USGS
science for a changing world

Overview of evapotranspiration studies in the USGS Caribbean-Florida Water Science Center

John Stamm
U.S. Geological Survey
Caribbean-Florida Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

Outline

- *Contributing researchers*
- *Climate setting for Florida*
- *USGS ET stations*
- *Gridded ET products*
  - *applications*
- *MODIS actual ET*
- *Future work*

USGS

Contributing researchers

- *USGS*
  - *David Sumner, Ph.D., Associate Director for Studies, CFWSC*
  - *Barclay Shoemaker, Ph.D., Research Hydrologist, CFWSC*
  - *Michael Wacker, Hydrologist, CFWSC*
- *Academia*
  - *John Mecikalski, Associate Professor, University of Alabama in Huntsville*
  - *Johnna Infanti, Ph.D., University of Miami, University Cooperation for Atmospheric Research (UCAR) Cooperative Programs for the Advancement of Earth System Science, Postdoctoral Researcher*
  - *Gabriel Senay, Ph.D., USGS Earth Resource Observation and Science (EROS) Center and Colorado State University*

USGS

Climate setting for Florida

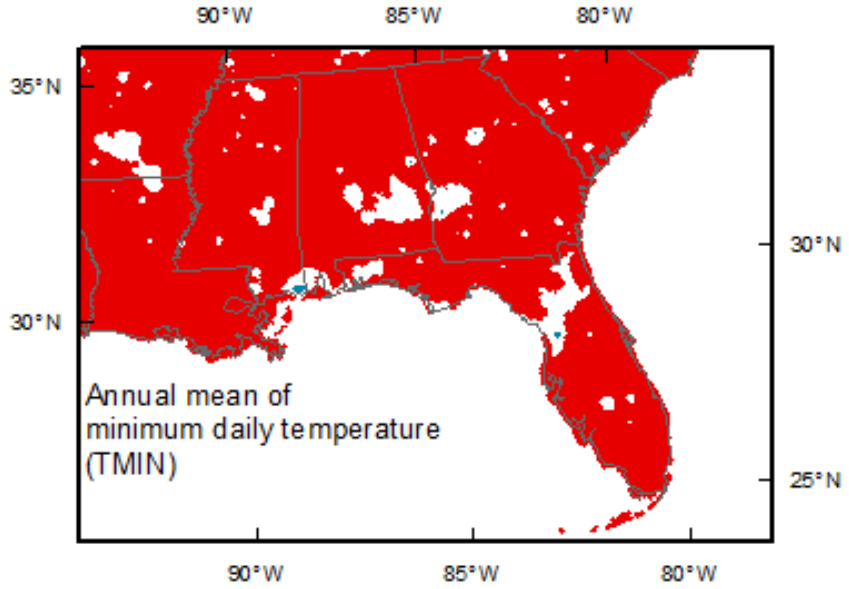
- *Historical climate: 1961–2016*
- *Projected climate to 2099*

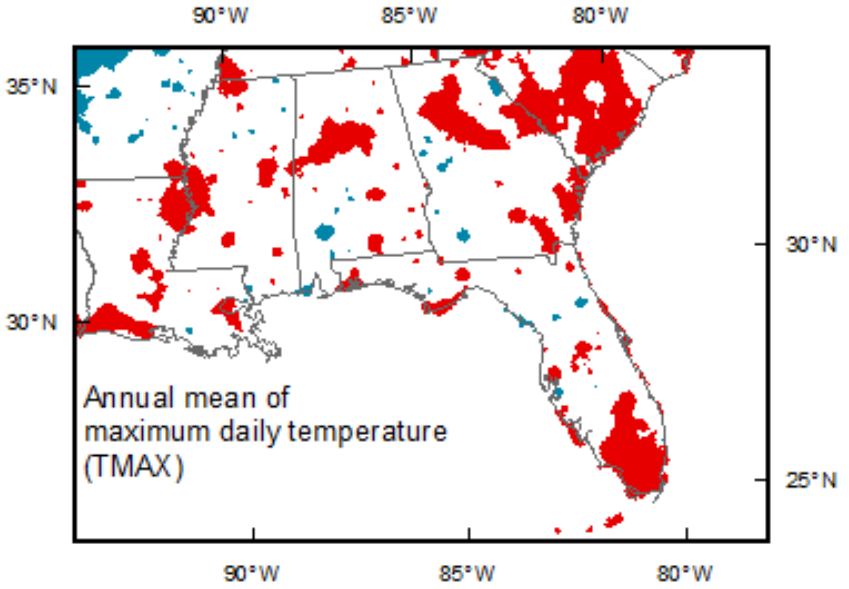
USGS

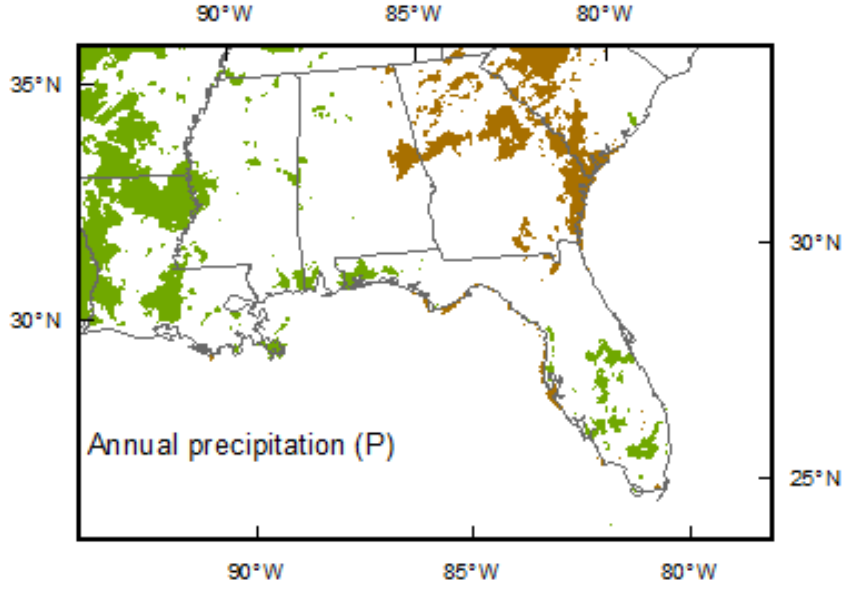
Historical climate

- *Parameter-elevation Regressions on Independent Slopes Model*
  - *Oregon State University*
  - *Interpolates weather station data to a gridded dataset*
    - *conterminous United States*
    - *monthly mean of daily T_{min} and T_{max}*
    - *monthly P*
    - *1895–present*
    - *2.5 minute resolution (~4.0x4.5 km in Florida)*

