View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Purdue E-Pubs

Purdue University
Purdue e-Pubs

LARS Technical Reports | Laboratory for Applications of Remote Sensing

1-1-1982

# Extension of Laboratory-Measured Soil Spectra to Field Conditions

E. R. Stoner

M. F. Baumgardner

R. A. Weismiller

L. L. Biehl

B. F. Robinson

Follow this and additional works at: http://docs.lib.purdue.edu/larstech

Stoner, E. R.; Baumgardner, M. F.; Weismiller, R. A.; Biehl, L. L.; and Robinson, B. F., "Extension of Laboratory-Measured Soil Spectra to Field Conditions" (1982). *LARS Technical Reports.* Paper 46.
http://docs.lib.purdue.edu/larstech/46

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

# AgRISTARS

SR-P2-04326
NAS9-15466

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

June 1982

Supporting Research

Technical Report

# Extension of Laboratory-Measured Soil Spectra to Field Conditions

by E.R. Stoner, M.F. Baumgardner, R.A. Weismiller, L.L. Biehl, and B.F. Robinson

Purdue University
Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907

Published in the Soil Science Society of America Journal 44(3):572-574, May-June 1980.

SR-P2-04326
NAS9-15466
LARS 052680

# EXTENSION OF LABORATORY-MEASURED SOIL SPECTRA TO FIELD CONDITIONS

E.R. Stoner, M.F. Baumgardner, R.A. Weismiller,
L.L. Biehl, and B.F. Robinson

Purdue University
Laboratory for Applications of Remote Sensing
West Lafayette, IN 47907

June 1982

# Star Information Form

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| SR-P2-04326 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Extension of Laboratory-Measured Soil Spectra to Field Conditions | June 1982 |
| | 6. Performing Organization Code |

| 7. Author(s) | 8. Performing Organization Report No. |
|---|---|
| E.R. Stoner, M.F. Baumgardner, R.A. Weismiller, L.L. Biehl, and B.F. Robinson | LARS 052680 |

| 9. Performing Organization Name and Address | 10. Work Unit No. |
|---|---|
| Purdue University<br>Laboratory for Applications of Remote Sensing<br>1220 Potter Drive<br>West Lafayette, IN 47906-1399 | 11. Contract or Grant No.<br>NAS9-15466 |

| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
|---|---|
| NASA Johnson Space Center<br>Earth Resources Research Division<br>Houston, TX 77058 | Technical |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

Spectral responses of two glaciated soils, Chalmers silty clay loam and Fincastle silt loam, formed under prairie grass and forest vegetation, respectively, were measured both in the laboratory under controlled moisture equilibria and in the field under various moisture and crop residue conditions. An Exotech Model 20C spectroradiometer was used to obtain spectral data in the laboratory under artificial illumination. Reflectance measurements ranged from 0.52 to 2.32 μm in 0.01 μm increments. Asbestos tension tables were used to maintain a 0.10-bar moisture equilibrium following saturation of crushed, sieved soil samples. The same spectroradiometer was used outdoors under solar illumination to obtain spectral response from dry and moistened field plots with and without corn residue cover, representing the two different soils. Results indicate that laboratory-measured spectra of moist soil are directly proportional to the spectral response of that same field-measured moist bare soil over the 0.52 to 1.75 μm wavelength range. The magnitudes of difference in spectral response between identically treated Chalmers and Fincastle soils are greatest in the 0.6 to 0.8 μm transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied.

| 17. Key Words (Suggested by Author(s)) | 18. Distribution Statement |
|---|---|
| Remote Sensing, Spectroradiometry, Crop Residue, Soil Moisture | |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price* |
|---|---|---|---|
| Unclassified | Unclassified | | |

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA - JSC

# Extension of Laboratory-measured Soil Spectra to Field Conditions[1]

ERIC R. STONER, MARION F. BAUMGARDNER, RICHARD A. WEISMILLER, LARRY L. BIEHL, AND BARRETT F. ROBINSON[2]

