Retrieval of Water and Dry Matter Content from Leaf, Canopy and Image Scales

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Why Measure Canopy Water Content?

Plant water relations determine fundamental ecosystem processes through carbon and water cycles

- transpiration & carbon gain
- energy partitioning (H and LE)
- drought stress and wildfire risk
- agricultural water demand

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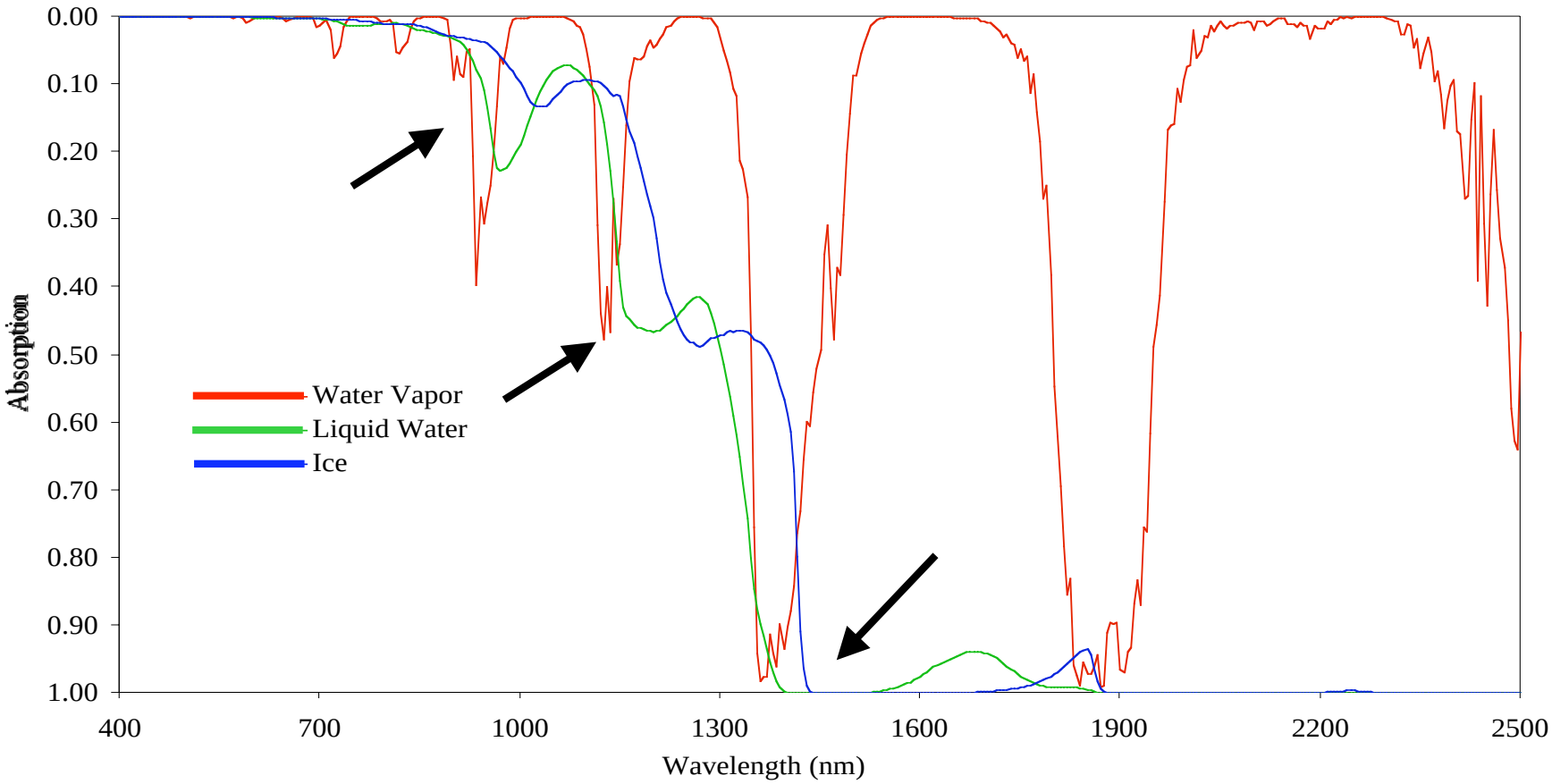
Objective: A multi-scale approach to validate estimates of canopy water content from MODIS data

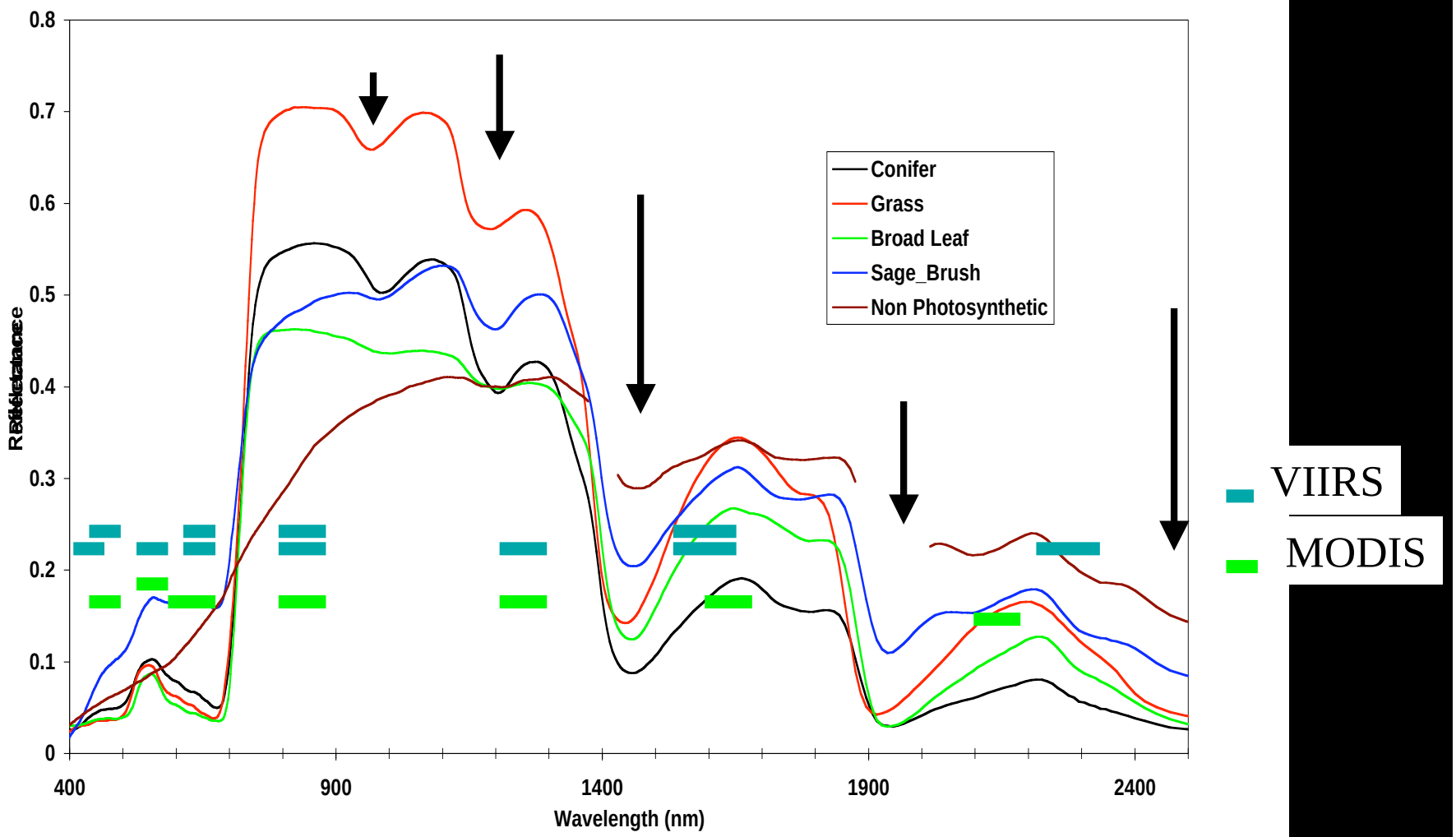
- Theoretical basis: RTM Leaf & Canopy
- Empirical: Leaf to canopy
- Cross Validation between Images
  - AVIRIS (~20m) -- EWT
  - MODIS (500m) -- band ratio indexes NDVI, EVI, NDWI, SIWSI
  - MODIS (500m) – RTM canopy water content MODIS PRODUCT
- Correlation of temporal variation in canopy water with hydrological and ecological processes

Atmospheric Absorption of Water Vapor, Liquid, & Solid in the Reflected Solar Spectrum



