MODIS VEGETATION INDICES

GLOBAL OBJECTIVE:

- Operational Monitoring of Earth's photosynthetic vegetation (phenologic and inter-annual)
- Precise and consistent, spatial and temporal comparisons of vegetation conditions
- Change detection
- Biome independent

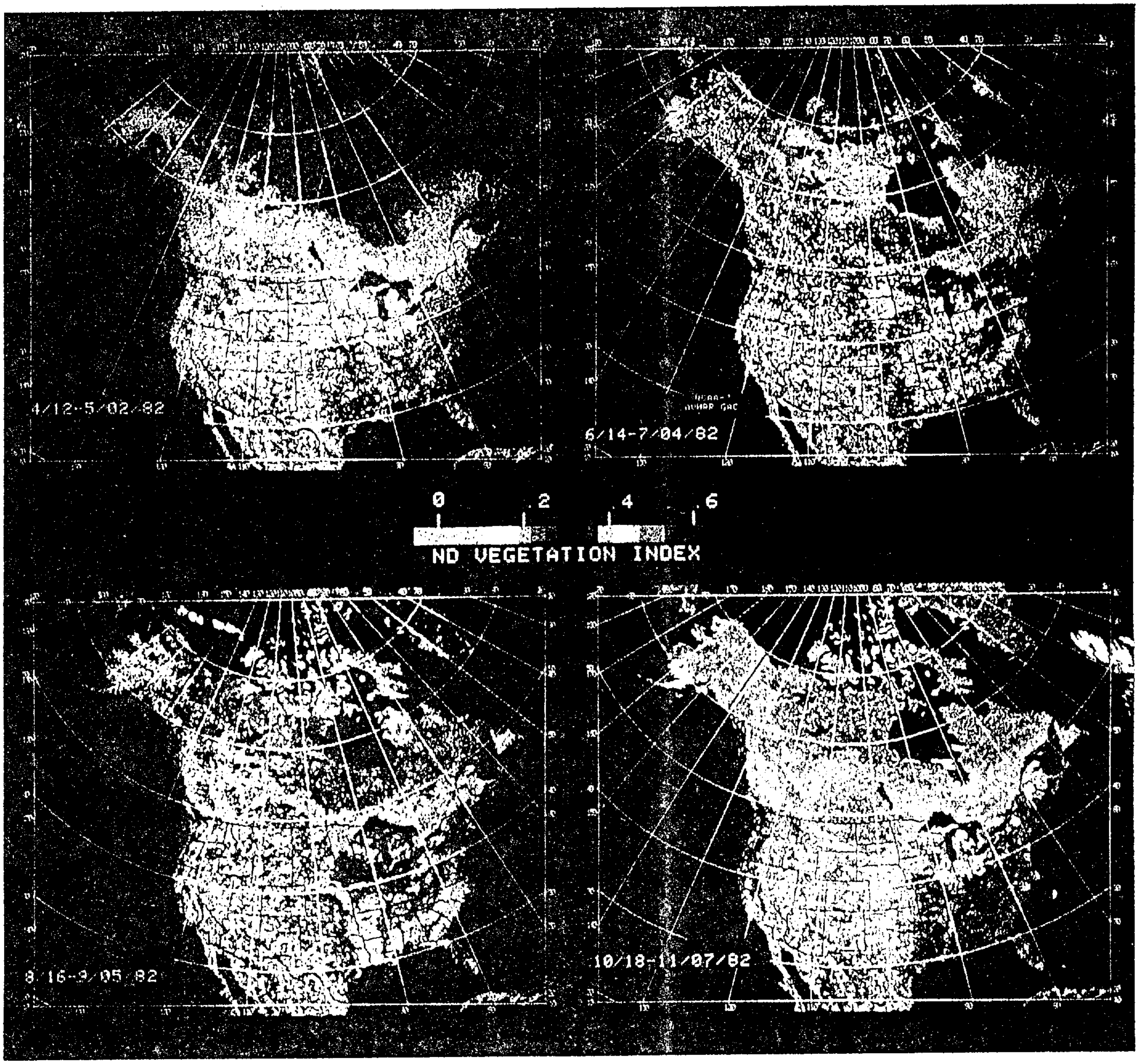
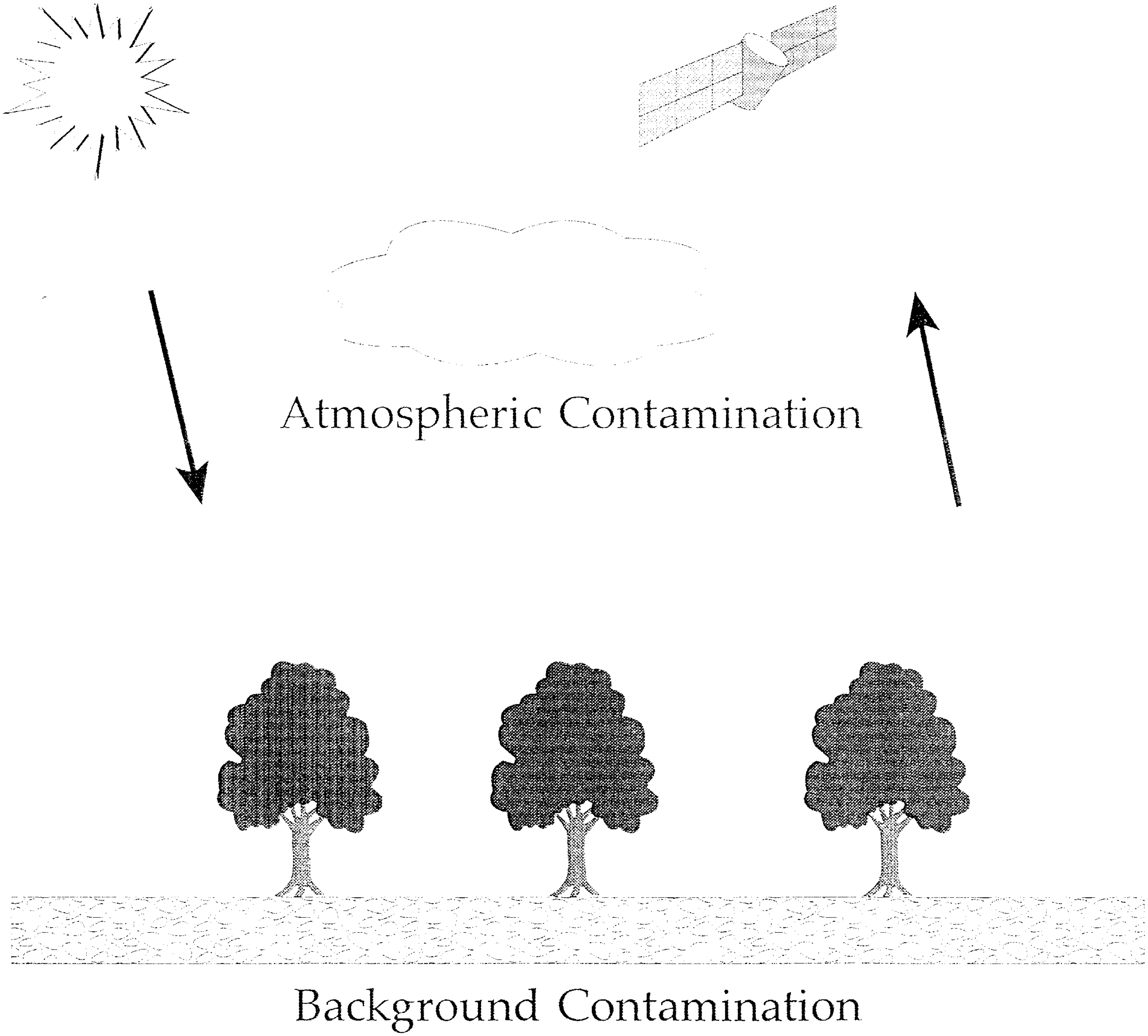
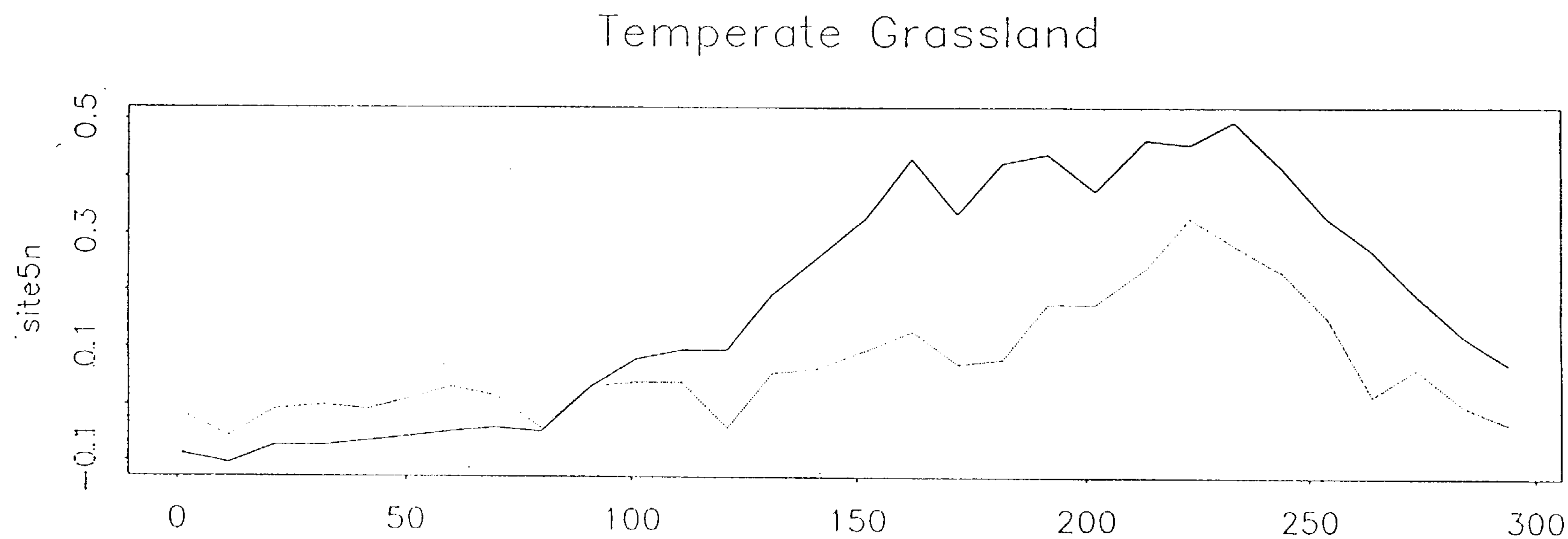


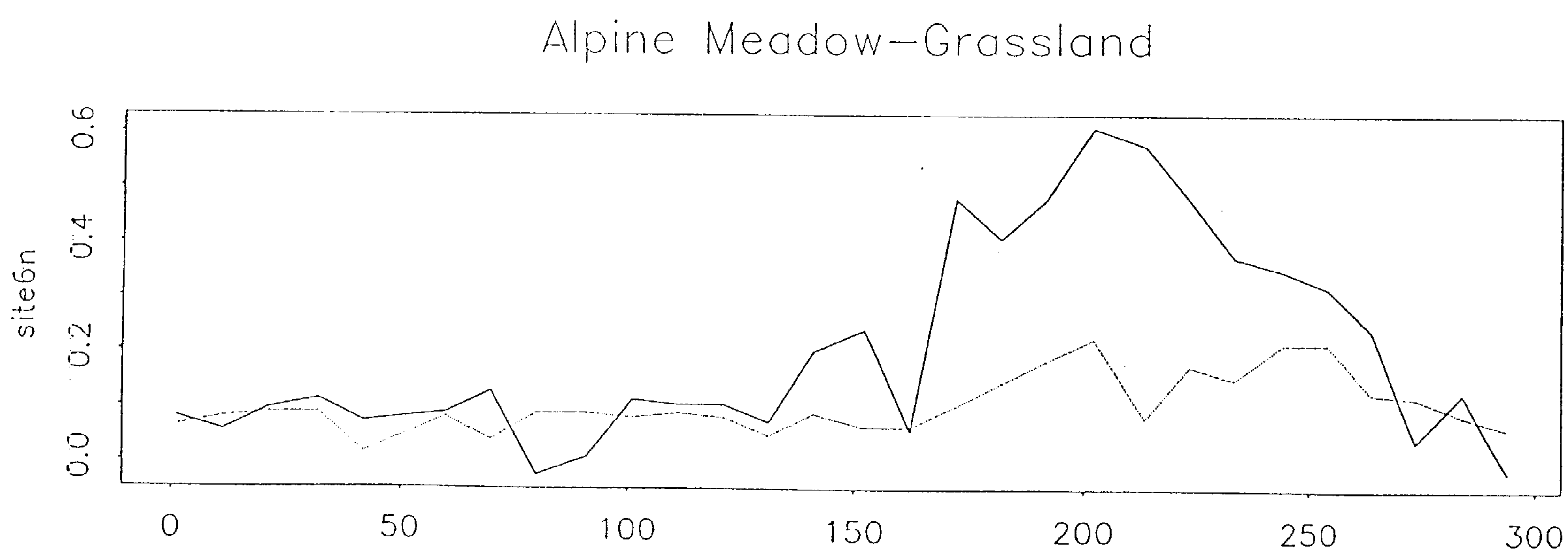
Fig. 1. Three-week composite maps of North American normalized difference vegetation index measurements for April, June, August and October, 1982. The measurements are color-coded dependent on magnitude as displayed on the color bar in the center of the figure