## ABSTRACT

**Spectral responses of two glaciated soils, Chalmers silty clay loam and Fincastle silt loam, formed under prairie grass and forest vegetation, respectively, were measured both in the laboratory under controlled moisture equilibria, and in the field under various moisture and crop residue conditions. An Exotech Model 20C spectroradiometer was used to obtain spectral data in the laboratory under artificial illumination. Reflectance measurements ranged from 0.52-to 2.32-$\mu$m in 0.01$\mu$m increments. Asbestos tension tables were used to maintain a 0.10-bar moisture equilibrium following saturation of crushed, sieved soil samples. The same spectroradiometer was used outdoors under solar illumination to obtain spectral response from dry and moistened field plots with and without corn residue cover, representing the two different soils. Results indicate that laboratory-measured spectra of moist soil are directly proportional to the spectral response of that same field-measured moist bare soil over the 0.52- to 1.75-$\mu$m wavelength range. The magnitudes of difference in spectral response between identically treated Chalmers and Fincastle soils are greatest in the 0.6-to 0.8-$\mu$m transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied.**

***Additional Index Words:*** **remote sensing, spectroradiometry, crop residue, soil moisture.**

Stoner, E. R., M. F. Baumgardner, R. A. Weismiller, L. L. Biehl, and B. F. Robinson. 1980. Extension of laboratory-measured soil spectra to field conditions. Soil Sci. Soc. Am. J. 44:572–574.

---

RECENT ADVANCES in remote sensing technology applied to soil survey have shown promise of enhanced speed and accuracy in the preparation of these surveys (Weismiller and Kaminsky, 1978; Westin and Frazee, 1976). Similar techniques have been applied to soil erosion monitoring and crop residue detection (Gausman et al., 1975). Such remote sensing applications rely on the existence of characteristic spectral differences among components of the soil scene.

A variety of soil parameters and conditions individually and in association with one another contribute to the spectral reflectance of soils. These parameters are known to include the physicochemical properties of organic matter, moisture, texture, and iron oxide content as well as other variables less well defined as contributors to reflectance (Beck, 1975;[3] Bowers and Hanks, 1965; Condit, 1970; Montgomery and Baumgardner, 1974; Montgomery, 1976). Conditions affecting the radiation and characteristics of soils in their natural state are green vegetation, shadows, surface roughness, and nonsoil residue, all of which vary according to tillage operations, cropping systems, or naturally occurring plant communities (Cipra et al., 1971; Gausman et al., 1975; Gausman et al., 1976; Gausman et al., 1977; Hoffer and Johannsen, 1969; Silva et al., 1971). Although spectroradiometric studies of soils under laboratory and field conditions have contributed to an understanding of soil reflectance, the validity of comparing laboratory-measured soil spectra to field conditions has not been documented.

The objectives of this study were to differentiate between two widely occurring glaciated soils on the basis of spectroradiometric response under varied field and laboratory conditions and to verify the validity of laboratory-measured soil spectra for characterizing soil reflectance in the field.

## MATERIALS AND METHODS

### Field Spectroradiometric Data

A field experiment to measure the effects of corn crop residue and soil moisture content on the reflectance of glaciated soils differing greatly in soil color, organic matter content, and natural drainage was conducted on 12 May 1977. Factorial treatment combinations consisted of two levels of soil moisture content (dry and moist) along with two surface soil conditions, i.e., with and without 2.2 metric tons/ha corn stover (about a 35% cover). Two plot sites were chosen at the Purdue University Agronomy Farm to represent the two soils under investigation: Chalmers silty clay loam, a fine-silty, mixed, mesic Typic Haplaquoll, and Fincastle silt loam, a fine-silty, mixed, mesic Aeric Ochraqualf (Soil Survey Staff, 1975).

At each soil site 12 plots measuring 3 by 3 m were delineated on soil which had been raked smooth to reduce crusting, providing three replications of each treatment combination randomized in three blocks. An Exotech Model 20C spectroradiometer was used in a 15° field of view mode to obtain spectral data at discrete 0.01-$\mu$m intervals over the 0.52- to 2.32-$\mu$m wavelength range from a 1.6-m diam viewing area on the ground (Leamer et al., 1973). A panel painted with $BaSO_4$ was used as a calibration standard.

### Laboratory Spectroradiometric Data

Composite surface soil samples from both of the above soil sites were collected from each of the 12 plots. Sample preparation involved drying, crushing, and sieving all soil samples to remove particles larger than 2 mm in diam. Special sample holders were designed and constructed of PVC rings 2 cm deep by 10 cm diam with 50-mesh brass strainer cloth stretched taut and fastened in a countersunk groove in one end. Nonreflecting black paint was applied to reduce unwanted reflection from the sample holders.

