Remote Sensing and Estimation

RLE Group
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Self-Organizing Spectrum Allocation

Sponsor
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Project Staff:
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This program seeks to determine approximate limits to the average communications bit rate per Hz per user that can be exchanged between pairs of wireless mobile users randomly distributed over a two-dimensional plane as a function of link length relative to user density. Of primary interest is the dependence of those limits upon coding, number of antennas employed, and multipath characteristics [1]. The work of S. Govindasamy has shown that the Signal-plus-Interference-to-Noise-Ratio (SINR) grows greater than linearly with the number of receive antennas N, when all transmitters radiate equal power. Furthermore, in random environments, if the node density increases, constant average SINR can be maintained by increasing the number of receive antennas per node linearly with node density.

Theses

F. S. Antic, *Capacity of Single-Hop Communication Links in Wireless ad hoc Networks*, MEng thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2004.

Blind Multivariate Source Separation

Sponsor
MIT Lincoln Laboratory
Contract BX-8463

Project Staff
Professor David H. Staelin, Keith T. Herring

The Second-Order algorithm for Order, Noise, and A estimation of Amy Mueller was improved further by K. Herring and designated SOON [1]. 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 colored Gaussian process characterized by the k-element vector *p*, **A** is the unknown mixing matrix, *w* is unknown Gaussian white noise of unity variance, and **G** is the unknown diagonal noise gain matrix. SOON can estimate all unknowns with useful accuracy if m is sufficiently large and **G** is sufficiently small. Tests using simulated auto-regressive Gaussian data show that SOON improves the quality of source separation in comparison to the standard second-order separation algorithms, i.e., Second-Order Blind Identification (SOBI) and Second-Order Non-Stationary (SONS) blind identification.

Theses

K. Herring, *Blind Separation of Noisy Multivariate Data Using Second-Order Statistics*, Master of Science thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2004.

AIRS/AMSU/HSB Algorithm Refinement

Sponsor

NASA Goddard Space Flight Center
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Project Staff

Professor David H. Staelin, Dr. Philip W. Rosenkranz, Chuck Choongyeun Cho

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 The HSB failed on February 5, 2003, but AIRS and AMSU-A are still operating. We have supplied algorithms for the purpose of calculating microwave brightness temperatures and for retrieving precipitation, cloud liquid water content [1], microwave surface emissivity [2], and first-guess profiles of temperature and water vapor from the microwave channels. The latter two profiles are used to initialize the cloud-clearing of infrared channels, and also constitute the product in overcast fields of view.

A stochastic algorithm for infrared cloud clearing has been developed [3,4]; for selected channels in the 4-μ CO_2 band, the rms differences between cloud-cleared and calculated brightness temperatures over nighttime ocean are as low as 0.2 to 0.3K.

Journal Articles

1. Rosenkranz, P. W., "Cloud Liquid-Water Profile Retrieval Algorithm and Validation," *Journal of Geophysical Research*, forthcoming.

2. Rosenkranz, P. W. and C. D. Barnet, "Microwave Radiative Transfer Model Validation," submitted to *Journal of Geophysical Research*.

3. Cho, C. and D. H. Staelin, "AIRS Observations Versus Numerical Weather Predictions of Cloud-Cleared Radiances," submitted to *Journal of Geophysical Research*.

Conference Papers Presented

Cho, C. and D. H. Staelin, "Stochastic Cloud-Clearing of Hyperspectral Radiances Observed by the Atmospheric Infrared Sounder (AIRS) on the Aqua Satellite," *Proc. 13th American Meteorological Society Conference on Satellite Meteorology and Oceanography*, Norfolk, Virginia, September 20-23, 2004.

ATMS Contributions to Sounding Products

Sponsor
NASA Goddard Space Flight Center
Grant 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.

During this year, we made recommendations concerning (1) future antenna measurements and (2) software architecture. We also analyzed (3) the channel interactions ("gain stealing') that could result from receiver nonlinearity and (4) the impact on climate-data records if the ATMS channels above 100GHz were to fail.

NPOESS Passive Microwave Instrument Support

Sponsor
NOAA Integrated Program Office
Contract DG133E-02-CN-0011

Project Staff
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This program supports the NOAA Integrated Program Office effort to develop a National Polar Orbiting Environmental Satellite System (NPOESS) [4]; instrument, algorithm, and calibration/validation issues are being addressed. In support of this effort 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 2004 there were 4 flights in July of these four spectrometers off the east coast of the United States, 4 flights in August and September near or from Naples, Italy, and 3 flights in September originating from England. These aircraft data are 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 [1,3].

Other research includes: 1) improvement of precipitation-rate retrievals using the spatial structure of entire storm systems to supplement traditional pixel-level passive microwave spectral information [2], and 2) development of stochastic-model methods for reducing the influence of clouds on atmospheric hyperspectral infrared radiances observed from meteorological satellites.

Theses

1. R. V. Leslie, *Geophysical Parameter Estimation with a Passive Microwave Spectrometer at 54/118 /183/425 GHz*, Doctor of Science thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2004.