Atmospheric Contamination
Background Contamination

CHINA CERN SITES

8km AVHRR - Pathfinder

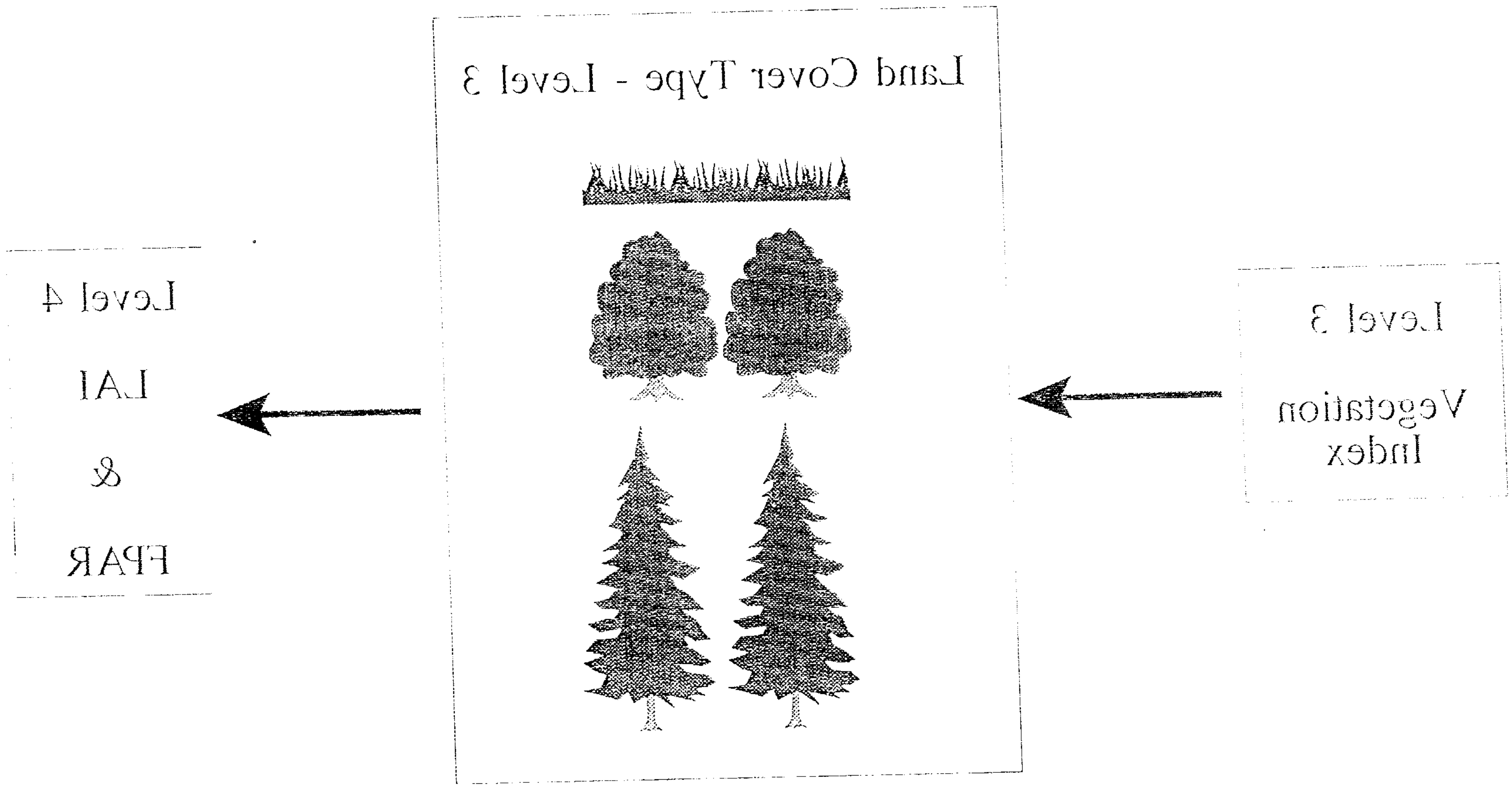


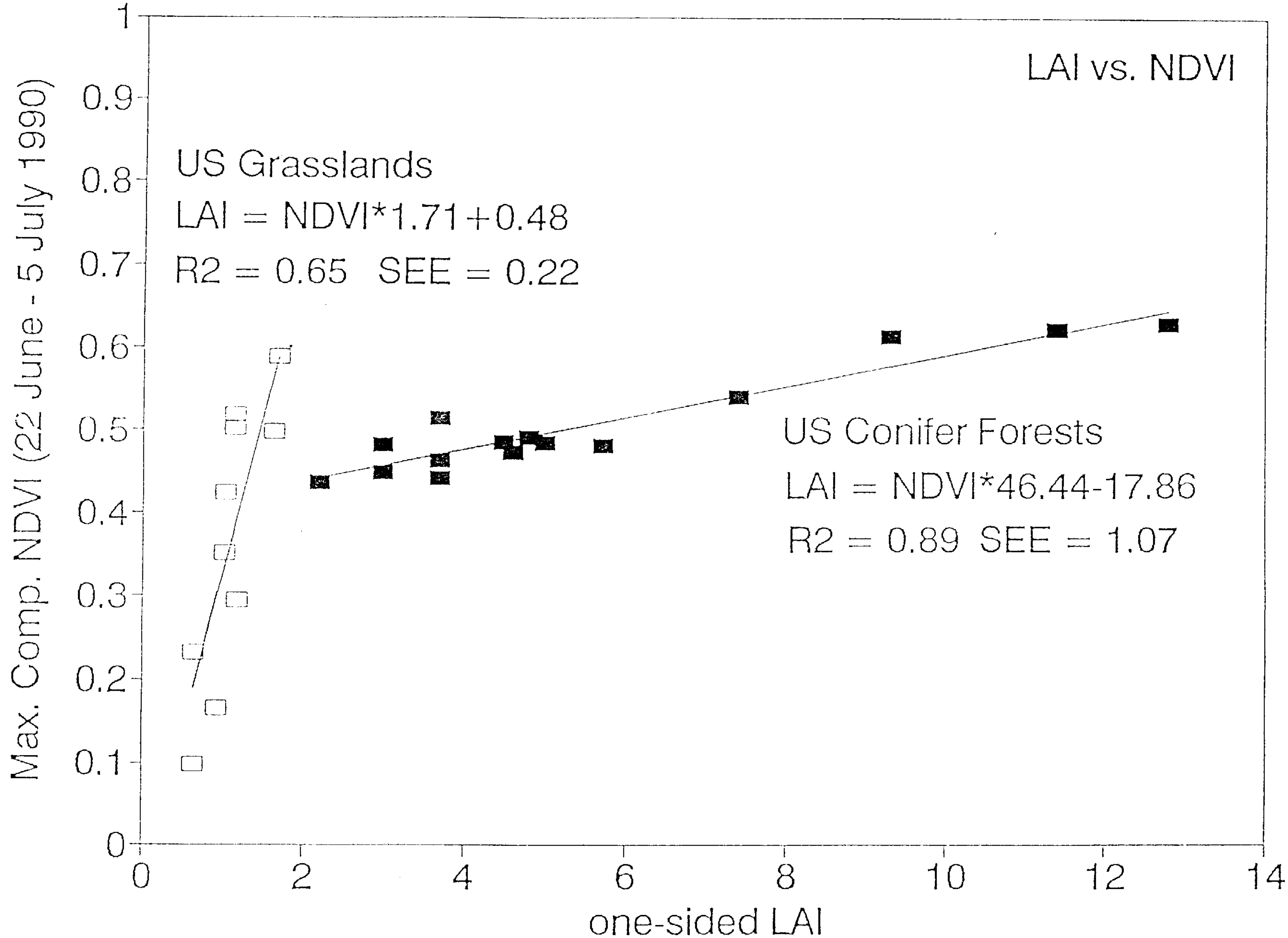


MODIS VEGETATION INDICES

BIOPHYSICAL OBJECTIVE:

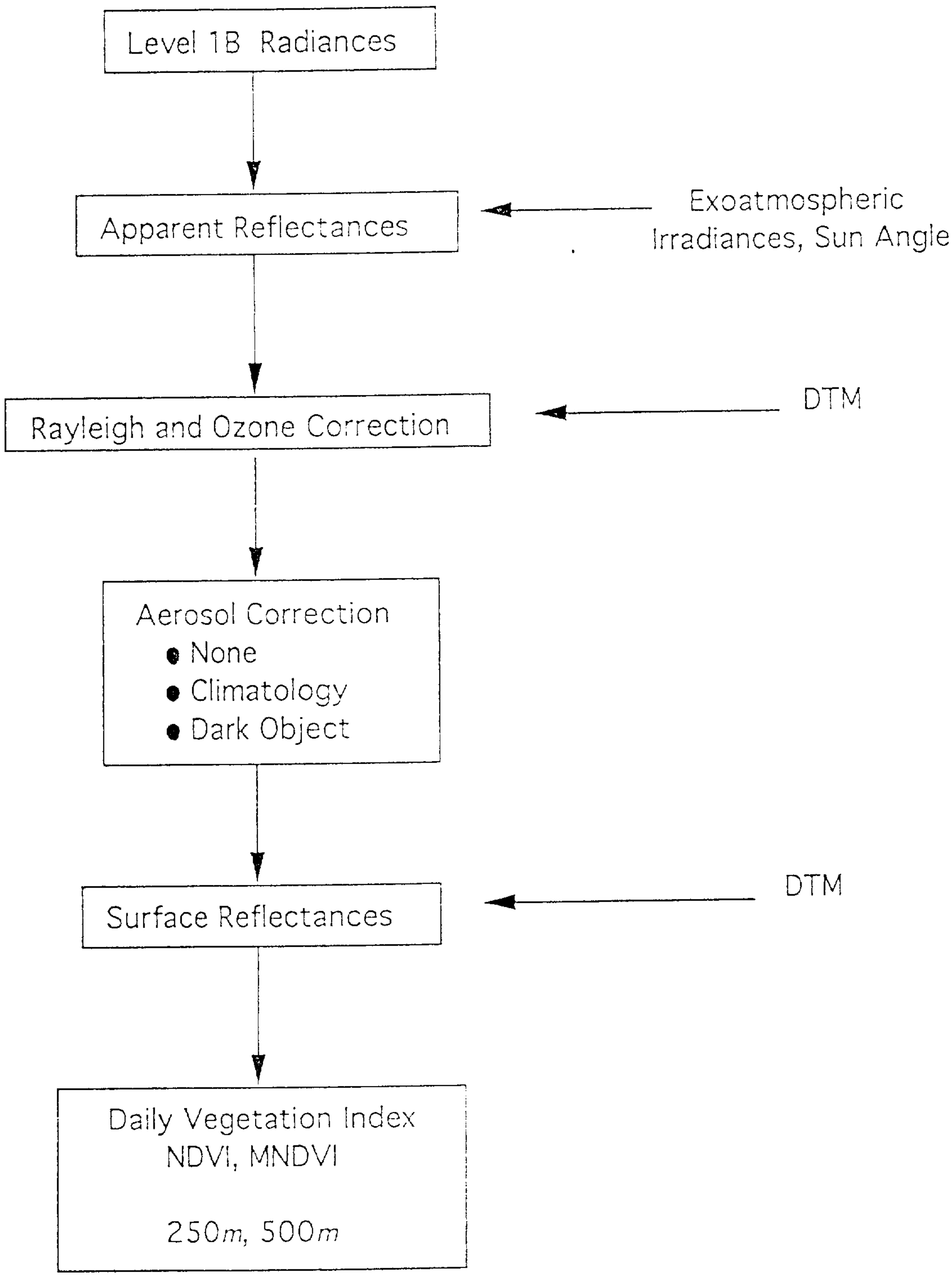
- LAI and FPAR
- Biome dependent
  - Canopy Architecture
  - Leaf Optics
  - Species Composition

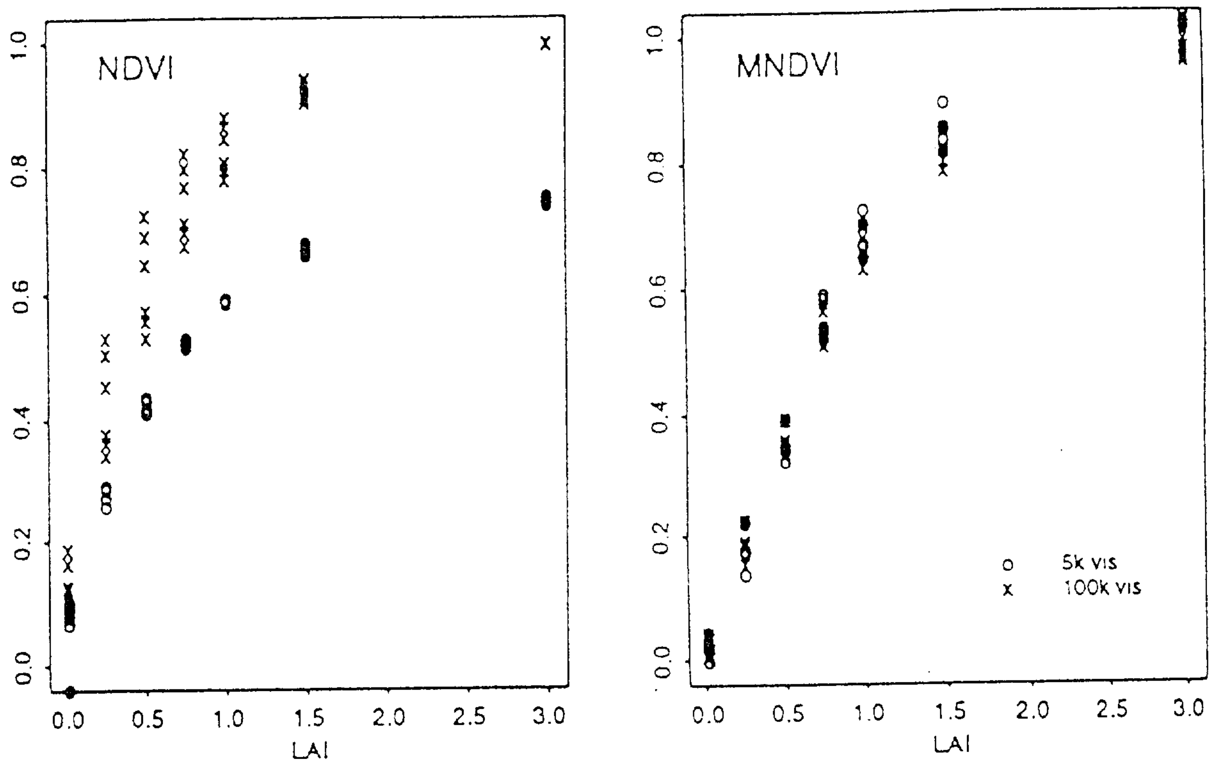

Level 4
LAI
&
FPAR
Land Cover Type - Level 3
Level 3
Vegetation Index



LAI vs. NDVI
US Grasslands
LAI = NDVI*1.71+0.48
R2 = 0.65   SEE = 0.22
US Conifer Forests
LAI = NDVI*46.44-17.86
R2 = 0.89 SEE = 1.07
Max. Comp. NDVI (22 June - 5 July 1990)
one-sided LAI
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14

LEVEL 2 VEGETATION INDEX





$$MNDVI = NDVI\ [1 + C_2H_2)] / [1 + C_1H_1],$$

$$H_1 = L_s\, L_a\, L_v,$$

$$H_2 = 1 / L_a.$$

$$L_s = 1 / [\rho_{nir} + \rho_{red}],$$

$$L_a = C_{11}\, \rho_{red} - \rho_{blue} + C_{12}\,,$$

$$L_v = 1 / [\rho_{nir} - \rho_{red}].$$

Physics of the Algorithm:

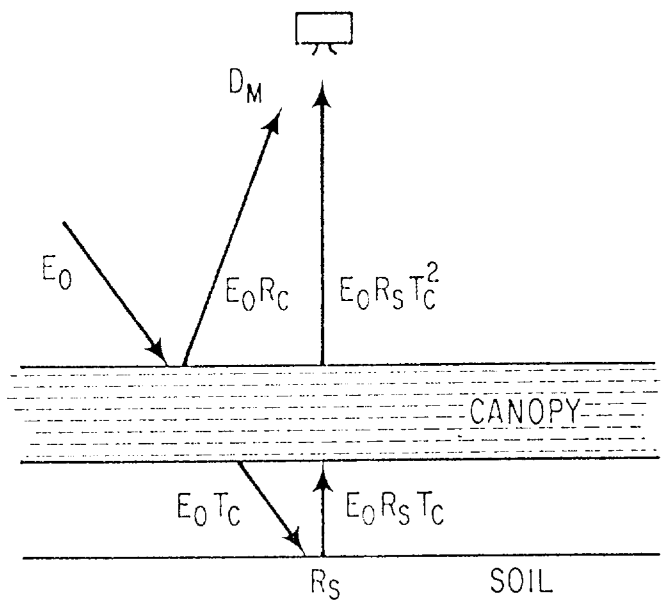
$$E_{soil} = E_{canopy} \exp(-k\ LAI)$$

$$T_{canopy} = \exp(-k\ LAI)$$

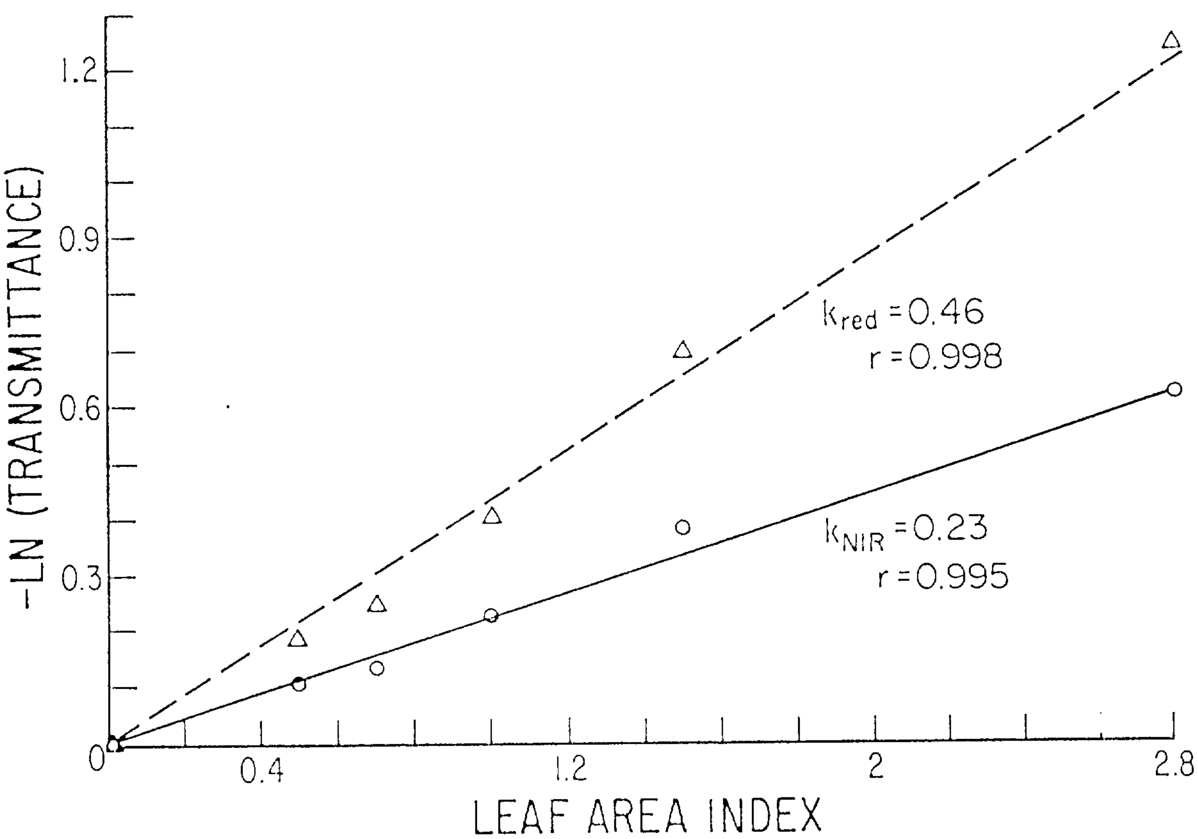
$$\rho_{canopy} = \rho_{veg.} (\gamma\ LAI) + \rho_{soil} \exp(2k\ LAI)$$

- Slope of a vegetation isoline is a function of LAI and the optical extinction properties of a canopy.

$$M_{LAI} = M_0 \exp\{2(k_{red} - k_{nir})\ LAI\}$$



D_M
E_0
$E_0 R_C$
$E_0 R_S T_C^2$
CANOPY
$E_0 T_C$
$E_0 R_S T_C$
R_S
SOIL



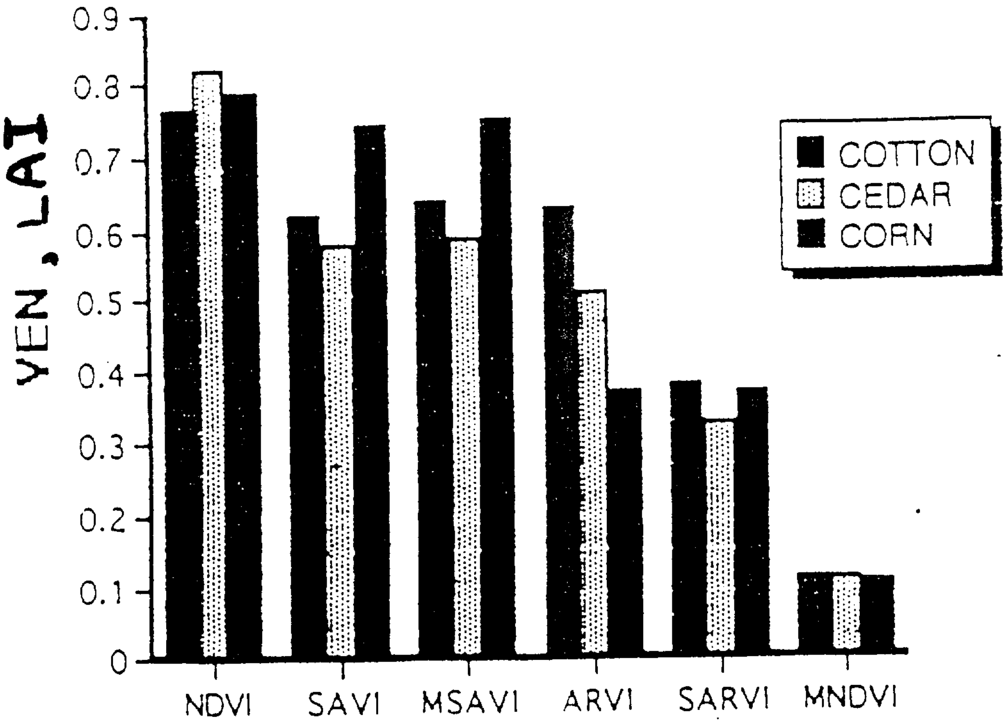
-LN (TRANSMITTANCE)
1.2
0.9
0.6
0.3
0
0.4
1.2
2
2.8
LEAF AREA INDEX
k red =0.46
r =0.998
k NIR =0.23
r =0.995

$$\varepsilon_a = VI_p - VI,$$

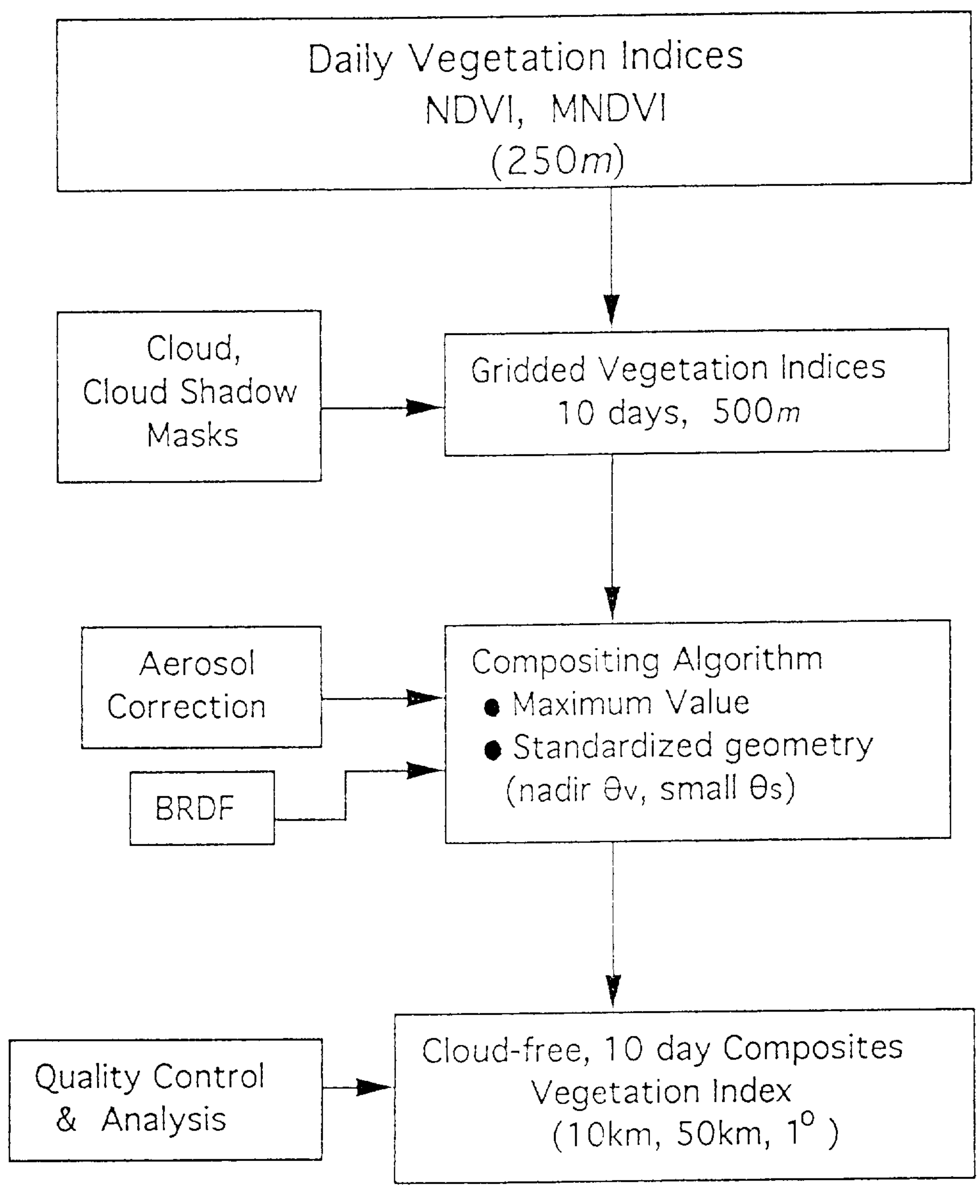
$$\varepsilon_r\ (\%) = 100 \times (VI_p - VI) \,/\, (VI - VI's),$$

$$S/N = (VI - VI's) \,/\, (VI_p - VI),$$

$$VEN = (VI_p - VI) \,/\, \delta(LAI),$$


YEN , LAI
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
COTTON
CEDAR
CORN
NDVI
SAVI
MSAVI
ARVI
SARVI
MNDVI

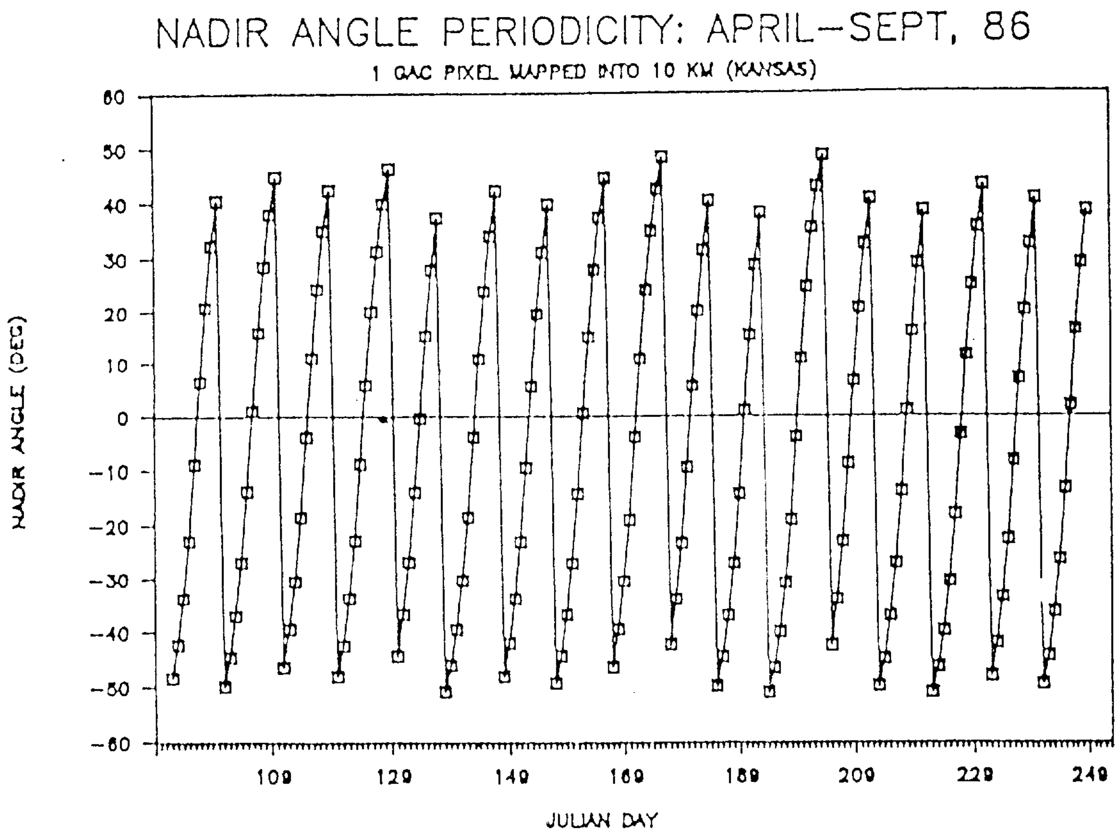
LEVEL 3 VEGETATION INDEX



COMPOSITING

GOAL:

1. Cloud-free Vegetation Product
2. Minimize Atmospheric Contamination
3. Near Nadir View Angles
4. Smallest Solar Zenith Angles



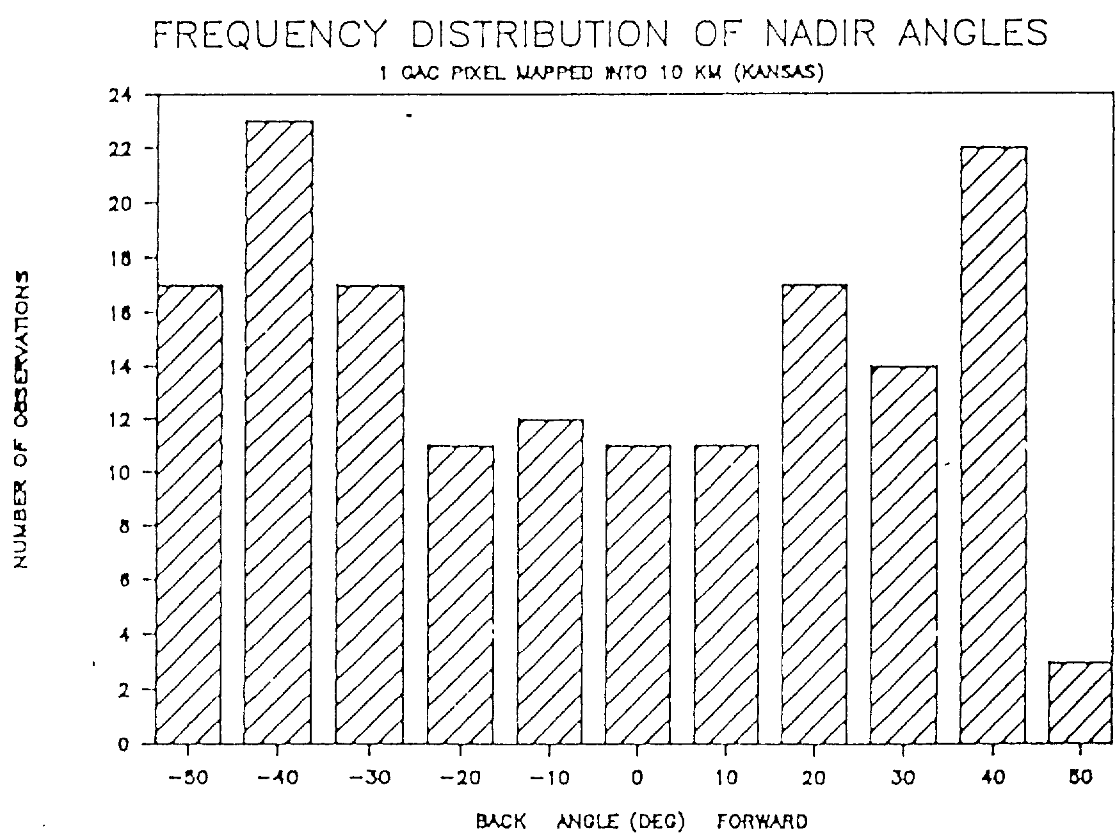


Figure 1. Nadir angle periodicity (top) and frequency distribution (bottom) for one 10-km map cell in eastern Kansas during April–September 1986.

