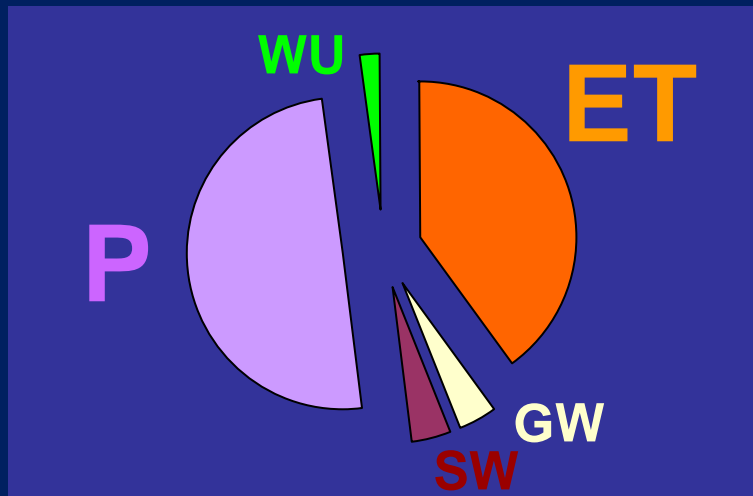


USGS evapotranspiration infrastructure in Florida



USGS Florida Water Science Center
David Sumner – Orlando
Amy Swancar – Tampa
Barclay Shoemaker – Ft. Lauderdale

Why measure ET ?



Water budget

inches per year

ET is big part of water budget

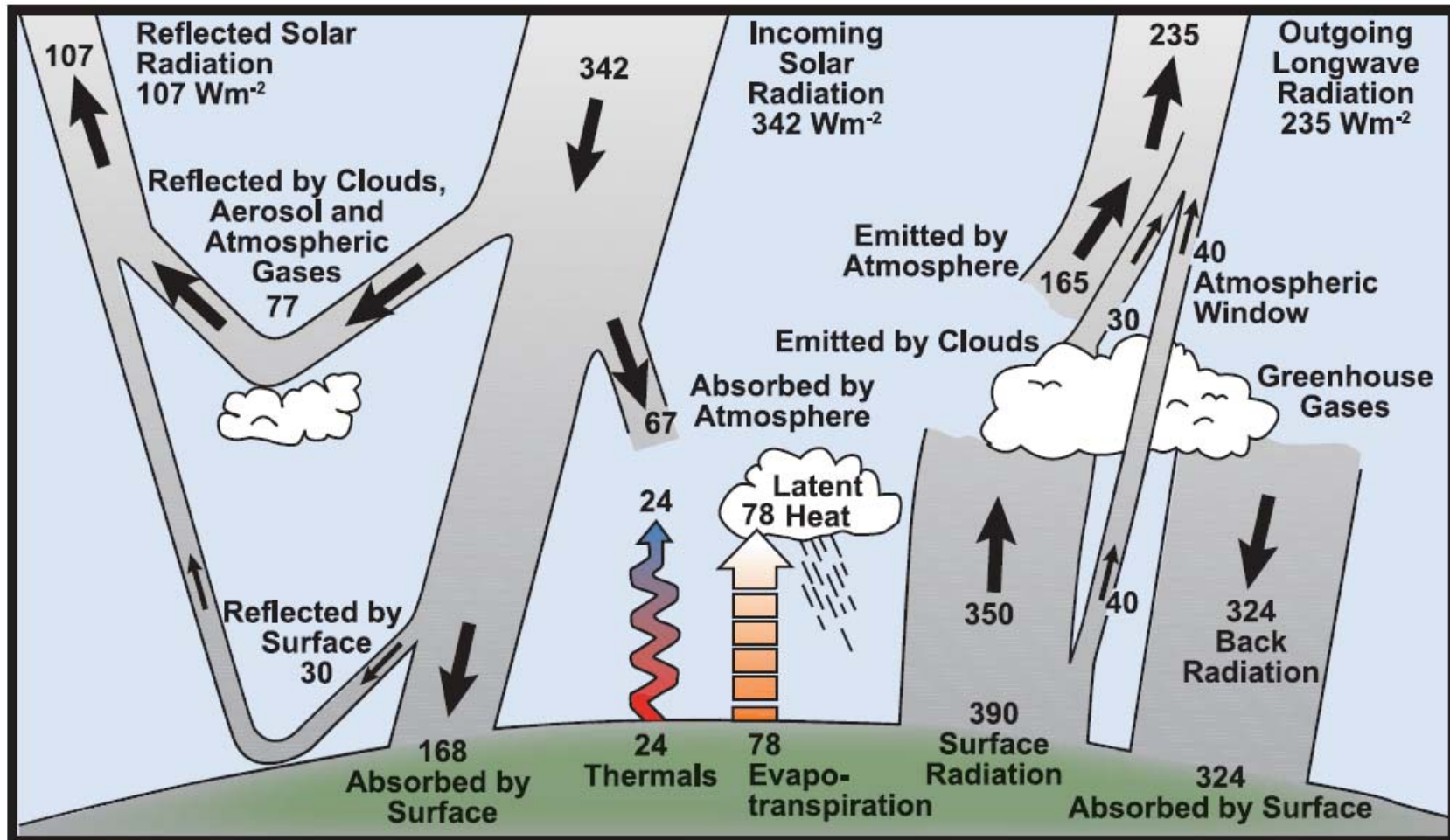
ET is link between water and energy budgets

What drives ET?

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a} \right)}$$

Penman-Monteith equation

Earth's energy budget



FAQ 1.1, Figure 1. Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).

USGS ET infrastructure

- 1) “Point” measurements of actual ET, radiative fluxes, and environmental conditions
- 2) Statewide, distributed daily estimates of ET surrogates and solar insolation

Mass and heat fluxes

Eddy covariance method

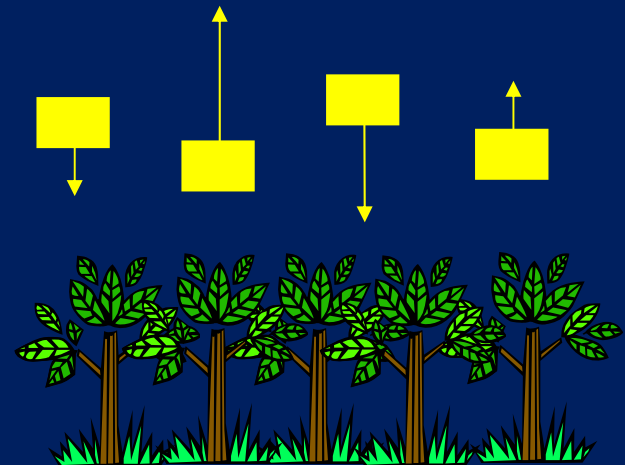
$$F_{\text{H}_2\text{O}} = c_{\text{H}_2\text{O}} w = \text{mean}(c_{\text{H}_2\text{O}}' w')$$