2. J. Loparo, *Storm-wide Precipitation Retrievals*, Master of Science thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2004.

Journal Articles

R. V. Leslie and D. H. Staelin, "NPOESS aircraft sounder testbed-microwave: observations of clouds and precipitation at 54, 118, 183, and 425 GHz," *IEEE Transactions on Geoscience and Remote Sensing*, **42**(10), 2240-2247 (2004).

Conference Papers Presented

D. H. Staelin, "Contributions of passive microwave sounders to severe weather understanding and predictive capabilities", 84th American Meteorological Society Annual Meeting, Seattle, Washington, January 11-15, 2004.

Retrievals and Global Studies of Precipitation Rate and Cloud-Base Pressure

Sponsor

NASA Goddard Space Flight Center
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Project Staff

Professor David H. Staelin, Dr. Philip W. Rosenkranz, Frederick W. Chen, and Chinnawat Surussavadee

This year development of precipitation estimation methods using AMSU/HSB and AMSU-A/B passive microwave satellite observations trained with NEXRAD data was concluded and documented in the doctoral thesis of F. W. Chen. The method employs 13 channels 23-190 GHz near water vapor and oxygen resonances. These frequencies have been observed globally by four polar orbiting satellites with 15- and 50-km resolution. Comparisons with passive microwave observations by AMSR-E over ocean permitted adjustment of the NEXRAD-trained precipitation-rate retrievals for those higher latitudes not observed by NEXRAD, which is an extensive 3-cm wavelength doppler radar network deployed over the continental United States. AMSR-E is another imaging microwave spectrometer that uses lower more transparent frequencies and is more sensitive to the absorption characteristics of precipitation, unlike AMSU which relies more on the scattering signatures of glaciated precipitation cells. AMSU accuracies compare favorably with those of NEXRAD, as evidenced by the ability of AMSU to detect degradation in NEXRAD soundings at low rain rates when the radar range exceeds ~110 km. At these greater distances NEXRAD sounds higher in the atmosphere and consistently performs well only for rain cells that reach high altitudes.

In order to improve the current precipitation retrievals from the AIRS/AMSU/HSB instrument on the NASA Aqua satellite better training data is required. Numerical weather prediction models are being developed for this purpose. The first step has been reconciliation of the 15-km resolution microwave radiances observed by AMSU on NOAA satellites with those predicted by radiative transfer equations (TBSCAT) driven by the MM5 numerical weather prediction model with 15-km resolution. The MM5 predictions were synchronized with satellite overpasses and initialized with global analysis fields. Histograms of the resulting MM5-predicted radiances were made congruent with histograms of coincident AMSU observations by optimizing in a least-squared-error sense the presumed frequency-dependent models for different species of ice aloft (graupel, snow, and cloud ice). Good agreement was achieved for plausible ice models, thus partially validating both the MM5 cloud predictions and the program TBSCAT, which evaluates the microwave radiative transfer expression for both clear air and hydrometeors that scatter radiation. This work was also supported by other NASA and NOAA programs.

Theses

F. W-M Chen, *Global Estimation of Precipitation Using Opaque Microwave Bands*, Doctor of Philosophy thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 2004.

Conference Papers Presented

Chen, F. W. and D. H. Staelin, "Global Precipitation Climatology from AMSU Passive Microwave Satellite Observations," *Proc. 14th American Meteorological Society Conference on Applied Climatology and 84th American Meteorological Society Annual Meeting*, Seattle, Washington, January 11-15, 2004.

Multi-Year Global Precipitation Statistical Studies

Sponsor

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Project Staff

Professor David H. Staelin, Dr. Philip W. Rosenkranz, F. W. Chen, Chinnawat Surussavadee

This effort focused on study of multi-year global precipitation data obtained by the AMSU passive microwave imaging spectrometer on the NOAA-15/16/17 satellites. The retrieved precipitation frequencies for 10-degree resolution in longitude/latitude were found to be more repeatable year-to-year than precipitation-rate statistics, and repeatability tended to fail when the averaging periods were reduced to one month. Global diurnal rain frequency statistics were also compared with the same spatial resolution, and both diurnal amplitude and phase were repeatable for seasonal and annual averages. Typical diurnal amplitudes of precipitation-frequency variations over land were noticeably greater than over ocean; the same comparison for average precipitation frequency revealed little difference, however. These global statistics were approximately the same whether data from two or three satellites were used. One limitation of this method involves the weaknesses in the ground-based radar network that was used to train the AMSU-based estimator.

To overcome these weaknesses work began on use of the mesoscale numerical weather prediction model MM5 as a source of ground-truth data for developing and evaluating new passive microwave methods for estimating global precipitation from satellites. This work was co-sponsored by other NASA and NOAA programs.

Conference Papers Presented

Chen, F. W., D. H. Staelin, and C. Surussavadee, "Global and Monthly Diurnal Precipitation Statistics Based on Passive Microwave Observations from AMSU," *Proc. 13th American Meteorological Society Conference on Satellite Meteorology and Oceanography*, Norfolk, Virginia, September 20-23, 2004.