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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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COLLEGE ON SOIL PHYSICS
14 - 30 APRIL 1998

"Soil and Water Scientist"

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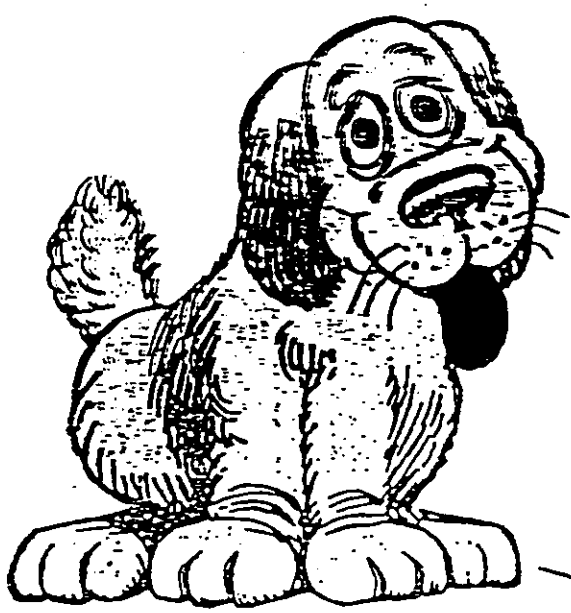
These are preliminary lecture notes, intended only for distribution to participants

"SOIL & WATER SCIENTIST"



NEW INSTRUMENTS AND LABORATORY WORK

LANDSCAPE OBSERVATIONS

NEW THEORIES & STATISTICS

EDUCATIONAL REFORMS

THE FUTURE

WHAT SOIL PHYSICISTS HAVE ACCOMPLISHED IS NOT AS IMPORTANT AS WHAT SHOULD THEY NOW DO

Continue fundamental research that underpins pragmatic decisions in agriculture

Be integrators of other disciplines (chemistry, hydrology, biology, mathematics as well as agronomy)

Provide leadership in the development of a field technology to monitor, measure and manage our soil resources

Convert our thinking from deterministic to more realistic stochastic processes

FUTURE AGRICULTURAL & ECOLOGICAL RESEARCH

- WILL NOT DEPEND UPON SMALL PLOTS TREATED DIFFERENTLY.

- WILL TAKE ADVANTAGE OF SPATIAL AND TEMPORAL VARIABILITY OF SOILS RATHER THAN IGNORING IT.

¿ 20th ACHIEVEMENT OF CIVILIZATION ?

— A GLOBAL POPULATION SUFFICIENTLY EDUCATED TO MANAGE ITS CONTINENTAL RESOURCES WITHOUT SOIL EXHAUSTION AND WITH SUSTAINED WATER QUALITY