METHODS: 10-day Compositing

- Maximum Value Compositing
  - — selects maximum VI regardless of sun-sensor geometry
- Standardized Geometry
  - — selects near nadir view angles and smallest solar zenith angle
  - — utilize BRDF models
    - empirical
    - physical
- Hemispherical Spectral albedos
  - — utilize BRDF models

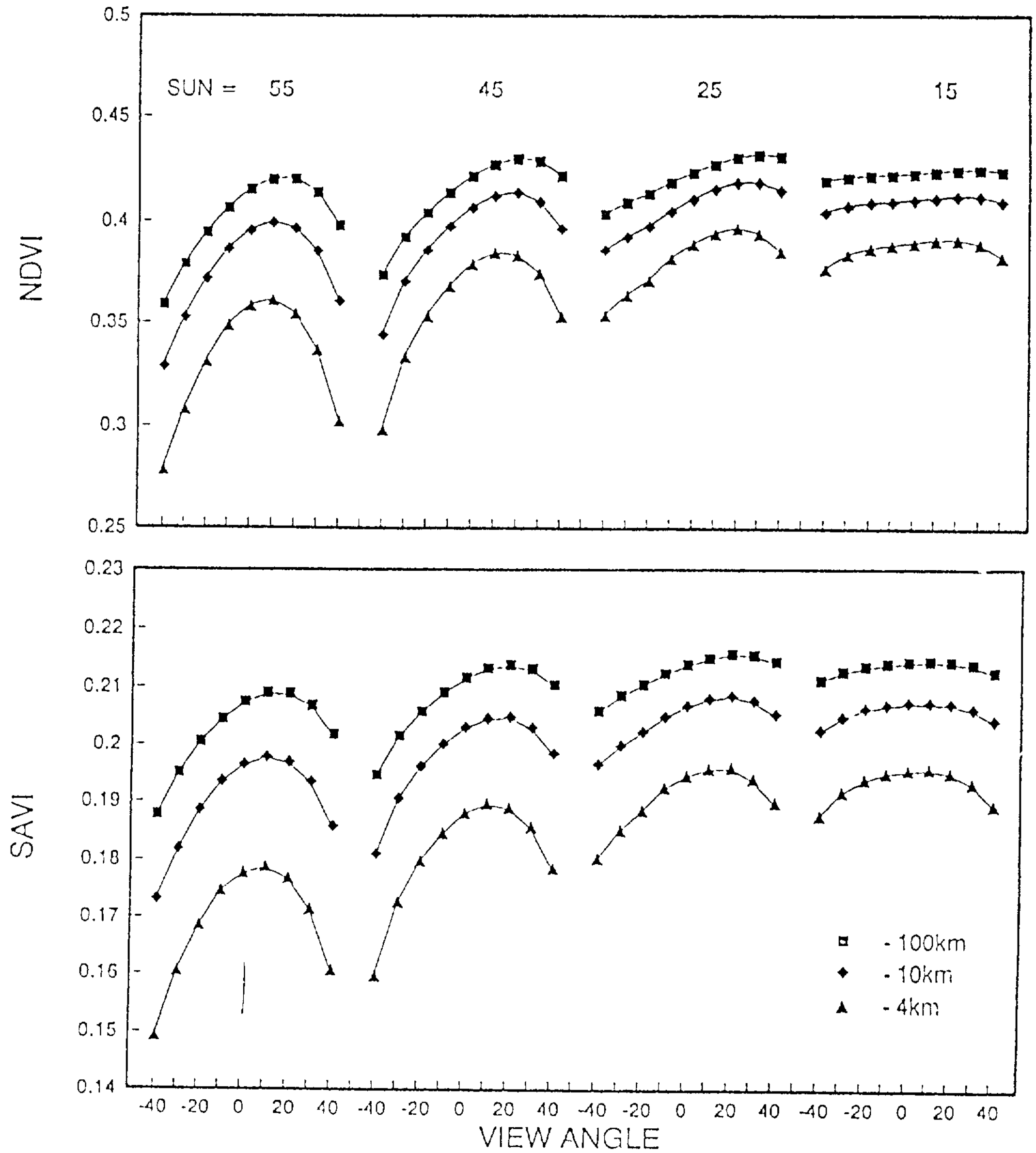


Figure 1. Top of the atmosphere NDVI and SAVI responses of a Lambertian grassland canopy (40% green cover) at 9 view angles, 4 sun angles, and 3 atmospheres.

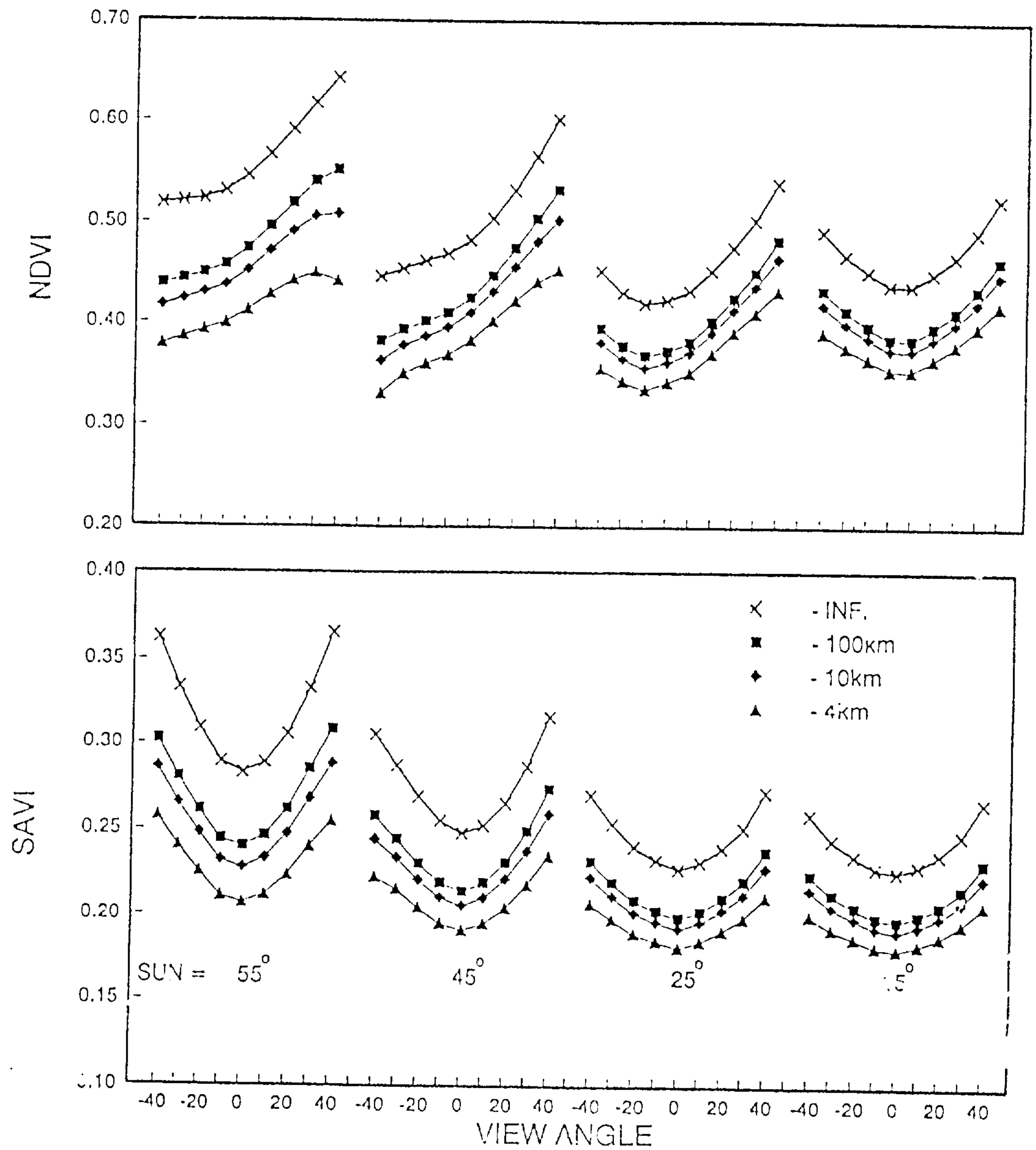
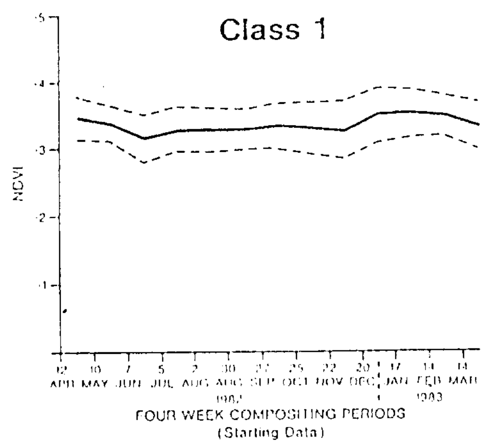
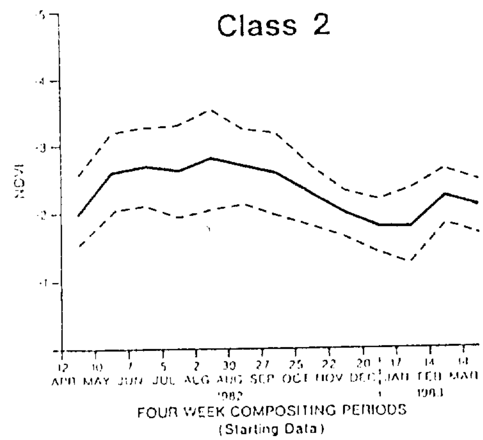
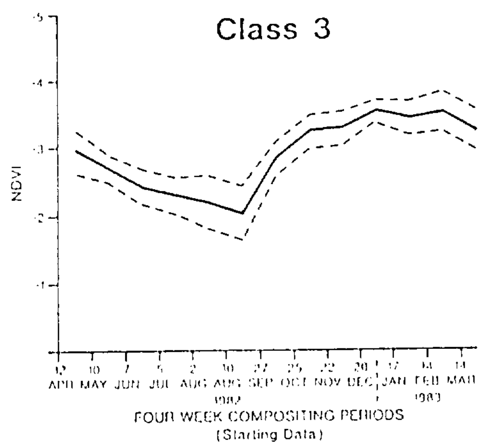
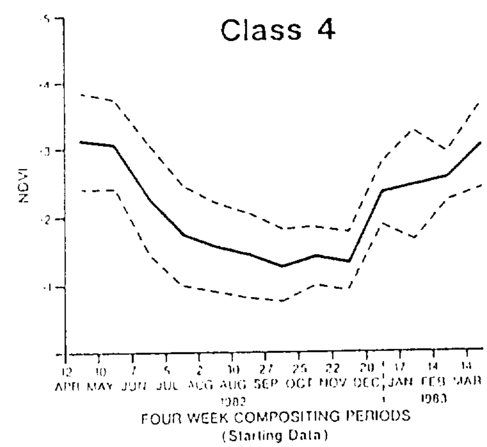


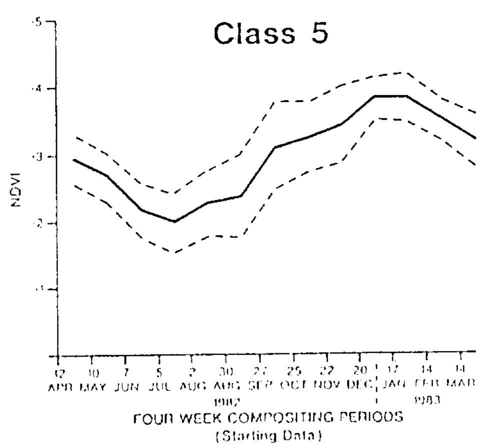
Figure 2. Top of the atmosphere NDVI and SAVI responses of an anisotropic grassland canopy (40% green cover) at 9 view angles, 4 sun angles, and 3 atmospheres.

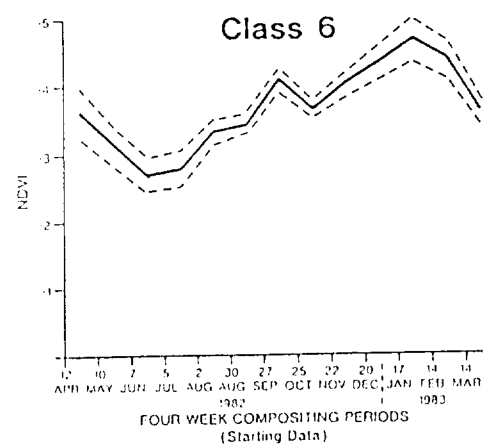

Class 1
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)

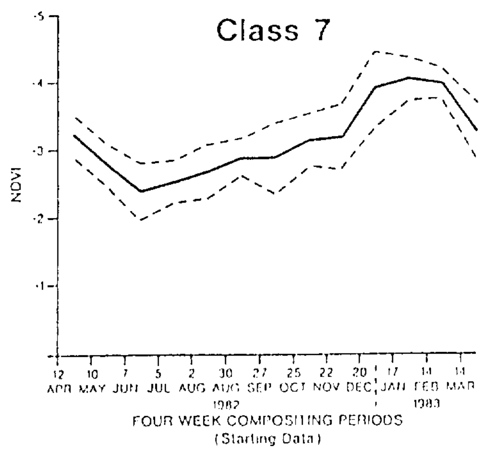

Class 2
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)

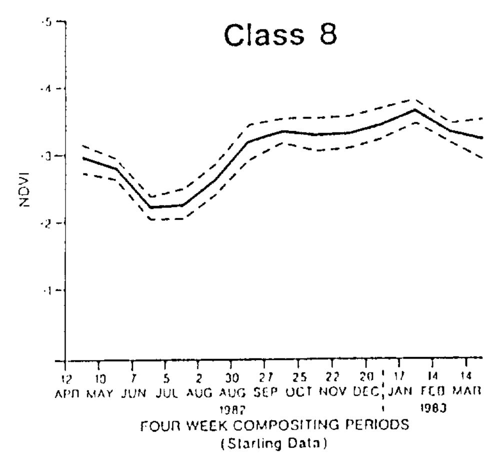

Class 3
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)


Class 4
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)


Class 5
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)


Class 6
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)


Class 7
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)


Class 8
NDVI
·5
·4
·3
·2
·1
12 APR 10 MAY 7 JUN 5 JUL 2 AUG 30 AUG 27 SEP 25 OCT 22 NOV 20 DEC 17 JAN 14 FEB 14 MAR
1982
1983
FOUR WEEK COMPOSITING PERIODS
(Starting Data)