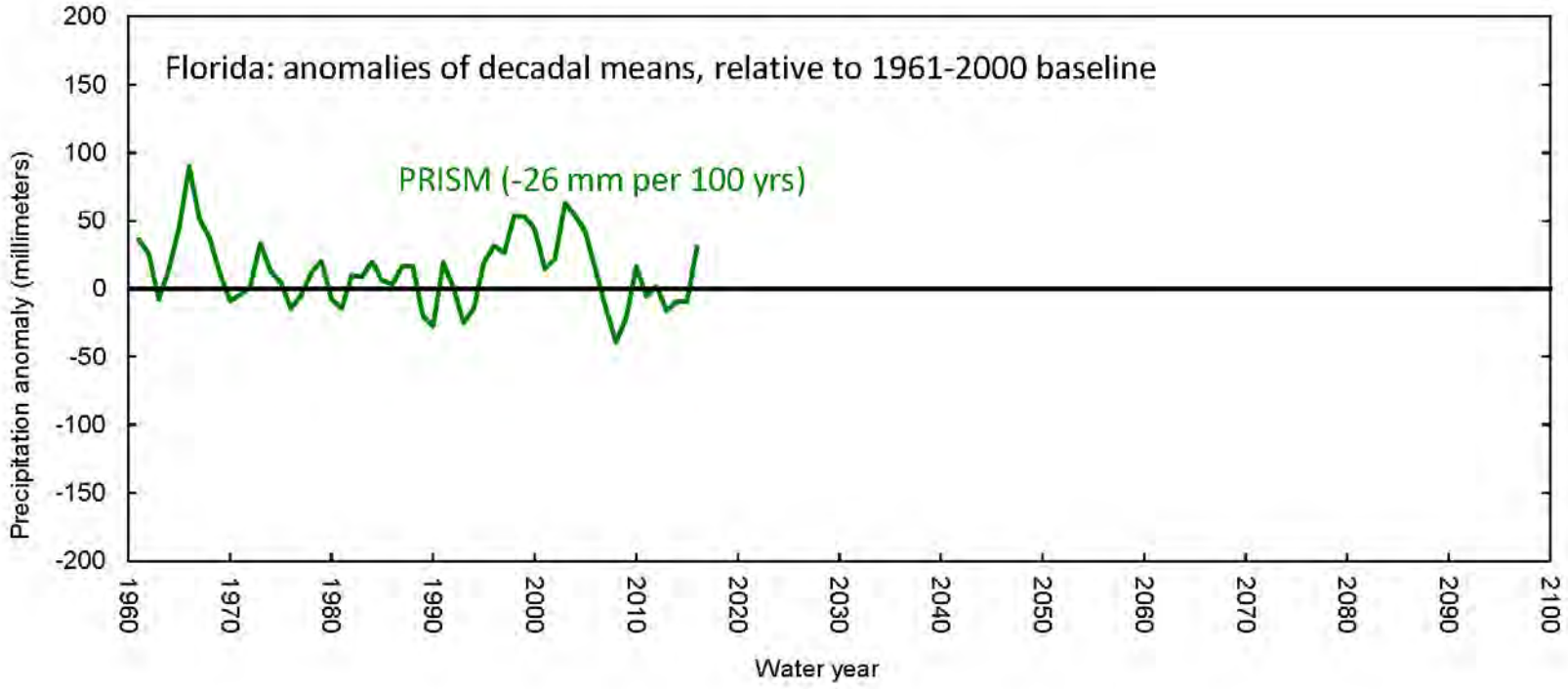
USGS

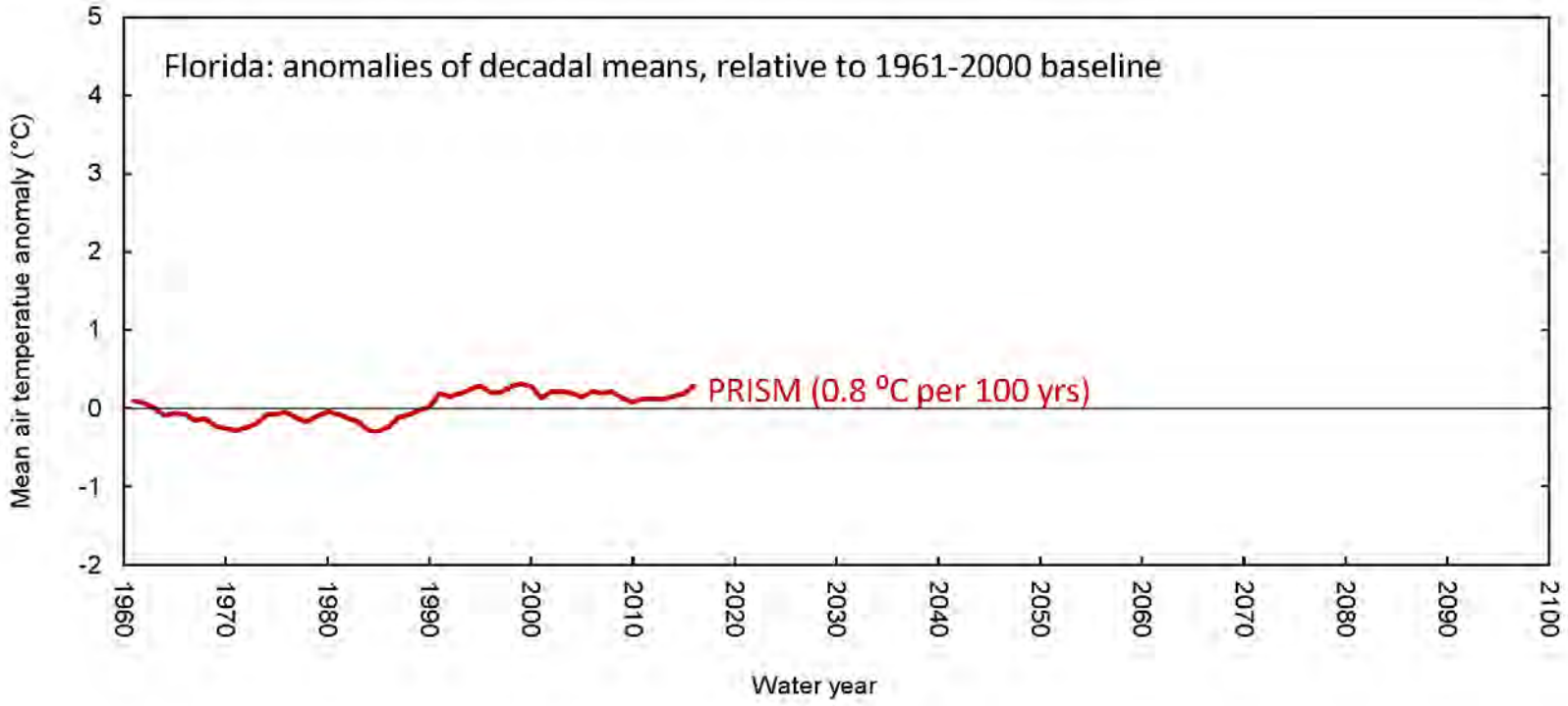

90°W
85°W
80°W
35°N
30°N
25°N
Annual mean of
minimum daily temperature
(TMIN)


90°W
85°W
80°W
35°N
30°N
25°N
Annual mean of
maximum daily temperature
(TMAX)


90°W
85°W
80°W
35°N
30°N
25°N
Annual precipitation (P)


Upward P trend
Downward P trend
Upward TMIN or TMAX trend
Downward TMIN or TMAX trend

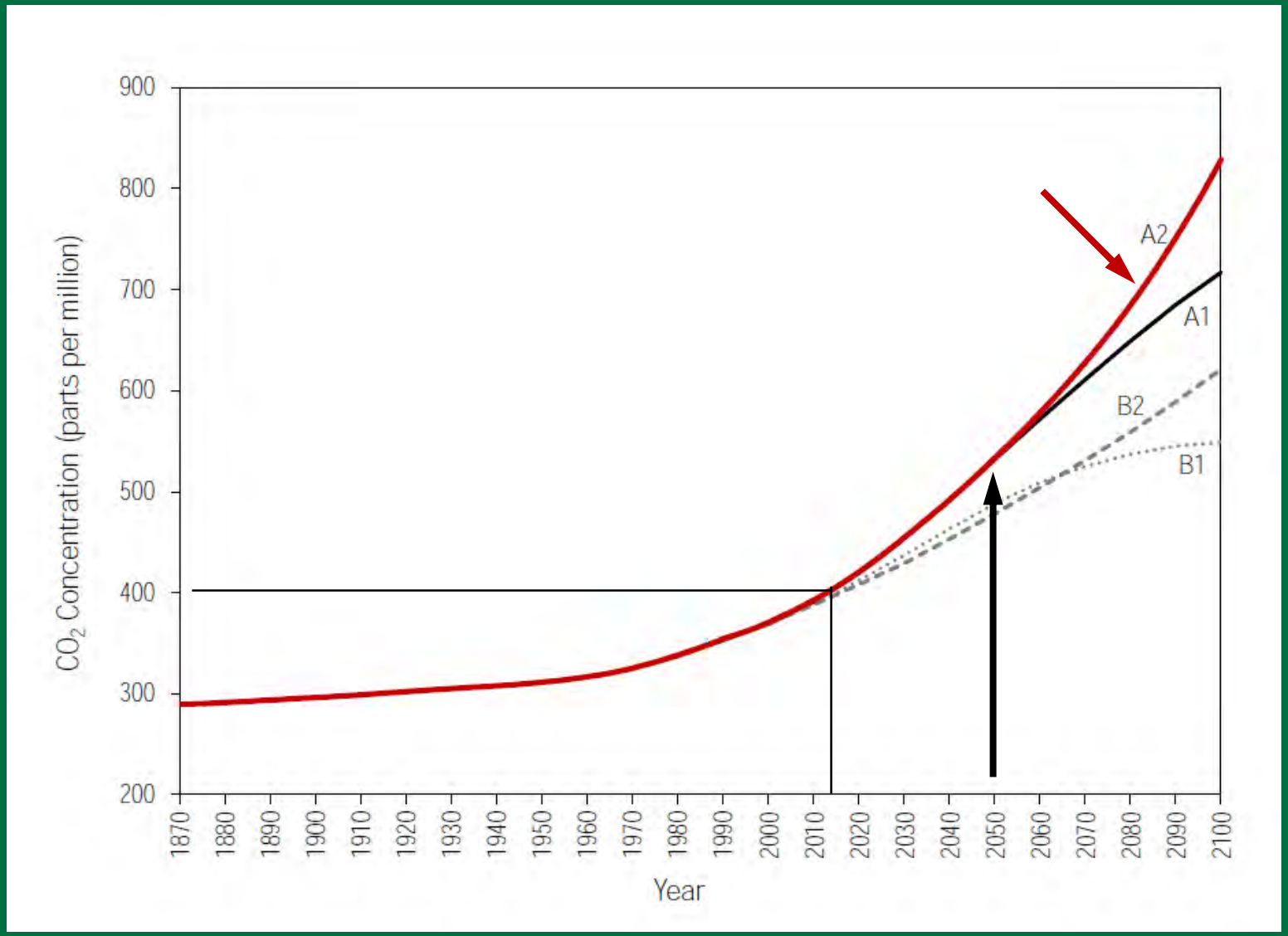

Florida: anomalies of decadal means, relative to 1961-2000 baseline
PRISM (-26 mm per 100 yrs)
Precipitation anomaly (millimeters)
200
150
100
50
0
-50
-100
-150
-200
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Water year


Florida: anomalies of decadal means, relative to 1961-2000 baseline
Mean air temperatue anomaly (°C)
5
4
3
2
1
0
-1
-2
PRISM (0.8 °C per 100 yrs)
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Water year

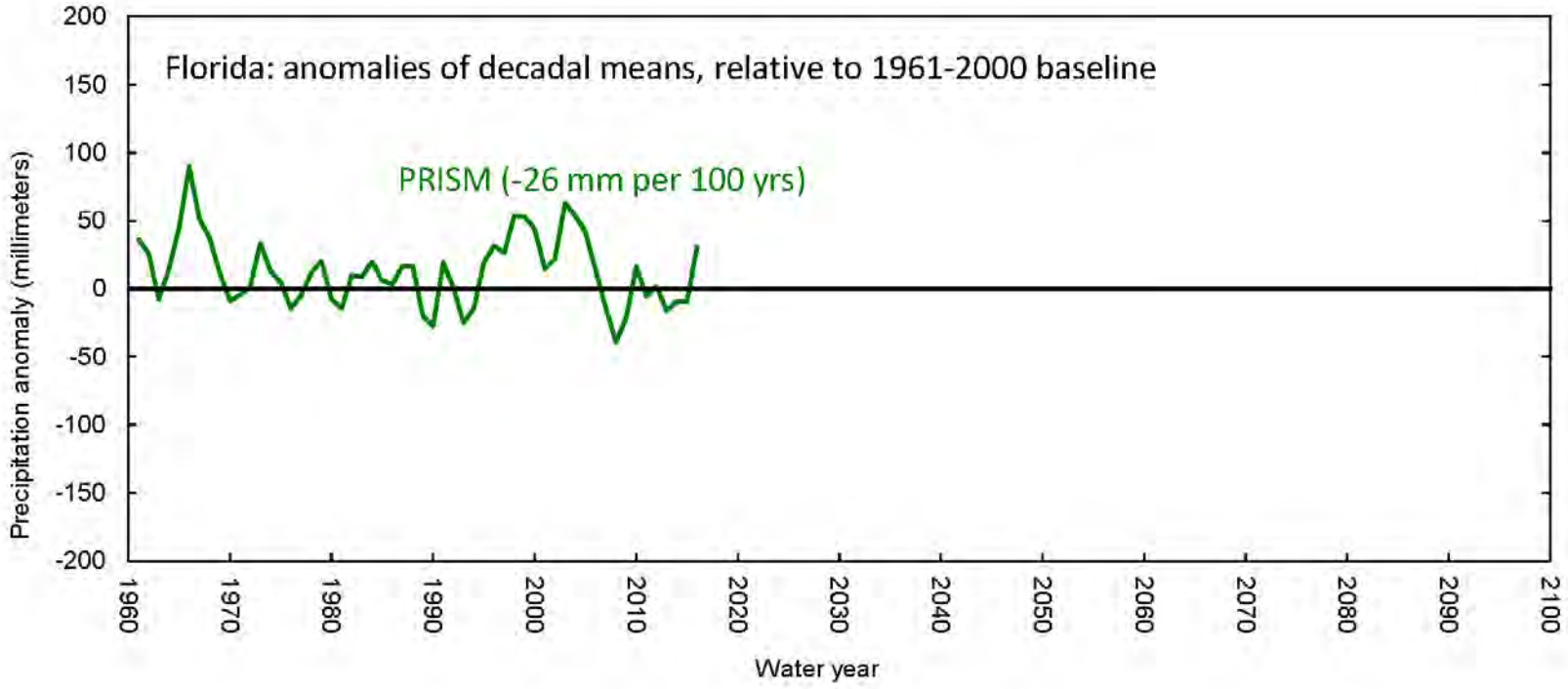
Projected climate

- Community Climate System Model
  - National Center for Atmospheric Research (NCAR), Boulder, CO
  - CCSM3: 1.4 ^{0} lon and lat resolution (~140 by 155 km in Florida)
    - A2 emission scenario
  - CCSM4: 1.25 ^{0} lon by 0.9 ^{0} lat resolution (~125 by 100 km in Florida)
    - RCP8.5 emission scenario