Water absorptions overlap, but are displaced between 800 and 1500 nm

Leaf Spectra and Water Absorption Features in the Optical Domain



- Equivalent water thickness

$$EWT\left(\frac{g}{cm^2}\right) = \frac{W_f - W_d}{A}$$

W_f = Fresh weight
W_d = Dry weight
A = Leaf Area
LAI = Leaf Area Index

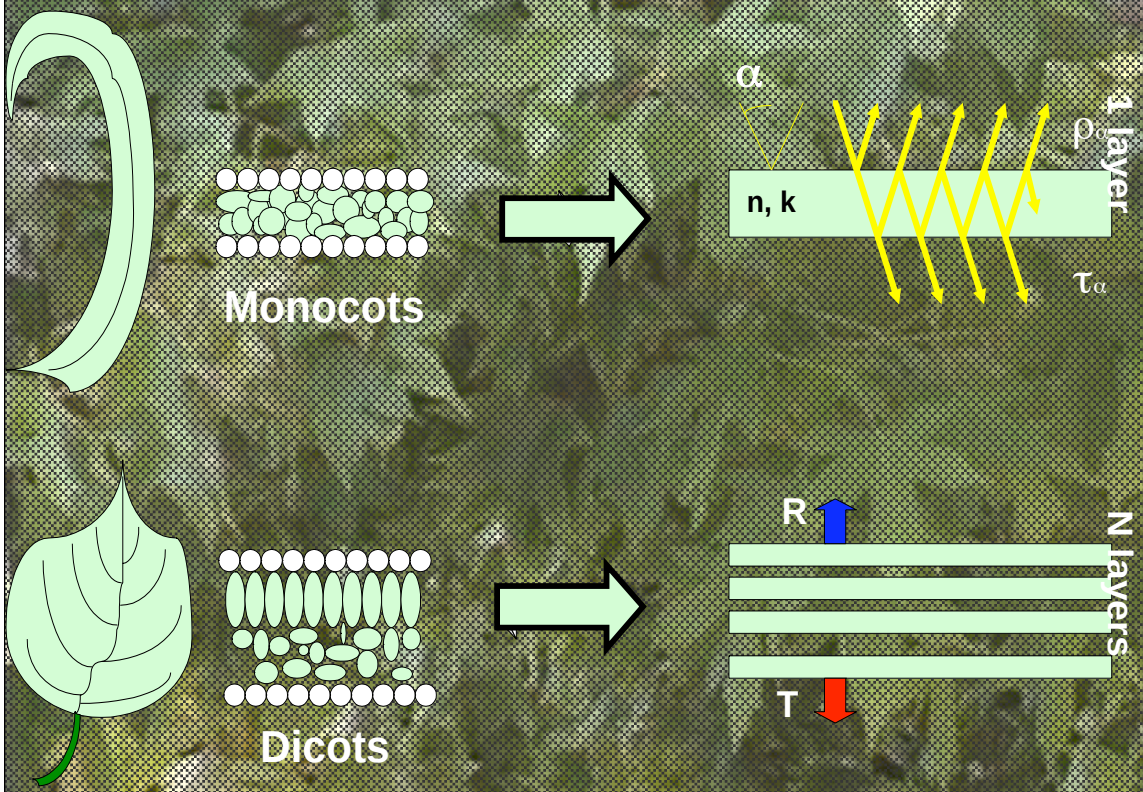
- Canopy water content

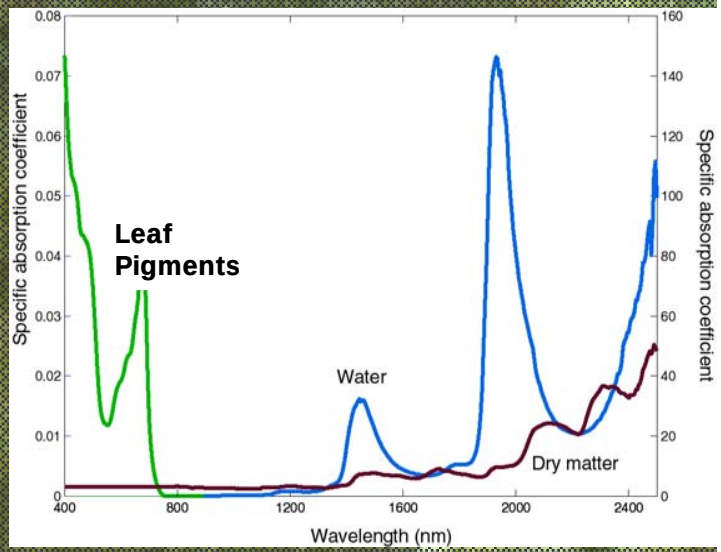
$$CWC = EWT_C = EWT_L * LAI$$

REMOTE SENS. ENVIRON. 34:75–91 (1990)

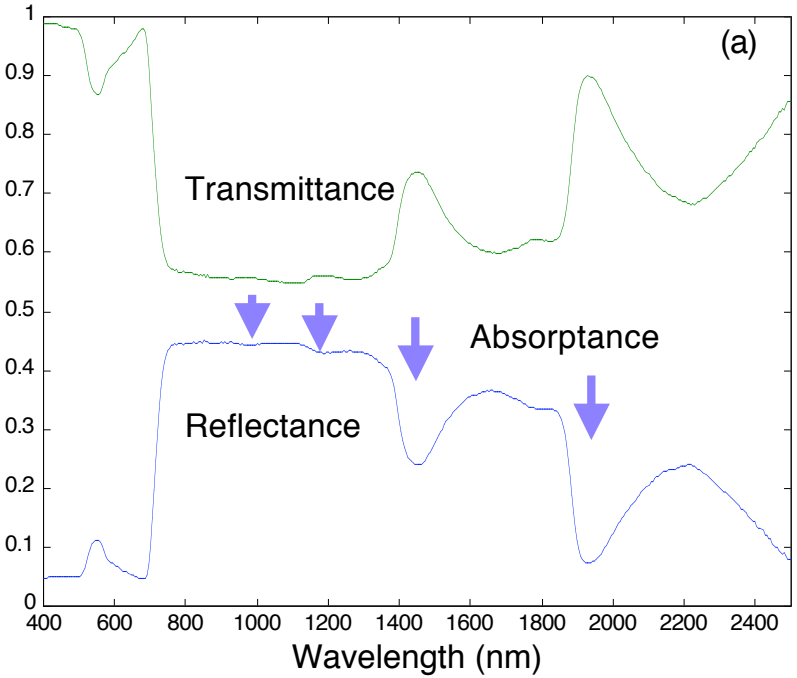
PROSPECT: A Model of Leaf Optical Properties Spectra

S. Jacquemoud and F. Baret
INRA, Station de Bioclimatologie, Montfavet, France

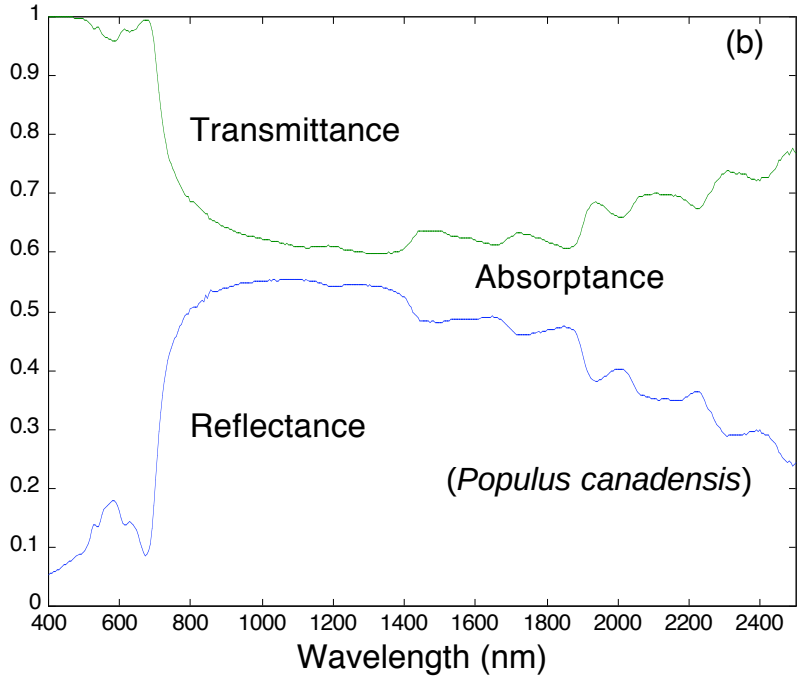




Fresh leaf



Dry leaf



Water Absorption Features:

V1 (H–O–H symmetric stretch mode transition),

V2 (H–O–H bending mode transition), and

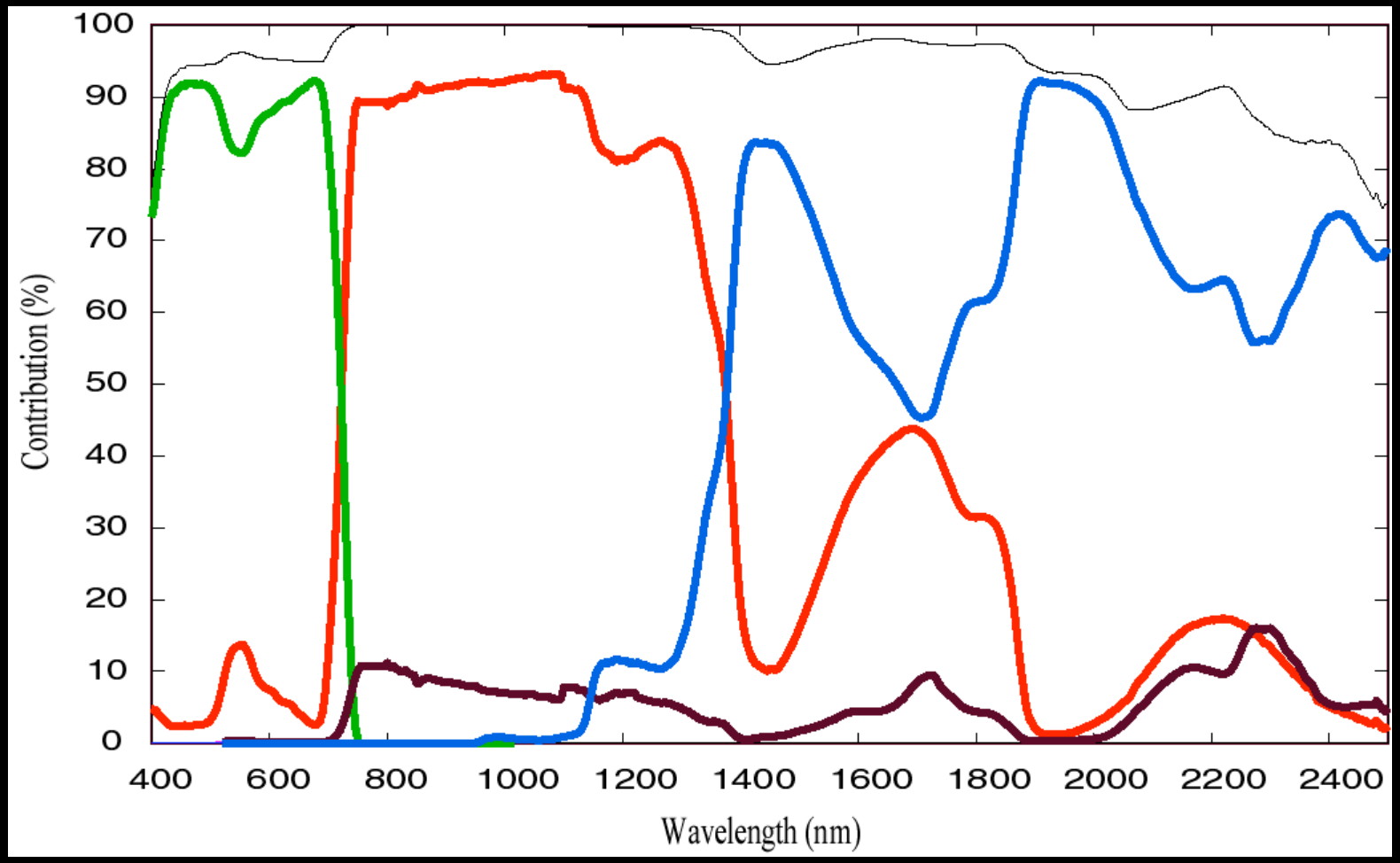
V3 (H–O–H asymmetric stretch mode transition)