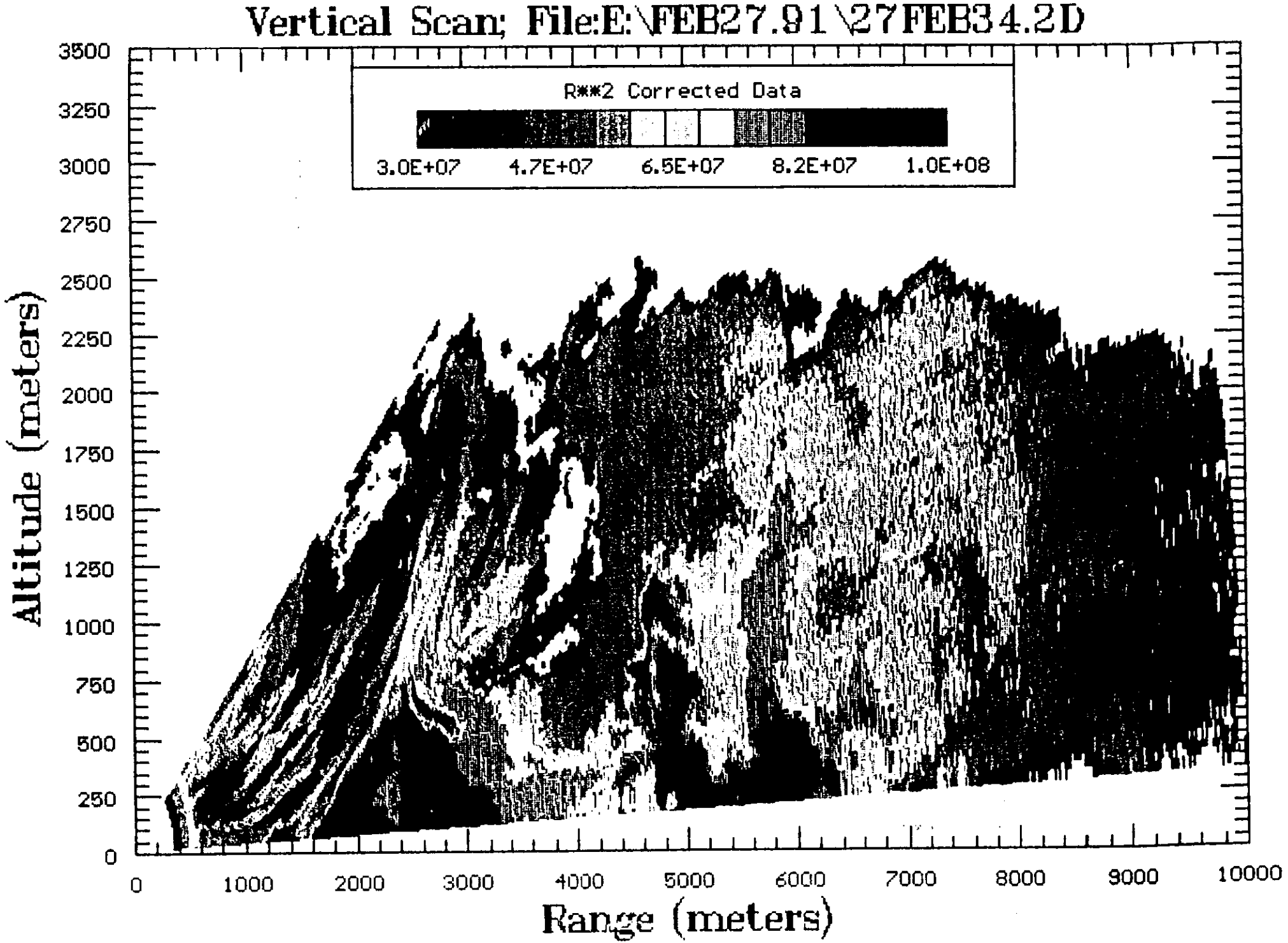
HAT DO WE HOPE TO ACHIEVE

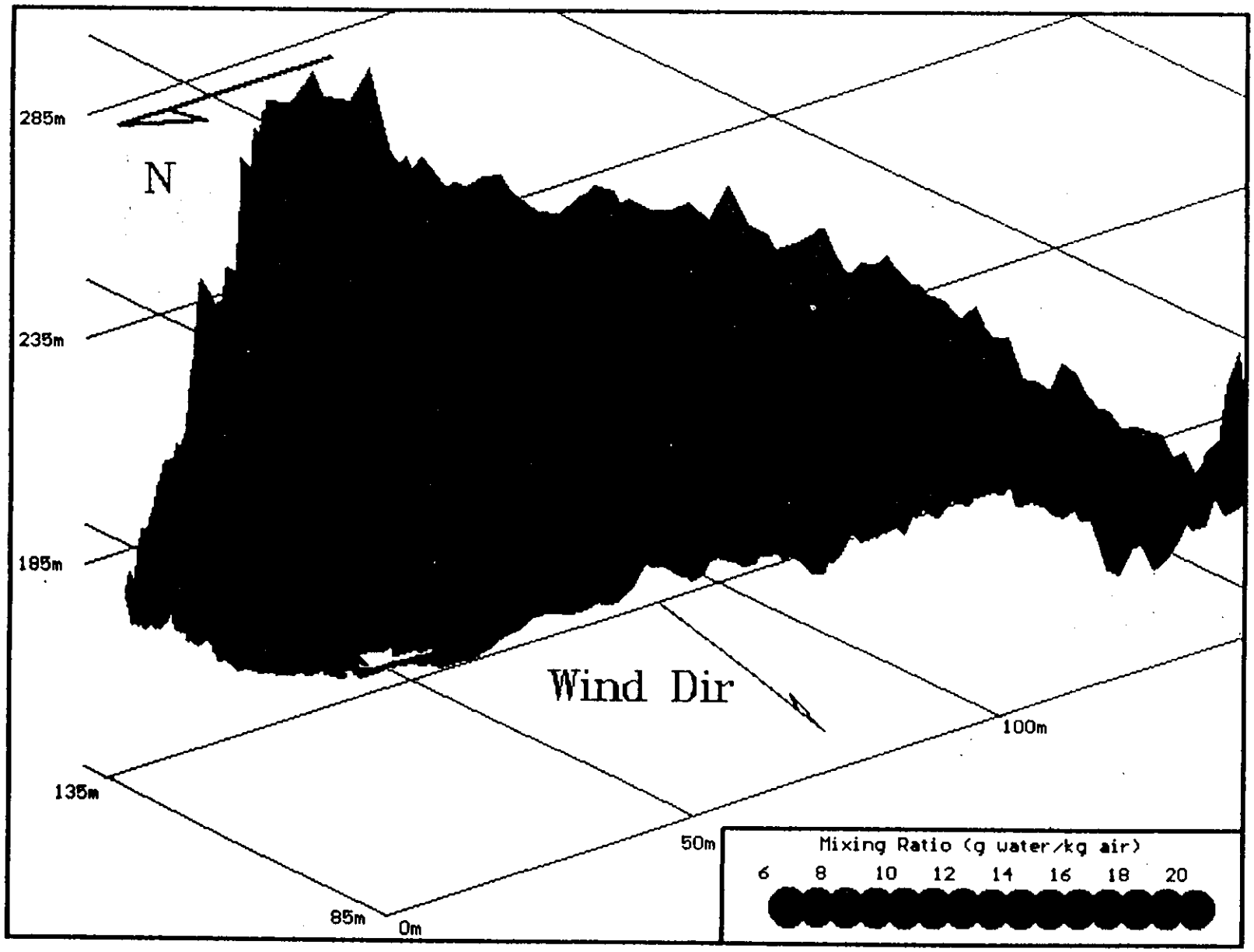
TODAY — SUSTAINABLE AGRICULTURE & QUALITY ENVIRON.
YESTERDAY — BIOTECHNOLOGY & CULTIVAR DEVELOPMEN.
DAY BEFORE YESTERDAY — CROP PRODUCTION
⋮
LAST CENTURY — FOOD & HEALTH FOR CIVILIZATION
⋮
LAST MILLENIUM — ?