USGS


900
800
700
600
500
400
300
200
CO_2 Concentration (parts per million)
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
A2
A1
B2
B1

USGS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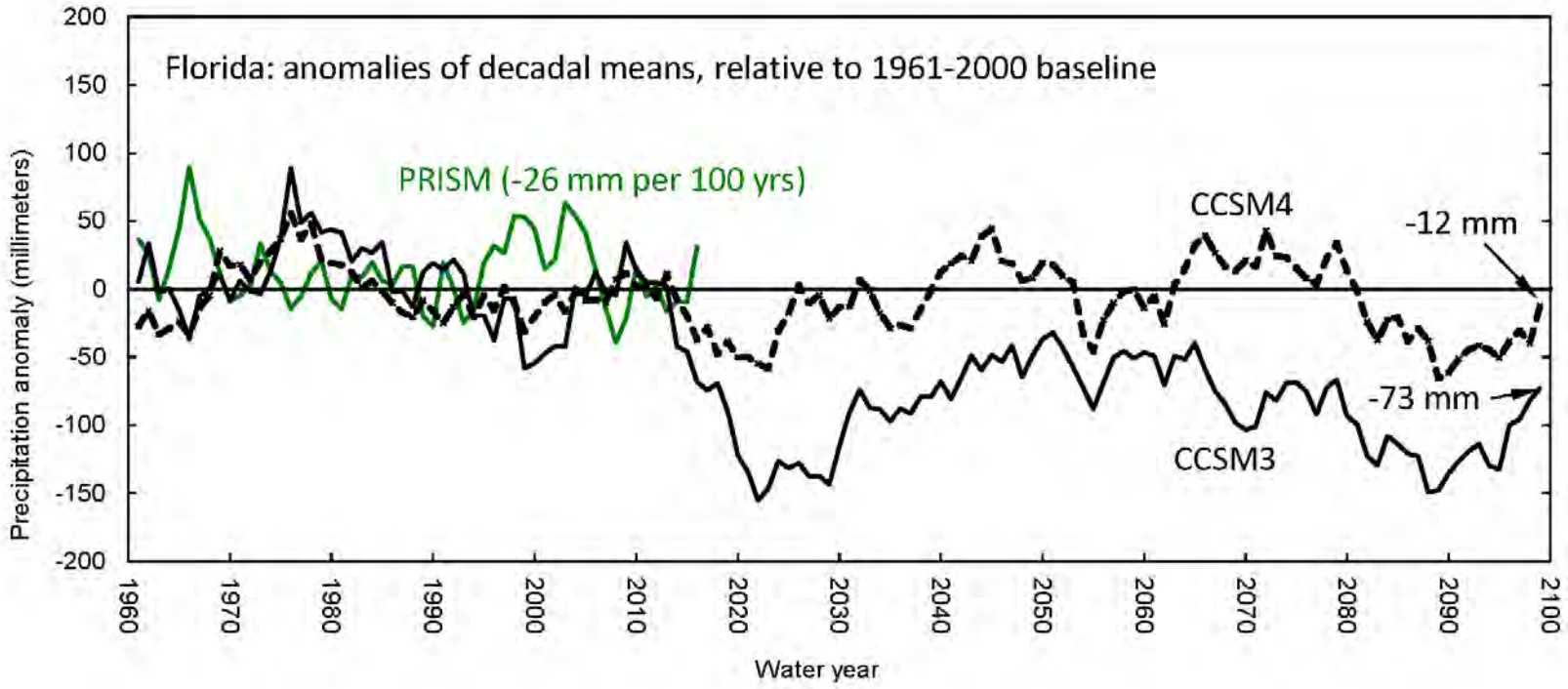
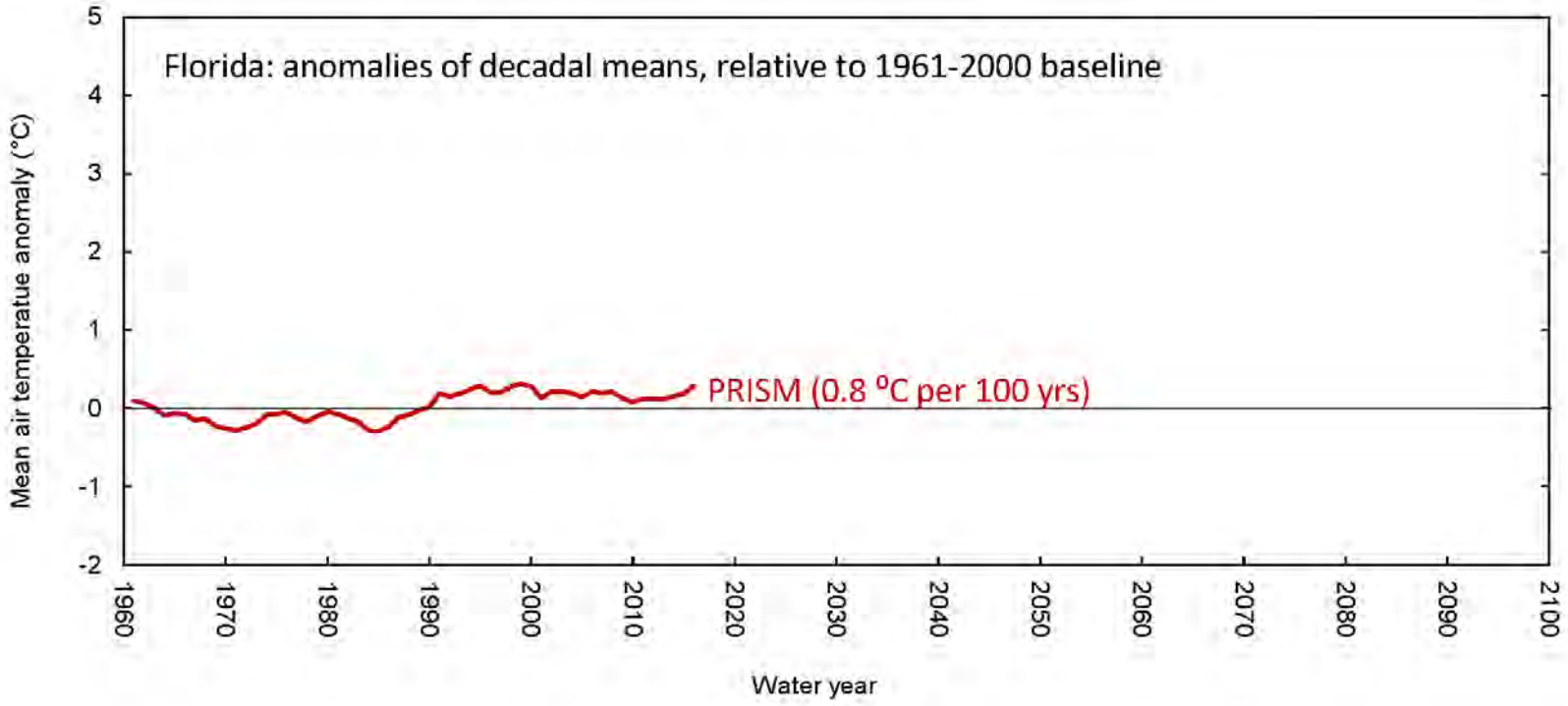
Precipitation anomaly (millimeters)
200
150
100
50
0
-50
-100
-150
-200
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Water year


Florida: anomalies of decadal means, relative to 1961-2000 baseline
PRISM (-26 mm per 100 yrs)
CCSM4
-12 mm
-73 mm
CCSM3
Precipitation anomaly (millimeters)
Water year
200
150
100
50
0
-50
-100
-150
-200
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100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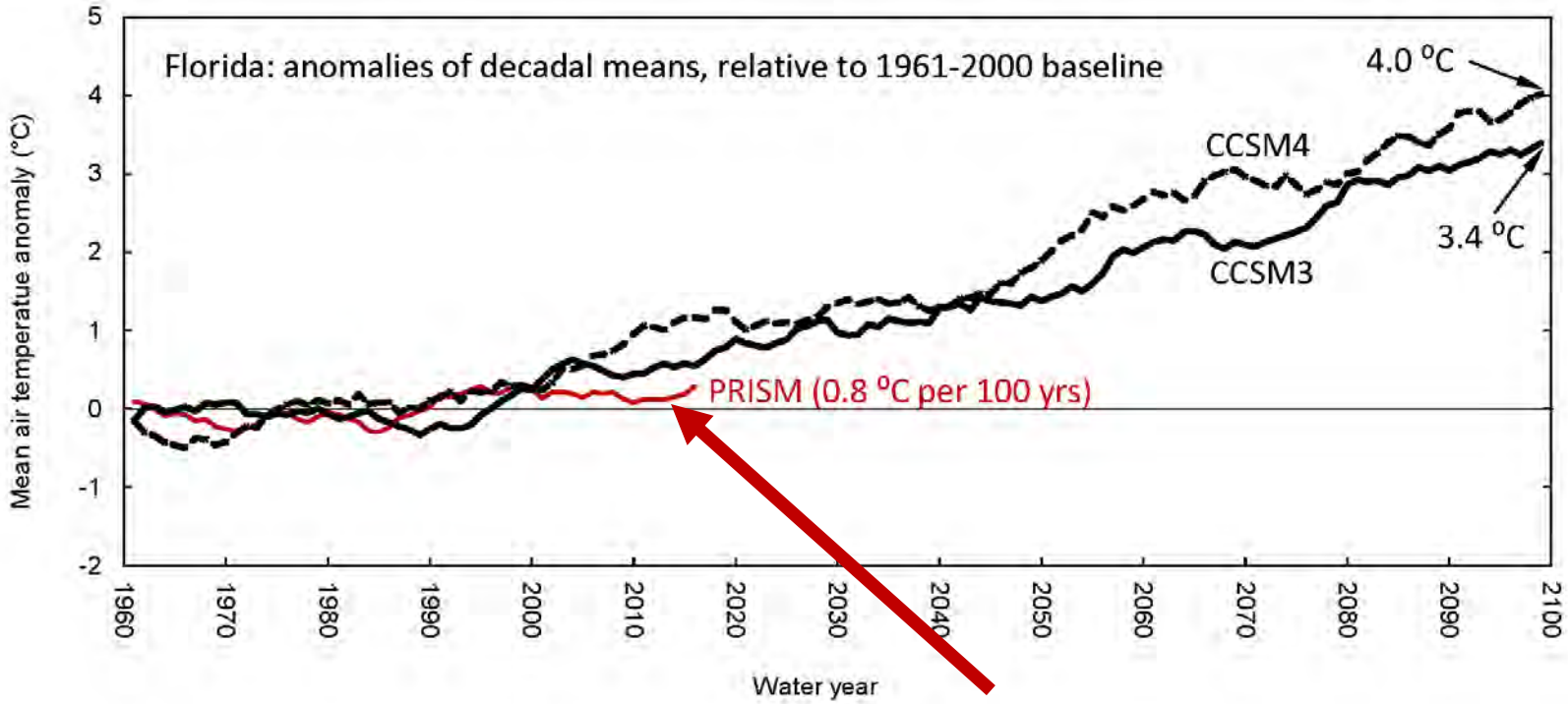
2020
2030
2040
2050
2060
2070
2080
2090
2100
Water year



