Remote Sensing and Estimation

RLE Group
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Self-Organizing Spectrum Allocation

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This program seeks to determine, as a function of link length relative to user density, approximate limits to the average communications rate (bits/second/Hz/user) that could be exchanged between pairs of wireless mobile users randomly distributed over a two-dimensional plane. Of primary interest is the dependence of those bit-rate limits upon protocols, numbers of antennas and data streams employed, and multipath characteristics. This year's effort focused on publication of prior work [1-3] and on development and analysis of multi-antenna protocols for wireless ad hoc network environments in which most links are single-hop.

Journal Papers

1. K. T. Herring, J. W. Holloway, D. H. Staelin, and D. W. Bliss, "Path loss characteristics of urban wireless channels," *IEEE Transactions on Antennas and Propagation*, in review, 2009.

Conference Papers

2. S. Govindasamy, D. W. Bliss, and D. H. Staelin, "Spectral efficiency of wireless networks with multi-antenna base stations and spatially distributed nodes," *Proceedings of the 42nd Asilomar Conference on Signals, Systems and Computers,* Pacific Grove, California, October 26-29, 2008, pp. 1130-1134.

3. S. Govindasamy, D. W. Bliss, and D. H. Staelin, "Spectral efficiency of multi-antenna links in ad-hoc wireless networks with limited TX CSI," *43rd Asilomar Conference on Signals, Systems and Computers,* Pacific Grove, California, November 1-4, 2009, accepted.

NPOESS Program Science Team Support

Sponsor
Lincoln Laboratory
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This program supports Lincoln Laboratory and NOAA Integrated Program Office efforts to develop a National Polar Orbiting Environmental Satellite System (NPOESS), with particular emphasis on the next generation Advanced Technology Microwave Spectrometer (ATMS) to be launched in the next few years. NPOESS instrument, algorithm, and calibration/validation issues are being addressed.

The RLE computer system that currently supports near-real-time precipitation retrievals for NOAA passive microwave satellites was upgraded to handle all NOAA, NASA, and DoD millimeter-wave meteorological satellites, perhaps nine or more, once the associated retrieval algorithms are developed. This system has estimated surface precipitation rates (mm/h) and retrieved water paths (mm) for rain water, snow, graupel, and other constituents, as well as peak layer vertical wind speed (m/s) for the NOAA-15, NOAA-16, and NOAA-17 satellites, with results as early as 2000.

The main scientific effort involved continued development and evaluation of improved precipitation and hydrometeor path retrieval algorithms using millimeter-wave spectra observed by satellites. Portions of this effort are also separately supported by NASA. Progress in this joint scientific effort is summarized here under “Study of Millimeter-Wave Satellite Precipitation Retrieval Algorithms Using MM5 Simulations”.

Study of Millimeter-Wave Satellite Precipitation Retrieval Algorithms Using MM5 Simulations

Sponsor
NASA Goddard Space Flight Center
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This effort extended prior advances in global millimeter-wave precipitation measurements by relating for the first time systematic biases in retrievals to surface classification. Interestingly, the biases appear to be strongly correlated with surface type, as suggested in Table 1, which shows two-year average ratios between global satellite retrievals and surface rain gauge measurements for several land classifications [1]. Based on numerical weather prediction (NWP) models, we found that surface-dependent rain evaporation was the most likely explanation for overestimation by satellites. One surface property found to promote evaporation was the fraction of exposed soil, particularly sand (see Table 1). The solar superheating of sand is well known, and is presumably enhanced by a variation of the greenhouse effect where quartz-like soils transmit solar heat to some small depth, and the low infrared emissivity of glass-like materials then significantly raises the soil temperature and that of the air above. This suggests that forestation promotes rainfall by reducing air temperatures and thereby rain evaporation (virga). More interesting are grasslands that, like desert, promote rain evaporation to a surprising degree. If this grassland-rain-evaporation effect proves to be real, then it could impact future plans to rely heavily on switch-grass or similar fast growing grass-like crops to produce fuel. The potential danger is that widespread planting of grass crops might increase the risks of local drought. This potential linkage between rain evaporation and surface type will be studied further.

Apparent overestimates of North Pole precipitation were compensated by bias corrections based on two years of data from seven rain gauges on the coast of the Arctic Sea; this led to the retrieval images shown in Fig. 1 [2]. The uniqueness of these new results is suggested by (e) and (f) in the figure, which correspond to 24-hour accumulations estimated for June 16, 2006 by AMSU (e) and a standard alternative system (GPCP) (f) that combines data from a variety of satellite and ground sensors. The standard GPCP system missed the heavy precipitation above 80 North latitude, although it lasted roughly seven hours, based on multiple AMSU images and a comparison of the instantaneous rain rate retrieved in Fig. 1a with the 24-hour accumulation shown in Fig. 1e. Fig. 1b and 1c show the rapid evolution of precipitation over the pole in 24 hours and reveal the strong coriolis effects near the pole. Fig. 1d is near the end of the observing season when cold air raises the risks of erroneous precipitation retrievals as a result of dry microwave-transparent air that exposes the problematic icy surface.