Directional Reflectance of Vegetation

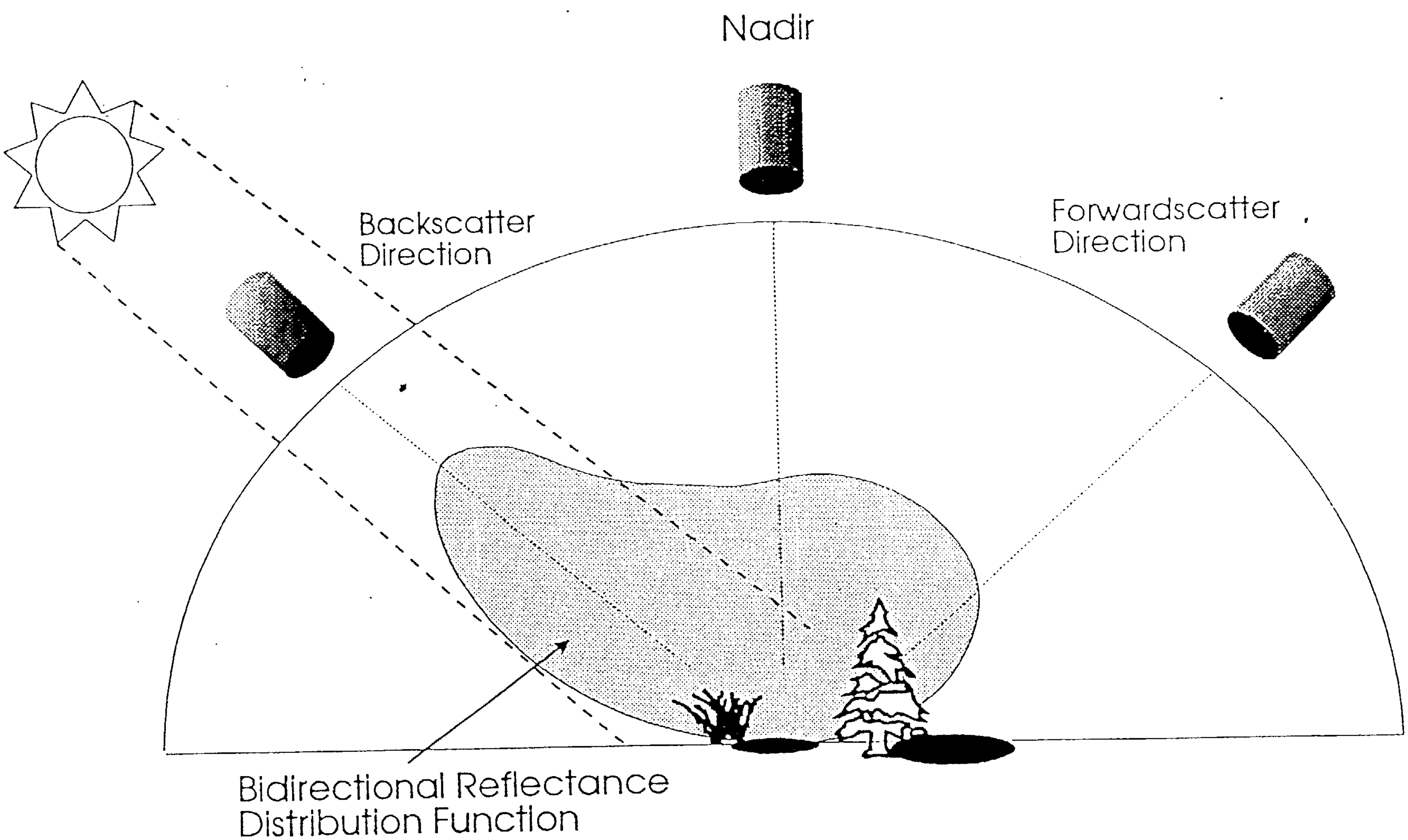
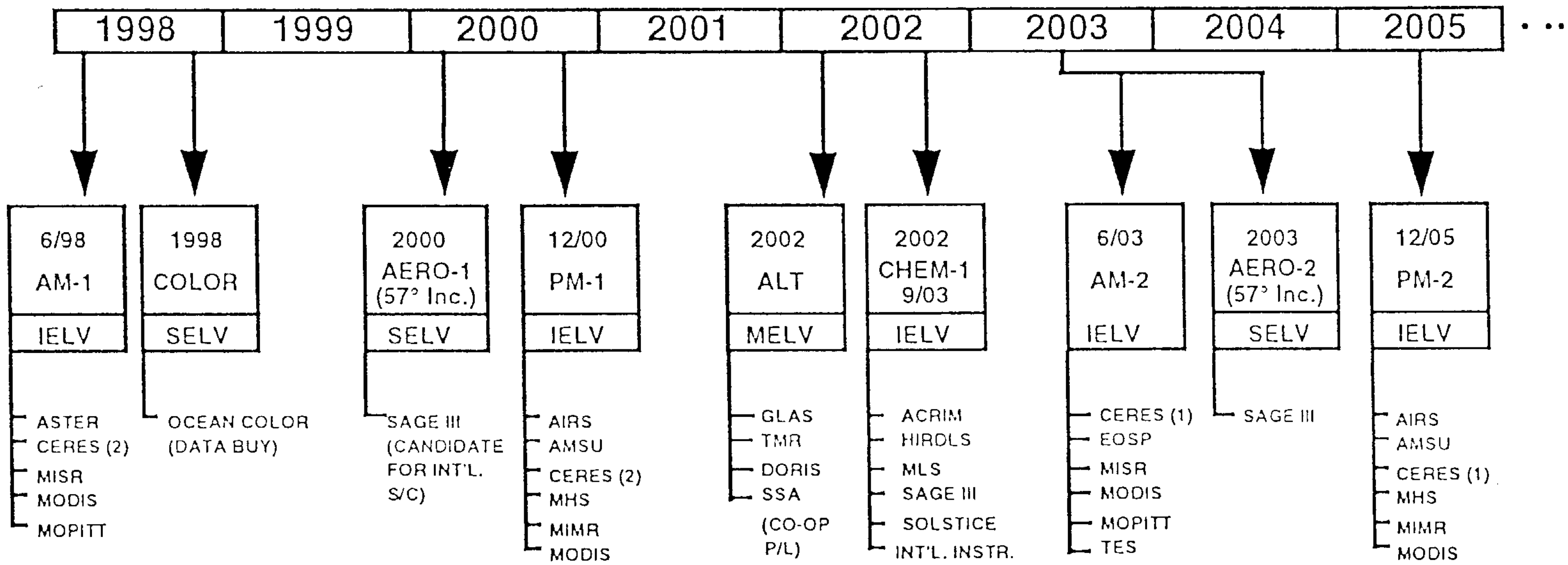


FIGURE 5

EOS Mission Profile



IELV - INTERMEDIATE EXPENDABLE LAUNCH VEHICLE
MELV - MEDIUM EXPENDABLE LAUNCH VEHICLE
SELV - SMALL EXPENDABLE LAUNCH VEHICLE

NOTE:

- SPACECRAFT REFLIGHTS CONTINUE BEYOND 2005 TO SUPPORT GENERATION OF THE 15-YEAR SCIENCE DATA SET
- CERES AND LIS ARE FUNDED FOR THE TRMM MISSION PLANNED FOR LAUNCH IN 1997
- NSCAT II IS FUNDED FOR THE ADEOS II MISSION SCHEDULED FOR LAUNCH IN 2000
- CERES IS FUNDED FOR A MID-INCLINATION FLIGHT PLANNED FOR 2000

Validation Approach:

- Establish relationships to physical parameters
- Use precursor sensors (MAS, ASAS, TM, SeaWifs, AVHRR) to test algorithm
- IFC's, MACs, Modis Test Sites (LTERs, GLCTS, IGBP GCTE sites) to develop validation

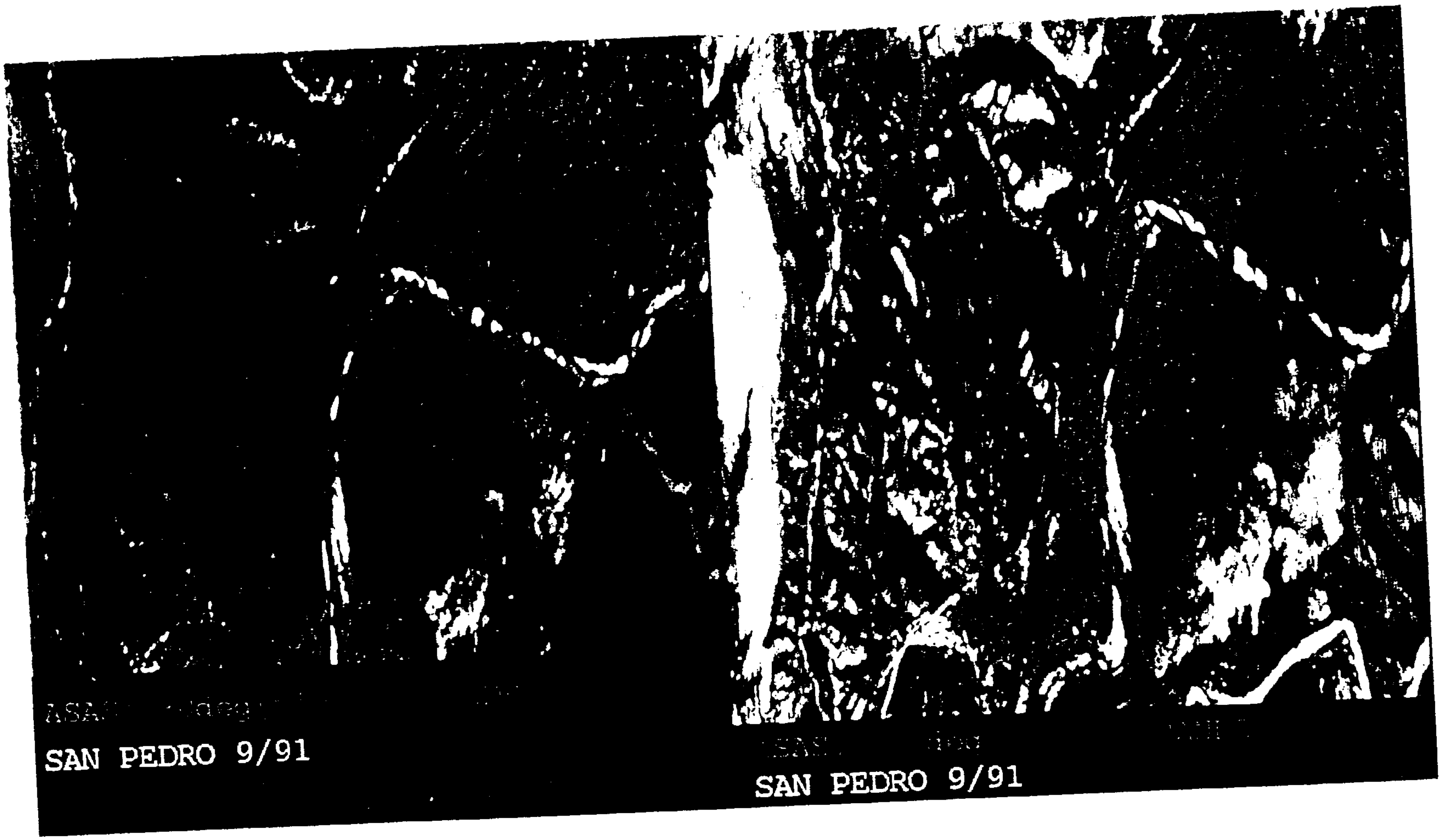
Pre - Launch Research Agenda:

- Test MNDVI for major land cover types
- Develop and evaluate global fields - SeaWifs
- BRDF correction - (nadir / view and sun angle)
- Evaluate impact of surface reflectance product inputs
- Evaluate impact of cloud mask product

CALIBRATION & VALIDATION EXAMPLE

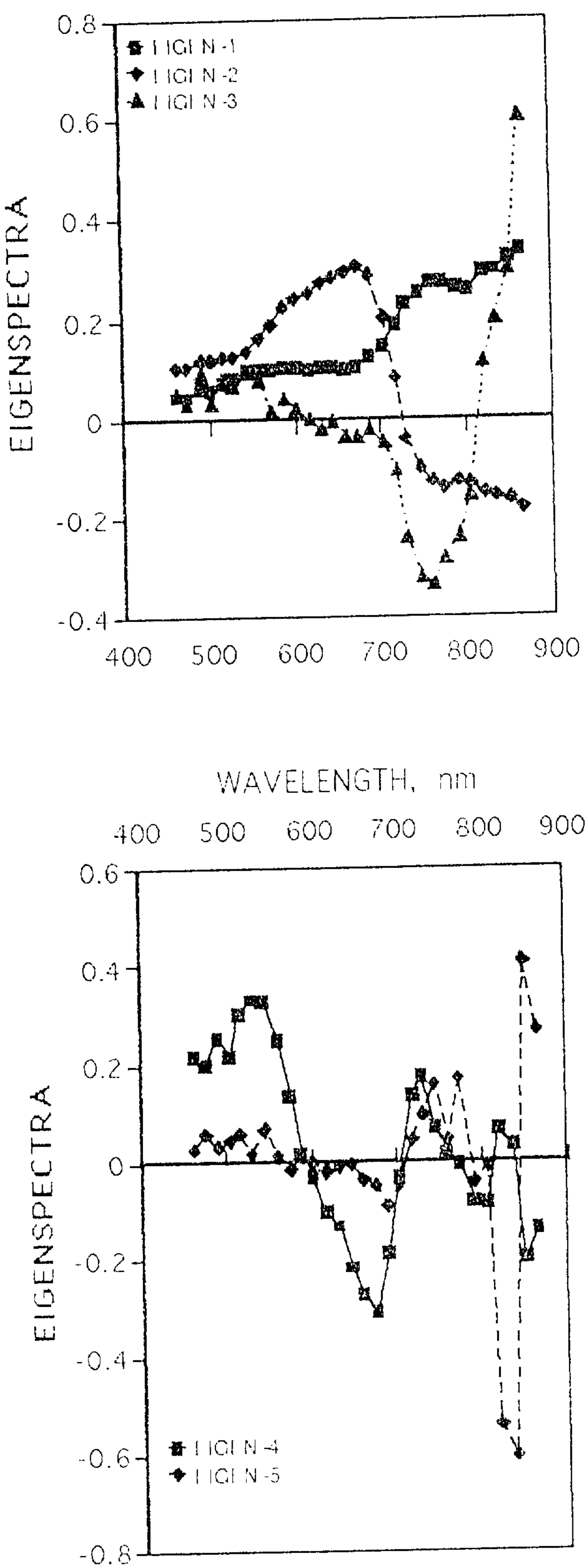
- ASAS data of OTTER and Walnut Gulch experiments
  - — 3-5m pixel size
  - — Biophysical coupling
  - — BRF strings
- TM data of OTTER and Walnut Gulch
  - — MODIS-VIEW Simulation (250 & 500m pixels)
- MODIS VI comparisons over desert, grassland, shrubland, riparian, forest, and rainforest land cover types.