970 nm attributed to a V1 + V3 combination
1200 nm to a V1 + V2 + V3 combination
1450 nm to a V1 + V3 combination
1900 nm to a V2 + V3 combination

(Jacquemoud and Ustin, EARSeL, 2003)

PROSPECT Sensitivity Analysis

Sum of the contributions to reflectance



Leaf structure parameter, N

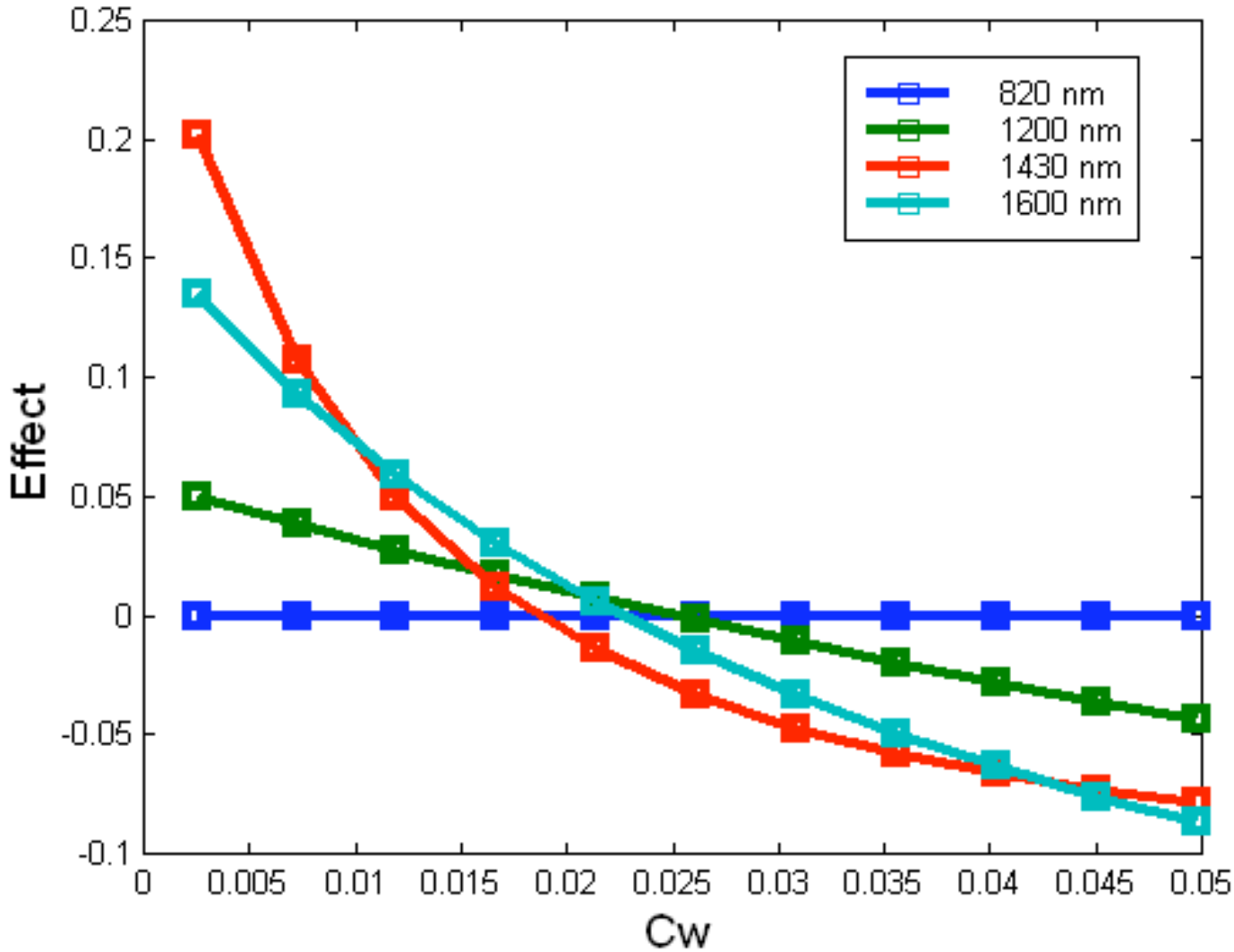
Chlorophyll content, C_{ab}

Equivalent water thickness, C_w

Dry matter content, C_m

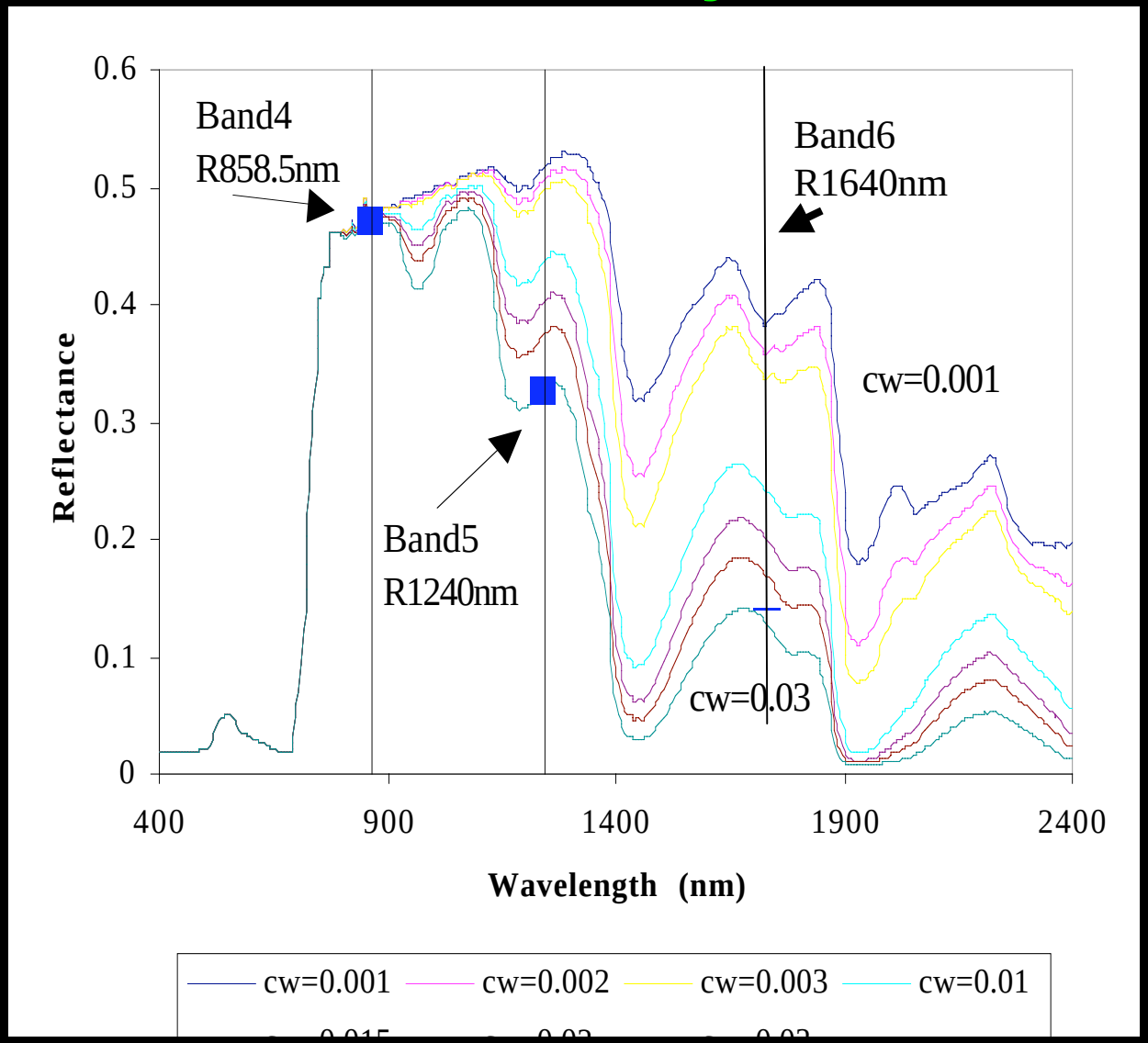
Source: Gabriel Pavan (LED)