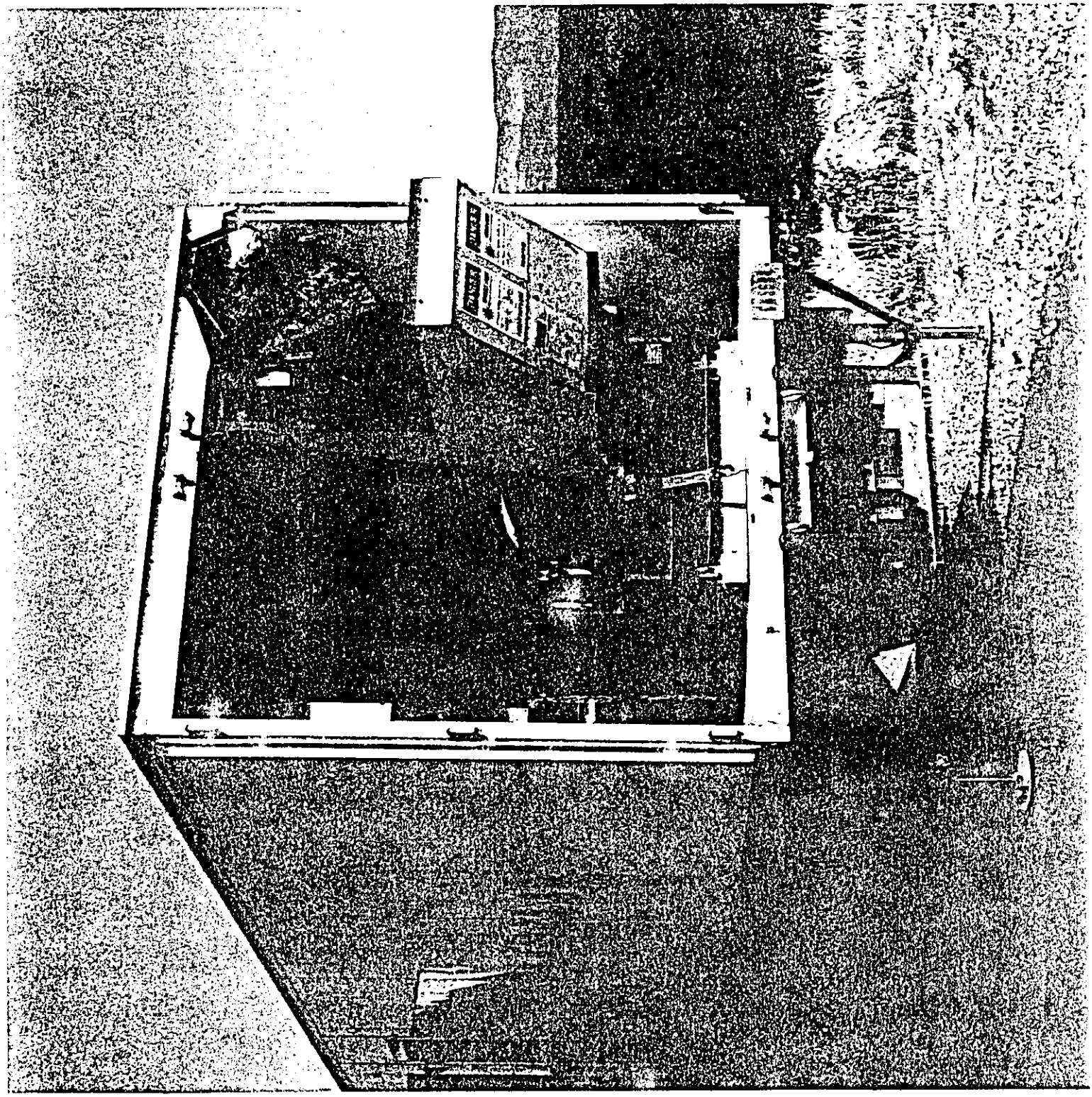
LAST 300,000 YEARS

ACHIEVEMENTS OF CIVILIZATION (V. GORDON CHILDE 1882-1957)