To provide a uniform moisture environment two plexiglass-framed 61 by 91 cm asbestos tension tables were constructed and set up with a 100-cm column of water in order to maintain a 0.10-bar moisture tension (Jamison and Reed, 1949; Leamer and Shaw, 1946). The 0.10-bar moisture tension can be thought to approximate the drainage tension of soils tiled at the 1-m depth. The pore space at this tension has been closely associated to the yield response of many field crops (Leamer and Shaw, 1946). After saturation of the soil samples for about 4 hours, the samples were placed on the tension tables for 24 hours equilibration.

Duplicate subsamples of the composite surface soil samples were measured with an Exotech Model 20C spectroradiometer in an outdoor configuration with a bidirectional reflectance factor (BRF) reflectometer (DeWitt and Robinson, 1976). The illumination source was a 1,000-W tungsten iodide coiled filament lamp which transfers a highly collimated beam by means

---

[1] Journal Paper no. 7719, Purdue Univ., Agric. Exp. Stn. Received 16 Aug. 1979. Approved 21 Jan. 1980.

[2] Graduate Research Assistant, Professor of Agronomy, and Research Agronomist, respectively, Dep. of Agronomy; Research Engineers, School of Electrical Engineering; Laboratory for Applications of Remote Sensing, Purdue Univ., West Lafayette, IN 47906. Senior author is now Soil Scientist, NASA Earth Resources Laboratory, NSTL Station, MS 39529.

[3] R. H. Beck. 1975. Spectral characteristics of soils related to the interaction of soil moisture, organic carbon and clay content. M.S. Thesis, Purdue Univ., West Lafayette, Ind.

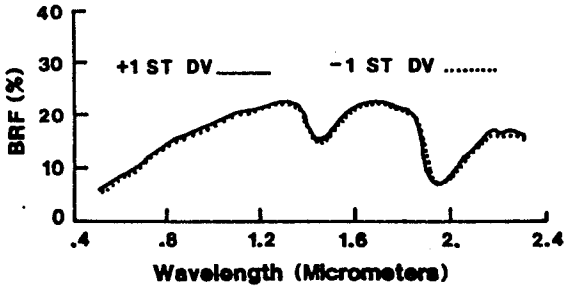


Fig. 1—Spectral bounds of the 95% confidence limits on reflectance of 20 Fincastle silt loam check samples measured on 10 different days.

of a paraboloidal mirror to the sample-viewing plane. A three-fourths degree field of view mode was used with the detector placed 2.4 m above the sample. Spectral measurements of soil samples as well as the pressed $BaSO_4$ laboratory reflectance standard were recorded on analog tape for later conversion to annotated digital format for computer processing using the LARSPEC analysis program (Simmons et al., 1975).

As with field measurements, reflectance is reported as percent bidirectional reflectance factor (BRF) to correctly express the geometry of the spectral measurement. Bidirectional reflectance factor (BRF) can be described as the ratio of the flux reflected by an object under specified conditions of irradiation and viewing to that reflected by the ideal, completely reflecting, perfectly diffusing surface, identically irradiated and viewed with the restriction that measurements are made through negligibly small solid angles of illumination and viewing (Nicodemus et al., 1977).

## RESULTS

The standard deviations from the average spectral reflectance of 20 Fincastle silt loam check samples measured on 10 different days attest to the reproducible nature of soil spectra measured under a controlled moisture tension equilibrium (Fig. 1). Soil moisture contents for the 20 check samples equilibrated at 0.10-bar tension ranged from 30.3 to 33.1% water by weight with an average of 31.3%. The slight differences in reflectance and water content of these check samples can be attributed to sample preparation and do not represent significant procedural errors.

Laboratory- and field-measured spectra for Chalmers silty clay loam and Fincastle silt loam are shown in Fig. 2. The familiar concave trend of the high organic matter Chalmers soil from 0.5 to 1.3 $\mu$m, typical of soils in the Mollisol soil order, is altered only by the presence of residue cover (Condit, 1970; Montgomery and Baumgardner, 1974). Similarly, the convex trend of all spectral curves in the 0.5- to 1.3-$\mu$m region for the Fincastle soil is typical of observed spectral response for the Alfisol soil order (Montgomery and Baumgardner, 1974). Field-measured spectral curves do not contain data in the 1.4- and 1.9-$\mu$m water absorption bands because of practical difficulties in collecting data in this region where the solar illumination is almost completely absorbed.