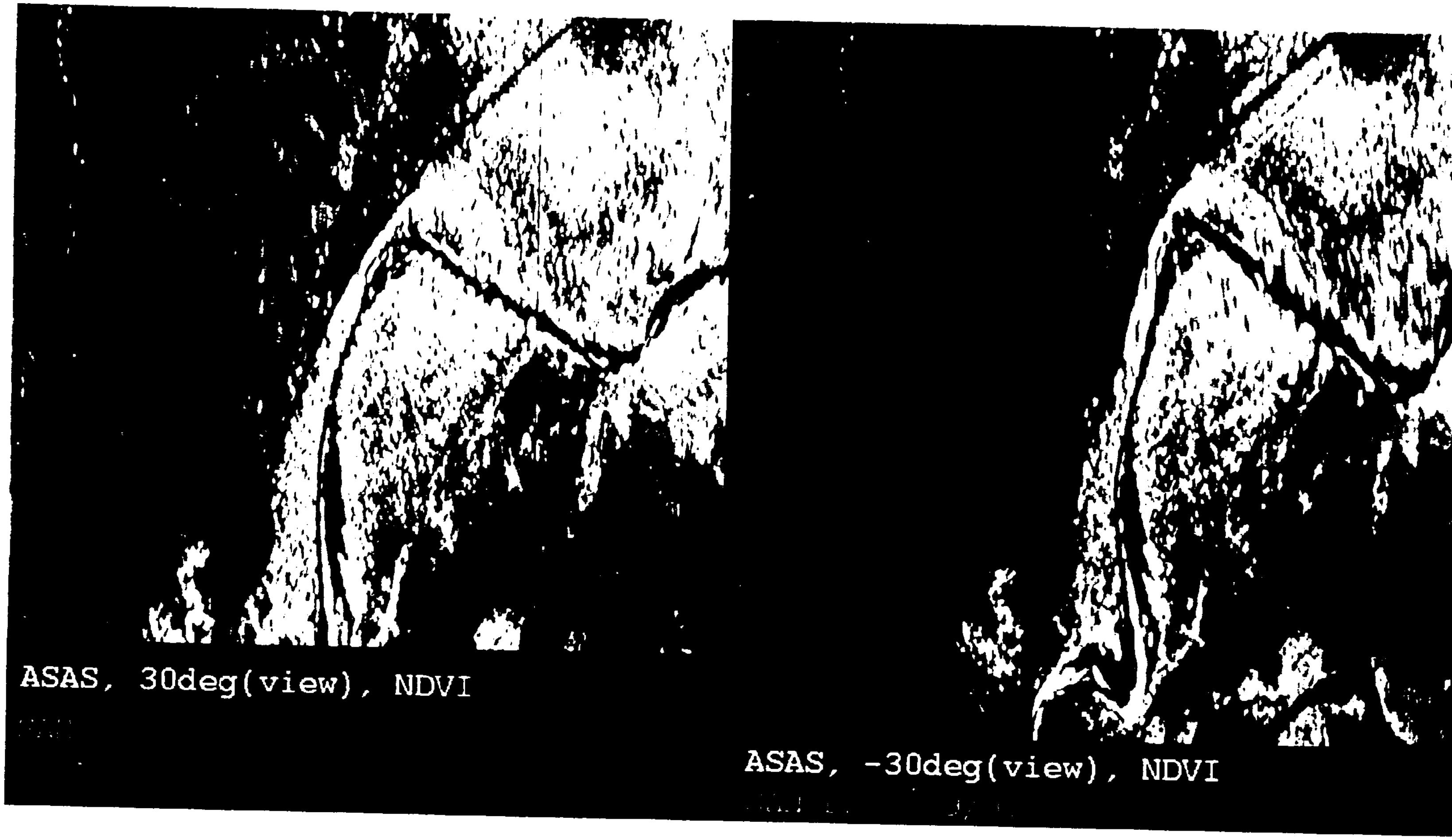
2

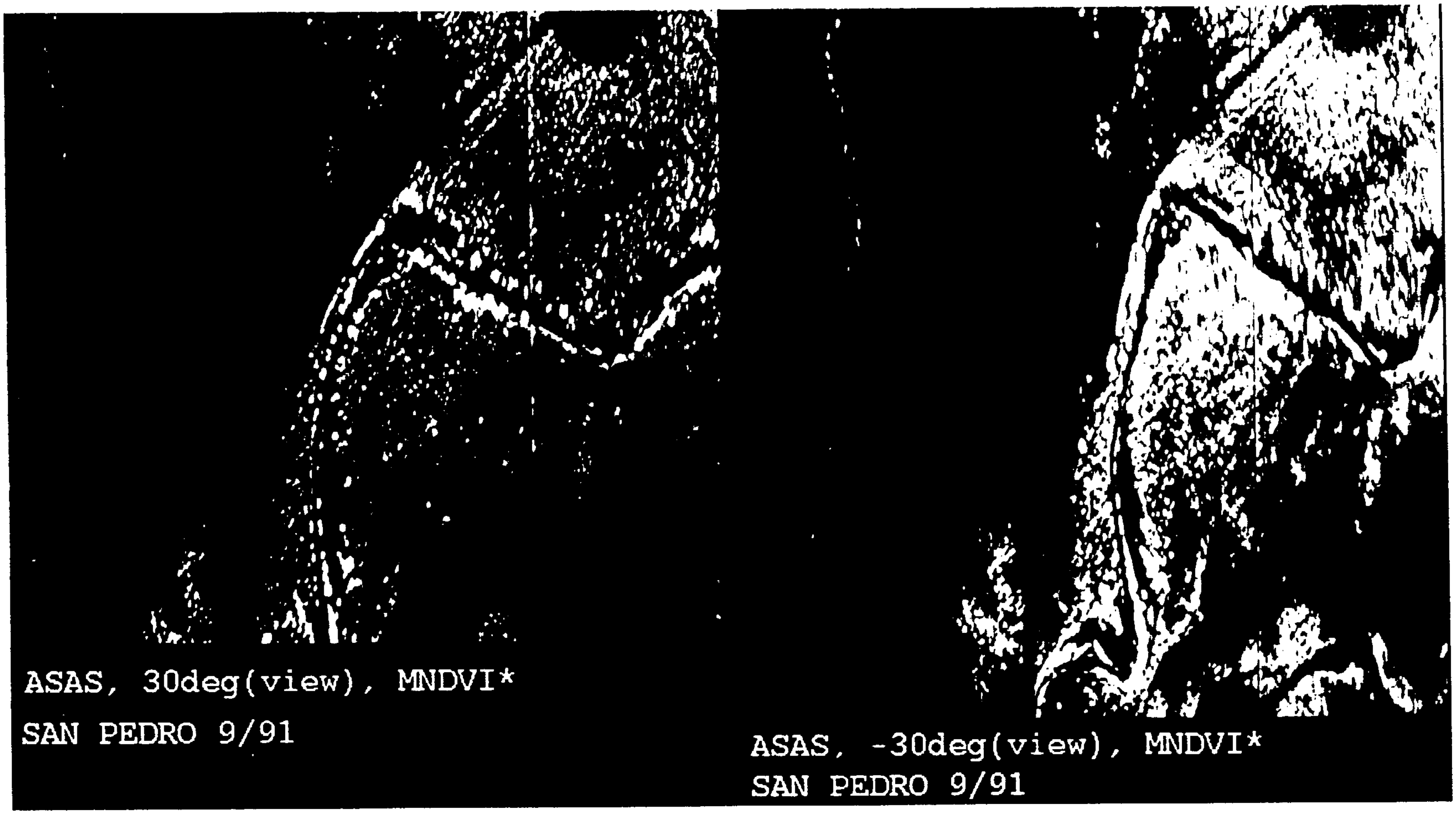

SAN PEDRO 9/91
SAN PEDRO 9/91

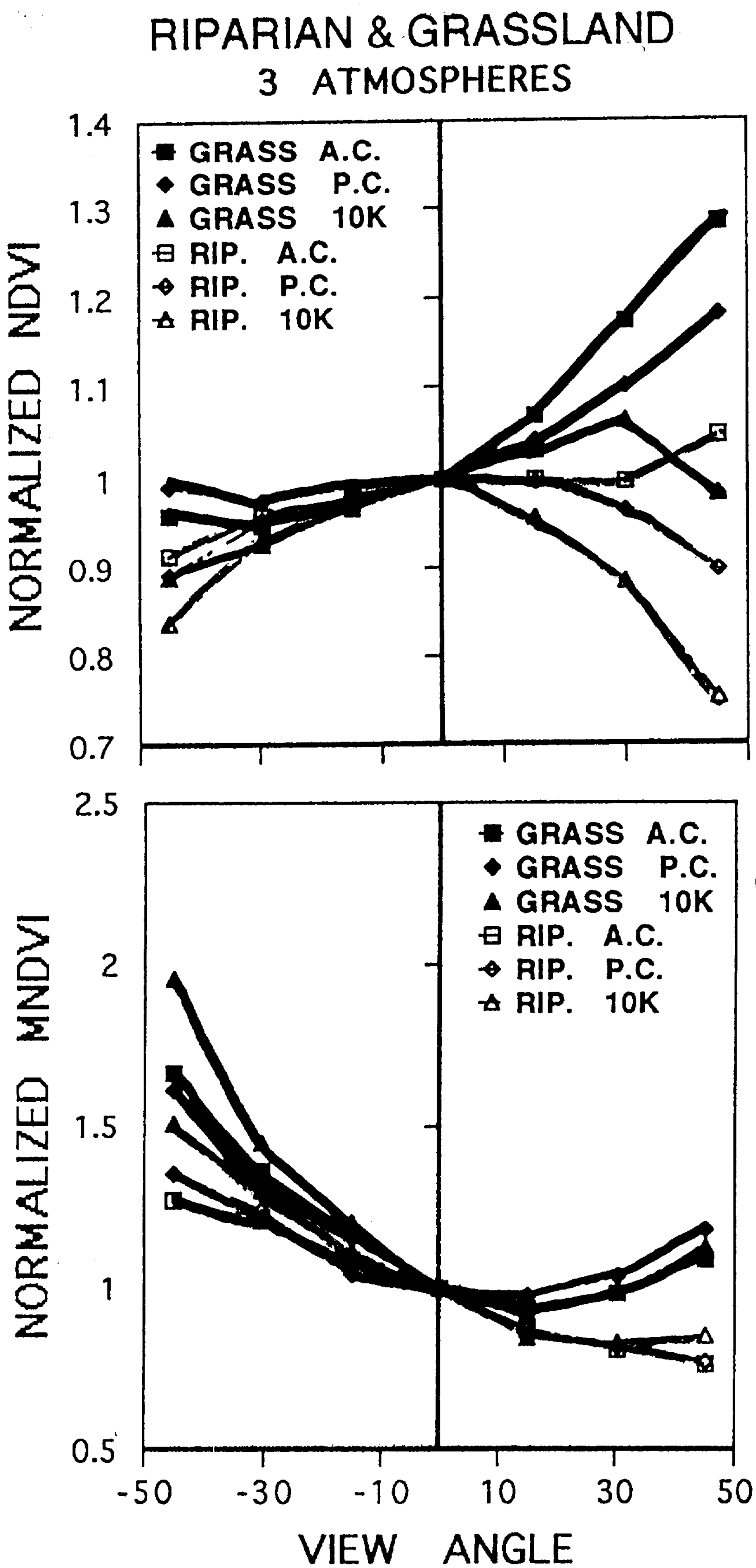
SAN PEDRO ASAS (9/91)

NADIR DATA, ATMOS. CORR.

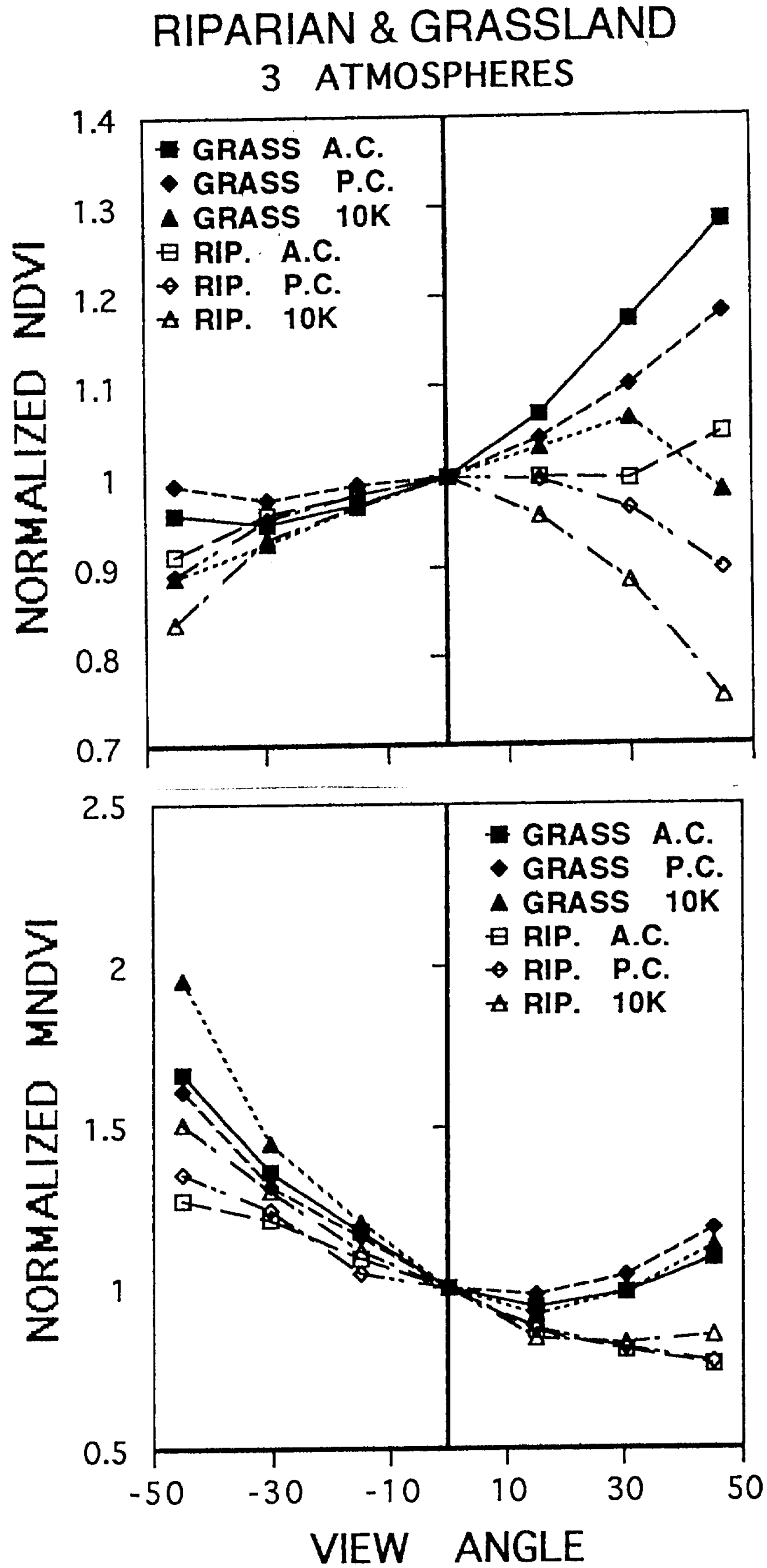


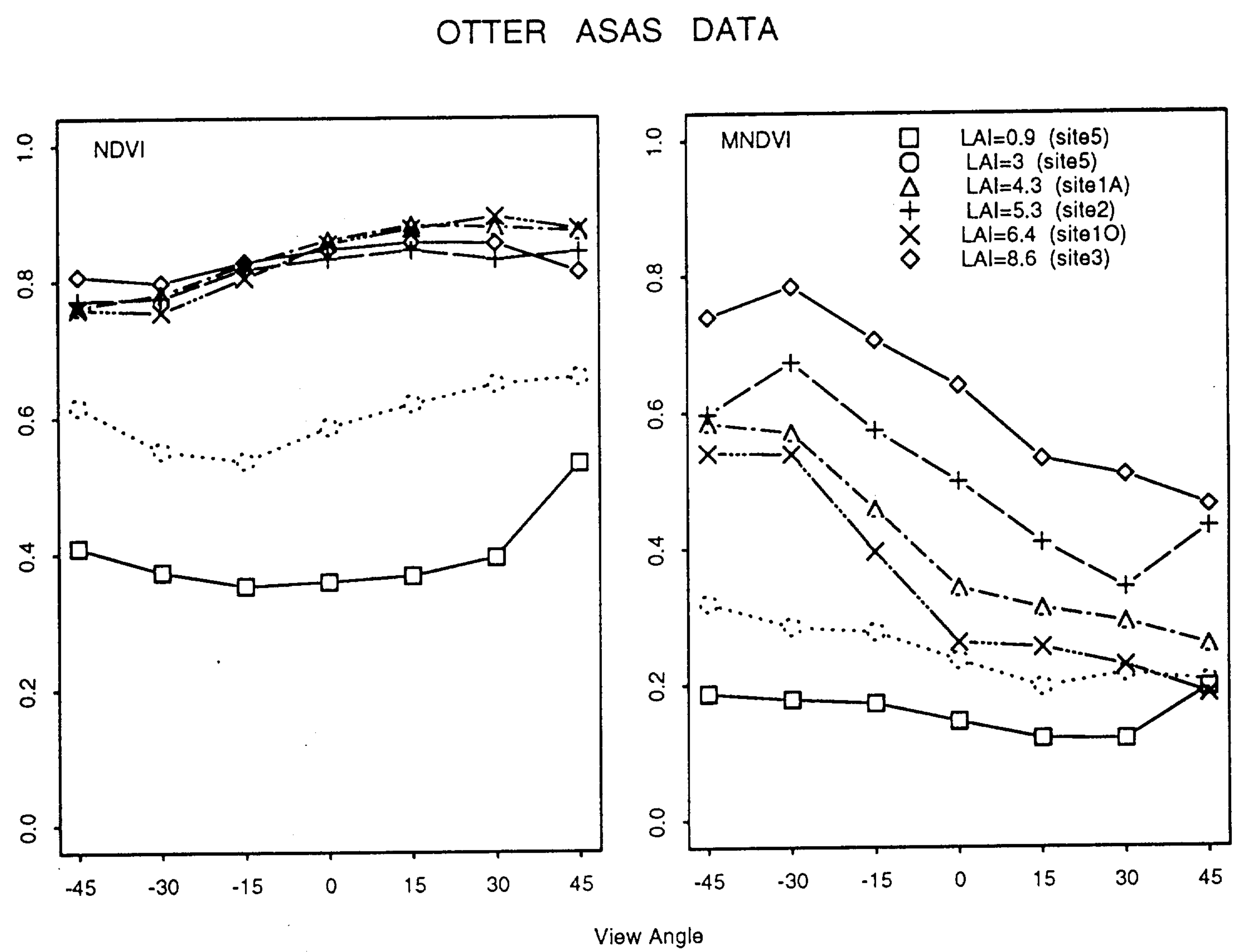

ASAS, 30deg(view), NDVI
ASAS, -30deg(view), NDVI


ASAS, 30deg(view), MNDVI*
SAN PEDRO 9/91
ASAS, -30deg(view), MNDVI*
SAN PEDRO 9/91