$$= \text{cov}(c_{\text{H}_2\text{O}}, w)$$

$c_{\text{H}_2\text{O}}$ = vapor density

w = vertical wind speed

' = fluctuation about average

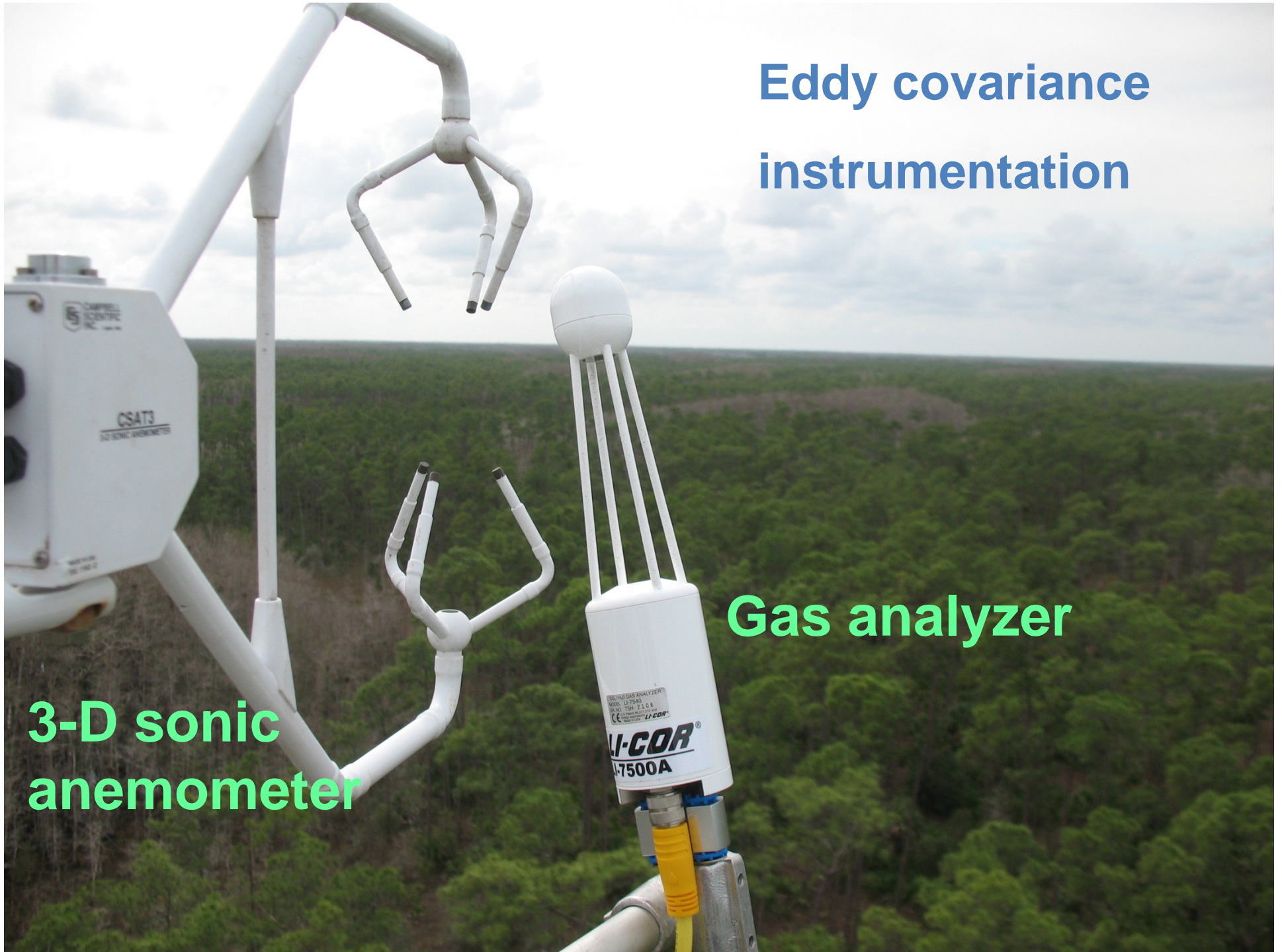




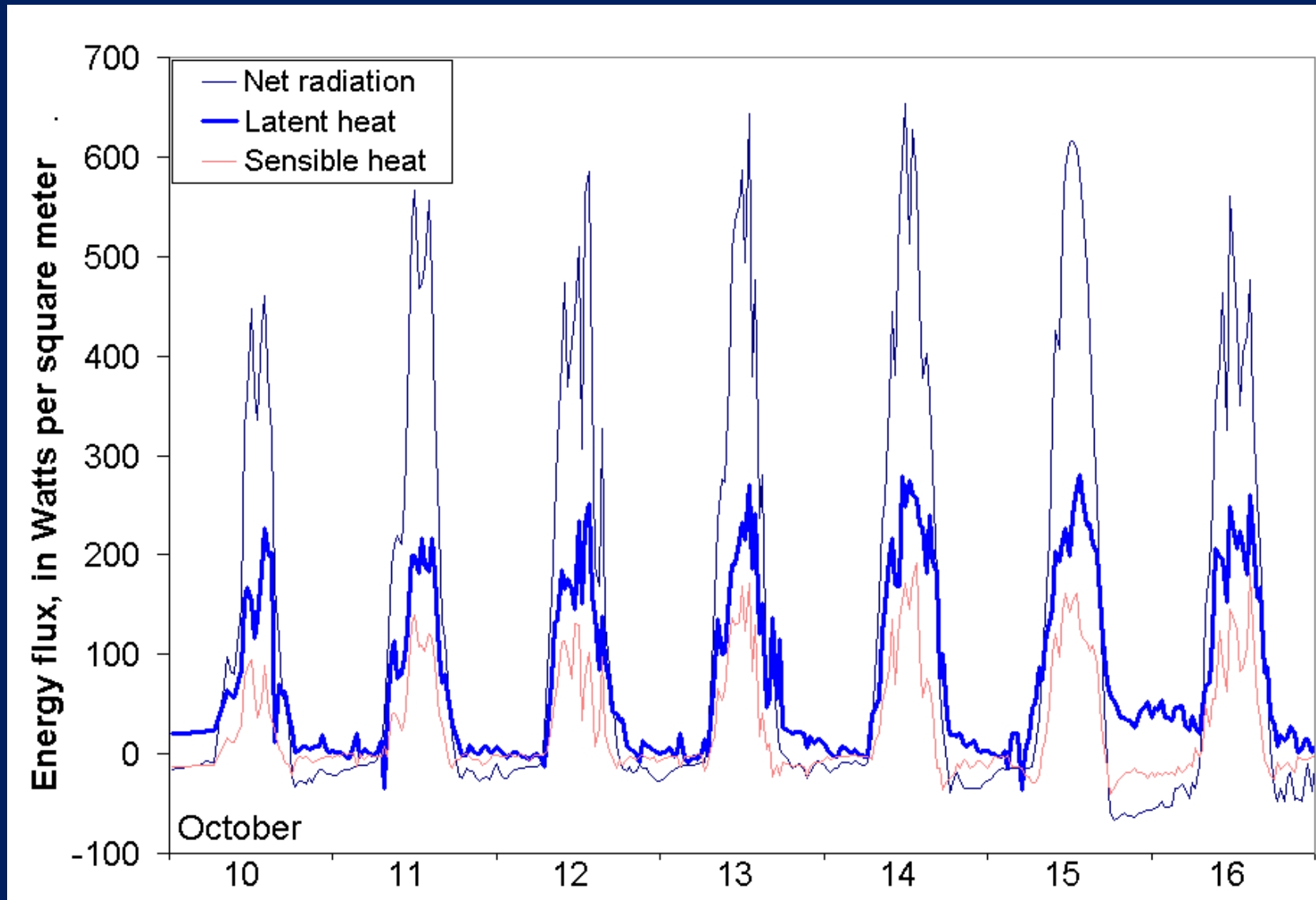
Eddy covariance instrumentation

Gas analyzer

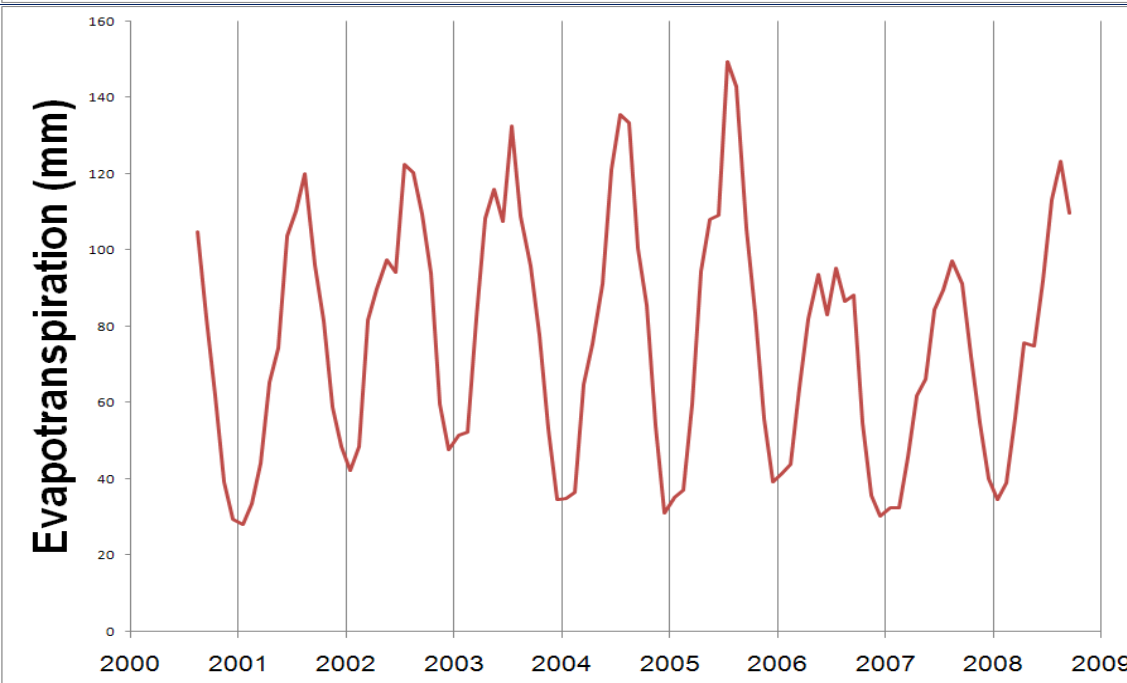
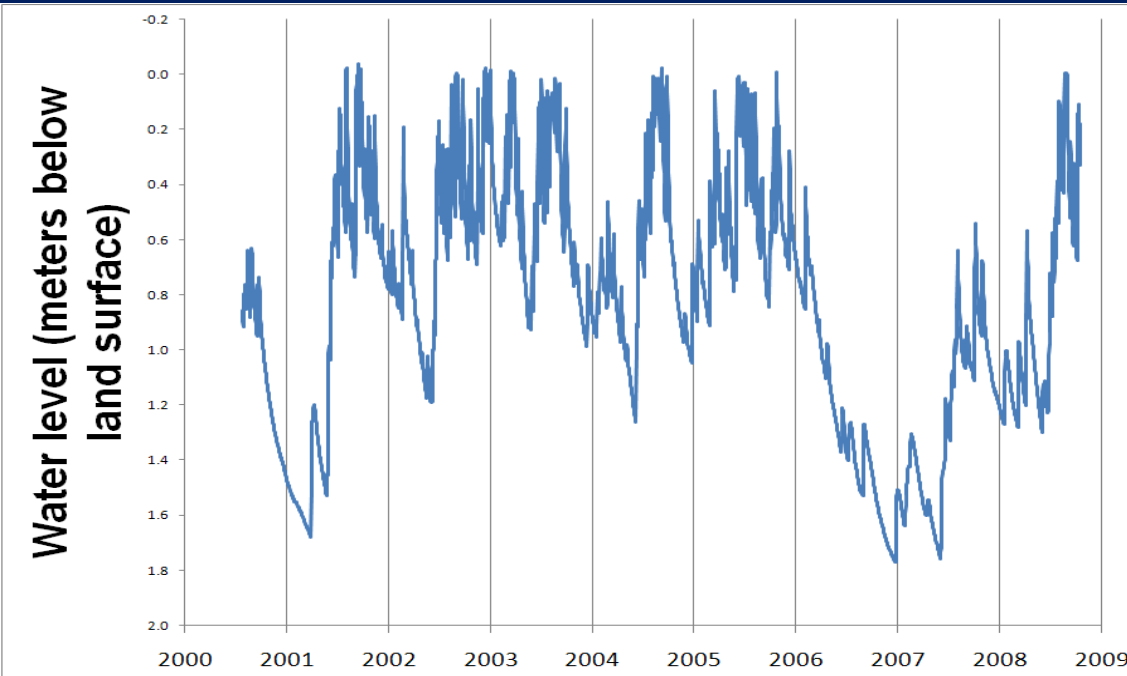
3-D sonic
anemometer