Chalmers and Fincastle soils under similar field conditions appear to be spectrally separable throughout the reflective wavelength region regardless of soil moisture level or surface residue cover. This would seem to confirm the observed separability of different soils when areas with similar tillage practices are isolated and classified separately using airborne multispectral scanner data (Stoner and Horvath, 1971).

Dividing the spectral response of a given soil by

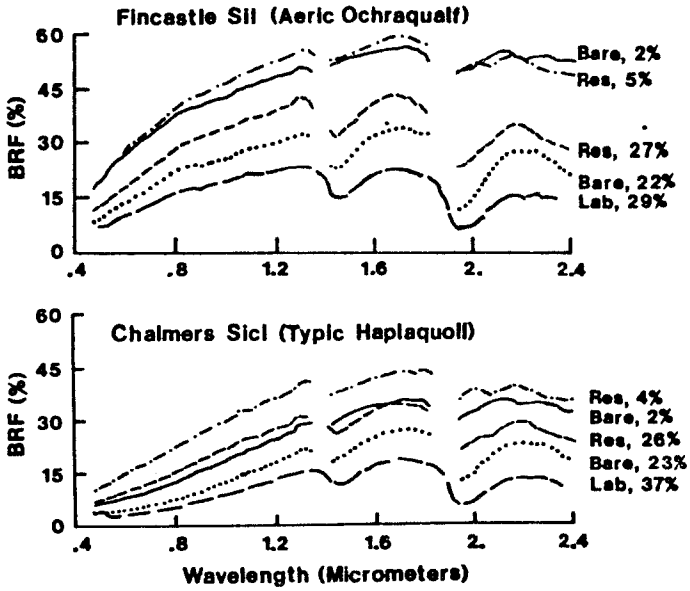


Fig. 2—Comparison of field- and laboratory-measured spectra of two soils. Percentage figures are moisture content by weight; RES = field-measured, corn residue-covered soil; BARE = field-measured, residue-free soil; LAB = laboratory-measured soil.

the spectral response of another identically treated soil allows for identification of the spectral regions in which the greatest magnitudes of difference occur. Response ratios for Fincastle/Chalmers soil comparisons indicate that the greatest difference in spectral response between indentically treated soils appears in the 0.6- to 0.8-$\mu$m transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied (Fig. 3). Field- and laboratory-measured moist soils show similar magnitudes of spectral difference between the two soils. Corn residue cover reduces the spectral difference between these two soils by an equal magnitude for both moist and dry soils.

Using the same ratio technique, it was demonstrated that laboratory-measured spectra of soils at 0.10-bar tension are directly proportional to the spectral response of the same soil when measured in the field under bare moist conditions (Fig. 4). This relationship holds for the 0.52- to 1.32-$\mu$m region as well as for the 1.55- to 1.75-$\mu$m region. Reflectance of either the Fincastle or Chalmers soil as measured under bare moist field conditions was found to be about 1.5

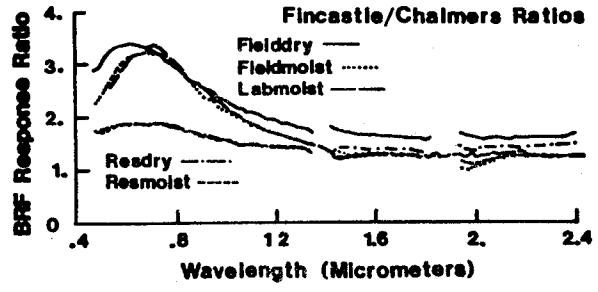


Fig. 3—Response ratios demonstrating the magnitude of differences in spectral response between spectral curves for identically treated Fincastle/Chalmers soils. FIELDDRY = bare dry soil; FIELDMOIST = bare moist soil; RESDRY = dry soil with corn residue; RESMOIST = moist soil with corn residue; LABMOIST = laboratory-measured moist soil.