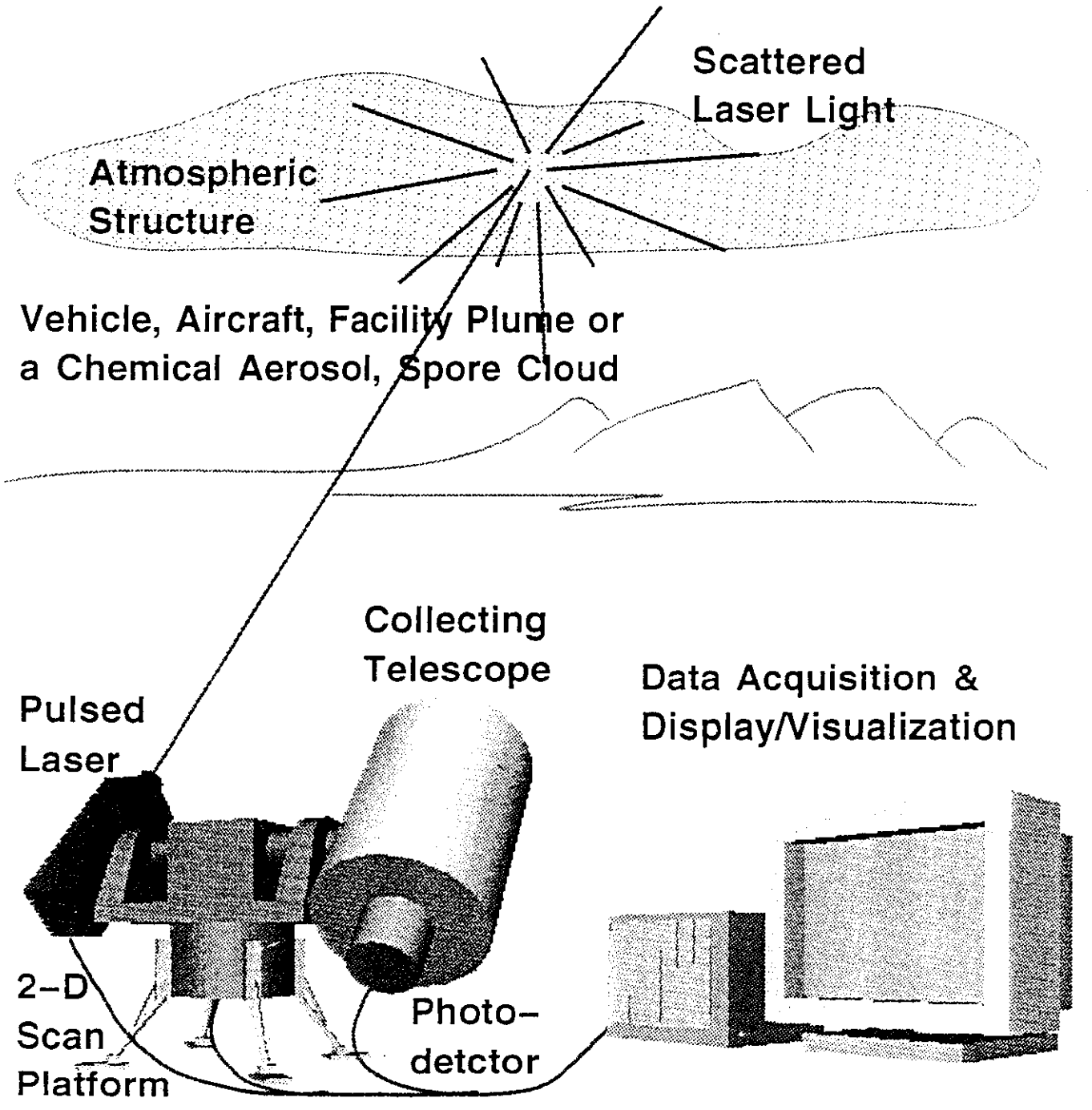
1 IRRIGATION
2 THE PLOW
3 HARNESSING ANIMAL POWER
4 SAILING BOATS
5 WHEELED VEHICLES
6 ORCHARD HUSBANDRY
7 FERMENTATION
8 PRODUCTION & USE OF COPPER
9 BRICKS
10 THE ARCH
11 GLAZING
12 CONFIDENTIAL SEAL OR LETTER
13 SOLAR CALENDAR
14 ALPHABET
15 WRITING
16 NUMERICAL NOTATION
17 BRONZE
18 SMELTING IRON
19 AQUEDUCTS - CITY WATER
20 ? ? ?