- GRASSLAND
- MESQUITE BOSQUE


RIPARIAN & GRASSLAND
3 ATMOSPHERES
NORMALIZED NDVI
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
GRASS A.C.
GRASS P.C.
GRASS 10K
RIP. A.C.
RIP. P.C.
RIP. 10K
NORMALIZED MNDVI
2.5
2
1.5
1
0.5
GRASS A.C.
GRASS P.C.
GRASS 10K
RIP. A.C.
RIP. P.C.
RIP. 10K
-50
-30
-10
10
30
50
VIEW ANGLE


OTTER ASAS DATA
NDVI
MNDVI
LAI=0.9 (site5)
LAI=3 (site5)
LAI=4.3 (site1A)
LAI=5.3 (site2)
LAI=6.4 (site1O)
LAI=8.6 (site3)
0.0
0.2
0.4
0.6
0.8
1.0
-45
-30
-15
0
15
30
45
View Angle

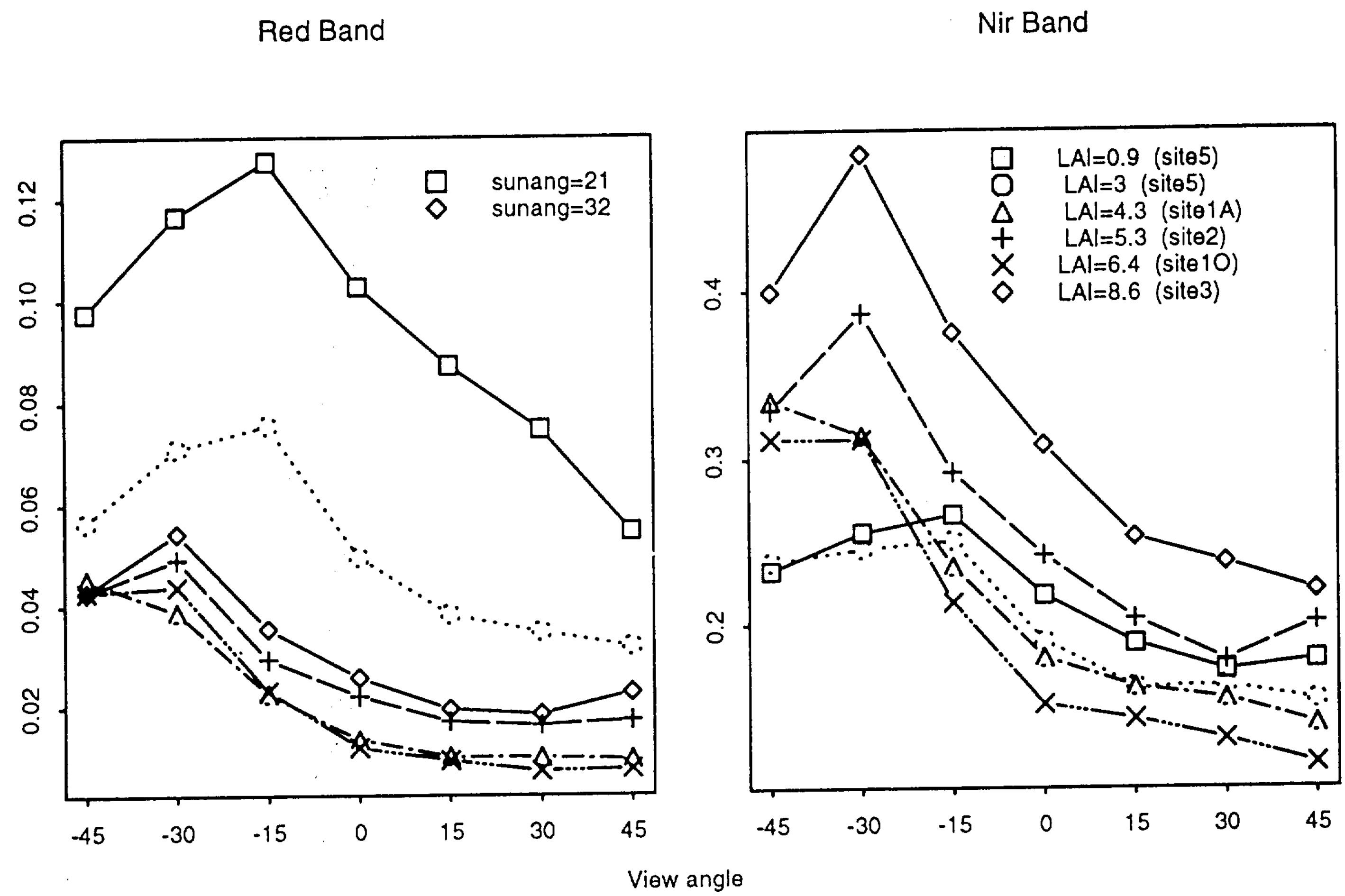
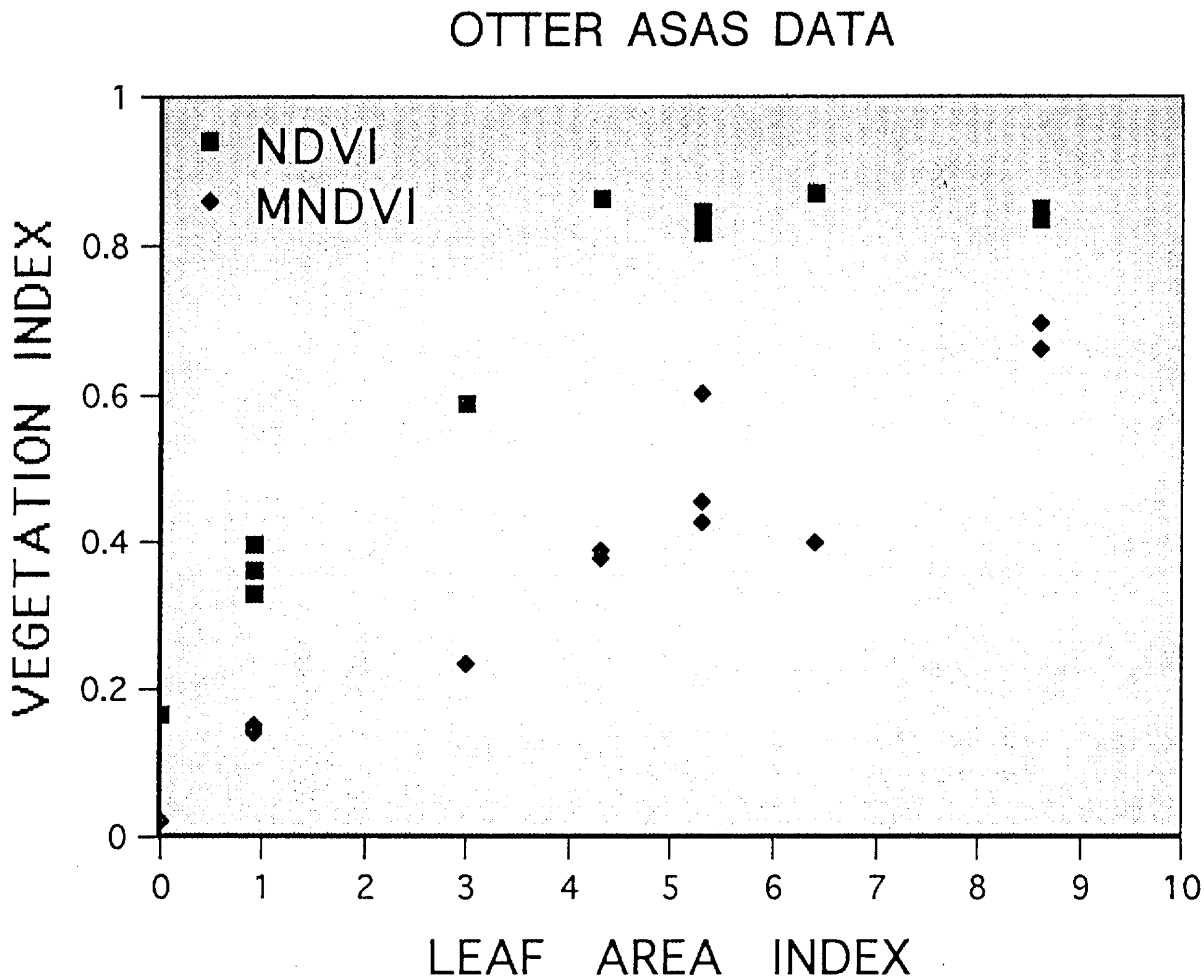


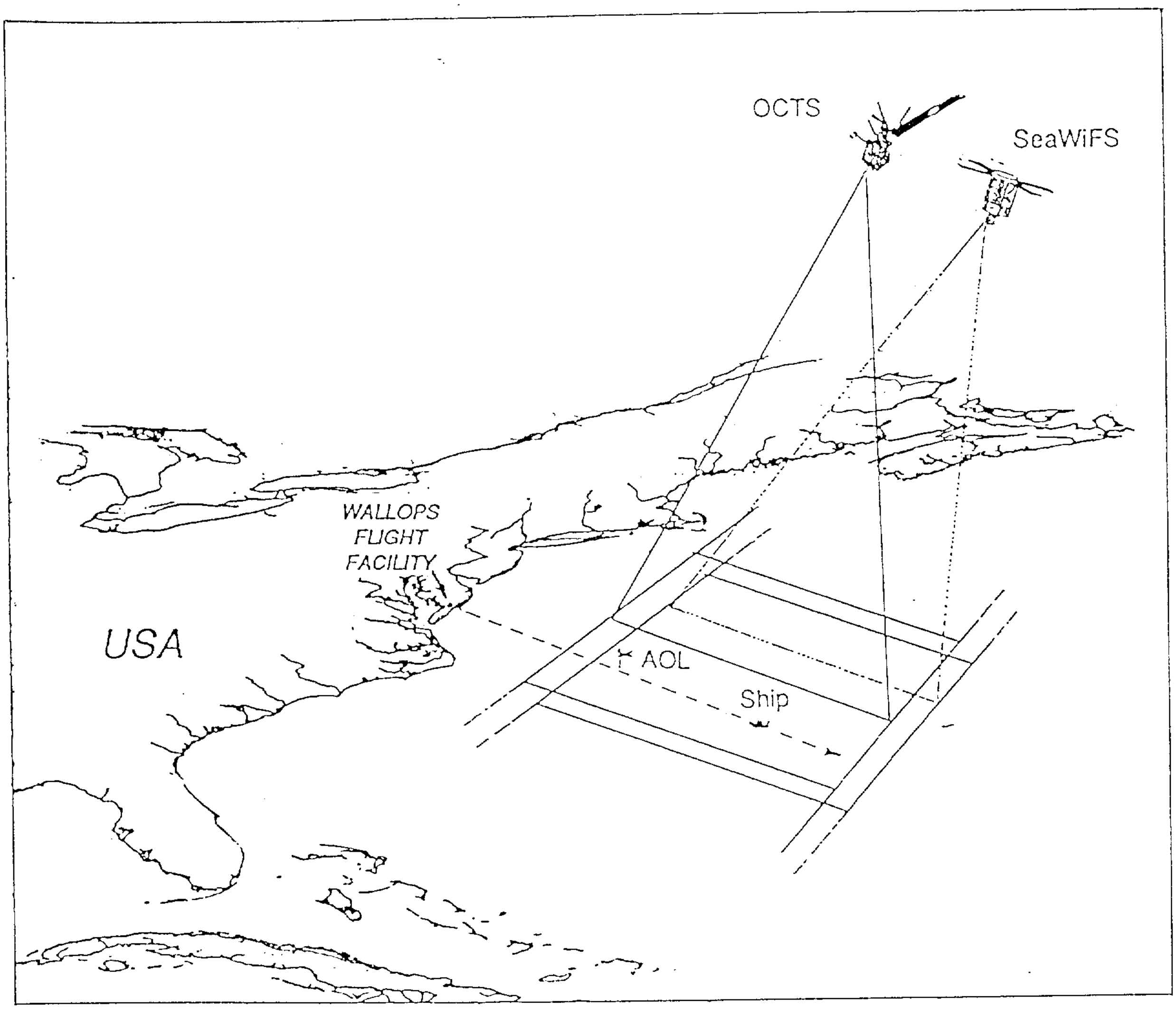
Fig Reflectance of Red and Nir bands with different LAI extracted from OTTER ASAS



OTTER ASAS DATA
NDVI
MNDVI
VEGETATION INDEX
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5
6
7
8
9
10
LEAF AREA INDEX

CALIBRATION & VALIDATION

- Current Activities
  - — TM-ASAS analyses over HAPEX-Sahel
  - — TM-MAS analyses over the Virginia LTER (SCAR)
  - — Biophysical coupling
    - empirical
    - SAIL and Myneni canopy models
  - — Atmosphere and background analyses
    - sun photometer network
    - field sampling
- Future Activities
  - — Field experiments
    - BOREAS
    - SCAR
    - LAMBADA