Effect of evapotranspiration on temperature?

CES Home / USGS / Downscaling-2.0 / CES - Downscaling

CONFERENCES & MEETINGS HOME

USGS-FAU MEET &

EVERGLADES RECOMMENDATIONS

PREDICTING ECOLOGICAL CHANGES

EVERGLADES HYDROLOGY

For more information, contact Mary Beth Hartman, CES Conference & Outreach Coordinator
Phone:(954) 236-1203
Email: mhartman@fau.edu

USGS-FAU Workshop on Increasing

Precipitation Projections for Everglades

September 28, 2017 - 9 a.m. to 6 p.m.
Florida Atlantic University - Davie Campus

ABOUT | AGENDA | LOGISTICS | HOTEL OPTIONS

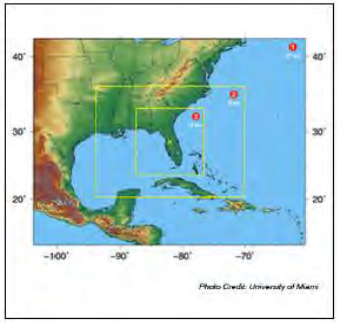
Evapotranspiration is an important variable for validation of climate models, and for selection of “best” climate models for Florida studies.

TOPIC

Improving confidence in precipitation projections for Everglades restoration.

MOTIVATION:

The uncertainty of climate projections is a significant barrier to the implementation of restoration and adaptive management programs. Our objective is to improve the utility of precipitation projections for South Florida water management and Everglades restoration efforts, particularly related to the time scales and time periods of interest, spatial scales of interest, parameters of interest, and characterization of uncertainty for 3 focal areas or domains.



USGS

USGS ET Stations

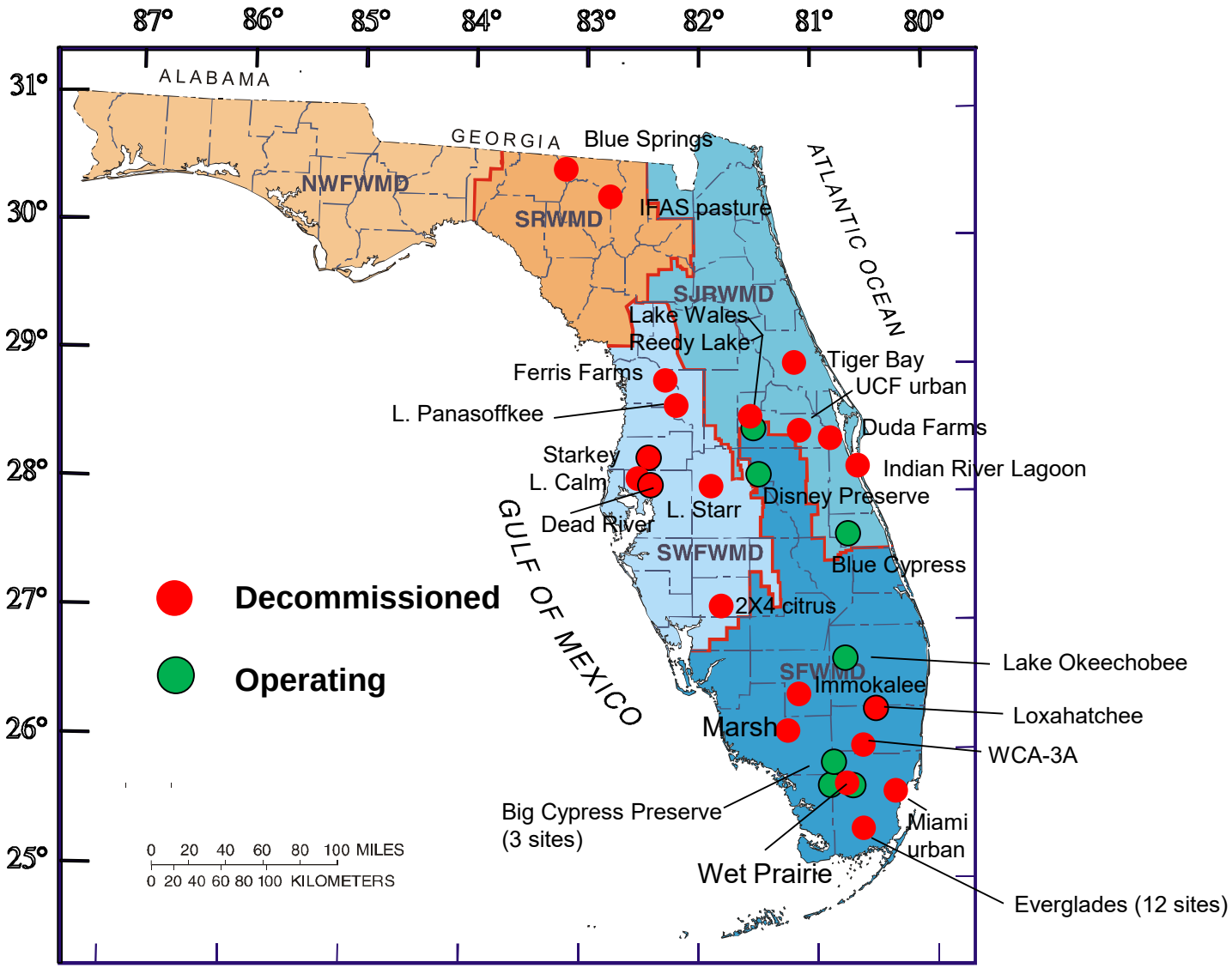
- *Barclay Shoemaker, Michael Wacker, David Sumner*
- *Variety of land types and water settings*

Starkey Park, meadow, near Tampa

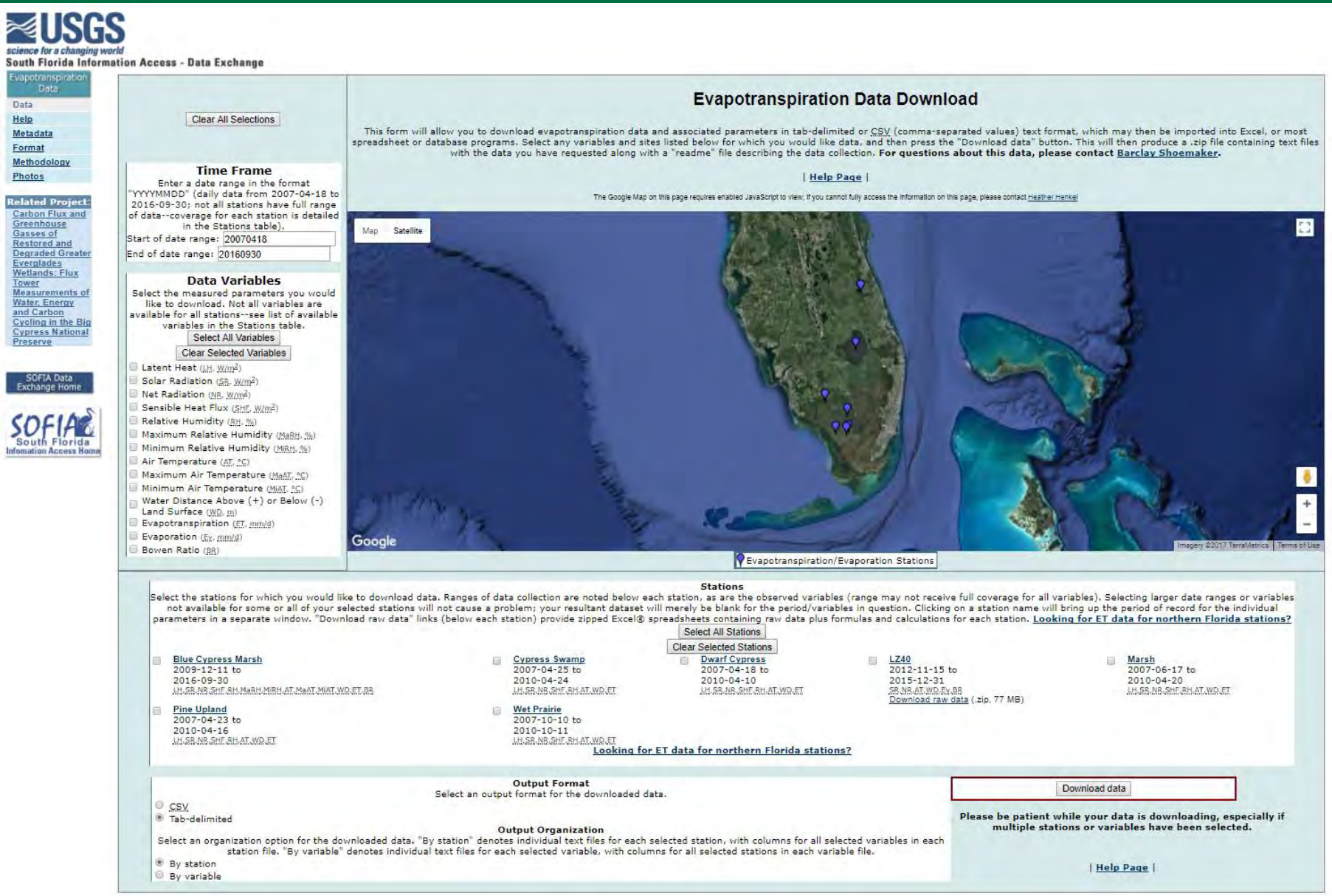
Dead River, forested wetland, near Tampa