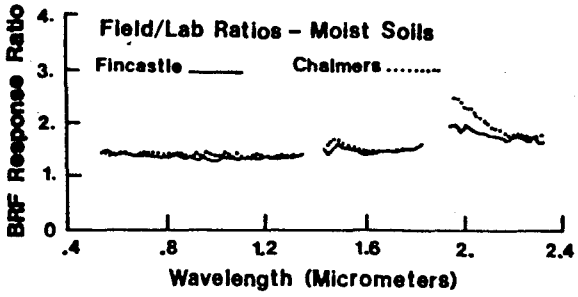


Fig. 4—Response ratios demonstrating the magnitude of difference in spectral response between spectral curves for field-measured bare moist soil and laboratory-measured soil at 0.01-bar tension. FINCASTLE — Fincastle silt loam soil; CHALMERS = Chalmers silty clay loam soil.

times greater than the reflectance of laboratory-measured moist soils at 0.10-bar tension at any given wavelength within these spectral ranges. Higher reflectances of field-measured soils are not inconsistent with lower field moisture contents, observations which previous studies indicate may explain reflectance differences of the magnitude seen here (Bowers and Hanks, 1965; Hoffer and Johannsen, 1969).

## CONCLUSIONS

The ability to extend laboratory-measured soil spectra to field conditions has important implications in applying remote sensing techniques to soil survey, monitoring of land degradation, and crop inventory. By bringing soil samples into a controlled laboratory environment it is possible to study the spectral properties of large numbers of soils from diverse climatic and geographic regions without having to transport a spectroradiometer to scattered field studies. Experimental results verify the validity of comparing laboratory-measured soil spectra under controlled moisture equilibria to field-measured spectral response from bare moist soil for two glaciated soils from a humid mesic climate.

A technique of ratioing comparably treated soils indicates that the spectral differences between Fincastle silt loam and Chalmers silty clay loam is most prominent in the transition region between visible and near infrared wavelengths. Current Landsat bands 5 (0.6–0.7 $\mu$m) and 6 (0.7–0.8 $\mu$m) would seem to be ideal for discrimination of spectral differences between these two unvegetated soils regardless of their field condition.