OCTS
SeaWiFS
WALLOPS
FLIGHT
FACILITY
USA
AOL
Ship

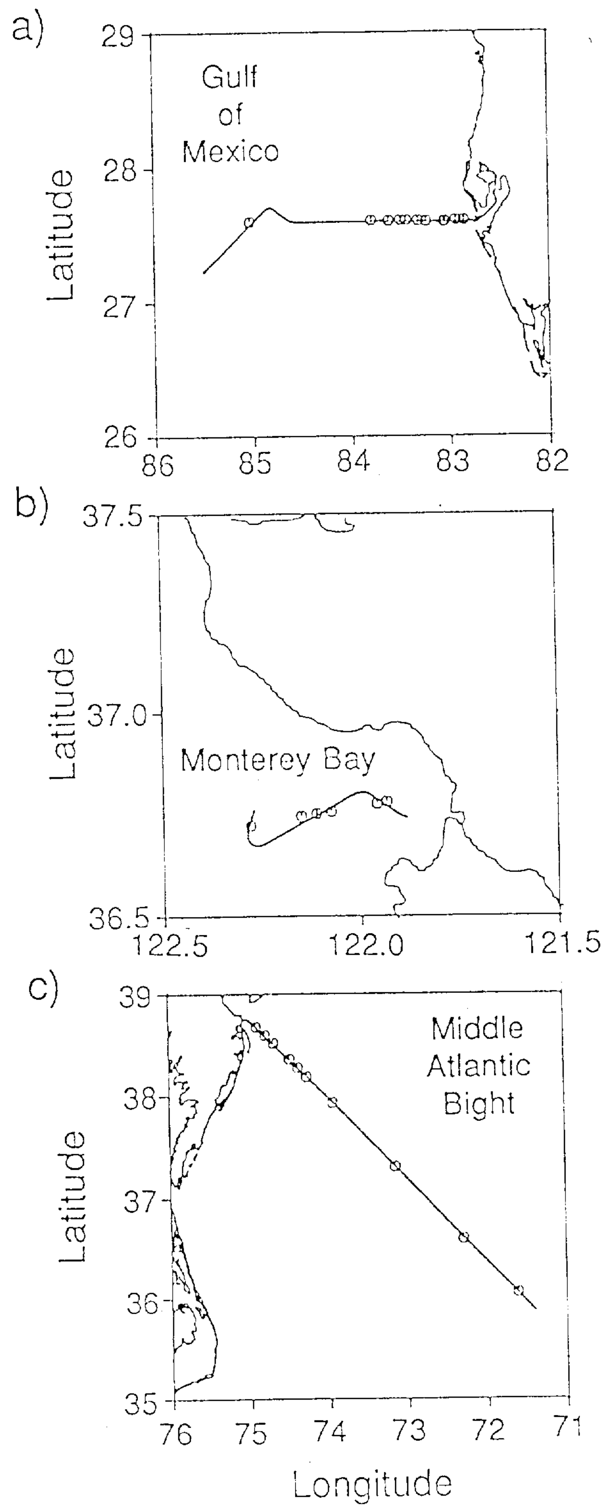
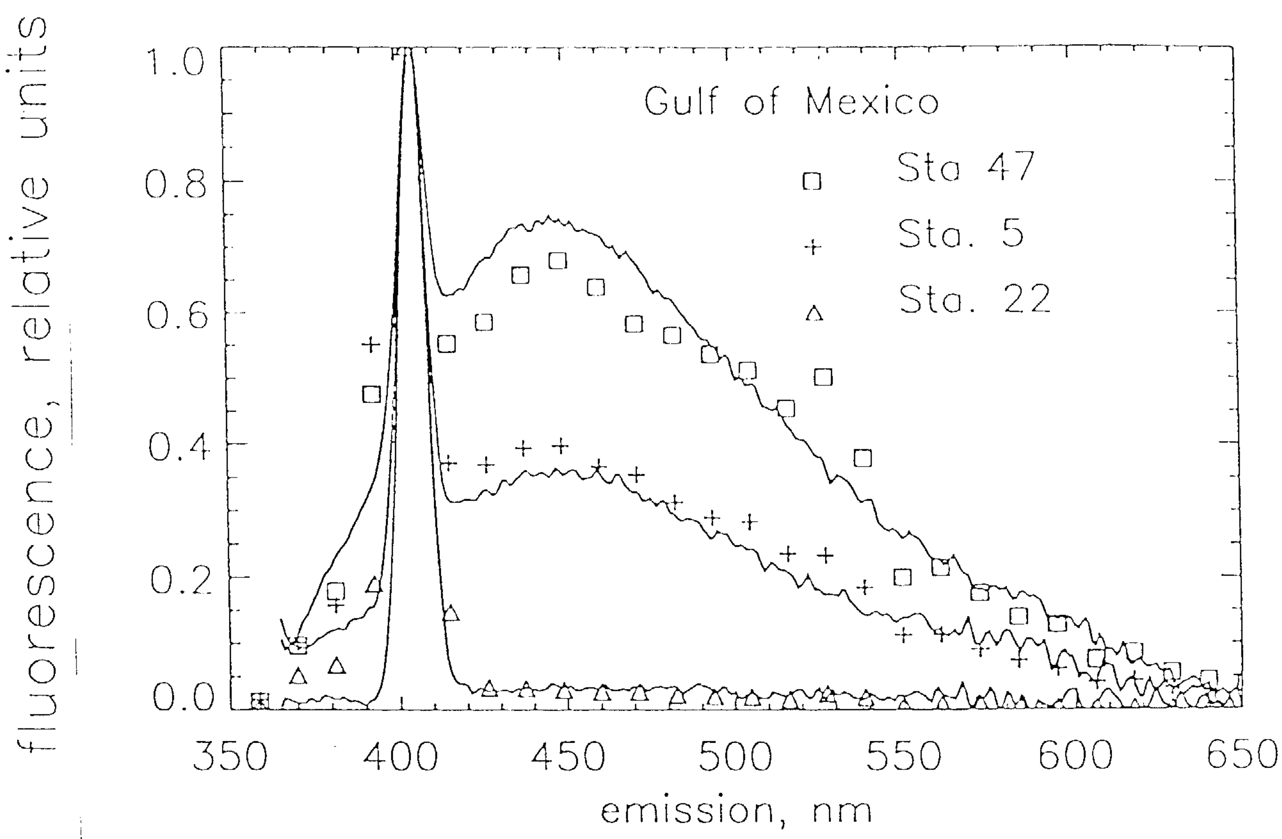
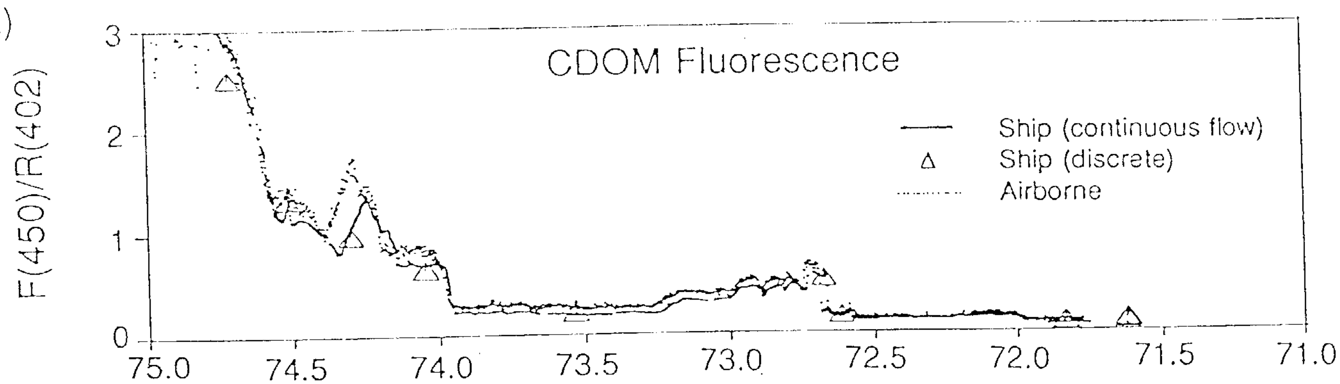

a)
b)
c)
Gulf
of
Mexico
Monterey Bay
Middle
Atlantic
Bight
Latitude
Longitude
29
28
27
26
86
85
84
83
82
37.5
37.0
36.5
122.5
122.0
121.5
39
38
37
36
35
76
75
74
73
72
71

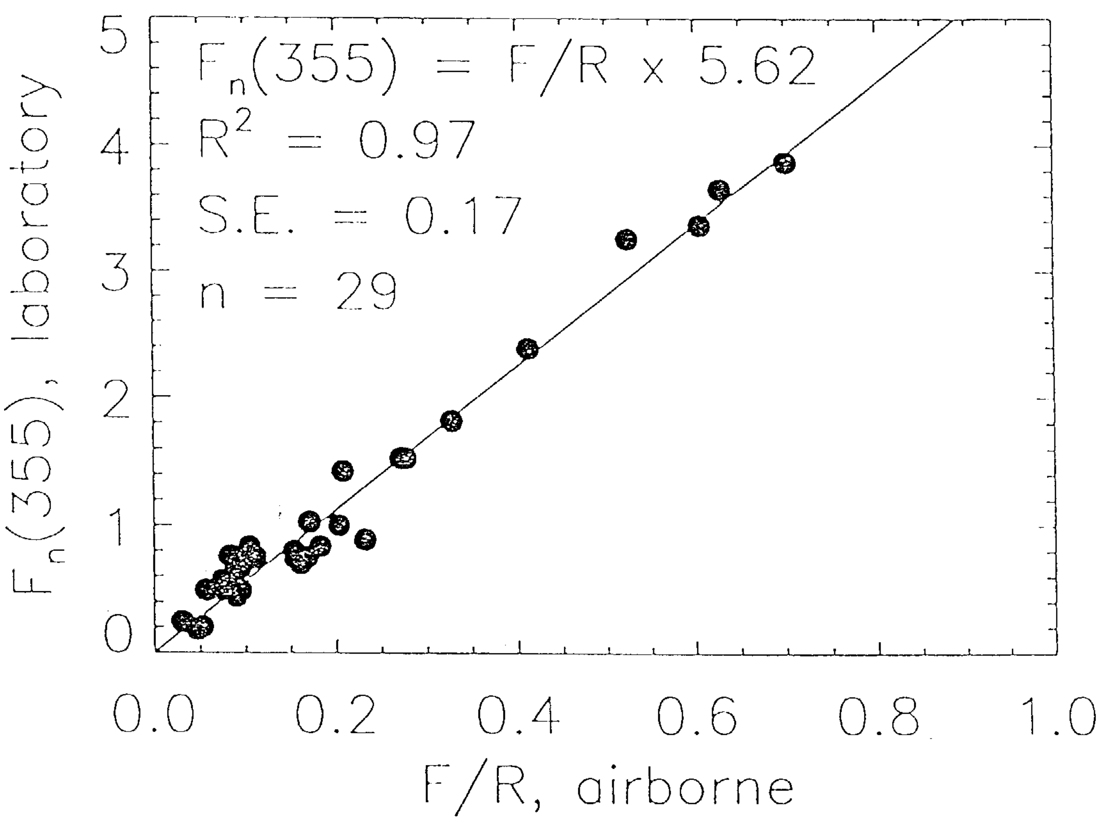
Figure 1



Gulf of Mexico
Sta 47
Sta. 5
Sta. 22
fluorescence, relative units
emission, nm
1.0
0.8
0.6
0.4
0.2
0.0
350
400
450
500
550
600
650

a)


CDOM Fluorescence
F(450)/R(402)
Ship (continuous flow)
Ship (discrete)
Airborne
0
1
2
3
75.0
74.5
74.0
73.5
73.0
72.5
72.0
71.5
71.0



$F_n(355) = F/R \times 5.62$
$R^2 = 0.97$
S.E. = 0.17
n = 29
$F_n(355)$, laboratory
F/R, airborne
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0

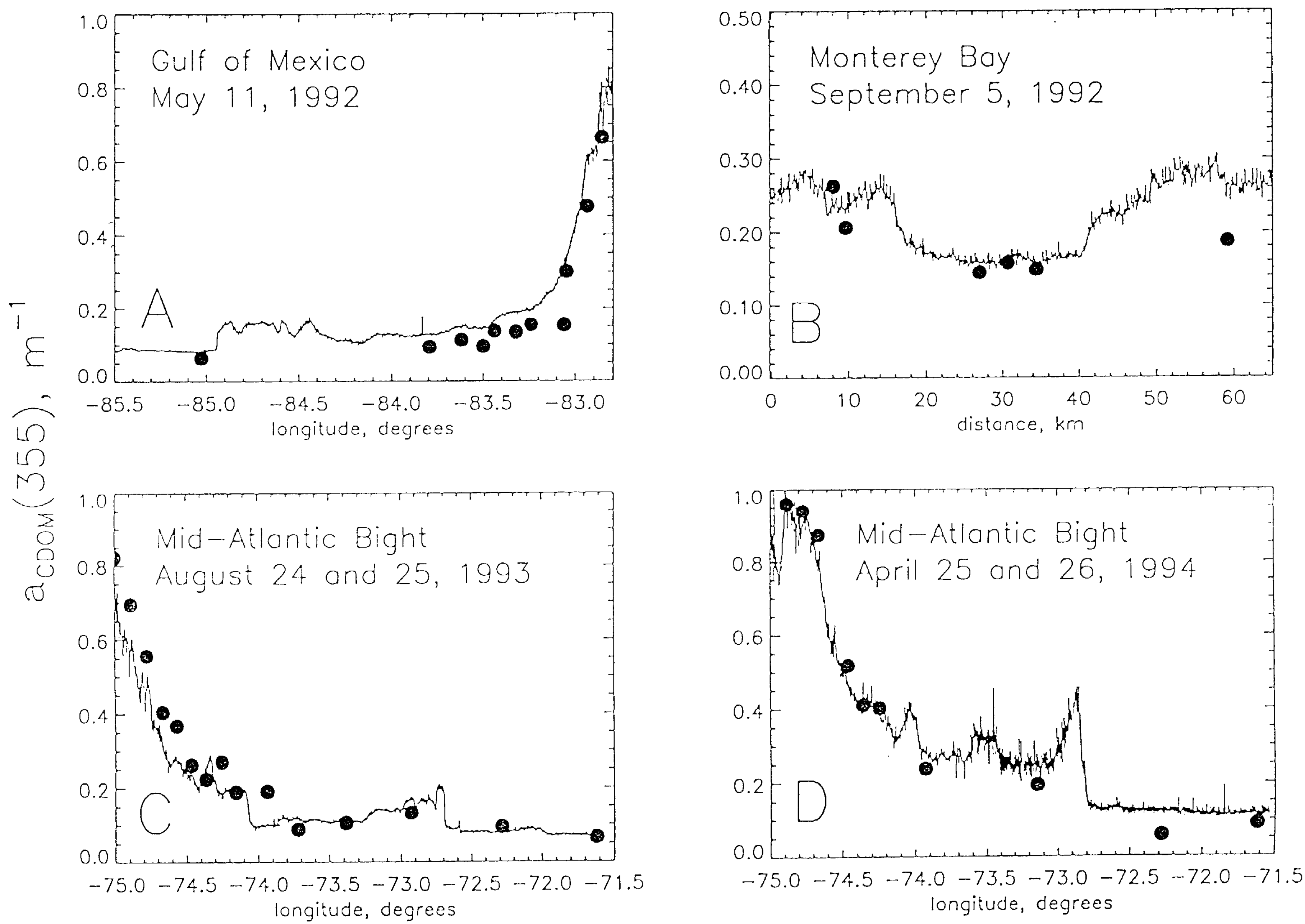

Gulf of Mexico
May 11, 1992
A
longitude, degrees
Monterey Bay
September 5, 1992
B
distance, km
Mid-Atlantic Bight
August 24 and 25, 1993
C
longitude, degrees
Mid-Atlantic Bight
April 25 and 26, 1994
D
longitude, degrees
$a_{CDOM}(355)$, m^{-1}

Figure 4