PROSPECT: Sensitivity Analysis



P. Bowyer, C. Bacour, S. Jacquemoud, F.M. Danson, 2006, Global sensitivity analyses in remote sensing,(in preparation)

Effect of Leaf Water Content on Leaf Reflectance Predicted by PROSPECT Model



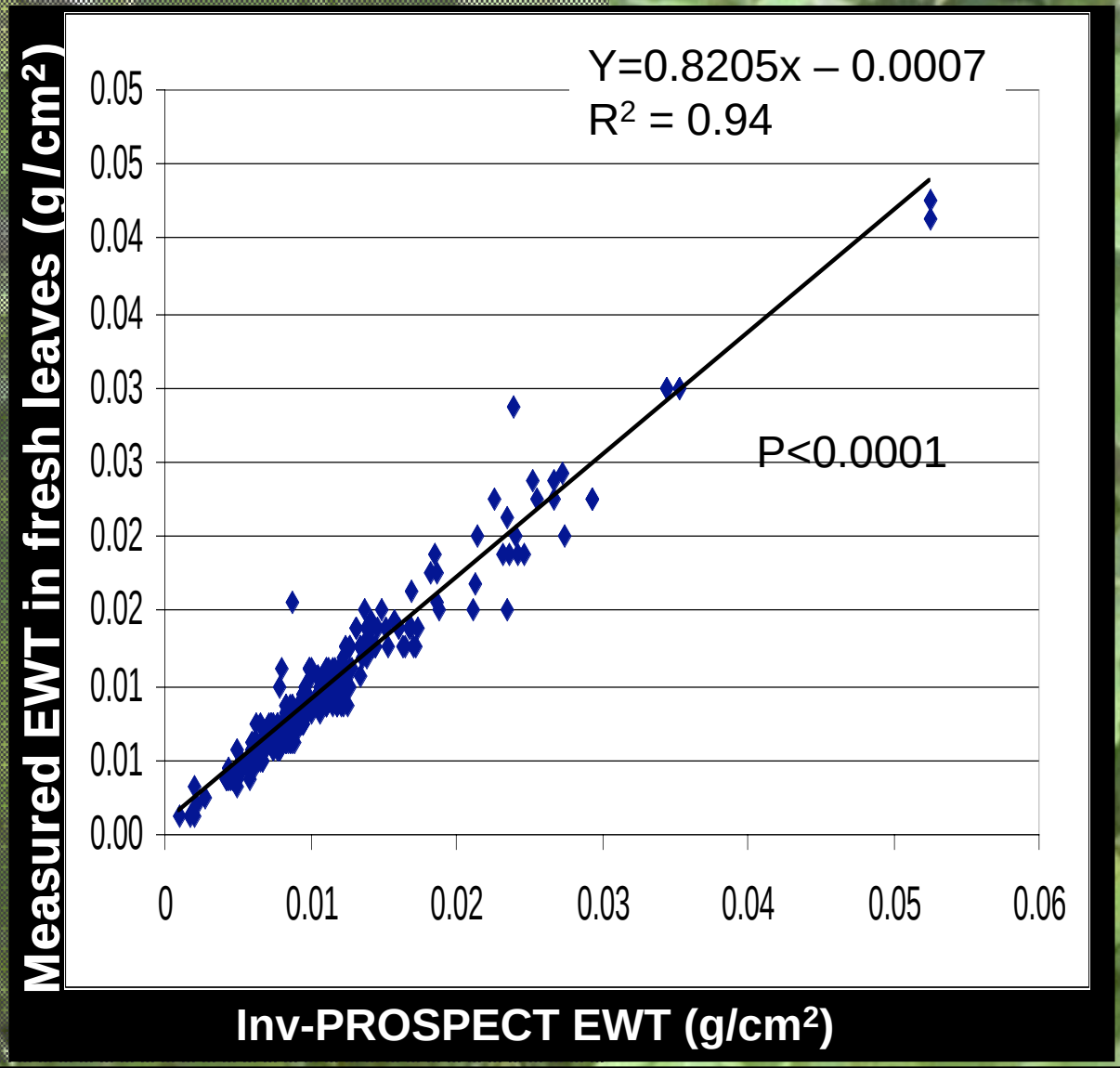
MODIS Band Placement and CWC

MODIS Water Index (SRWI):

$$\mathrm{SRWI} = \frac{R858}{R1240}$$

(Pablo Zarco-Tejada *et al.*, 2001 IGARS; Rem. Sens. Env. 2003)

EWT Estimated in Fresh Leaves



LOPEX data (n=245) Simulated Using PROSPECT

(Jacquemoud et al., 1996; (Riaño et al., IEEE 2005)