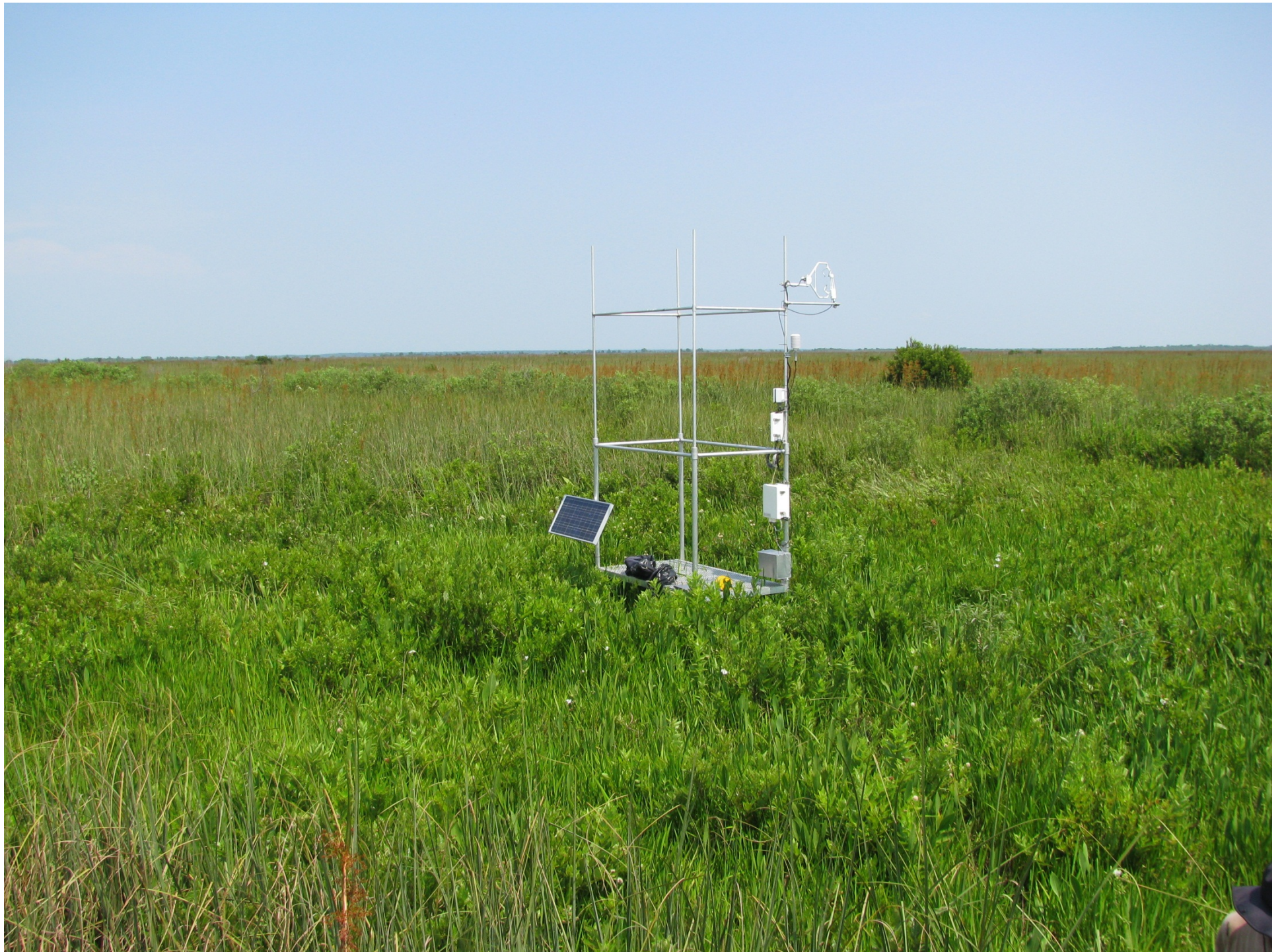
30-minute fluxes – Blue Cypress marsh



Disney Wilderness Preserve



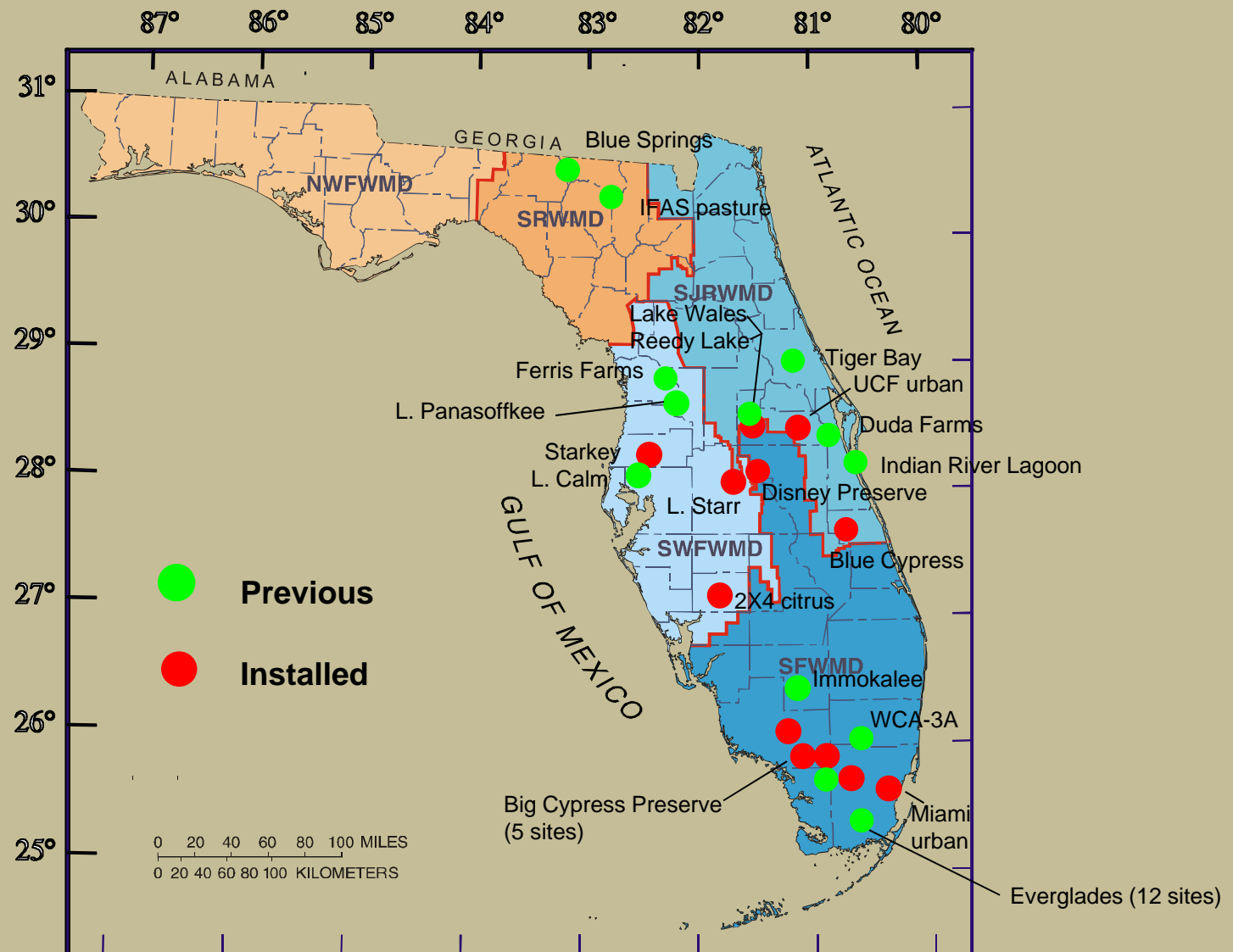
Water availability
Solar radiation
- important controls on ET
that can change with a
changing climate