USGS

USGS CFWSC ET Network- Past & Present



https://sofia.usgs.gov/exchange/evapotrans/

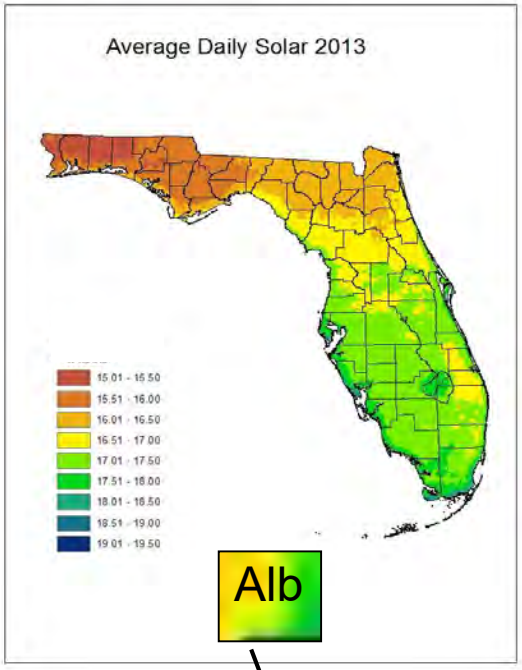


Gridded RET and PET products

- *Barclay Shoemaker, John Mecikalski*
- *Reference and Potential Evapotranspiration:*
  - *2 kilometer resolution for Florida*
    - *Identical to NEXRAD gridded precipitation dataset*
  - *daily*
  - *Geostationary Operational Environmental Satellite (GOES) estimates of solar insolation*
  - *Atmospheric variables interpolated from weather station data*

USGS

2015 Statewide GOES ET maps



Alb

Rn

T_{min} T_{max} RH_{min} RH_{max} W_s

Priestley-Taylor (1972) PET / Allen et al. (1998) RET (standardized PM)

PET / RET .com
http://fl.water.usgs.gov/et/

http://fl.water.usgs.gov/et/

Evapotranspiration Information and Data

The U.S. Geological Survey Florida Evapotranspiration Network is a network of 15 data collection sites representing various land cover types, which provide long-term, accurate, and unbiased information that meets the needs of many diverse users. The USGS collects the evapotranspiration data needed by Federal, State, and local agencies for planning and operating water-resources projects and regulatory programs.

The links below allow you to find information and data about Florida's evapotranspiration resources.

Evapotranspiration Data

Data Collection Sites

The map shows current and past evapotranspiration data collection sites in Florida; click the map to go to a full size version with links to NWISWeb data.

Statewide Evapotranspiration Data - (2km Daily)

ET Data County and State 1985-2016

- 1985 1986 1987 1988 1989
- 1990 1991 1992 1993 1994
- 1995 1996 1997 1998 1999
- 2000 2001 2002 2003 2004
- 2005 2006 2007 2008 2009
- 2010 2011 2012 2013 2014
- 2015 2016

Information Resources

Evapotranspiration Publications

- USGS Evapotranspiration Publications for Florida
- Technical Report: Satellite-based Evapotranspiration Estimates Over Florida
- InTechWeb Report: Use of Visible Geostationary Operational Meteorological Satellite Imagery in Mapping Reference and Potential Evapotranspiration over Florida

Other USGS Evapotranspiration Resources

- USGS Nevada Water Science Center - Evapotranspiration Studies

Need More Information?

- Contact the Florida Evapotranspiration Specialists

USGS

Statewide Evapotranspiration Data - (2km Daily)

File	Size	File	Size	File	Size	File	Size
Alachua_2016	6,412,654	Flagler_2016	3,095,175	Lake_2016	7,680,098	Pinellas_2016	1,699,415
Baker_2016	4,067,558	Franklin_2016	3,453,638	Lee_2016	5,296,903	Polk_2016	13,176,262
Bay_2016	4,884,410	Gadsden_2016	3,250,057	Leon_2016	4,781,970	Putnam_2016	5,581,810
Bradford_2016	1,904,923	Gilchrist_2016	2,119,279	Levy_2016	7,213,457	SantaRosa_2016	6,660,772
Brevard_2016	6,739,281	Glades_2016	6,585,205	Liberty_2016	5,782,353	Sarasota_2016	3,744,114
Broward_2016	8,119,784	Gulf_2016	3,811,593	Madison_2016	4,652,583	Seminole_2016	2,138,572
Calhoun_2016	3,745,912	Hamilton_2016	3,159,156	Manatee_2016	5,137,157	StJohns_2016	4,269,590
Charlotte_2016	4,579,016	Hardee_2016	4,290,226	Marion_2016	10,940,972	StLucie_2016	4,045,293
Citrus_2016	4,072,675	Hendry_2016	8,068,759	Martin_2016	4,522,732	Sumter_2016	3,996,311
Clay_2016	4,220,191	Hernando_2016	2,960,137	Monroe_2016	6,500,986	Suwannee_2016	4,737,152
Collier_2016	13,295,931	Highlands_2016	7,724,319	Nassau_2016	4,278,366	Taylor_2016	6,872,260
Columbia_2016	5,041,943	Hillsborough_2016	7,028,943	Okaloosa_2016	6,237,374	Union_2016	1,512,231
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DeSoto_2016	4,243,340	IndianRiver_2016	3,094,198	Orange_2016	6,607,163	Wakulla_2016	4,093,822
Dixie_2016	4,600,821	Jackson_2016	6,180,173	Osceola_2016	10,313,256	Walton_2016	6,811,257
Duval_2016	5,627,581	Jefferson_2016	4,040,008	PalmBeach_2016	14,322,146	Washington_2016	4,097,488
Escambia_2016	4,435,212	Lafayette_2016	3,283,216	Pasco_2016	5,006,794	Florida_2016	376,950,271

The above files are compressed, tab-delimited tables of numeric data that are generally software independent. Tab-delimited data can be imported into a variety of GIS, database or spreadsheet software packages.

Each compressed County archive file contains one data file having tab delimited columns of data, which include the following fields:

Column	Definition
1	Date of data representation (Year Month Day as yyyymmdd)
2	Latitude of Pixel value (Decimal degrees)
3	Longitude of Pixel value (Decimal degrees)
4	Pixel ID number
5	Potential ET(mm/day)
6	Reference ET(mm/day)
7	Solar Radiation - Daily Insolation (MegaJoules/sq meter/day)
8	Maximum Relative Humidity for day (%)
9	Minimum Relative Humidity for day (%)
10	Maximum Temperature for day (C)
11	Minimum Temperature for day (C)
12	Wind Speed (meters/second)

Notes concerning the current data sets:
Missing values are represented by the number -9999.900.

Daily data quality codes for January 1 through December 31

Daily Quality Codes	Size
Quality_Codes_2016	905

Each compressed Daily Quality Code file contains one data file having tab delimited columns of data, which include the following fields:

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Information regarding the methodology used in the ET computations are detailed in the InTechWeb Report:
Use of Visible Geostationary Operational Meteorological Satellite Imagery in Mapping Reference and Potential Evapotranspiration over Florida

Metadata file describing this year's GOES ET process (XML format): GOES_ET_metadata_2016

USGS

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Statewide Evapotranspiration Data - (2km Daily)

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12 Wind Speed (meters/second)

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USGS

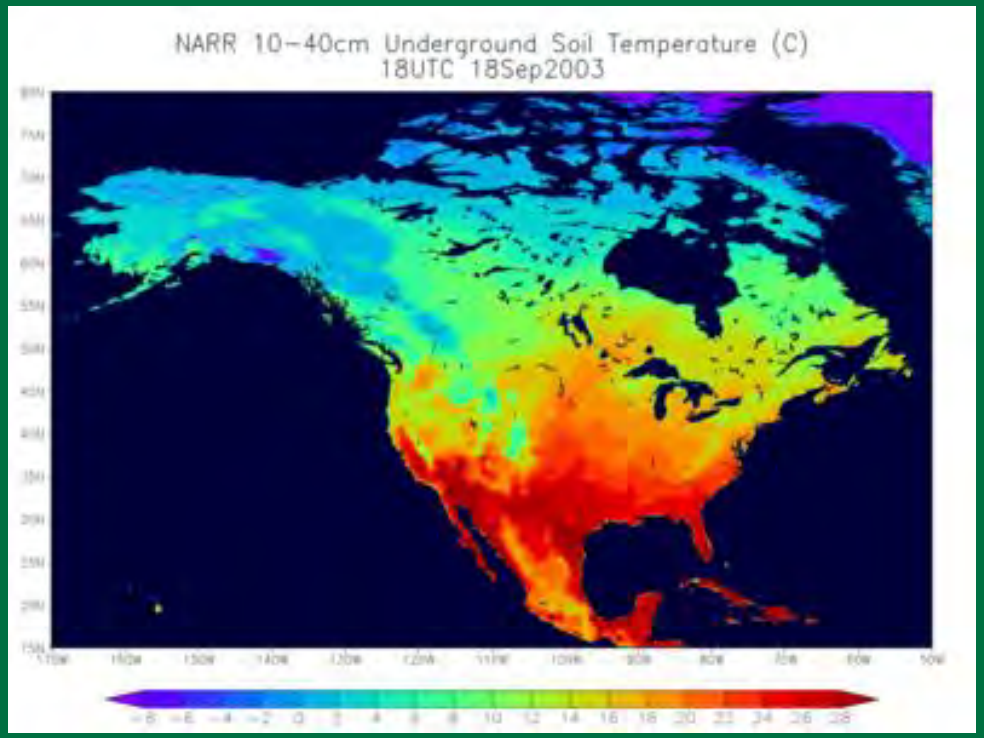
Current research / improvements

- *Estimates of albedo using MODIS data*
- *Interpolation of atmospheric variables using radial basis function*
  - *distance-squared interpolation currently used*
  - *RBF increases weights of distant points when computing weights for interpolation*
- *Atmospheric data from the North American Regional Reanalysis*
- *Atmospheric data from the Weather Research and Forecasting Model*