Vertical Scan; File:E:\FEB27.91\27FEB34.2D
R**2 Corrected Data
3.0E+07
4.7E+07
6.5E+07
8.2E+07
1.0E+08
Altitude (meters)
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Range (meters)


285m
N
235m
185m
Wind Dir
100m
135m
50m
85m
0m
Mixing Ratio (g water/kg air)
6
8
10
12
14
16
18
20



Lidar Methods (Light Detection and Ranging with a Range-Gated, Fast Optical Pulse)

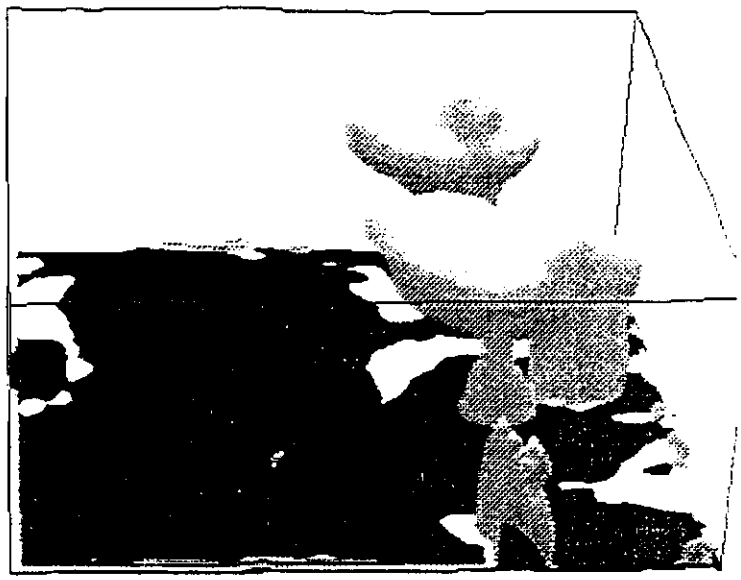


Detection, Classification, and Designation with Elastic Backscattering from Hydrocarbon Particulates, Aerosols, Particulates, Molecules, and Spores
Identification with Absorption, Fluorescence, or Raman Spectral Signatures from Hydrocarbons, Chemicals, Water Vapor, and Spores