Lake Starr



USGS flux stations- past & present



Land use categories of current USGS ET sites

	ET	Carbon
Open water	2	
Sawgrass/marsh/wet prairie	3	1
Pasture	1	
Palmetto/mixed	1	
Pine/cypress forested wetland	1	1
Citrus	1	
Hardwood swamp	1	
Cypress swamp	2	
Urban residential/commercial	2	2
Total	14	4

Regional evaluation of evapotranspiration in the Everglades

Edward German – USGS Water Resources Investigations Report 00-4217

Two years of data collection (1996-1997)

Nine stations in multiple Everglades landscapes

Annual ET ranged from:

42.4 in – at drier vegetated sites

57.4 in – at open water sites

Summary – ET increases with solar radiation
and higher water levels

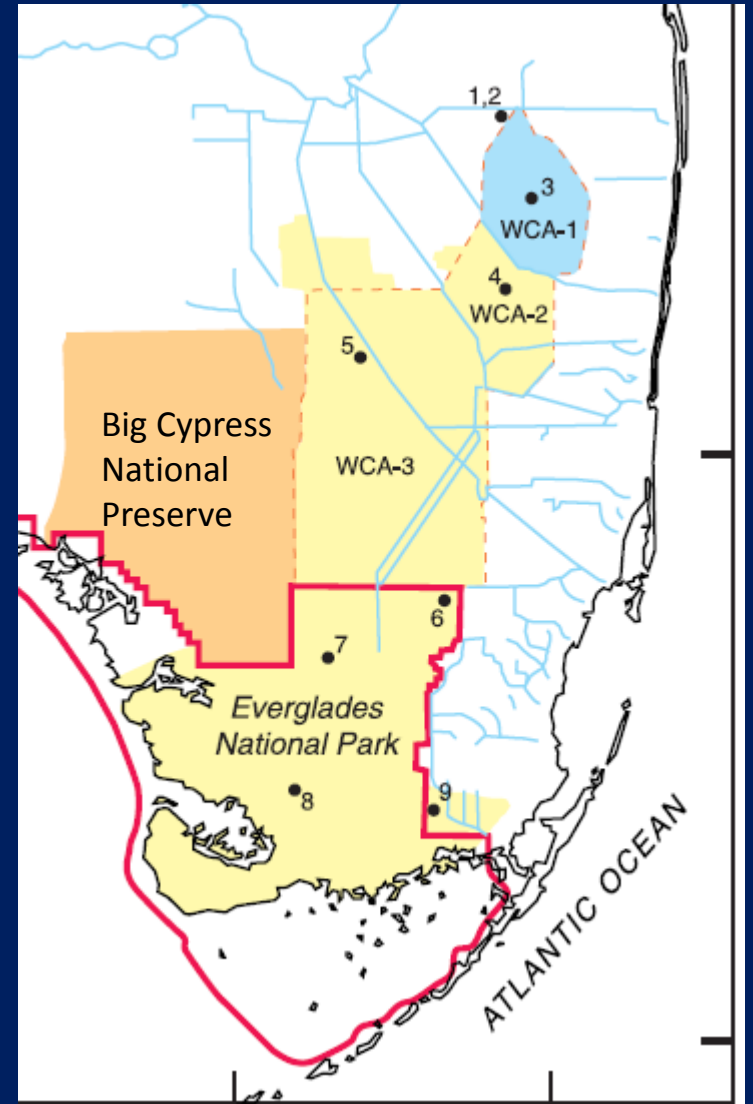


Table 1. Evapotranspiration-monitoring site characteristics

[Site numbers refer to fig. 1; THP refers to air temperature and humidity sensor]

Site	Latitude/longitude	Plant community	Height above land surface, in feet			Comments
			Vege- tation	Lower THP	Wind sensor	
1	263910 0802432	Cattails	10	14	18	Considerable flow regulation, nutrient-rich water, abundant duckweed
2	263740 0802612	Open water	0	5	none	
3	263120 0802011	Open water	0	4.7	8	Some lily pads at times
4	261855 0802257	Dense sawgrass	6.5	10	19	
5	261530 0804417	Medium sawgrass	6	8.2	18	Dry part of some years
6	254443 0803011	Medium sawgrass	6	9	13	
7	253659 0804208	Sparse sawgrass	5	7.7	14	
8	252111 0803802	Sparse rushes	3	4	12	Dry part of each year
9	252135 0803146	Sparse sawgrass	3.5	5.3	12	Dry part of each year

Evolution of ridge and slough in Everglades landscapes could
complicate future ET estimation - - ->

Need to know individual ET signatures of “ridge” and “slough” along
with landscape evolution projections

Evapotranspiration over spatially extensive plant communities in the Big Cypress National Preserve, southern Florida

USGS Scientific Investigations Report 2011-5212

Barclay Shoemaker

Three-year data collection
(2007-2010)