Case Studies and Methods

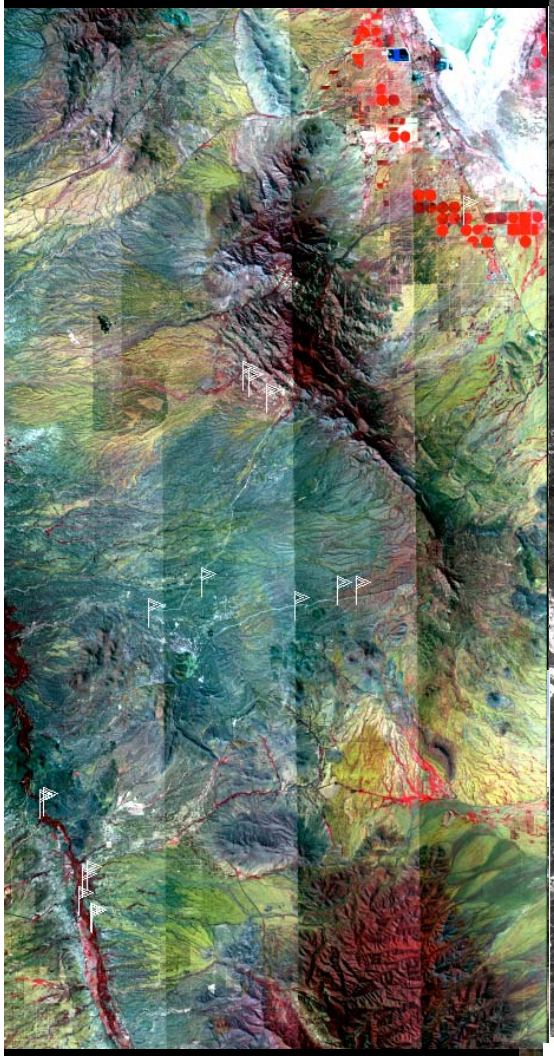
Walnut Gulch, AZ
semiarid grass-shrub

- Field data
- AVIRIS EWT
- MODIS indexes
- Precipitation

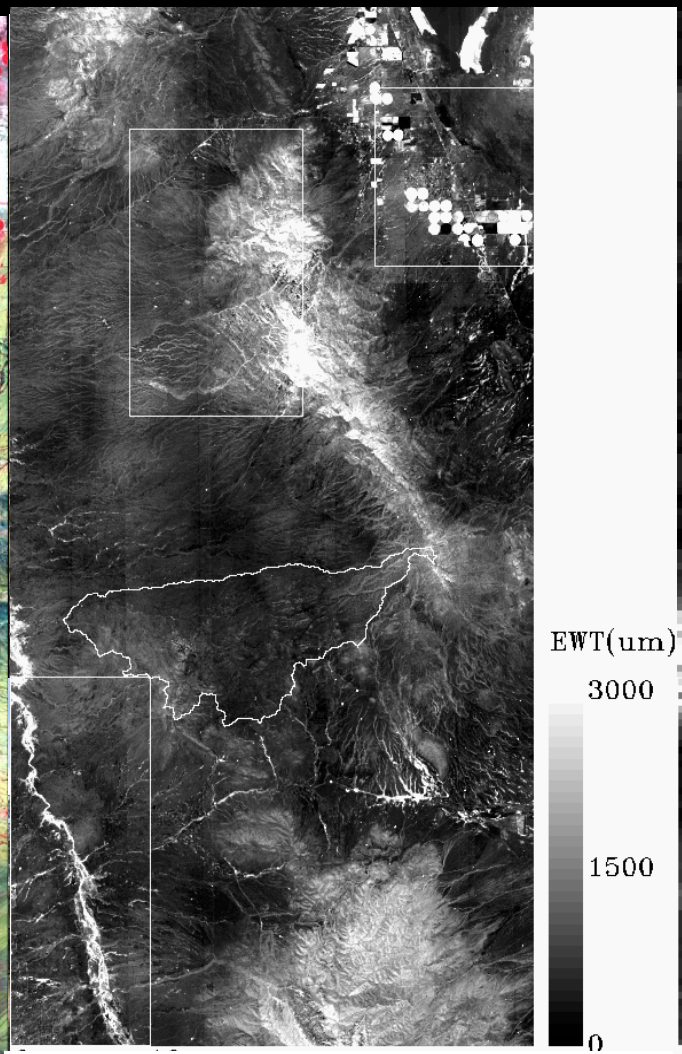
Wind River, WA
temperate conifer forest

- AVIRIS EWT
- MODIS indexes
- NEE

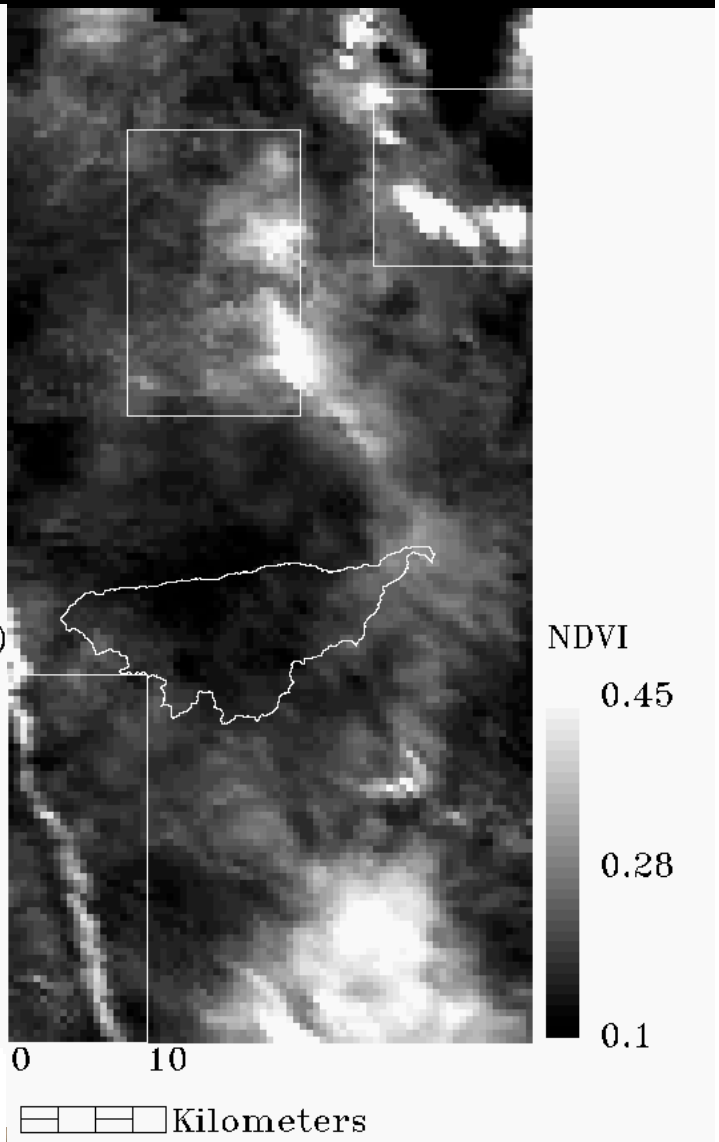
Soil Moisture Experiments ’04
SMEX: North American Monsoon Experiment



AVIRIS



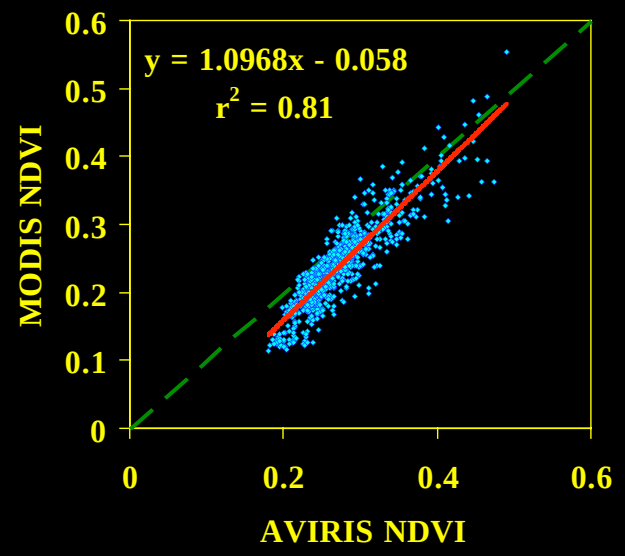
AVIRIS EWT, 25 Aug 2004

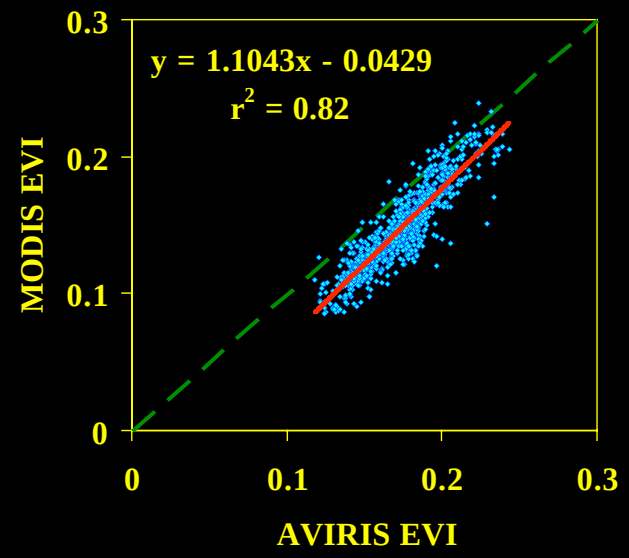


MODIS NDVI, 21-29 Aug 2004

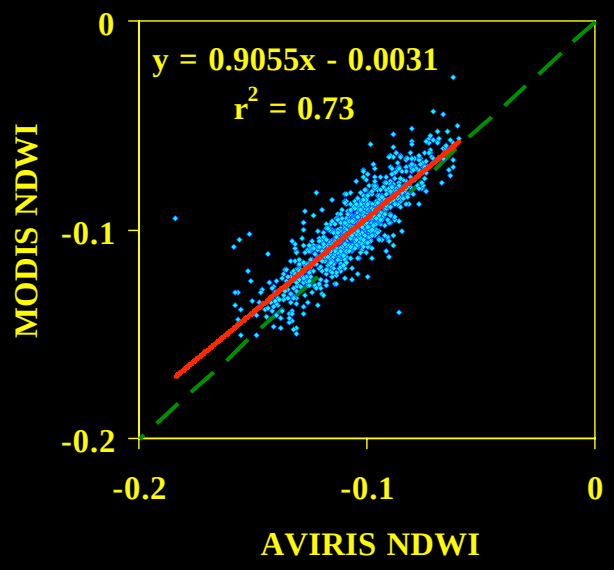
Cross Calibration between AVIRIS and MODIS Walnut Gulch, Arizona

