellite Observations of Polar Precipitation Using AQUA," *7th Conference on Polar Meteorology and Oceanography and Joint Symposium on High-Latitude Climate Variations American Meteorological Society*, Hyannis, MA, May 2003

ATMS Contributions to Sounding Products

Sponsor
NASA Goddard Space Flight Center

Contract
NGG04GE56A

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The NPOESS Preparatory Project is an effort to ensure that the next generation of U.S. weather satellites will meet NASA's needs for climate data records. We provide advice on design and testing of instruments, in particular the Advanced Technology Microwave Sounder (ATMS), and on geophysical-parameter retrieval algorithms, particularly with respect to effects produced by clouds and by surface emissivity and roughness. These activities draw on experience with satellite and aircraft instruments such as AIRS, AMSU-A/B, HSB, NAST-M, and NAST-I.

Initial work on this project is concerned with analysis of antenna patterns provided by the ATMS instrument vendor

NPOESS Passive Microwave Instrument Support

Sponsor
NOAA Integrated Program Office
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The RLE-developed NPOESS Aircraft Sounder Testbed – Microwave (NAST-M) incorporates scanning passive microwave spectrometers with 6-8 channels operating in each of the 50-56, 118.75±4, and 425±6 GHz oxygen absorption bands, and in the 183±12 GHz water vapor band. By scanning ~±60^{o} from 16-20 km altitude they image a broad swath beneath the aircraft with ~ 2-km resolution. During calendar year 2003 there were 15 flights of these four spectrometers over Hawaii, California, and the intervening ocean between January 31 and March 14, and 12 flights over the eastern U.S. and Atlantic Ocean between November 6 and December 14. This data is being used to support interpretation of NAST-I hyperspectral infrared data obtained on the same aircraft and to help characterize precipitation and the progression of its properties as convective cells form and dissipate.

Research initiated under other programs was transferred in part to this program in the areas of: 1) improvement of precipitation-rate retrievals using the spatial structure of entire storm systems to supplement the traditional passive microwave spectral information available at each observed pixel, and 2) development of stochastic-model methods for reducing the influence of clouds on atmospheric hyperspectral infrared radiances observed from meteorological satellites.

Conference Papers Presented (2003)

Leslie, R.V., W.J. Blackwell, P.W. Rosenkranz, and D.H. Staelin, "183-GHz and 425-GHz Passive Microwave Spectrometers on the NPOESS Aircraft Testbed-Microwave (NAST-M), *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

Leslie, R.V., J.A. Loparo, P.W. Rosenkranz, and D.H. Staelin, "Cloud and Precipitation Observations With the NPOESS Aircraft Sounder Testbed-Microwave (NAST-M) Spectrometer Suite at 54/118/183/425 GHz," *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

Microwave Observations of Precipitation and the Atmosphere

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This grant ended in November, 2003, and the work continues under separate sponsorship. The research had three elements devoted to improving satellite-derived passive microwave retrievals of precipitation rate: morphological rain-rate retrievals, warm rain retrievals, and extension of a study of passive microwave geostationary satellite options.

The morphological precipitation-rate retrieval method uses for the first time the morphological character of the observed storm microwave spectra. The basic concept involves: 1) retrieval of point rainfall rates using current algorithms, 2) segmentation of the resulting rainfall images into regions associated with single convective cells, 3) computation of spatial feature vectors characterizing each cell, 4) estimation of the integrated rainfall rate for each segmented region (m^3s^{-1}), and 5) normalization of the original point rain-rate retrievals to ensure consistency with each retrieved cell-wide precipitation rate. Two key steps were completed under this grant: development of a segmentation algorithm for defining spatial regions corresponding to single storms for purposes of estimation, and reduction of some of the data from NAST-M.

The warm rain retrieval method involved extension of algorithms for cloud water profile retrievals for non-glaciated clouds. The data is from the AIRS/AMSU/HSB instrument on the NASA Aqua satellite. The central concept relies on the fact that passive microwave cloud water retrievals above ~0.4 mm are very likely associated with precipitation. By permitting precipitation retrievals for non-glaciated events, this new method complements precipitation-rate retrieval techniques based on the scattering signatures evident in the surface-blind 54- and 183-GHz bands. The warm-rain method is most successful over ocean, but has detected non-glaciated convective cells over land, perhaps in their early formative stages. This work will require additional exploration and validation prior to publication.

Passive microwave instrument configurations for use in geostationary orbit were studied. They employ parabolic reflectors between 2 and 4 meters in diameter, and frequencies up to ~430 GHz; this corresponds to nadir spot diameters as small as 10 km. It is believed that such sensors

could provide an important complement to existing and planned polar orbiting satellite systems monitoring precipitation; 15-30 minute repeat observations of storms are feasible from geostationary orbit, whereas economics currently limits polar satellites to observations at intervals of ~4+ hours, long compared to the duration of the intensity maxima of many important storms. Such geostationary microwave systems could be quite helpful for climate, hydrological, and weather prediction purposes.

Conference Papers Presented (2003)

Leslie, R.V., W.J. Blackwell, P.W. Rosenkranz, and D.H. Staelin, "183-GHz and 425-GHz Passive Microwave Spectrometers on the NPOESS Aircraft Testbed-Microwave (NAST-M), *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

Leslie, R.V., J.A. Loparo, P.W. Rosenkranz, and D.H. Staelin, "Cloud and Precipitation Observations With the NPOESS Aircraft Sounder Testbed-Microwave (NAST-M) Spectrometer Suite at 54/118/183/425 GHz," *IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.