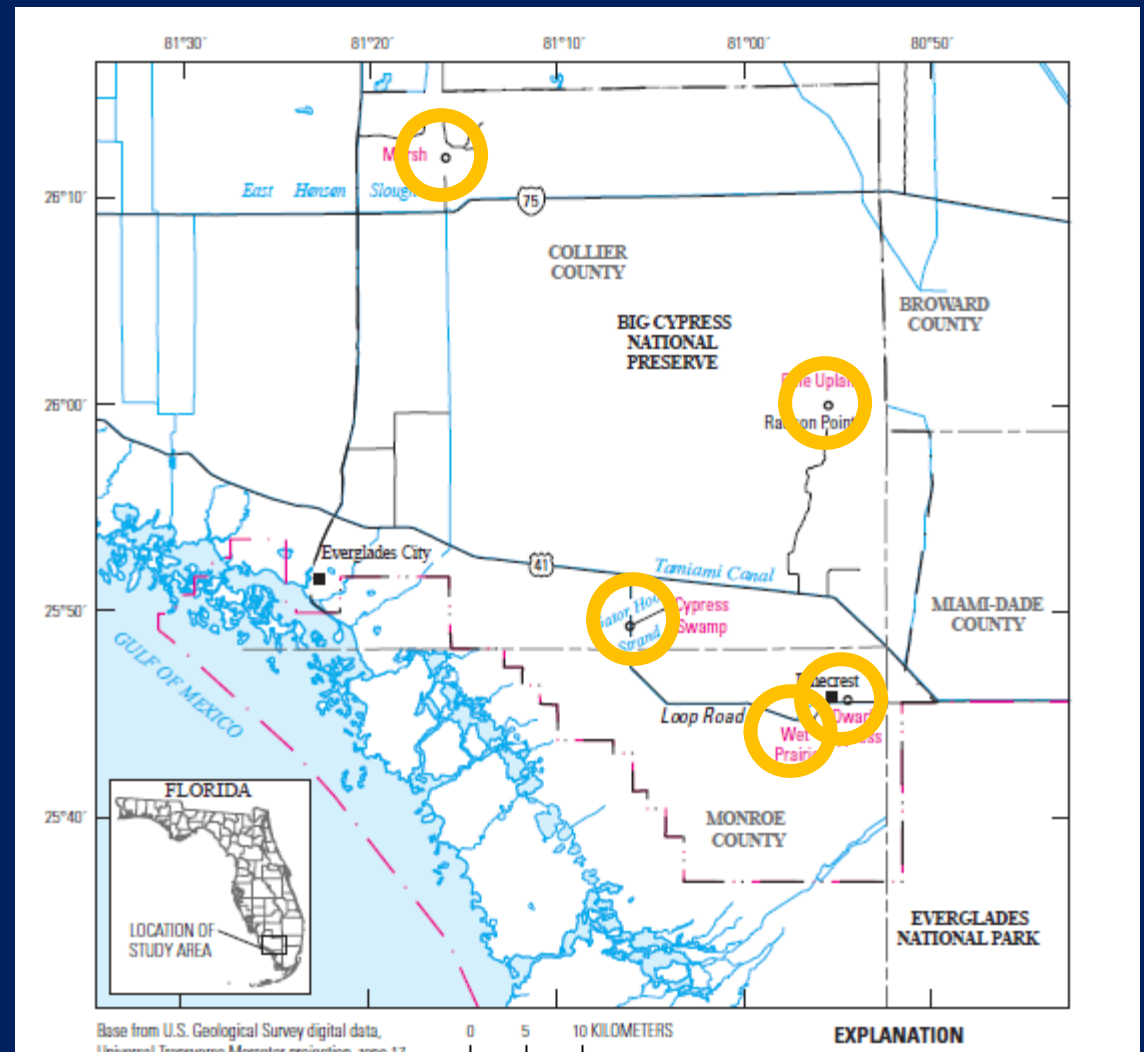
Dwarf cypress 1,000 mm

Wet prairie 1,050 mm

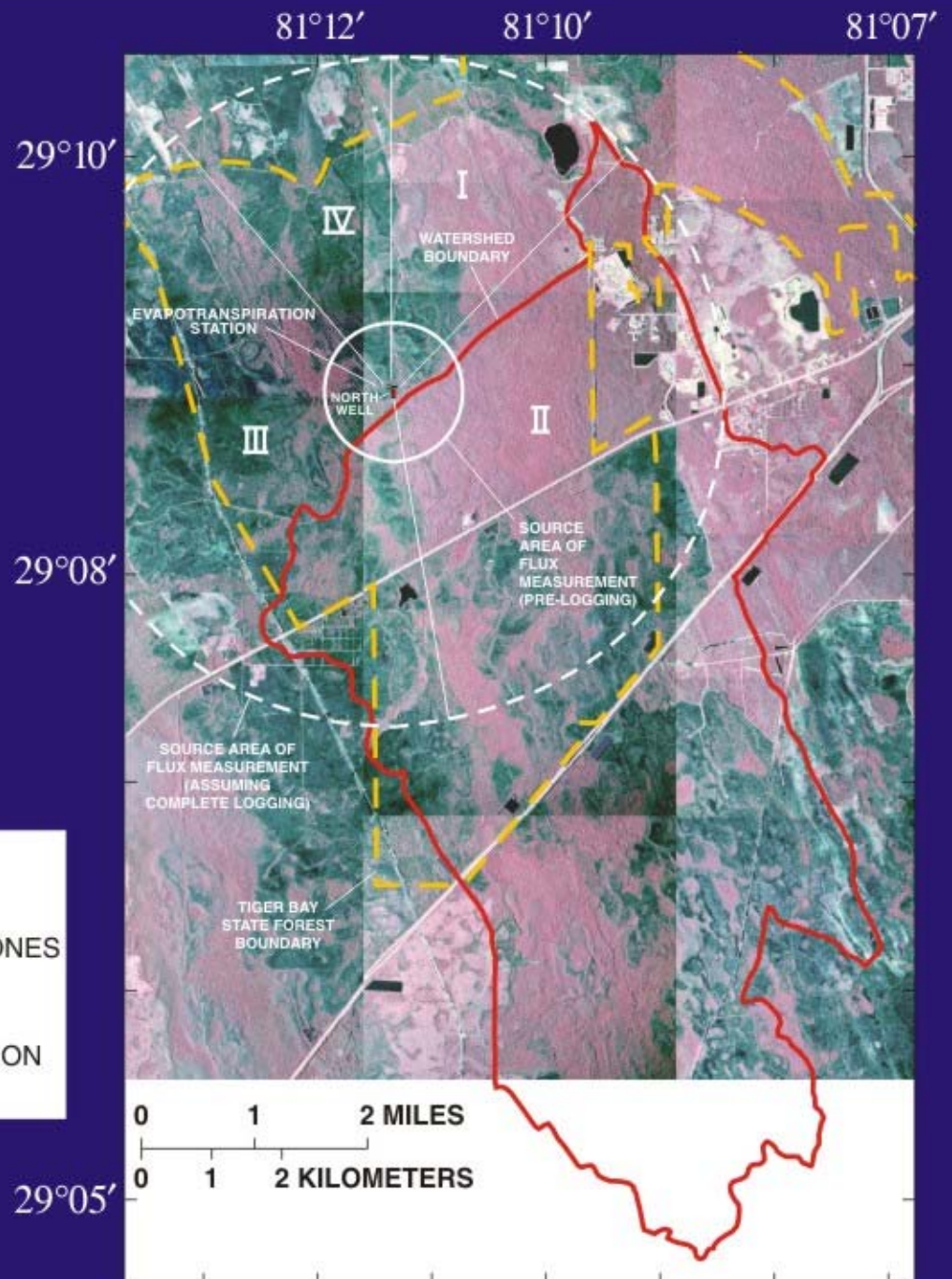
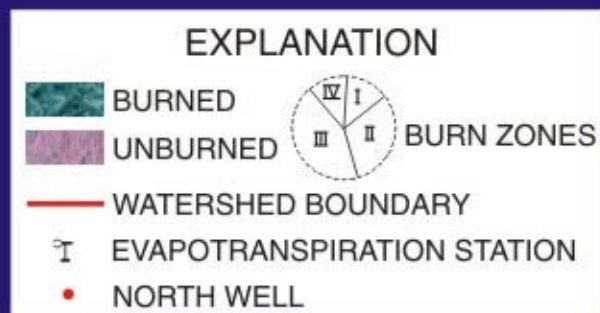
Tall cypress 1,100 mm