IN THE VICINITY OF ATLANTA, GEORGIA

CLOUD CELLS ON JULY 26, 1987

PRESENT- DAY LAND-USE

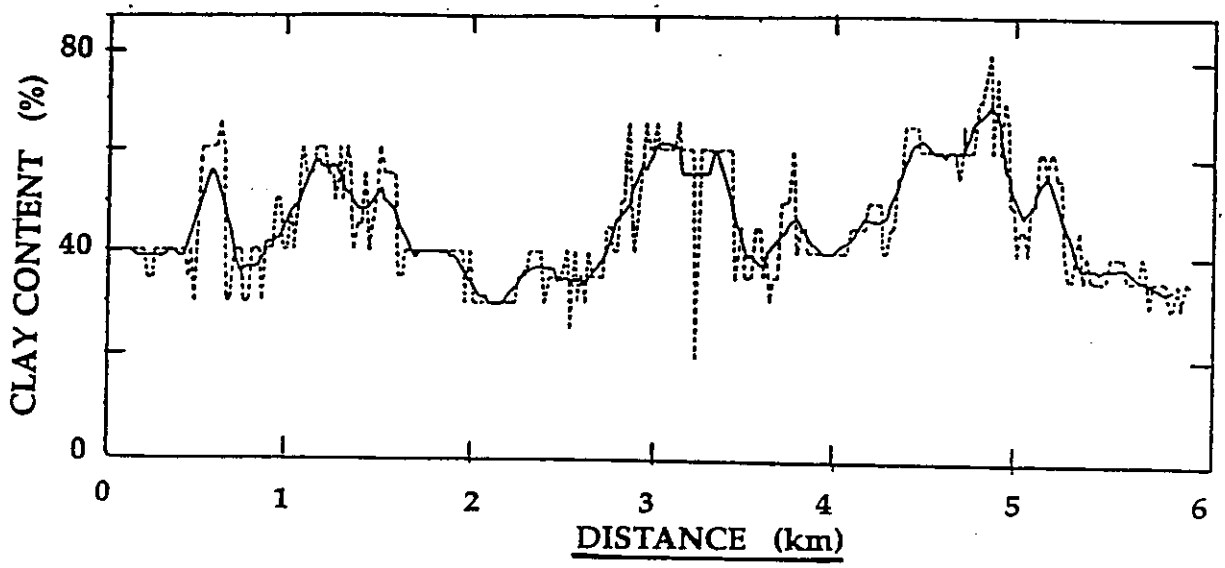


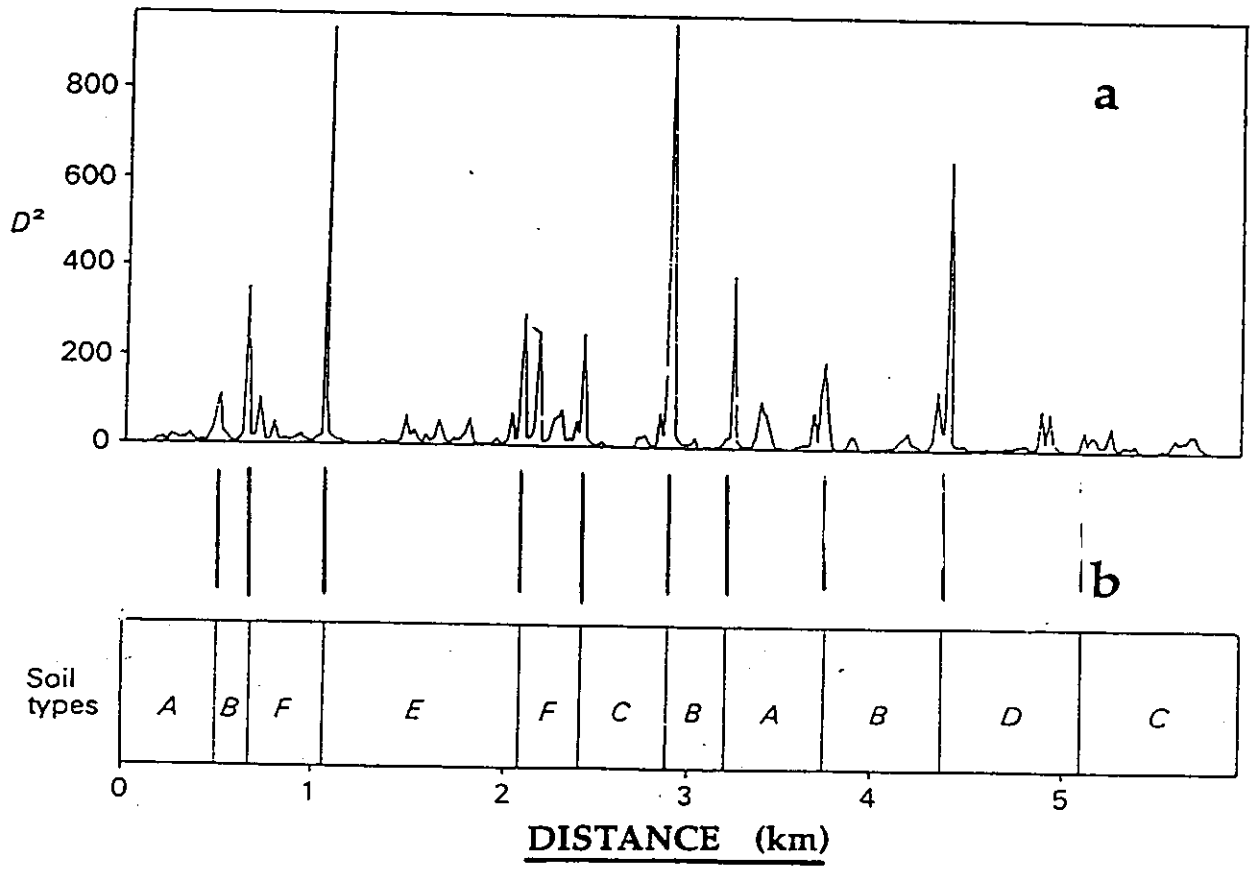
HOMOGENEOUSLY FORESTED

IMPROVED REGIONAL SCALE MODELS OF LAND-ATMOSPHERE EXCHANGE PROCESSES

ENSEMBLES OF FIELDS

SPLIT MOVING WINDOW TECHNIQUES





FUZZY SET ANALYSES

SOIL MICROBIOLOGY

- Identification of state variables of microbiological populations related to surface soil water distributions.