USGS

North American Regional Reanalysis

- *32 km spatial resolution*
- *3 hour time step*
- *Full suite of atmospheric variables*

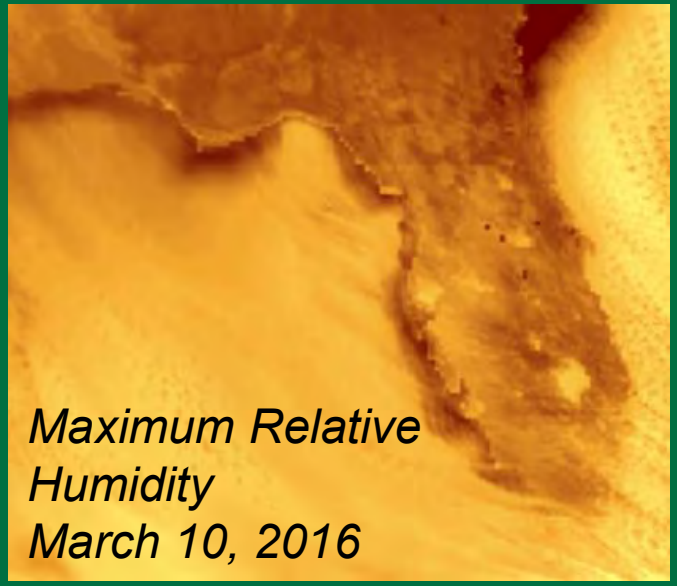


USGS

Weather Research and Forecasting Model

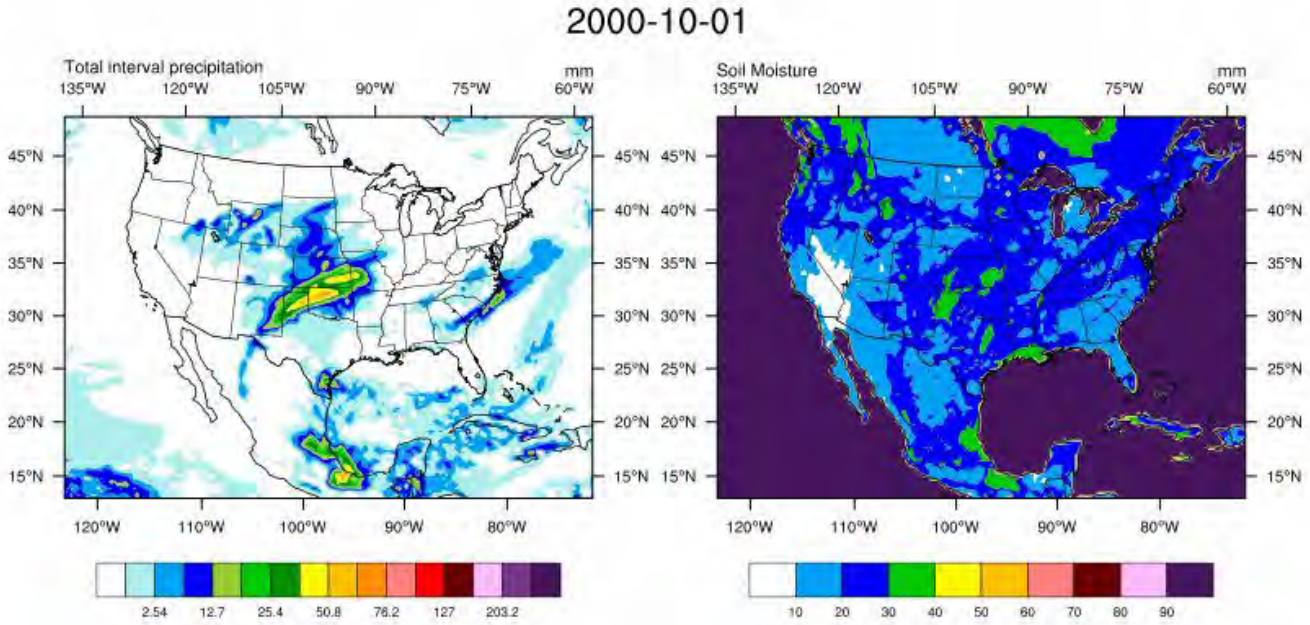
- *2 km spatial resolution*
- *1 hour time step*
- *Grid overlaps with PET, RET, NEXRAD grids*
- *Full suite of atmospheric variables*

WRF simulation at 2-km grid spacing for Florida



Maximum Relative Humidity
March 10, 2016

USGS


2000-10-01
Total interval precipitation
mm
135°W
120°W
105°W
90°W
75°W
60°W
45°N
40°N
35°N
30°N
25°N
20°N
15°N
120°W
110°W
100°W
90°W
80°W
2.54
12.7
25.4
50.8
76.2
127
203.2
Soil Moisture
mm
10
20
30
40
50
60
70
80
90

Research applications of ET data

- *Calibration of simple estimators of evapotranspiration*
- *Water budget for Tsala Apopka system of lakes*

USGS

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation
DOI: 10.13031/aim.201700912
Paper Number: 1700912

Use of eddy-covariance methods to "calibrate" simple estimators of evapotranspiration

David Sumner[1], Jeff Geurink[2], and Amy Swancar[3]
[1]U.S. Geological Survey, Lutz, Florida
[2]Tampa Bay Water, Clearwater, Florida
[3]Cherokee Nation Technology Services under contract to the U. S. Geological Survey, Lutz, Florida

Written for presentation at the
2017 ASABE Annual International Meeting
Sponsored by ASABE
Spokane, Washington
July 16-19, 2017

ABSTRACT. *Direct measurement of actual evapotranspiration (ET) provides quantification of this large component of the hydrologic budget, but typically requires long periods of record and large instrumentation and labor costs. Simple surrogate methods of estimating ET, if "calibrated" to direct measurements of ET, provide a reliable means to quantify ET. Eddy-covariance measurements of ET were made for 12 years (2004-2015) at an unimproved bahiagrass (Paspalum notatum) pasture in Florida. These measurements were compared to annual rainfall derived from rain gage data and monthly potential ET (PET) obtained from a long-term (since 1995) U.S. Geological Survey (USGS) statewide, 2-kilometer, daily PET product. The annual proportion of ET to rainfall indicates a strong correlation (r^2=0.86) to annual rainfall; the ratio increases linearly with decreasing rainfall. Monthly ET rates correlated closely (r^2=0.84) to the USGS PET product. The results indicate that simple surrogate methods of estimating actual ET show positive potential in the humid Florida climate given the ready availability of historical rainfall and PET.*

Keywords. Evapotranspiration, eddy covariance, humid subtropical, potential evapotranspiration, unimproved pasture, west-central Florida.

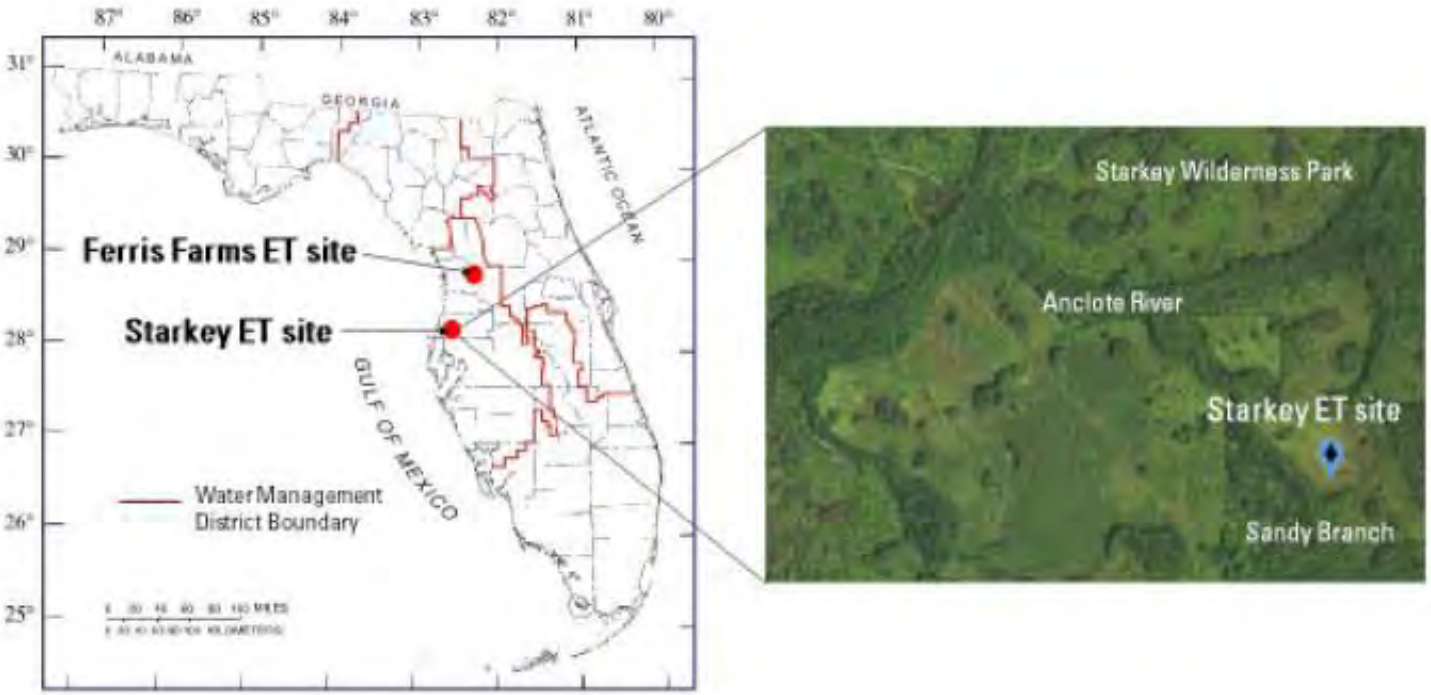


Figure 1. Location of Starkey ET site, in Pasco County, Florida. Also shown are the boundaries of the five Florida State Water Management Districts.