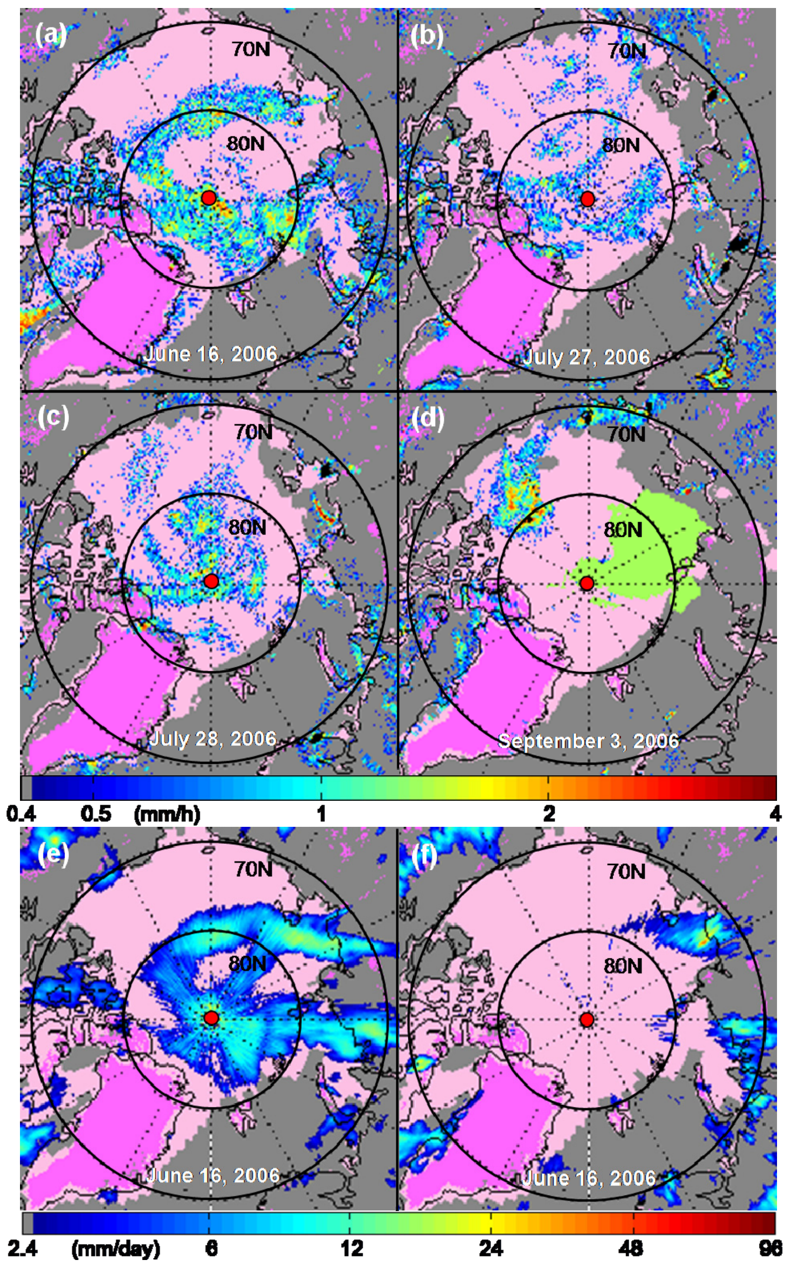

Figure 1. AMSU-retrieved Arctic precipitation rates over sea ice (light pink) during 2006; the precipitation rate is color coded for: (a) June 16, (b) July 27, (c) July 28, and (d) September 3. (e) and (f) are 24-hour accumulations (mm/day) estimated by AMSU and GPCP, respectively, for June 16. Light pink is snow or sea ice, green indicates tropospheric air temperatures that are too low to permit reliable retrievals, dark pink is high elevation land, and black represents occasional rejected retrievals over 3 mm/h for snow/ice surfaces [2].

Table 1. AMSU vs. rain gauges for different surface land classes, 2006-2007 [1]

Land Class	Sat. mm/y	Gauge mm/y	Ratio	No. Rain Gauges
Tundra	429	490	0.88	8
Water	1379	1571	0.88	30
Hi-lat deciduous forest	524	526	1.00	24
Broadleaf evergreen forest	2925	2831	1.03	2
Mixed conif. forest	788	739	1.07	82
Conif. evergreen forest	596	536	1.11	60
Broadleaf decid. forest	1113	900	1.24	18
Wooded grassland	1238	988	1.25	66
Cultivated crops	949	693	1.37	102
Coastal (< 55 km)	1439	928	1.55	260
Grassland	837	349	2.40	77
Shrubs, bare ground	771	252	3.06	22
Bare ground	559	62	9.08	29

An effort began to explain the small systematic differences between predicted and observed millimeter-wave brightness temperatures near the limb. A multi-stream radiative transfer model is being applied by Dr. Bennartz to NWP data that includes the three-dimensional structure of precipitation. The current radiative transfer model is planar and uses only two-stream radiative transfer.