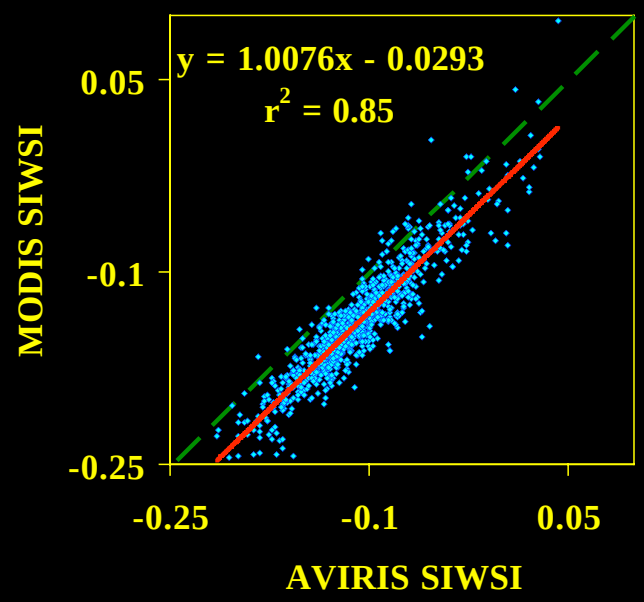
Chlorophyll Indexes





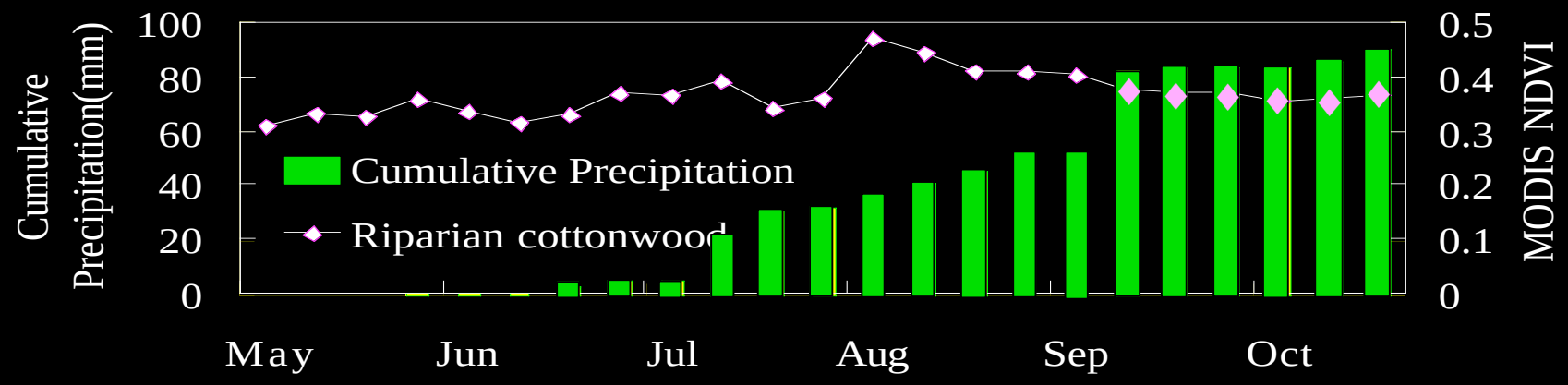
Water Indexes



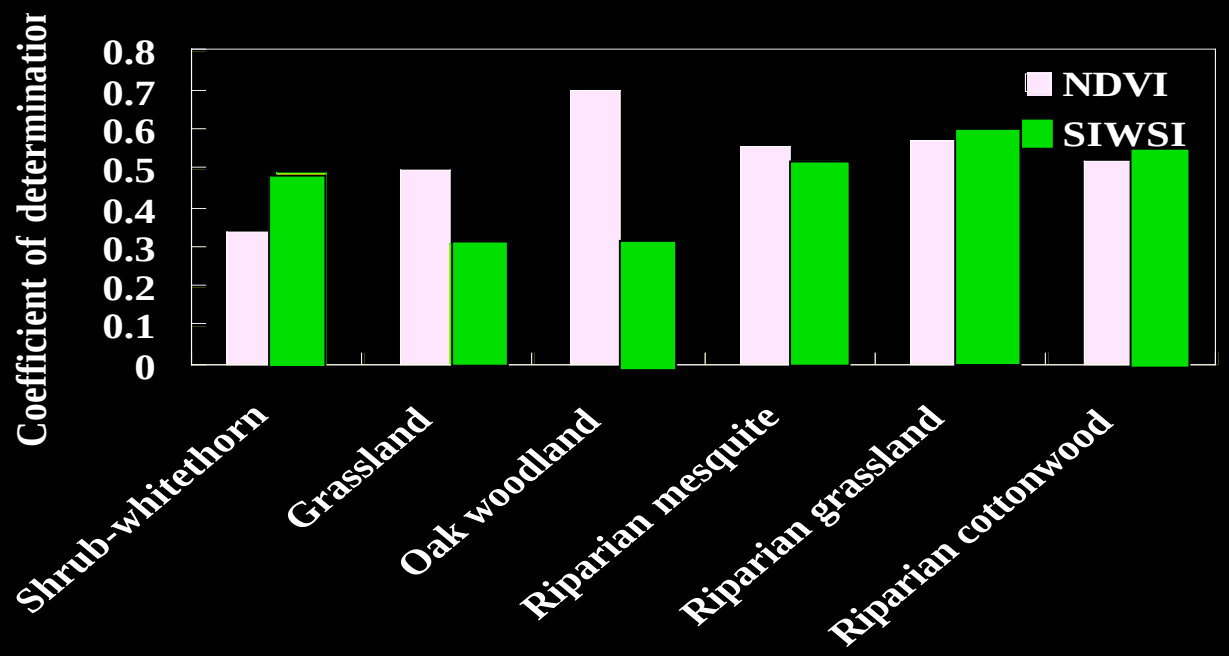


Cheng et al., submitted RSE 2006

Response of Desert Vegetation to Summer Monsoon Precipitation

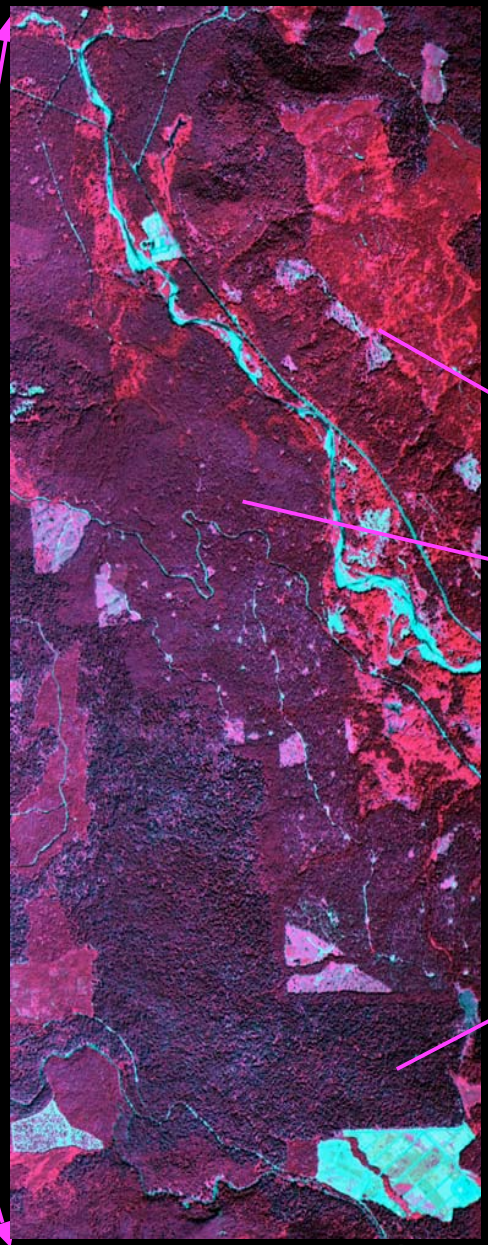


	R^2
NDVI	0.89
SIWSI	0.81

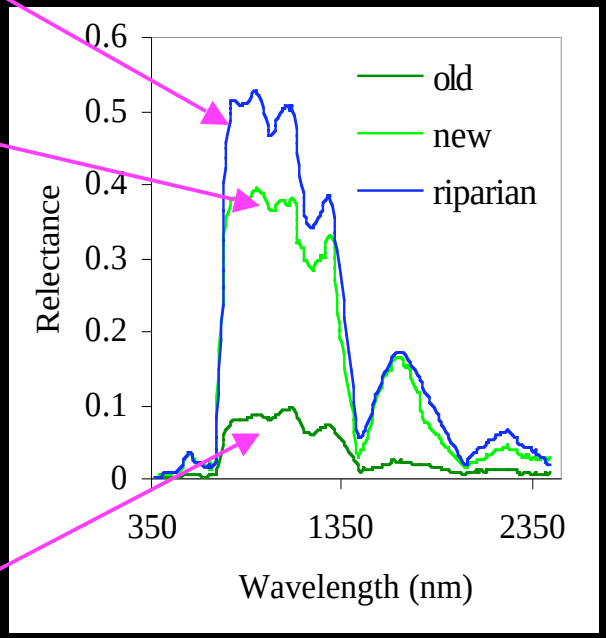


Wind River, Ameriflux Site Washington

MODIS CIR, 12-19 July 2003

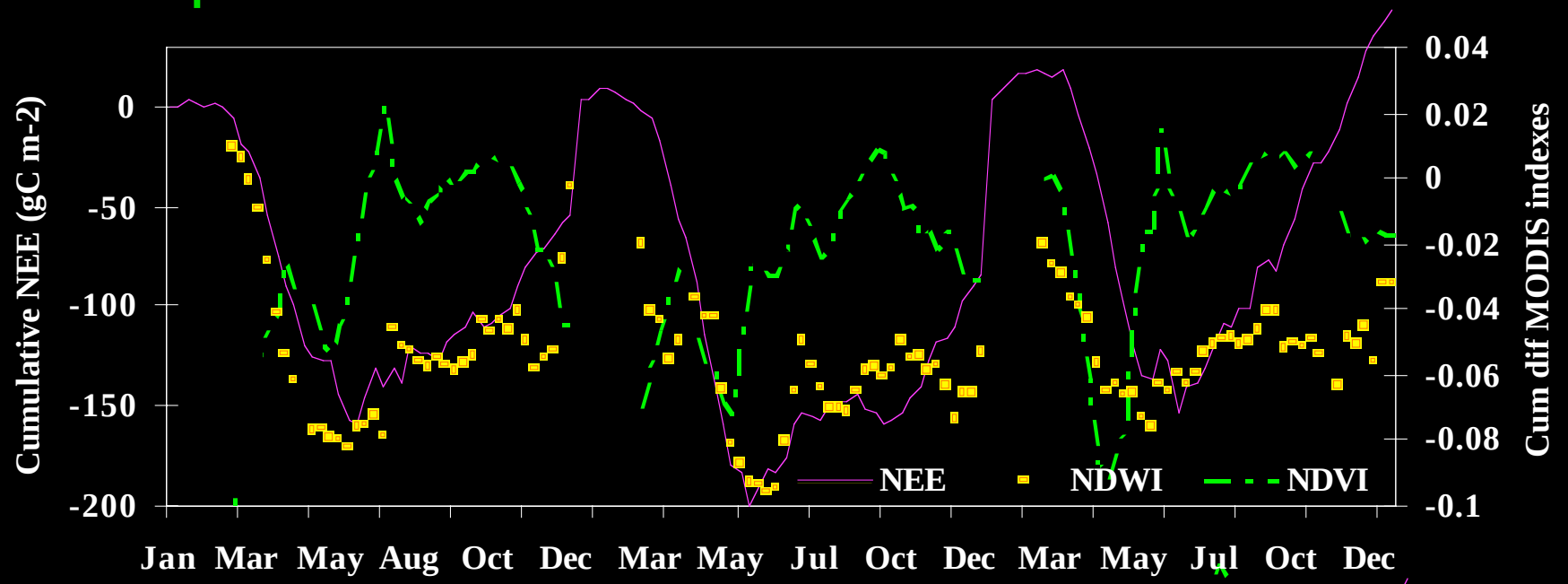