## LITERATURE CITED

1. Bowers, S. A., and R. J. Hanks. 1965. Reflectance of radiant energy from soils. Soil Sci. 100:130–138.
2. Cipra, J. E., M. F. Baumgardner, E. R. Stoner, R. B. MacDonald. 1971. Measuring radiance characteristics of soil with a field spectroradiometer. Soil Sci. Soc. Am. Proc. 35: 1014–1017.
3. Condit, H. R. 1970. The specral reflectance of American soils. Photogramm. Eng. 36:955–966.
4. DeWitt, D. P., and B. F. Robinson. 1976. Description and evaluation of a bidirectional reflectance factor reflectometer. Information Note 091576. Laboratory for Applications of Remote Sensing, Purdue Univ., West Lafayette, Ind.
5. Gausman, H. W., A. H. Gerbermann, C. L. Wiegand, R. W. Leamer, R. R. Rodriguez, and J. R. Noriega. 1975. Reflectance differences between crop residues and bare soils. Soil Sci. Soc. Am. Proc. 39:752–755.
6. Gausman, H. W., R. W. Leamer, J. R. Noriega, R. R. Rodriguez, and C. L. Wiegand. 1977. Field-measured spectroradiometric reflectances of disked and nondisked soil with and without wheat straw. Soil Sci. Soc. Am. J. 41:793–796.
7. Gausman, H. W., R. R. Rodriguez, and A. J. Richardson. 1976. Infinite reflectance of dead compared with live vegetation. Agron. J. 68:295–296.
8. Hoffer, R. M., and C. J. Johannsen. 1969. Ecological potentials in spectral signature analysis. p. 1–29. *In* P. L. Johnson (ed.) Remote sensing in ecology. Univ. of Georgia Press, Athens, Ga.
9. Jamison, V. C., and I. F. Reed. 1949. Durable asbestos tension tables. Soil Sci. 67:311–318.
10. Leamer, R. W., V. I. Meyers, and L. F. Silva. 1973. A spectroradiometer for field use. Rev. Sci. Instrum. 44:611–614.
11. Leamer, R. W., and B. Shaw. 1946. A simple apparatus for measuring non-capillary porosity on an extensive scale. J. Am. Soc. Agron. 33:1103–1108.
12. Montgomery, O. L., and M. F. Baumgardner. 1974. The effects of the physical and chemical properties of soils on the spectral reflectance of soils. Information Note 112674. Laboratory for Applications of Remote Sensing, Purdue Univ., West Lafayette, Ind.
13. Montgomery, O. L. 1976. An investigation of the relationship between spectral reflectance and the chemical, physical and genetic characteristics of soils. Ph.D. Thesis, Purdue Univ., West Lafayette, Ind. (Libr. Congr. Card no. NUC. 79-32236) Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 19:1146).
14. Nicodemus, F. E., J. C. Richmond, J. J. Hsia, I. W. Ginsberg, and T. Limperis. 1977. Geometrical considerations and nomenclature for reflectance. National Bureau of Standards Monograph 160. U.S. Govt. Printing Office, Washington, D.C.
15. Silva, L. F., R. M. Hoffer, and J. E. Cipra. 1971. Extended wavelength field spectroradiometry. Proc. 7th Intern. Symp. on Remote Sensing of Environment, Ann Arbor, Mich. 2: 1509–1518.
16. Simmons, W. R., S. Wilkinson, W. C. Zurney, and J. L. Kast. 1975. EXOSYS: analysis program for Exotech Model 20C data. LARS Program Abstract 5000, Laboratory for Applications of Remote Sensing, Purdue Univ., West Lafayette, Ind.
17. Soil Survey Staff. Soil taxonomy—a basic system of soil classification for making and interpreting soil survey. Soil Conservation Service. USDA. Agric. Handb. no. 436, Washington, D.C.
18. Stoner, E. R., and E. H. Horvath. 1971. The effect of cultural practices on multispectral response from surface soil. Proc. 7th Intern. Symp. on Remote Sensing of Environment. Ann Arbor, Mich. 3:2109–2113.
19. Weismiller, R. A., and S. A. Kaminsky. 1978. Application of remote sensing technology to soil survey research. J. Soil Water Conserv. 33:287–289.
20. Westin, F. C., and C. J. Frazee. 1976. Landsat data, its use in a soil survey program. Soil Sci. Soc. Am. J. 40:81–89.

DISTRIBUTION LIST

NASA Johnson Space Center

SA: W. Rice
SK: R. Erb
SG: R. MacDonald
SH: J. Erickson
SG3: F. Hall
C. Hallum
A. Houston
A. Feiveson
D. Pitts
D. Thompson
K. Henderson
G. Badwahr
J. Paris
SH2: M. Trichel
SH3: J. Dragg
R. Bizzell
R. Eason
V. Whitehead
JM6: Technical Library (4)
AP: Public Affairs Office

NASA Headquarters

ER-2: P. Thome

NASA Scientific and Technical
Information Facility

| | | | |
|---|---|---|---|
| R. Horvath: | ERIM | C. Hay: | Univ. Calif.-Berkeley |
| W. Malila: | ERIM | E. Kanemasu: | Kansas State Univ. |
| R. Cicone: | ERIM | B. Blad: | Univ. Nebraska |
| R. Jackson: | USDA-SEA | J. Norman: | Univ. Nebraska |
| C. Wiegand: | USDA-SEA | B. Gardner: | Univ. Nebraska |
| G. Boatwright: | USDA-SEA | J. Heilman: | Texas A&M Univ. |
| V. Salomonson: | NASA-GSFC | E. LeMaster: | Pan American Univ. |
| C. Tucker: | NASA-GSFC | M. Hall: | Oregon State Univ. |
| J. Barker: | NASA-GSFC | J. Harlan: | S. Dakota State Univ. |
| D. Deering: | NASA-GSFC | V. Pederson: | N. Dakota State Univ. |
| E. Stoner: | NASA-NSTL | M. Seeley: | Univ. Minnesota |
| D. Phinney: | LEMSCO | F. Ulaby: | Univ. Kansas |
| B. Carroll: | LEMSCO | J. Smith: | Colorado State Univ. |
| K. Copeland: | USDA-ARS | D. Major: | Agriculture Canada |
| | | P. Hobbs: | CIMMYT |