USGS

Actual ET from Starkey station

Actual ET from USGS PET gridded product, calibrated to station actual ET

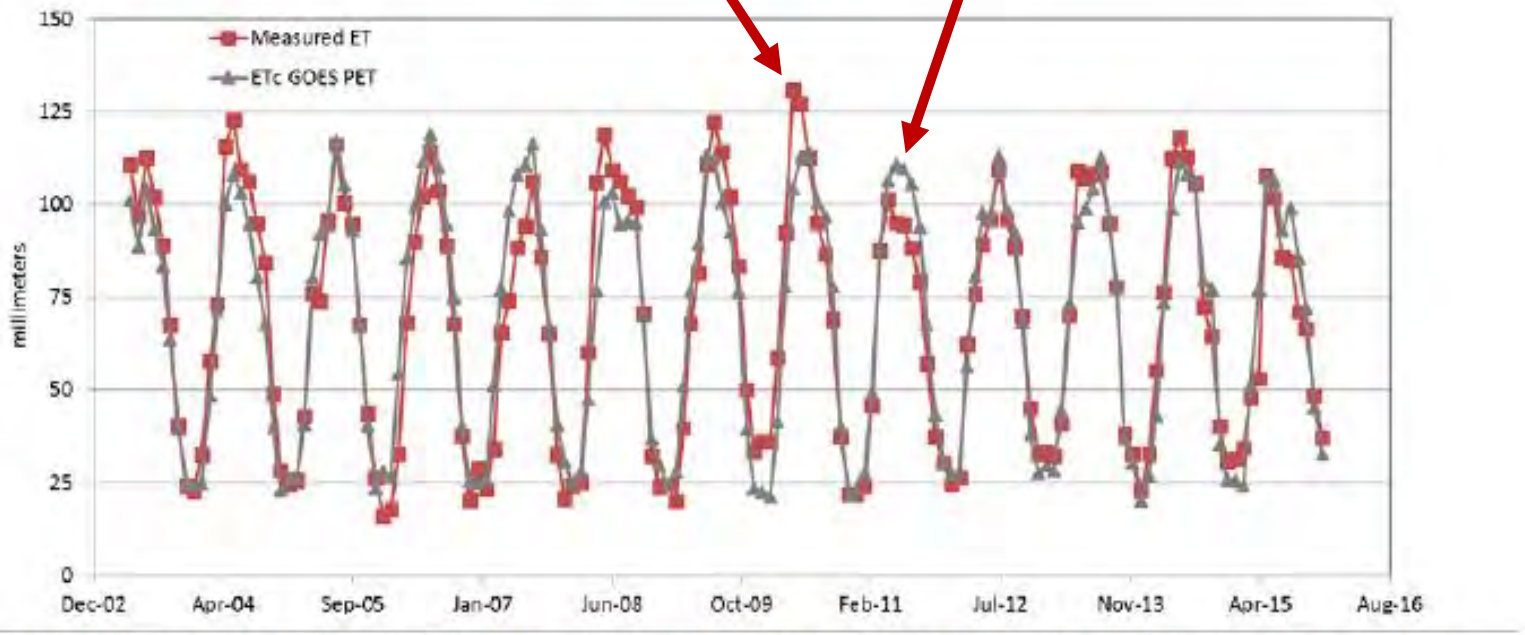


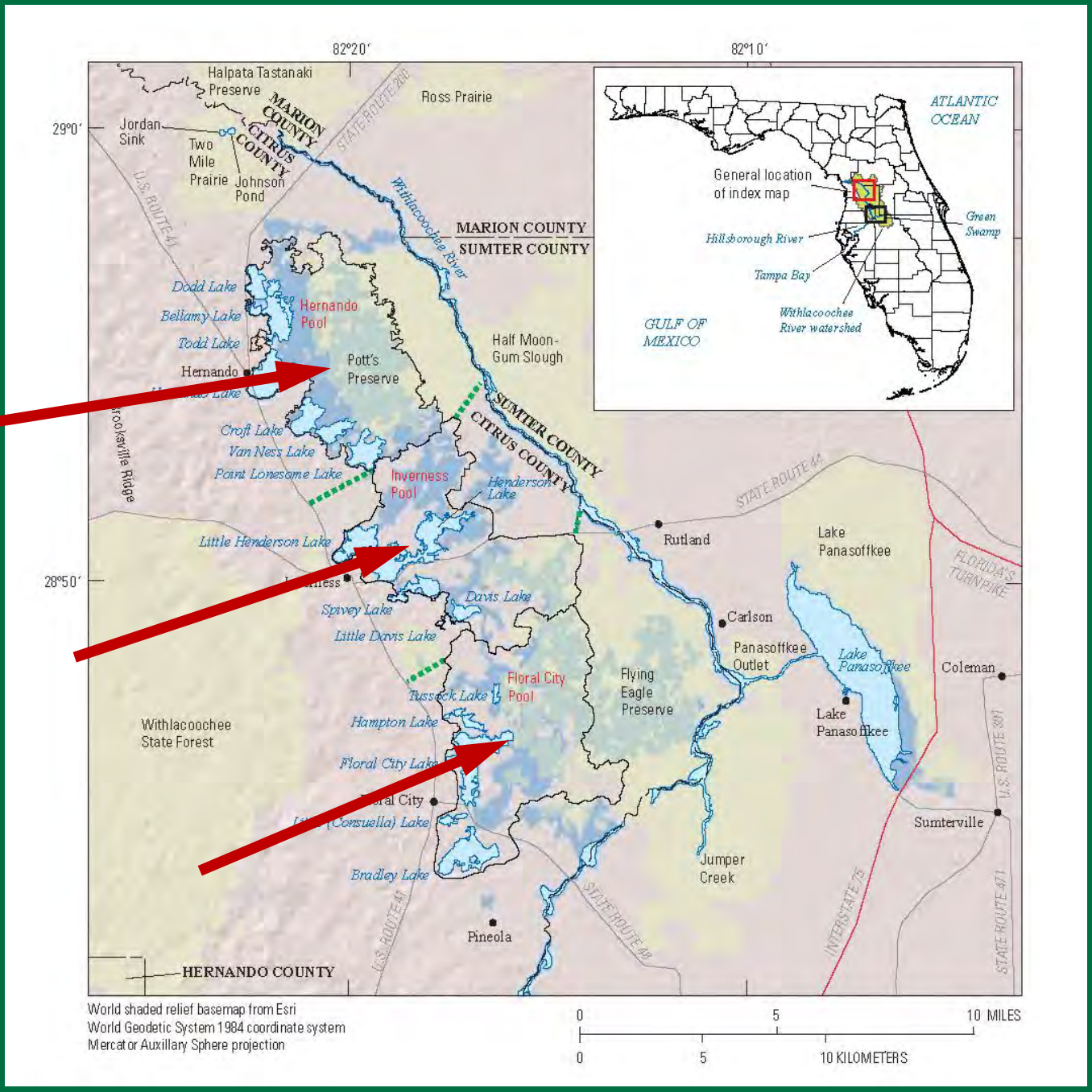
Figure 7. Monthly measured, actual ET and actual ET estimated from GOES PET and crop coefficient at Starkey site, Pasco County, Florida.

USGS

Research applications of ET data

- *Calibration of simple estimators of evapotranspiration*
- *Water budget for Tsala Apopka system of lakes*

USGS


82°20′
82°10′
29°0′
28°50′
Halpata Tastanaki Preserve
Jordan Sink
Two Mile Prairie
Johnson Pond
MARION COUNTY
CITRUS COUNTY
Ross Prairie
STATE ROUTE 200
U.S. ROUTE 41
Withlacoochee River
MARION COUNTY
SUMTER COUNTY
Dodd Lake
Bellamy Lake
Todd Lake
Hernando Pool
Hernando
Pott's Preserve
Half Moon-Gum Slough
SUMTER COUNTY
CITRUS COUNTY
Croft Lake
Van Ness Lake
Point Lonesome Lake
Inverness Pool
Henderson Lake
Brooksville Ridge
Little Henderson Lake
Davis Lake
Spivey Lake
Little Davis Lake
Floral City Pool
Tussock Lake
Hampton Lake
Floral City Lake
Withlacoochee State Forest
Flying Eagle Preserve
Rutland
STATE ROUTE 44
Lake Panasoffkee
FLORIDA'S TURNPIKE
Carlson
Panasoffkee Outlet
Lake Panasoffkee
Coleman
Lake Panasoffkee
U.S. ROUTE 301
Sumterville
Jumper Creek
INTERSTATE 75
STATE ROUTE 471
STATE ROUTE 48
U.S. ROUTE 41
Pineola
HERNANDO COUNTY
ATLANTIC OCEAN
General location of index map
Green Swamp
Hillsborough River
Tampa Bay
GULF OF MEXICO
Withlacoochee River watershed
World shaded relief basemap from Esri
World Geodetic System 1984 coordinate system
Mercator Auxillary Sphere projection
0
5
10 MILES
0
5
10 KILOMETERS