- Are rates of microbially induced transformations of organic materials linked with surface soil water distributions? Do they have a covariance structure according to soil taxonomy?

- Can changes of microbial growth, metabolism and death be associated with surface soil water distributions at different scales of time?

- Are the mobility and persistence of soil borne disease organisms related to surface soil water distributions?

SOIL GENESIS AND PEDOLOGY

- Development of criteria for soil mapping units based upon spatial and temporal variance structures of physical, chemical and biological state variables.

- Are covariance structures of soil water properties consistent with present-day soil mapping units?

- What are the most promising opportunities to quantify covariance structures of soil water properties with soil profile and landscape attributes?

- Identify scales of observation most useful or informative for different soil and land processes consistent with soil taxonomy and their application.

SOIL PHYSICS

- Ascertain soil physical properties and conditions within soil profiles based upon surface soil water content distributions.

- Quantification of correlation lengths of soil water content in time and space relative to precipitation and evaporation events.

- Is there a useful covariance structure between soil water properties and those associated with water and heat fluxes at the land-atmosphere interface identifiable at a soil mapping unit scale?

- Can vertical and horizontal fluxes of energy and matter in gaseous and liquid phases below the soil surface be ascertained from surface soil water distributions?

SATELLITE DEDICATED TO CONTINUOUSLY MONITOR THE WATER CONTENT OF THE EARTH'S SURFACE

FUNDAMENTAL, UNRESOLVED ISSUES

- SOIL WATER CONTENT - ENERGY RELATIONS BASED UPON FIRST PRINCIPLES

- BUCKINGHAM FLUX LAW : NONISOTHERMAL CONDITIONS WITH & WITHOUT SOLUTES

- THEORETICAL FRAMEWORK FOR TRANSIENT, COUPLED TRANSPORT (WATER, HEAT, SOLUTES) WITH & WITHOUT MICROBIAL POPULATIONS

- PARADIGMS OF NON-AQUEOUS LIQUIDS & GASES

- SCALING OF OBSERVATIONS & THEORIES

- CHAOTIC AND STOCHASTIC CONCEPTS TO DEAL WITH SPATIAL & TEMPORAL HETEROGENEITY

Future work

Characterize soil properties in relation to soil mapping units

Ascertain spatial and temporal variance structures within soil mapping units

Examine spatial and temporal covariances between soil parameters and agroecological parameters

Develop ability to translate from one space or time scale to another

Shift from deterministic to stochastic methods to improve our technology to manage natural resources

Develop field technology to answer:

What sample size?
How many samples?
How far apart?
How often?

PRESENT-DAY METHODS FOR MEASURING SOIL PROPERTIES

MICROSCALE

- Radiography
- Computed Tomography
- Magnetic Resonance Microscopy
- Fiber Optic Systems
- Optical and Scanning Electron Microscopy
- Microscopic Pressure Probe

LABORATORY COLUMN OR SMALL FIELD PLOT SCALE

- Time Domain Reflectometry
- Soil-Water Potential Devices
- Soil Solution Extraction Devices
- Heat Pulse Probe

OBSERVATIONS IN LARGE FIELDS

- Lysimetry
- Invasive Techniques
- Isotope hydrology
- Electromagnetic Induction
- Electrical Resistivity
- Seismic Reflection & Refraction
- Ground Penetrating Radar
- Nuclear Magnetic Resonance
- Cross-Borehole Techniques