Pine 930 mm

Marsh 900 mm



Tiger Bay watershed
Volusia County, Florida



Hotter and drier climate -> more fires -> ET changes

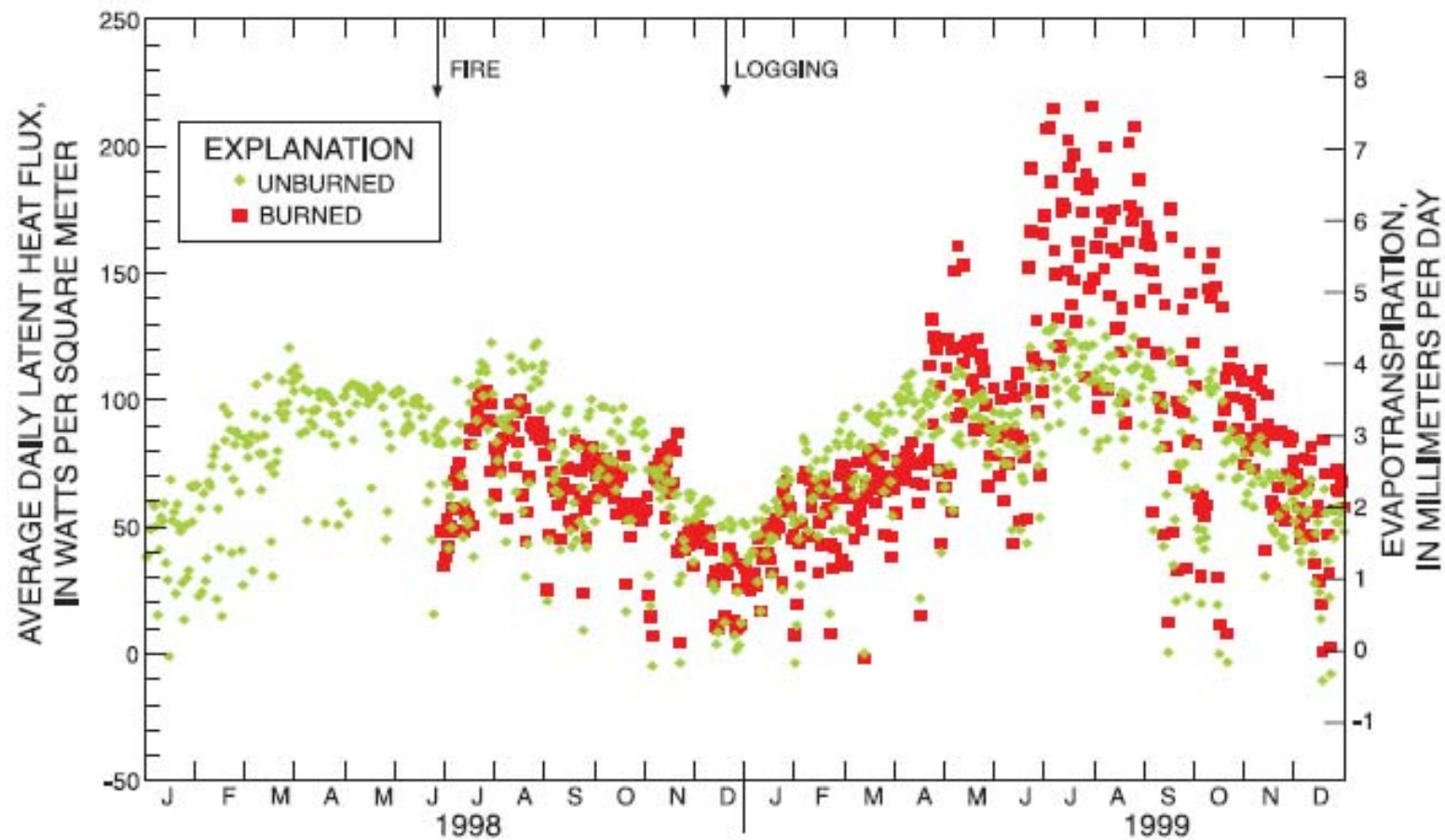
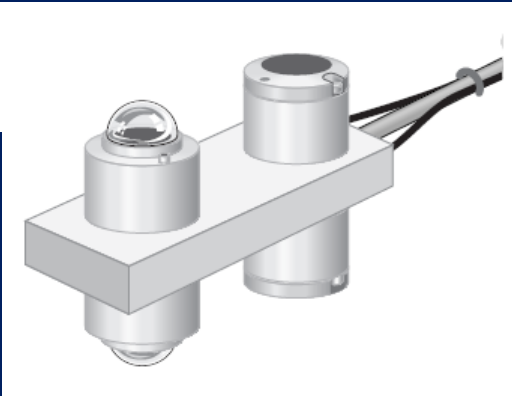
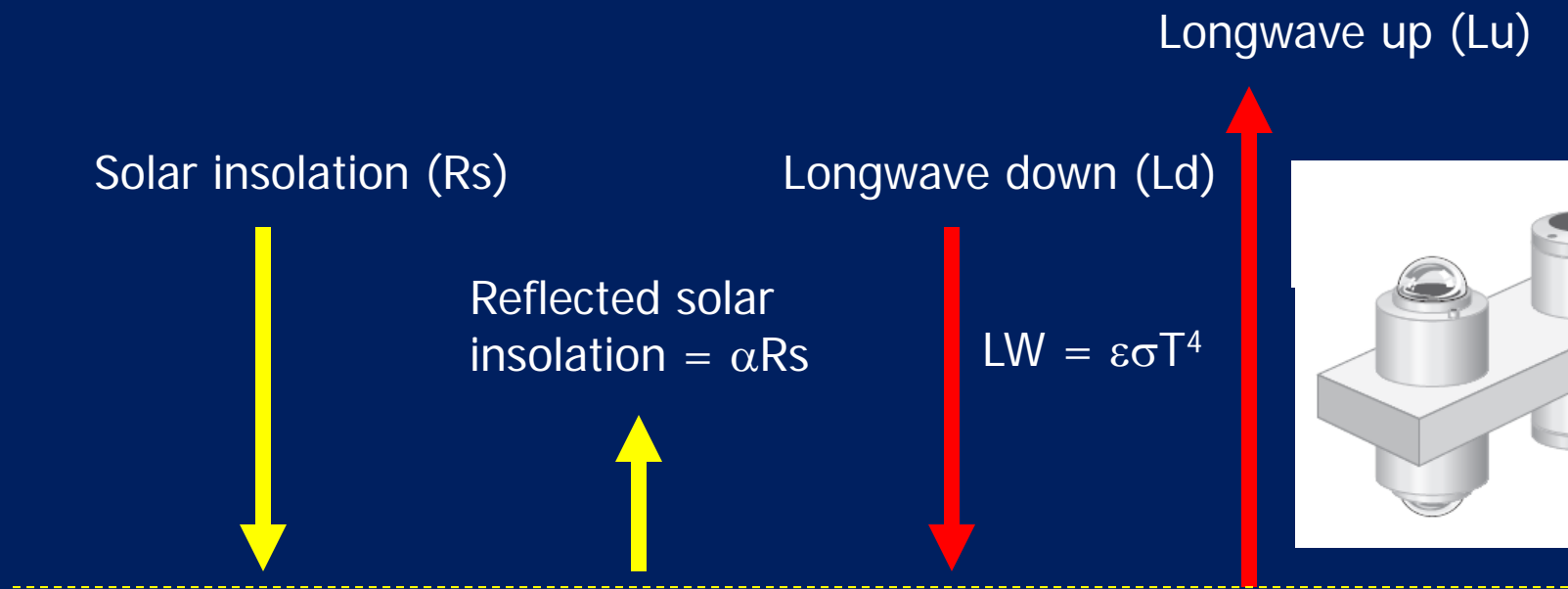


Figure 29. Average daily latent heat flux and evapotranspiration.

