035004-1-T

Annual Report – 1997
NASA Grant NAGW-5203

# Estimating Water Stored in Soil and Vegetation Using LSP/R Models and Assimilated Satellite Radiobrightness

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Period of Performance: July 1, 1996 - June 30, 1997
Reporting date: June 30, 1997

35004-1-T = RL-2481

## CONTENTS

## I Products this year

### Journal Articles

(1) Liou, Y.A., and A.W. England, Annual temperature and radiobrightness signatures for bare soils, IEEE Trans. Geosci. Remote Sensing, 34, pp.981-990, 1996.

(2) Liou, Y.A., and A.W. England, A Land Surface Process/Radiobrightness model with coupled heat and moisture transport in soil, accepted IEEE Trans. Geosci. Remote Sensing, March, 1997.

(3) Liou, Y.A., and A.W. England, A Land Surface Process/Radiobrightness model with coupled heat and moisture transport for freezing soils, accepted IEEE Trans. Geosci. Remote Sensing, May, 1997.

(4) Galantowicz, J.F., and A.W. England, Seasonal snowpack radiobrightness interpretation using a SVAT-linked emission model, submitted to J. Geophys. Res. – Atmospheres, December, 1996.

(5) Judge, J., J.F. Galantowicz, A.W. England, and P. Dahl, Freeze/thaw classification for prairie soils using SSM/I radiobrightnesses, submitted to IEEE Trans. Geosci. Remote Sensing, January, 1997.

(6) Liou, Y.A., J.F. Galantowicz, and A.W. England, A Land Surface Process/Radiobrightness model with coupled heat and moisture transport for prairie grassland, submitted to IEEE Trans. Geosci. Remote Sensing, February, 1997.

(7) Liou, Y.A., E.J. Kim, and A.W. England, Radiobrightness of prairie soil and grassland during dry-down simulations, submitted to Radio Science, March, 1997.

### Symposia - Reviewed Proceedings

(8) Kim, E.J., Y.A. Liou, and A.W. England, Passive microwave detection and modeling of frozen soils in tundra and grassland areas, accepted by Seasonally Frozen Soils Symposium, Fairbanks, AK, June 10-12, 1997.

(9) Y.A. Liou, Y.C. Tzeng, K.S. Chen, and A.W. England, Inversions of Land surface parameters using a neural network trained with a 1-dimensional hydrology/radiobrightness model, accepted by PIERS'97, Boston, MA, June, 1997.

(10) England, A.W., HYDROSTAR: An ESSP Project to Provide a 2-Year Global Record of Surface Soil Moisture, accepted by International Geoscience and Remote Sensing Symposium (IGARSS'97), Singapore, Malaysia, August 3-8, 1997.

(11) Judge, accepted by International Geoscience and Remote Sensing Symposium (IGARSS'97) to be held in Singapore, Malaysia, August 3-8, 1997.

(12) Liou, Y.A., Y.C. Tzeng, E. Kim, and A.W. England, Retrieval of soil moisture using a dynamic learning neural network trained with a 1-dimensional hydrology/radiobrightness model, accepted by International Geoscience and Remote Sensing Symposium (IGARSS'97), Singapore, Malaysia, August 3-8, 1997.

**Symposia - Without Proceedings**

(13) Judge, J., A.W. England, and P. Dahl, Freeze/Thaw classification of prairie soils using SSM/I radiobrightnesses, 3rd International Workshop on the Application of Remotes Sensing in Hydrology, Greenbelt, MD, Oct. 16-18, 1996.

(14) Liou, Y.A., and A.W. England, The sensitivity of SSM/I and L-band frequencies to soil moisture in prairie grassland, 3rd International Workshop on the Application of Remotes Sensing in Hydrology, Greenbelt, MD, Oct. 16-18, 1996.

(15) Kim, E.J., and A.W. England, Linking passive microwave observations to a Land-Surface Process model of tundra areas, 3rd International Workshop on the Application of Remotes Sensing in Hydrology, Greenbelt, MD, Oct. 16-18, 1996.

(16) England, A.W., Y.A. Liou, J.F. Galantowicz, and Jasmeet Judge, Radiobrightness of prairie soil and grassland during dry-down simulations, *Special Session: Microwave Radiometer Observations of Soil Moisture and Surface Temperature*, URSI 5th Specialist Meeting, "Microwave Radiometry and Remote Sensing of the Environment", Boston, MA, November 4-6, 1996.

(17) Kim, E.J., and A.W. England, Passive microwave observations and land surface process modeling of arctic tundra regions, *Special Session: Microwave Radiometer Observations of Soil Moisture and Surface Temperature*, URSI 5th Specialist Meeting, "Microwave Radiometry and Remote Sensing of the Environment", Boston, MA, November 4-6, 1996.

(18) Kim, E.J., Y.-A. Liou, and A.W. England, A sensitivity study of a one-dimensional hydrology/radiobrightness model for grassland areas, Annual Meeting of the American Meteorological Soc., Long Beach, CA, February 2-7, 1997

(19) Liou, Y.A., and A.W. England, The sensitivity of a Land-Surface Process/Radiobrightness model to soil and vegetation parameters, A.G.U. Spring Meeting, Baltimore, MD, 1997.