New satellite architectures based on CubeSat modules were studied and found to be very attractive as a result of recent advances in millimeter-wave integrated circuits. An 8-channel 118-GHz imaging spectrometer based on three one-liter cubic modules was designed. The entire satellite would weigh approximately three kilograms, consume three watts, and map global precipitation and atmospheric temperature profiles with 13-km resolution near nadir based on a 400-km orbit. The estimated cost for this flight experiment was more than two-orders of magnitude below conventional meteorological satellite systems, leaving significant room for performance enhancements while retaining major cost advantages. This study was in collaboration with Prof. David W. Miller of the Department of Aeronautics and Astronautics and Dr. William J. Blackwell of Lincoln Laboratory.

During this period final modifications were made to our paper on blind separation of noisy multivariate data using second-order statistics. This technique offers an often better way to identify independent components in high-order multivariate remote sensing data that are well characterized by second-order statistics and jointly gaussian noise [3].

Earlier work on the microwave surface emissivity of Antarctic firn, polar precipitation retrievals, and the precipitation sensing potential of the future NASA/NOAA Advanced Technology Microwave Sounder (ATMS) were also presented [4-6].

Journal Papers

1. C. Surussavadee and D. H. Staelin, "Global precipitation retrievals using the NOAA/AMSU millimeter-wave channels: comparisons with rain gauges," *American Meteorological Society Journal of Applied Meteorology and Climatology*, in review (2009).

2. C. Surussavadee and D. H. Staelin, "Satellite retrievals of arctic and equatorial rain and snowfall rates using millimeter wavelengths," *IEEE Transactions on Geoscienceand Remote Sensing*, accepted for publication (2009).

3. K. W. Herring, A. Mueller, and D. H. Staelin, “Blind separation of noisy multivariate data using second order statistics: remote sensing applications,” *IEEE Transactions on Geoscience and Remote Sensing*, accepted for publication (2009).

4. P. W. Rosenkranz and C. Matzler, "Dependence of AMSU-A brightness temperatures on scattering from antarctic firn and correlation with polarization of SSM/I data," *IEEE Geoscience and Remote Sensing Letters*, *vol.* 5, No. 4, October, 2008, pp. 769-73.

Conference Papers

5. C. Surussavadee and D. H. Staelin, “Rain and snowfall retrievals at high latitudes using millimeter wavelengths,” *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2008),* Boston, Massachusetts, July 7-11, 2008, *vol.* 4, No. 1, pp. IV624-IV627.

6. C. Surussavadee and D. H. Staelin, “NPOESS precipitation retrievals using the ATMS passive microwave spectrometer,” *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2008),* Boston, Massachusetts, July 7-11, 2008, *vol.* 5, No. 1, pp. V570-V573.

Spike-timing model for neural signal processing and learning

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This effort extended our prior preliminary model for spike-based neural computation in cortex to a model that involves many more neurons with fewer connections between any pair, and where each connection involves spike propagation delays of many milliseconds. Learning involves strengthening those synapses excited by spikes having desired delays from desired neurons; contributing synapses are strengthened when an output spike is produced. It is assumed that incident spikes must superimpose within 1-2 msec in order to contribute efficiently to totals sufficent to trigger an output spike.

The study assumed a simple neural model based on neural observations, and then optimized the model parameters to maximize the average information stored per neuron. The hope is that cortex evolved to maximize the same or similar metric, and that clues to cortical function can therefore be deduced from the derived optimum model parameters. This model assumes that the input layer of N neurons is connected to the output by feed-forward axons that introduce randomly distributed fixed delays. Learning is assumed to occur by strengthening those synapses that are accidentally located so as to produce the desired delays and therefore subsequent spikes from the output neuron. Information content in this “minimal learning circuit” (MLC) is currently defined as the information that “Bob” could extract from the MLC after it was trained by “Alice” to recognize a random set of W words or input patterns. The optimum values of N, W, threshold H, and number of distinct possible delays D are sought, along with other parameters. The hope is that the optimal model configuration and performance will generally be consistent with, or help predict, the wide range of neural and performance observations that were not utilized when formulating the model. Examples of predicted parameters of interest include the numbers of synapses per neuron, average number of synapses connecting two random nearby neurons, bits of information stored per synapse, and speed limits for learning and recognition. Preliminary results for this model are encouraging but not yet definitive.