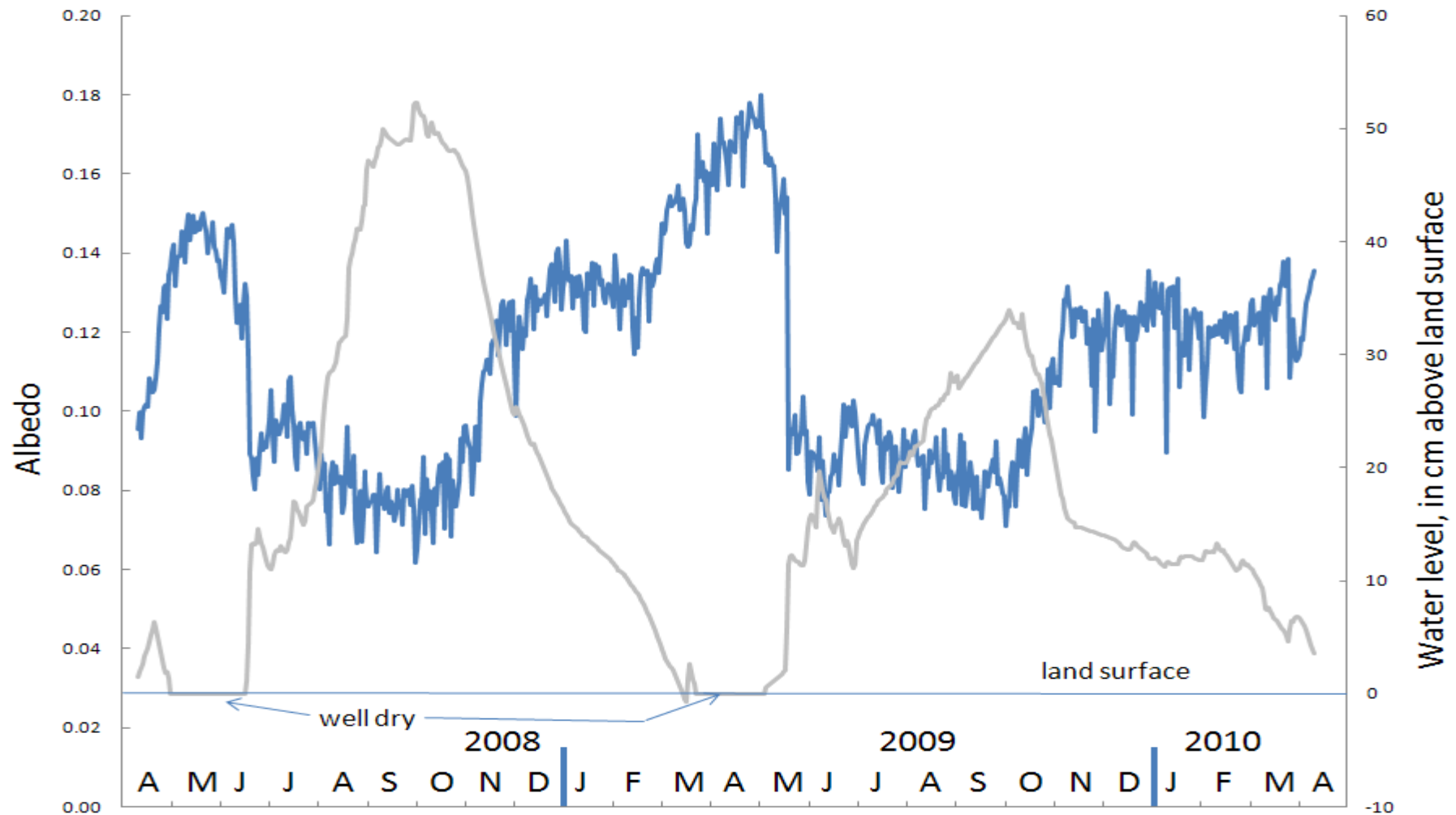
Radiation components

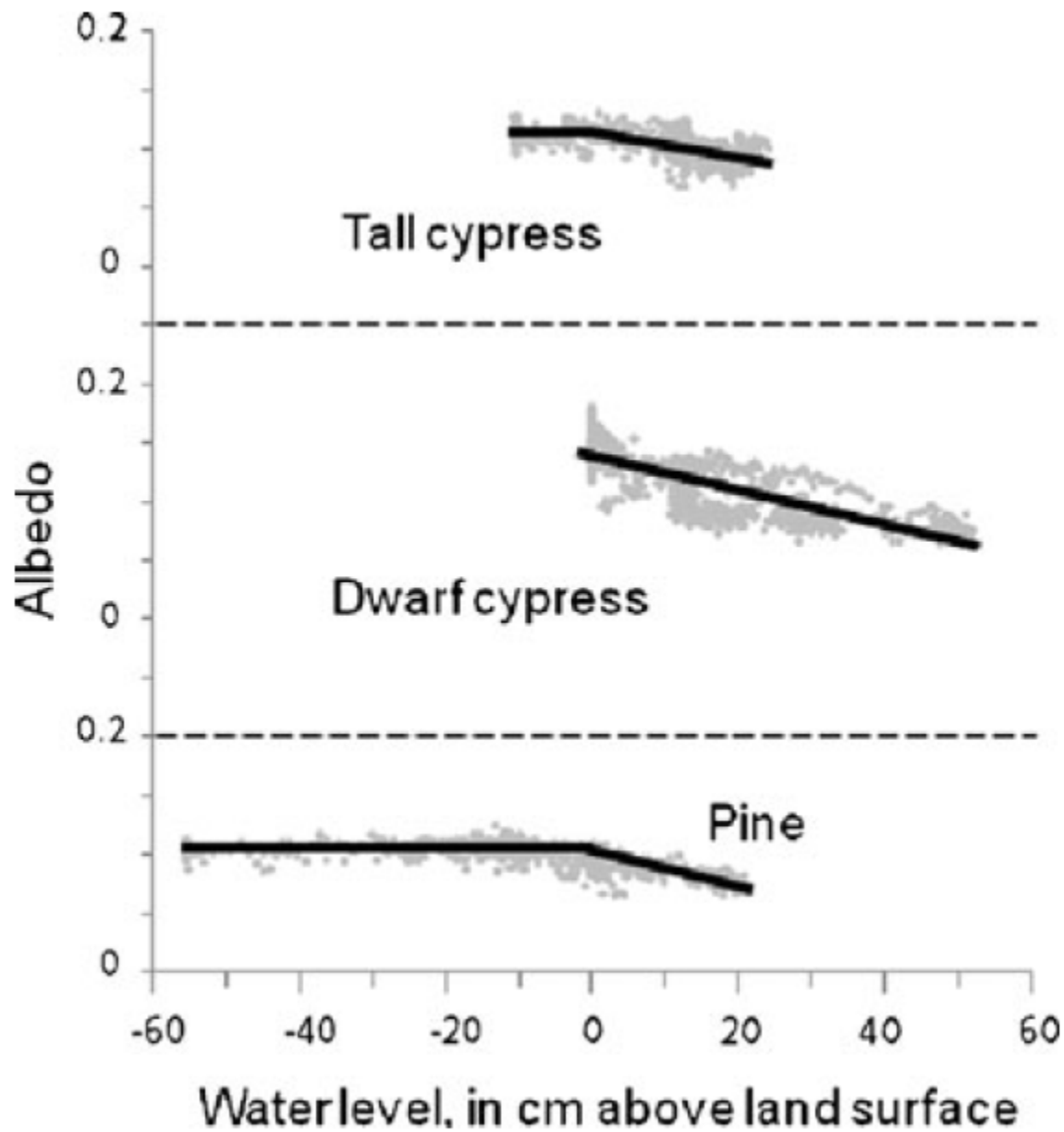
$$\text{Net radiation (Rn)} = R_s - \alpha R_s + L_d - L_u$$

Most of variability in R_n is explained by variation in R_s



Water levels – control on wetland albedo





Changing hydroperiod
can change
radiation balance and ET

These wetland feedbacks
are likely not well
simulated in GCMs

Statewide ET project

- Estimation of standardized *reference* and *potential* ET “everywhere”

Project manager: David Sumner (USGS)

Investigators: Jennifer Jacobs and Minha Choi (University of New Hampshire)
John Mecikalski and Simon Paech (University of Alabama)
Ellen Douglas (University of Massachusetts)
Shafik Islam (Tufts University)

Partners: **All five** Florida Water Management Districts

Most models use ET surrogates

- Hydrologic - MODFLOW, MIKESHE, HSPF

$$ET = f(PET)$$

- Agricultural

$$ET = k_c RET$$

Given complexity of actual ET relations with local land cover and water status

climate models are expected to produce coarse ET estimates ... but perhaps more robust estimates of PET and RET

Objectives

Estimate reference and potential ET

- - throughout State of Florida
- - from 1995 to present
- - at 2 km spatial resolution
- - at daily temporal resolution
- - with spatial grid consistent with NEXRAD grid

ET computations

Calculation of RET was performed using:

- ASCE 2000 reference ET method
(daily version of Penman-Monteith w/grass standard)

- Required input = incoming solar radiation
air temperature
relative humidity
wind speed

PET via Priestley-Taylor equation

- need net radiation and temperature data

Florida cloud cover = important control on solar radiation



GOES Insolation Model

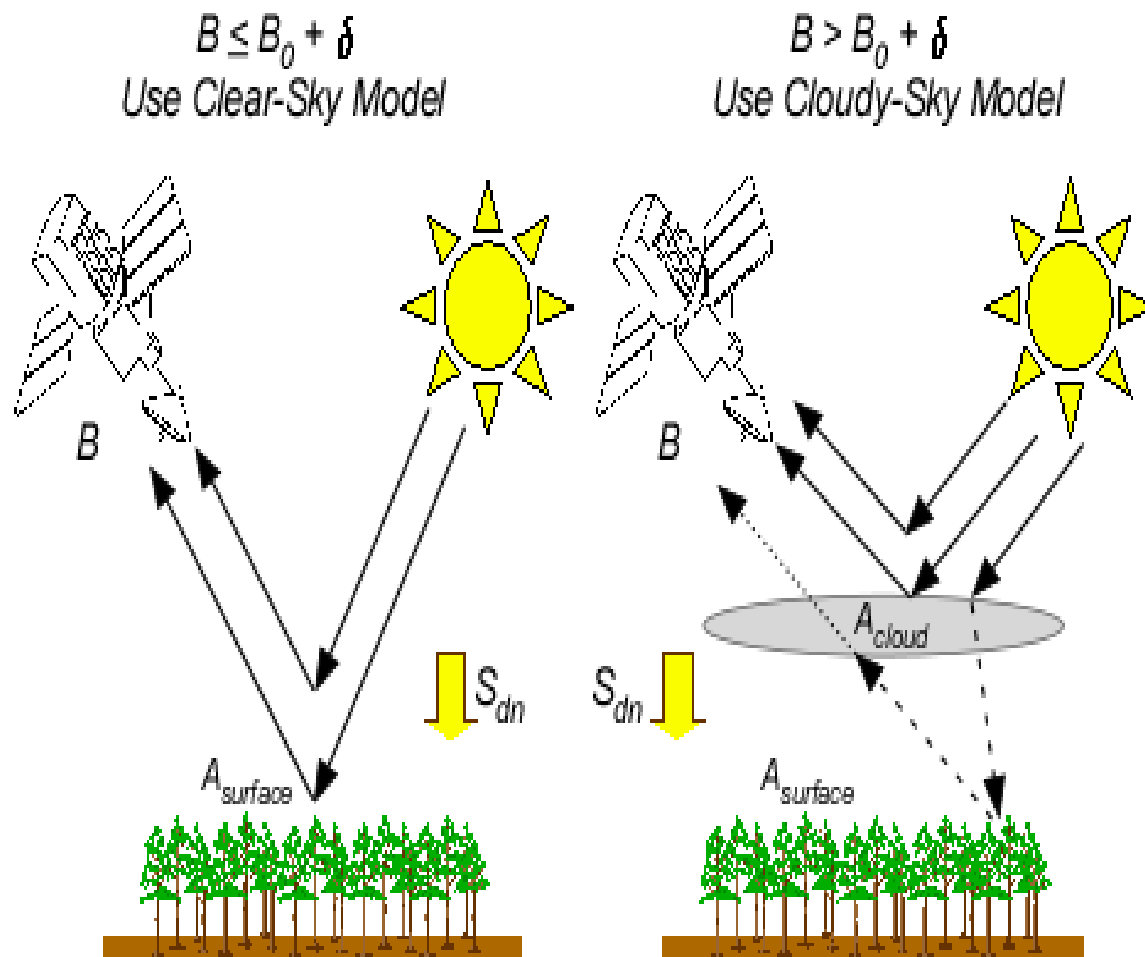


Fig. 1 Graphical depiction of the physical model employed for clear-sky conditions (left-hand side) and for cloudy-sky conditions (right-hand side). B refers to the brightness observed by the satellite, S_{dn} refers to the downward shortwave radiation flux, and $A_{surface}$ and A_{cloud} refer to the surface and cloud albedos, respectively.

Approach

1. 2-week minimum noon albedo
2. Is pixel cloudy?
3. If so, solve for cloud albedo.
4. Solve for incident solar radiation (full SW bandwidth)
5. Calibrate to Florida pyranometer data

Dr. John Mecikalski

University of Alabama

Downscaled PET and RET

- PET and RET projections via downscaled GCM output would provide a means to estimate ET in hydrologic models or crop water use projections.
- Maintaining consistency between historical and projected PET/RET is important.