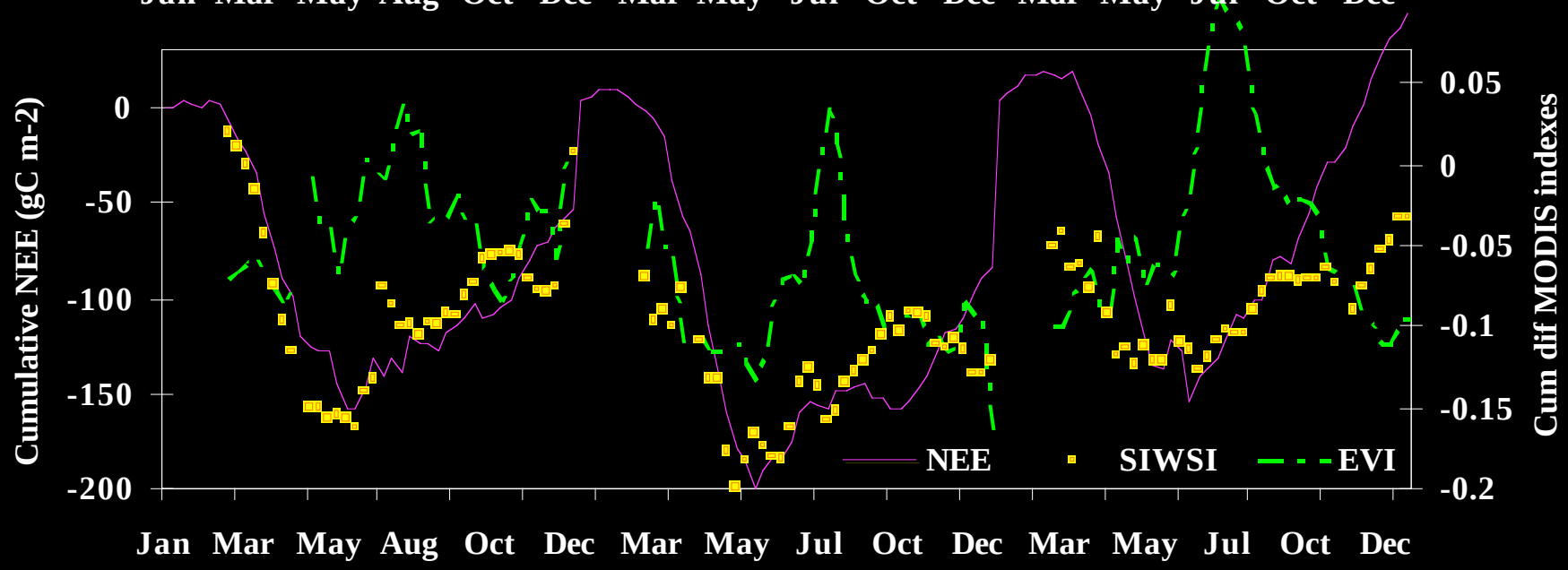
AVIRIS CIR, 19 July 2003



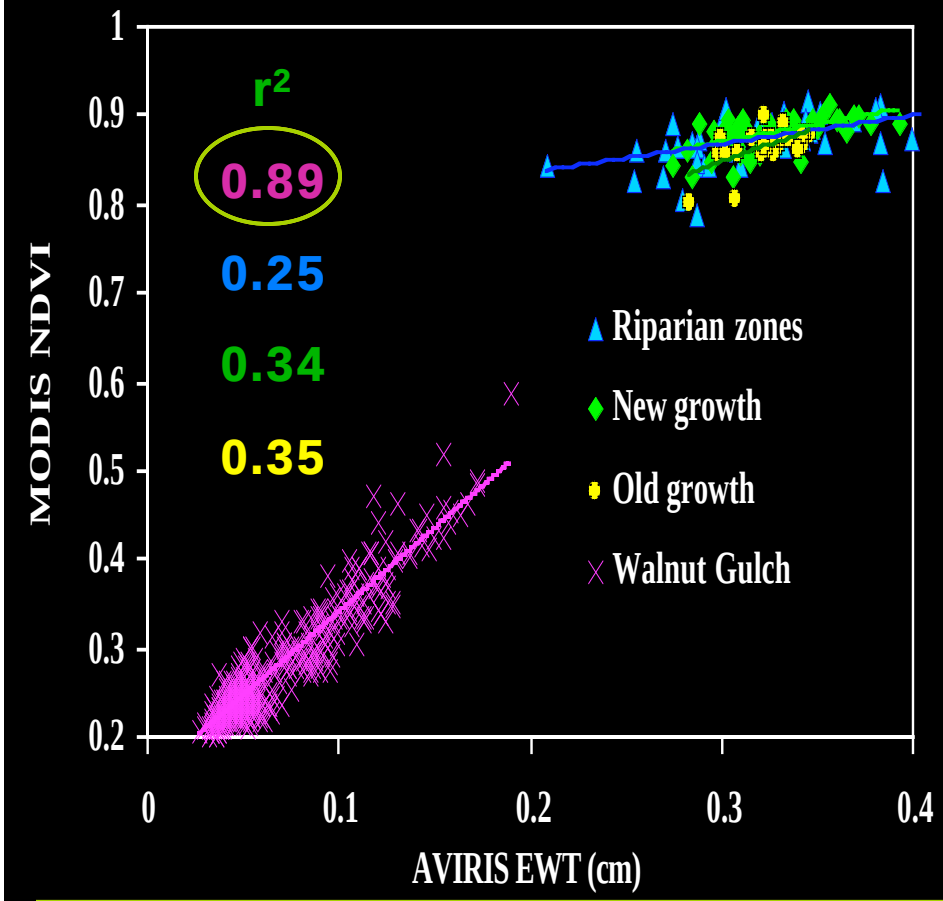
Paw U et al., 2004, Ecosystems

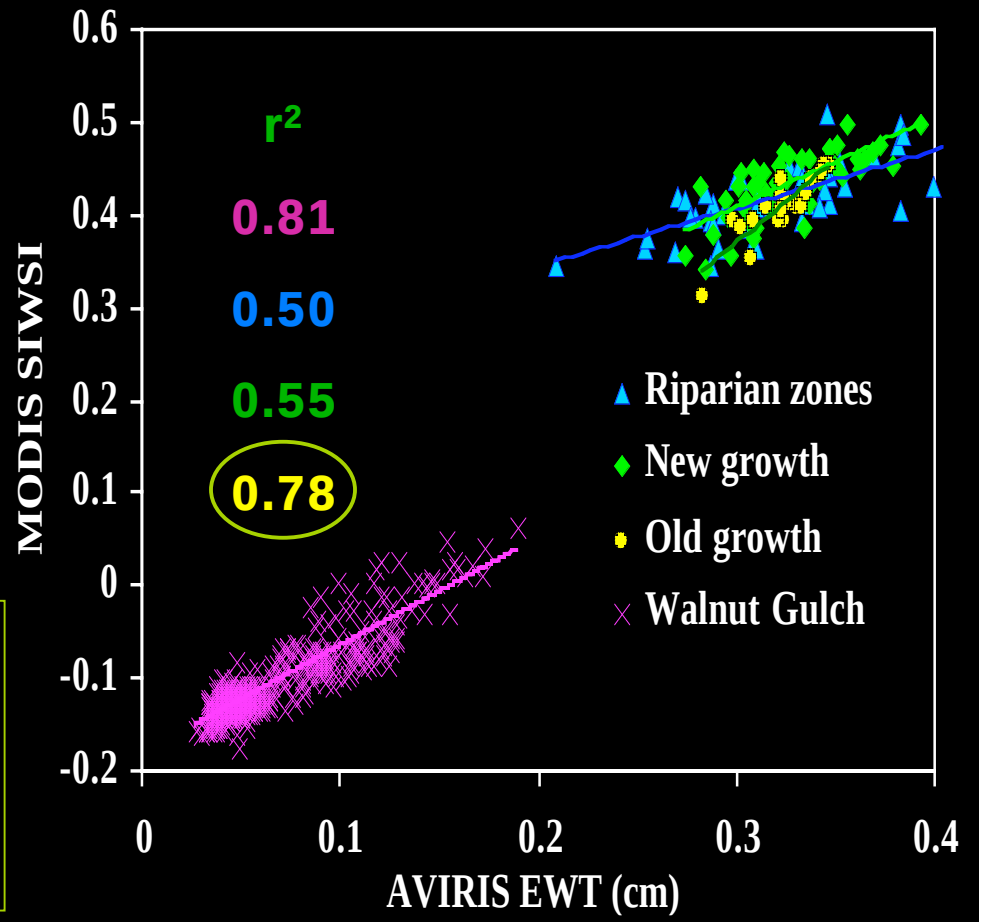
Temporal Correlation of MODIS Indexes and NEE





Comparison of MODIS NDVI and SIWSI with AVIRIS EWT at four Sites





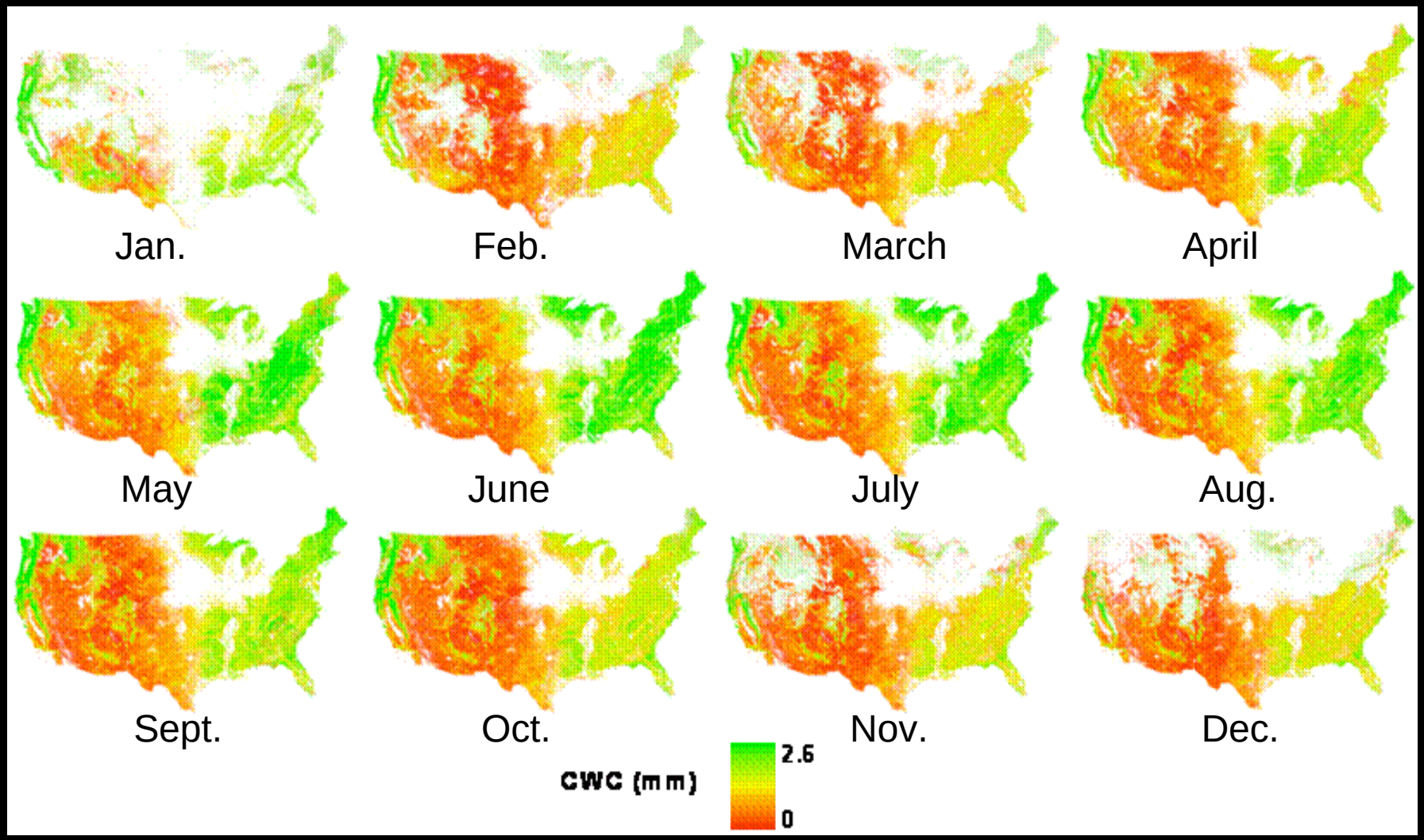
Sites:
Walnut Gulch, Arizona
Agriculture, San Joaquin Valley, CA
Conifer forest, Howland, ME
Wind River conifer forest, Washington