(20) Liou, Y.A., J.P. Su, Y.C. Tzeng, and A.W. England, Radiometric studies of the land surface: Applications of neural networks, A.G.U. Spring Meeting, Baltimore, MD, 1997.

## II Project objectives

Our research within this project has had four objectives:

(1) To develop Land-Surface Process (LSP) models that predict temperature and moisture distributions in bare soil, in grassland and agricultural prairie, in arctic tundra, and in snow;

(2) To develop radiobrightness models that use the LSP temperature and moisture profiles to predict Radiobrightness – i.e., to develop LSP/R models;

(3) To assimilate the differences between observed and predicted radiobrightnesses to achieve improved estimates of stored water/footprint; and

(4) To aggregate stored water/footprint to grid-scale soil wetness – i.e., to address the scaling issue.

Along the way we should discover two things: (1) Would assimilating satellite radiobrightness in an LSP/R model greatly improve the performance of a mesoscale atmospheric model? and (2) What is the relationship between stored water and an atmospheric model's soil wetness parameter? We have chosen to address these problems for prairie and arctic tundra because each terrain is relatively homogeneous on the scale of current and anticipated satellite microwave radiometers; each supports simple grasses, sedges, and mosses whose column densities are less than 4-5 kg/m$^2$; where there are crops on the prairie the fields are large with little variety among fields; each terrain exhibits large seasonal variations in stored water that influence land-atmosphere fluxes; each surface undergoes seasonal freezing and thawing; and each is large enough to play a significant role in continental weather and climate.

If we were to choose the optimum frequencies for deriving soil moisture from radiobrightness, we would certainly have followed the literature and chosen L-, S-, and, perhaps, S-bands for our modeling and experiments. We began by investigating the more difficult linkage between stored water and radiobrightness at the Special Sensor Microwave/Imager (SSM/I) frequencies of 19.35, 37.0, and 85.5 GHz because global data at a few day repeat are available from 1987 to the present or, if we include the very similar Scanning Multichannel Microwave Radiometer (SMMR) data, from 1978 to the present. While these higher frequency data are sensitive only to moisture in bare soil and in soils with sparse canopies, there is a simple evolutionary path from the SSM/I frequencies to lower frequencies like those of instruments like the Multichannel Imaging Microwave Radiometer (MIMR). With lower frequency we increase the variety of terrains that the data will be sensitive to surface soil moisture. We further argued that an understanding of the linkage between stored water and SSM/I radiobrightness would translate directly to an understanding of the linkage between stored water and L-band radiobrightness for complex terrains. The recent possibility that a medium resolution, L-band radiometer might be flown under the New Millennium Program within the next decade, has prompted us to expand our research plan to directly examine the linkage between surface soil moisture and L-band radiobrightness.

## III Tasks for year 1

Planned tasks for the first year were to be:

(a) Complete the refurbishment of our field system in preparation for REBEX-4.

(b) Begin building an L-band radiometer to add to TMRS.

(c) Undertake REBEX-4 – a prairie experiment during spring, and summer, 1996, near Sioux Falls, South Dakota, in cooperation with the Climate Research Branch of the Canadian Atmospheric Environmental Service.

(d) Cooperate with Russian scientists in a Priroda Prairie Experiment scheduled for the summer of 1996.

(e) Complete development of the LSP/R model for prairie grassland.

(f) Develop a LSP/R model for moist acidic tundra (this task is funded by the NSF Arctic System Science Program and complements this proposal).

## IV Accomplishments for year 1

Under the impetus of this project:

(a) We completed the refurbishment of our field system in preparation for REBEX-4.

(b) We are building a Synthetic Thinned Array Radiometer (STAR) technology, L-band radiometer that will be added to our Tower Mounted Radiometer System (TMRS). Because it is particularly vital to minimize system noise in STAR technology radiometers, we have chosen to develop a direct conversion design to avoid the mixer noise of a heterodyne receiver. Mark Fischman has completed a literature search of the problems of high speed analog-to-digital conversion and has proposed a strategy for his design that we have chosen to implement. He will be developing a breadboard instrument during the late summer and fall of 1997, and should complete a 3 channel system for TMRS by the summer of 1998. Designing, building, and characterizing noise in this system will be Mark's PhD thesis.

We have completed most of the very long-duration field experiments that we had planned in this project. There will be many more field projects, but these will focus upon comparing observations of new terrains with previous observations, and upon scaling from point measurements to satellite measurements. These new investigations require moving from site-to-site at intervals of a few days or even during a single day. This is unworkable with our current tower system because both erecting and stowing the tower require nearly a day. We have decided to replace the tower with a boom truck.

I have located nearly $70,000 of University funds for the boom truck, and will petition the NASA Hydrology Program to allow me to spend funds from this project to complete the truck system. I anticipate a need for approximately $10,000 from the project. Our goal is to have the new Truck Mounted Radiometer System – still called TMRS – ready for the 1998 field season.