Are coarse estimates of ET “good enough” ?

Major need for hydrologists:

Available water = Precipitation - ET

“Foes” of coarse ET estimates

- ET error, particularly biased error
- $ET \gg Precip$ (large absolute error)
- $ET \sim Precip$ (large relative error)

Amplification of ET error

Small error in ET



Example:

Precip = 1200 mm

ET = 1000 +/- 10%

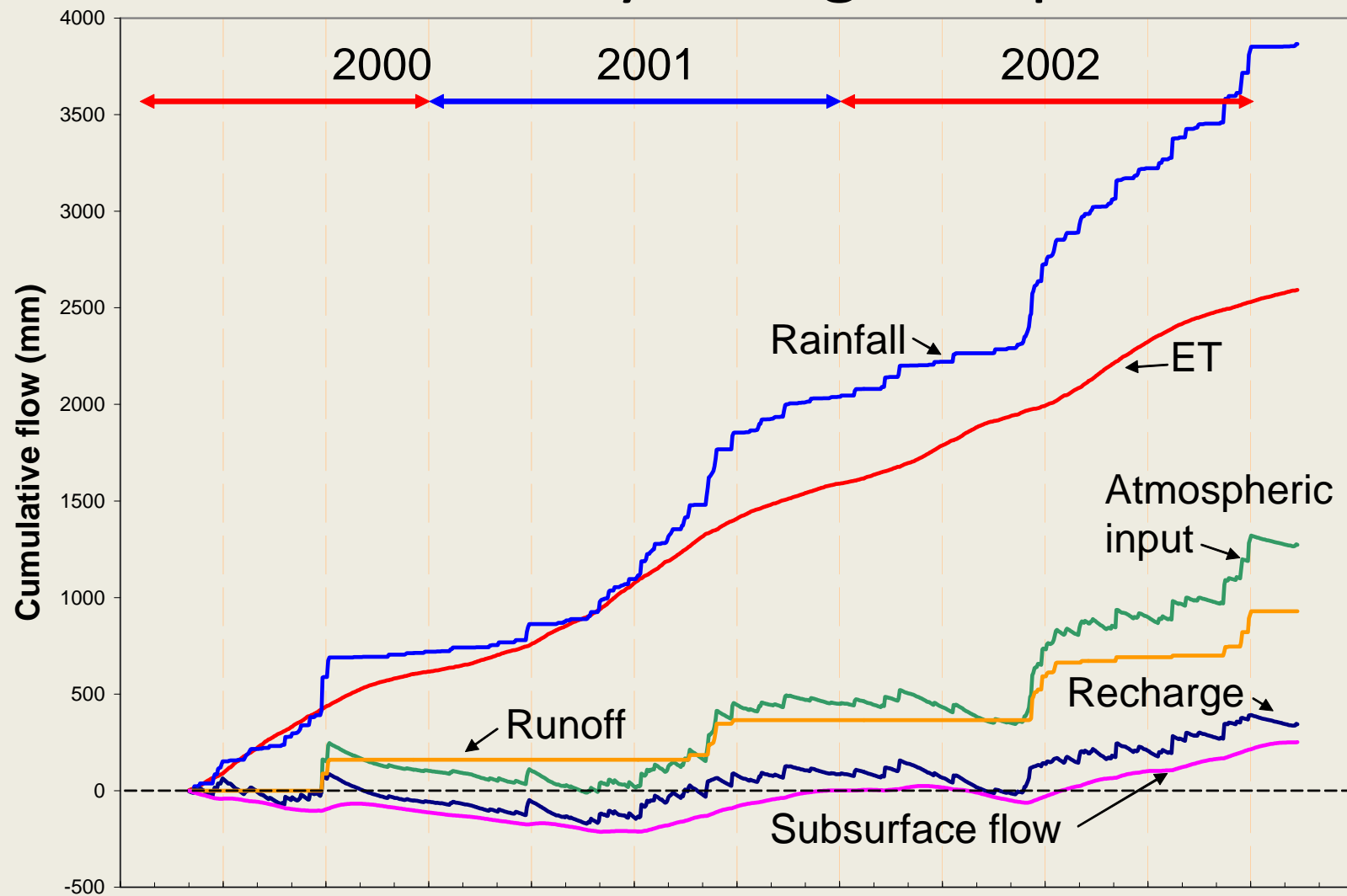
Available water = 200
mm +/- 50%

Large error in recharge/runoff when rainfall and
ET are comparable

“Friends” of coarse ET estimates

- Precip >> ET: error in ET is masked
- Most of variability in available water is contained within Precip

Measured rainfall and ET & Simulated hydrologic response



Impact of rising atmospheric CO₂ on ET

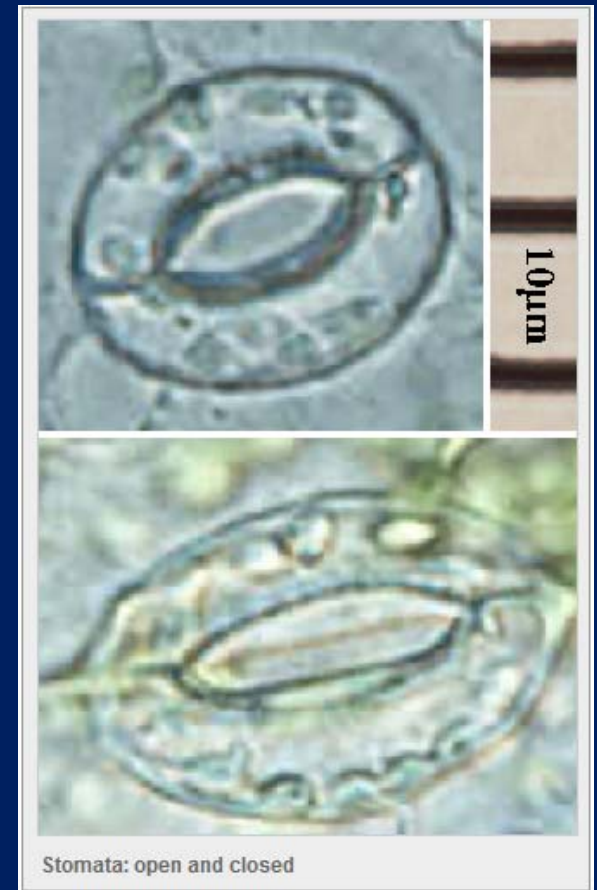
Plant canopy conductance (stomatal control, leaf area)

Rising atmospheric CO₂ leads to:

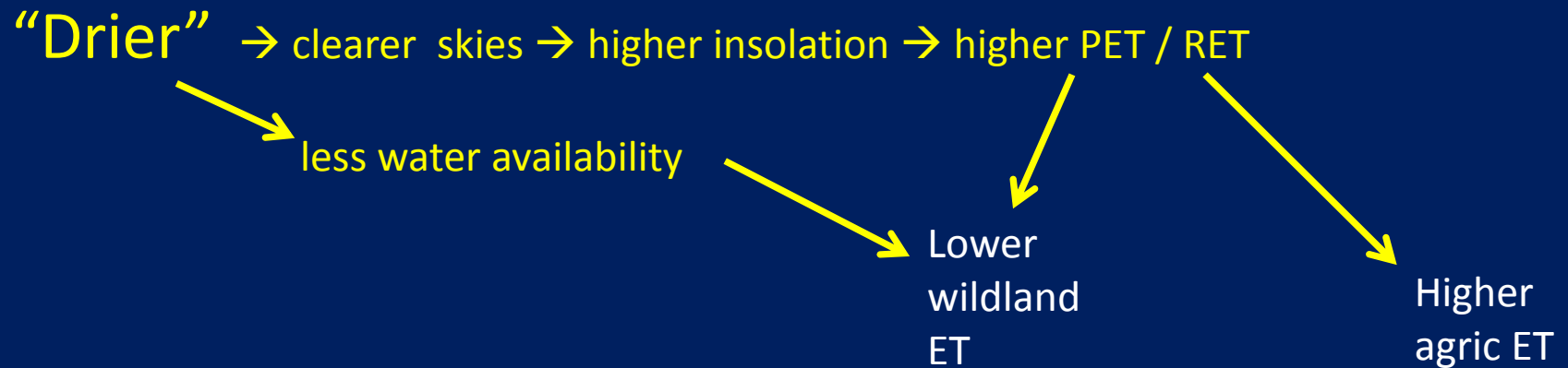
More restricted stomata → lower ET → more heating
More foliage → higher ET → more cooling

Much uncertainty on direction/magnitude of canopy conductance impact ... several field studies indicate a 0-20% reduction in ET

Much uncertainty in how these CO₂/ET/heating feedbacks are handled in GCMs



Expect: negative correlation between precipitation and PET/RET



Joint PDFs of precipitation and PET/RET