Artificial Neural Networks (ANN) of EWT

Leaf Training	Leaf Validation	Application
Training Dataset	Validation Dataset	Real Data MODIS
ANN	ANN	ANN
Both LOPEX data & PROSPECT	**Both LOPEX data & PROSPECT**	**PROSPECT-SAILH AVIRIS**

Riano et al., 2006 RSE

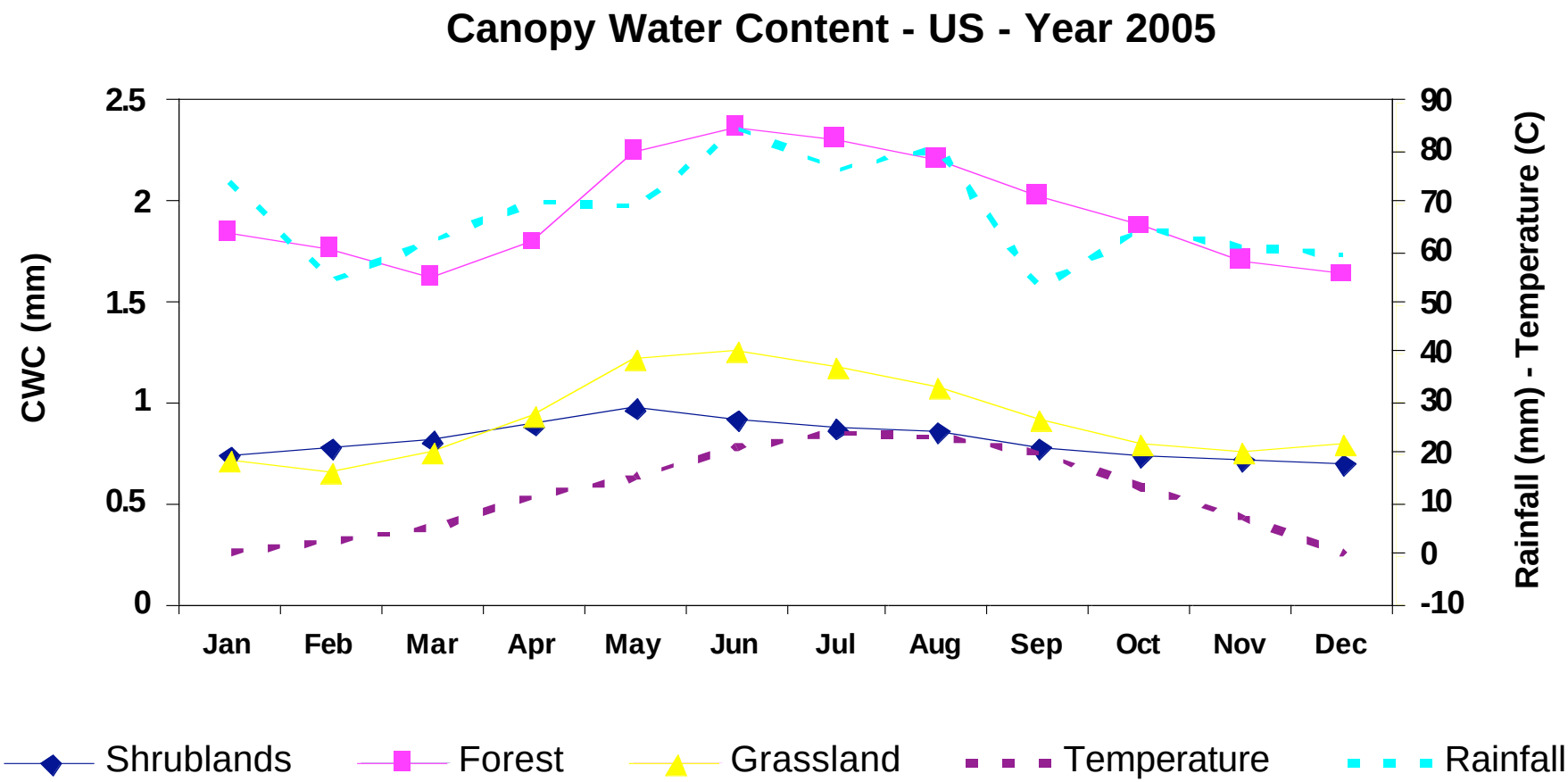
Mean Monthly 2005 CWC MODIS Data



Snow, Cloud, Agricultural & Urban Areas Masked

M. Trombetti et al., 2006

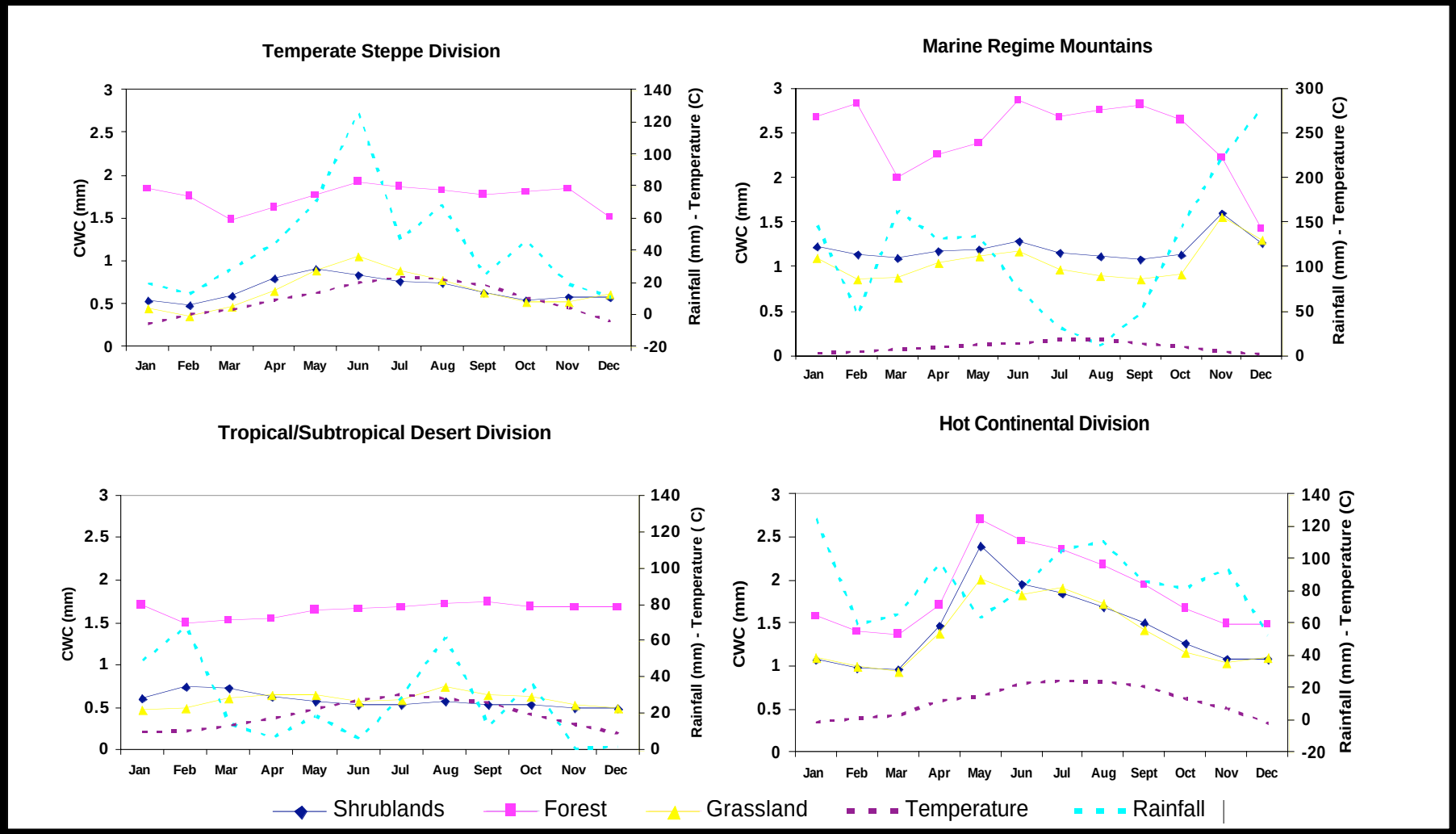
Monthly Trend in Canopy Water Content Averaged by Cover Type for Continental USA



Average rainfall and temperature in 2005

M. Trombetti et al., RSE submitted, 2006

Monthly Trend in CWC in 4 Ecoregions



Mean monthly temp. & rainfall for the period 1971-2000

M. Trombetti et al., RSE submitted, 2006

Conclusions

- Modeling of leaf EWT supports retrieval from spectral data
- Modeling & field data support retrieval of CWC from hyperspectral EWT_C data
- Multi-spectral data cross-calibrated with hyperspectral data demonstrate retrieval of CWC
- Seasonal variation in MODIS indexes show:
  - Large scale ecological patterns at regional to continental scales
  - Response to precipitation
  - Seasonal correlates with meteorological fluxes

Thank you

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USDA United States Department Of Agriculture Agricultural Research Service

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