(c) We have successfully completed REBEX-4 – a prairie experiment during spring, and summer, 1996, near Sioux Falls, South Dakota, in cooperation with the Climate Research Branch of the Canadian Atmospheric Environmental Service. We acquired 3 months of data – June through August – for adjacent grassland and bare soil. These data are being used to drive LSP/R models for the grassland and bare soil. The results will be the PhD thesis of Ms. Jasmeet Judge. She should finish her analyses and model development during the summer of 1998.

(d) Data from the Priroda IKAR-D radiometers have not been available until recently. In part because of the possibility of Priroda radiometer data, we chose to participate in NASA's Southern Great Plains 1997 experiment (SGP'97) in Oklahoma. TMRS is now deployed at the SGP'97/ARM site. We believe that ground, SSM/I, and Priroda data in southern sub-humid prairie will offer an interesting comparison with the ground and SSM/I data that we had already collected for northern humid prairie. We did not deploy our energy balance/meteorological sensors but will get these data from other investigators. In return, our radiometer data – dual-pol at 19 and 37 GHz, and V-pol at 85 GHz – will be made available to other investigators.

(e) We have completed development of the LSP/R model for prairie grassland and have validated the model for October. The paper is in press. Ms. Judge is currently testing the model with growth season data as part of her PhD thesis.

(f) We are developing a LSP/R model for moist acidic tundra. Mr. Ed Kim has already collected 1-year of data and is now developing the model that explains his observations. We anticipate that he will complete his work during the fall of 1997.

Estimating Water Stored in Soil and Vegetation Using LSP Model Soil Wetness and Satellite Radiobrightness

**Budget Summary**
YEAR TWO

From July 1, 1997 to June 30, 1998

| | | NASA USE ONLY | |
|---|---|---|---|
| | A | B | C |
| 1. Direct Labor (salaries, wages, and fringe benefits) | $ 90,550 | | |
| 2. Other Direct Costs: a. Subcontracts | 0 | | |
| b. Consultants | 0 | | |
| c. Equipment | 20,000 | | |
| d. Supplies | 1,393 | | |
| e. Travel | 5,500 | | |
| f. Other Tuition, Field Work | 29,064 | | |
| 3. Indirect Costs | 56,145 | | |
| 4. Other Applicable Costs | 0 | | |
| 5. Subtotal--Estimated Costs | $202,652 | | |
| 6. Less Proposed Cost Sharing (if any) | 35,052 | | |
| 7. Carryover Funds (if any) a. Anticipated amount ______ b. Amount used to reduce budget | | | |
| 8. Total Estimated Costs | $167,600 | | XXXXXXX |
| APPROVED BUDGET | XXXXXXX | XXXXXXX | |

Additional detail and budget breakdowns follow this page.

## Instructions

1. Provide a separate budget summary sheet for each year of the proposed research.

2. Grantee estimated costs should be entered in Column A. Columns B and C are for NASA use only. Column C represents the approved grant budget.

3. Provide in attachments to the budget summary the detailed computations of estimates in each cost category, along with any narrative explanation required to fully explain proposed costs.

---------------------- ADDITIONAL INSTRUCTIONS ON REVERSE -------------------------

Estimating Water Stored in Soil and Vegetation Using LSP Model Soil Wetness & Satellite Radiobrightness
Year Two Budget: 7/1/97-6/30/98

| Direct Costs | U of M | NASA | Total |
|---|---|---|---|
| Salaries and Wages* | | | |
| Principal Investigator: Prof. T. England | $10,422 | $10,422 | $20,843 |
| (10% 9 months Academic Year, 1 Summer Month | | | |
| Adm. Assistant, 5%, 12 months | | $2,378 | $2,378 |
| Graduate Students (2 @ 50% @ $2850/mo. for 12 months) | | $34,200 | $34,200 |
| Technician, 10%, 12 months | | $3,600 | $3,600 |
| Undergraduate Work-Study (3 summer mos.) | | $7,313 | $7,313 |
| Total Salaries and Wages | $10,422 | $57,913 | $68,334 |
| Fringe Benefits @ 27% | $2,814 | $19,402 | $22,216 |
| Other Direct Costs | | | |
| Tuition (2 graduate students for 2 terms) | $14,869 | $4,695 | $19,564 |
| Travel | | $5,500 | $5,500 |
| Field Work | | $9,500 | $9,500 |
| Expendables (liquid nitrogen, tapes, paper, copies, postage, communications, etc.) | | $1,393 | $1,393 |
| Equipment | | $20,000 | $20,000 |
| Workstation | | | |
| Instrument replacement and calibration for TMRS/MMS | | | |
| Total Direct Costs | $28,104 | $118,403 | $146,507 |
| Indirect Costs (52.5% less tuition and equipment) | $6,949 | $49,197 | $56,145 |
| **TOTAL COST** | **$35,052** | **$167,600** | **$202,652** |

*Salaries, Wages and Tuition reflect a 4% yearly increase from Year One.