USGS

Water Budget Equation

$$\Delta S = P - E + SW_i - SW_o + G_i - G_o$$

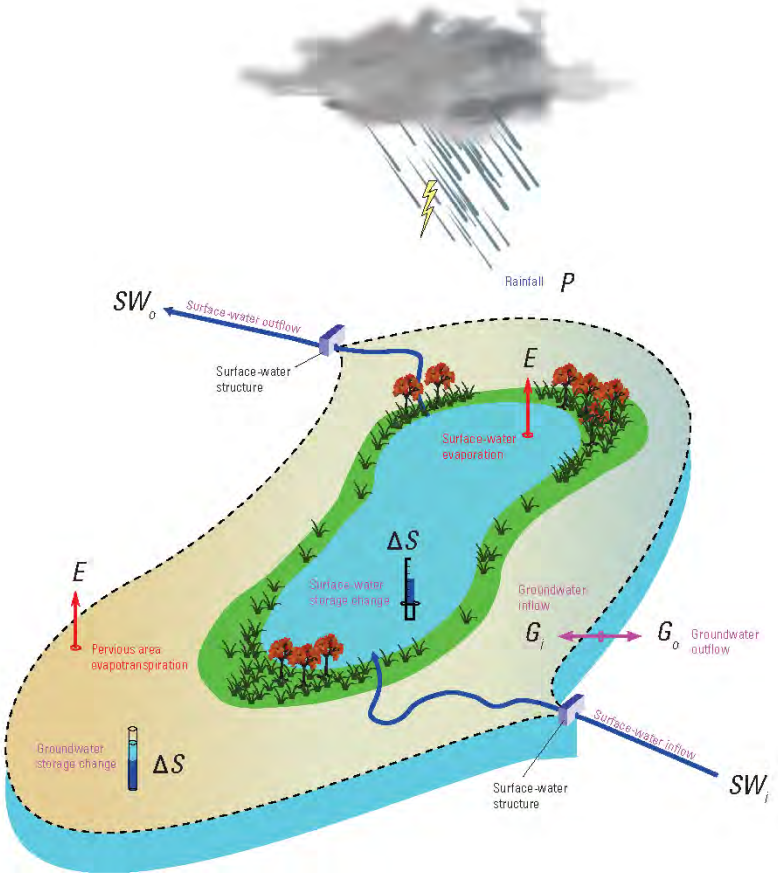
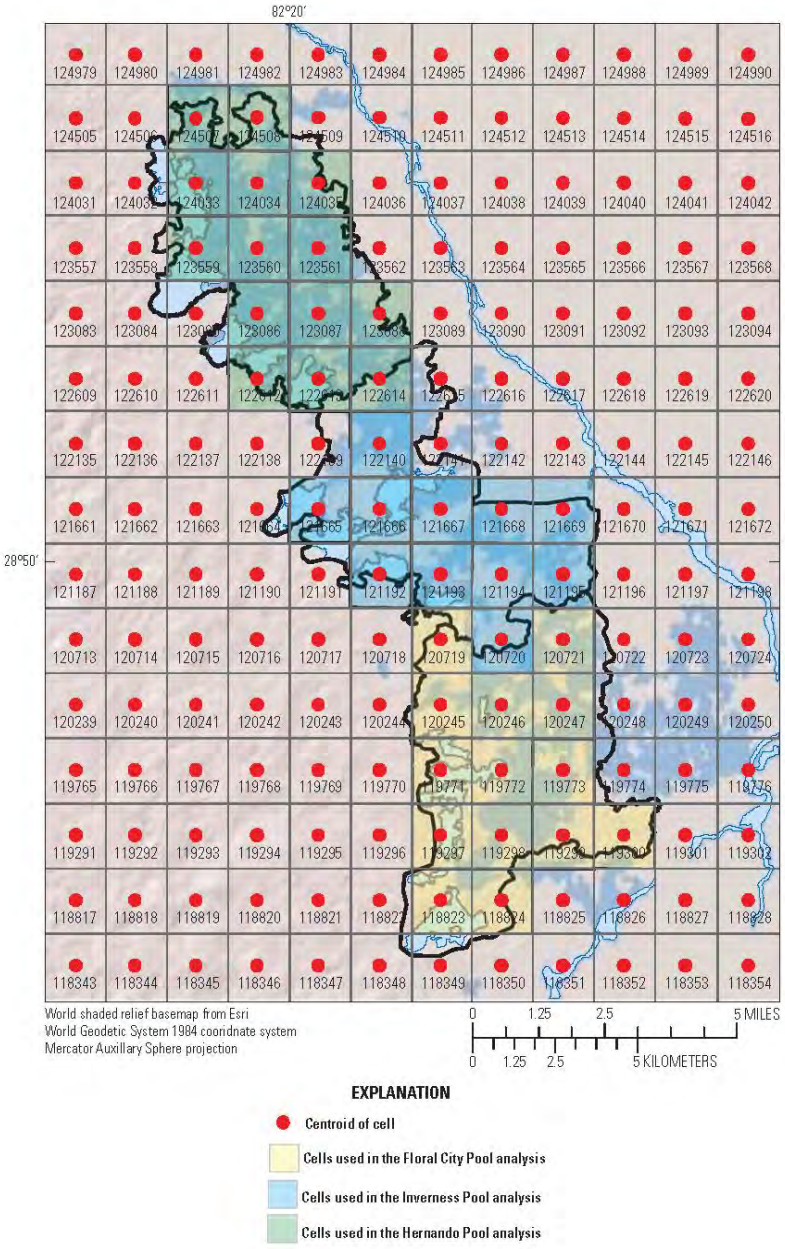


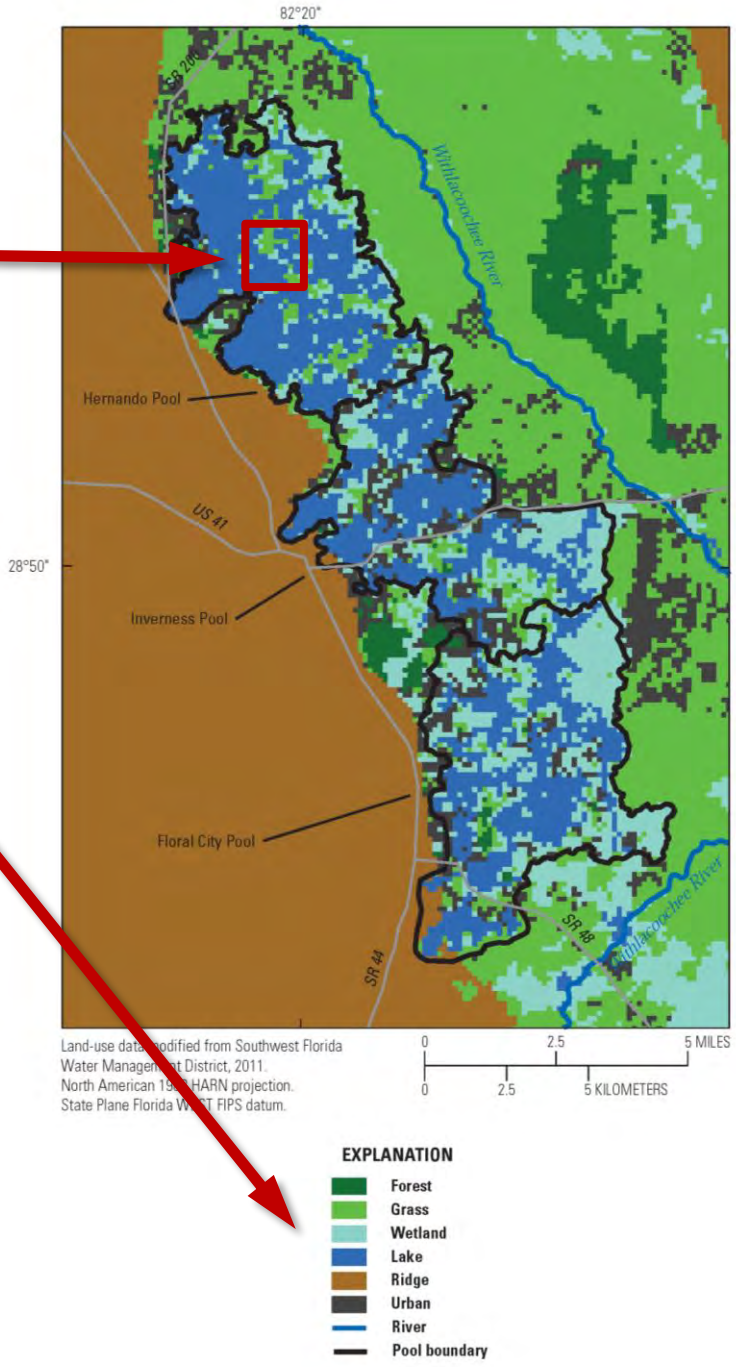
Figure 3. Diagram of idealized water budget for a pool. Change in storage (ΔS) includes the combined storage change of surface water and groundwater in the surficial aquifer. Evaporation (E) includes surface-water evaporation and evapotranspiration from pervious areas of each pool.

laf17-0847_mcbride_fig 03

USGS RET grid for Tsala Apopka area



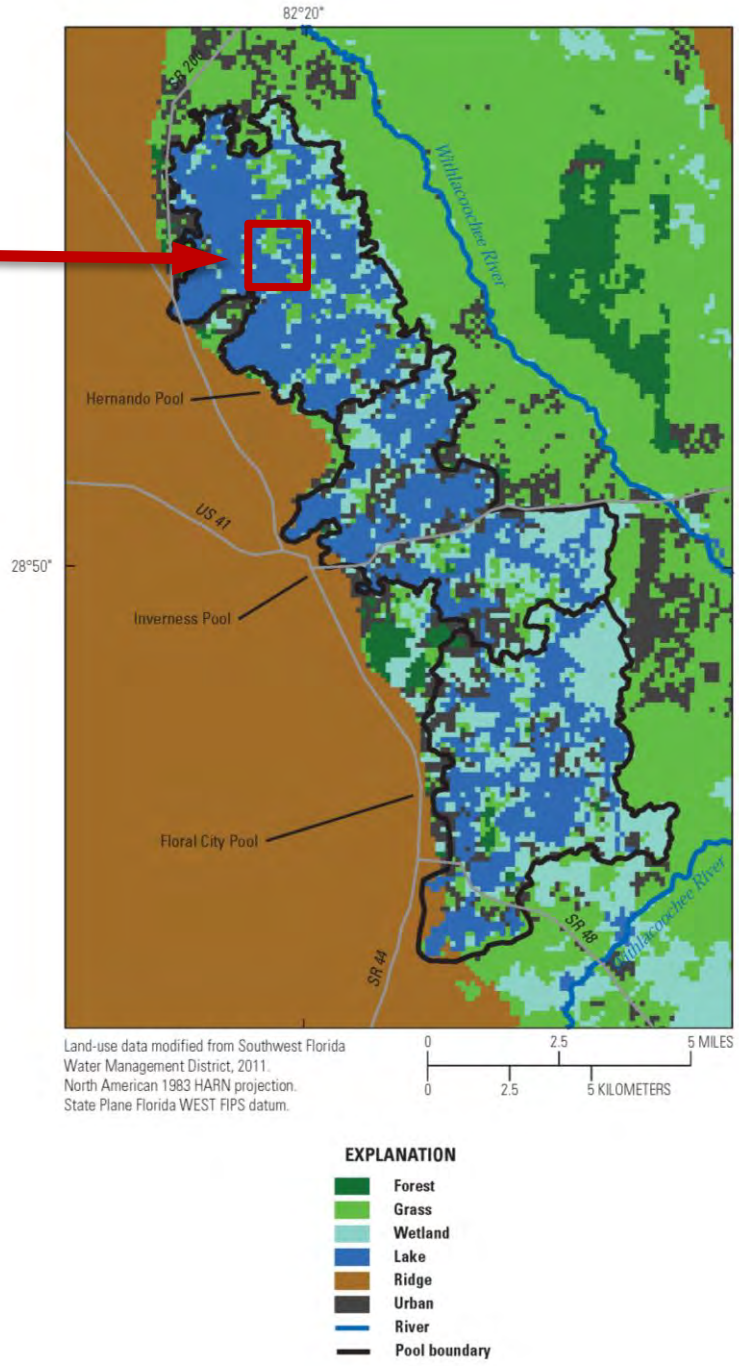
Percent of landuse type in each RET gridcell



Percent of landuse type in each RET gridcell

AET /RET ratio for each landuse computed from station data

AET computed for gridcell as function of RET multiplied by AET/RET ratios

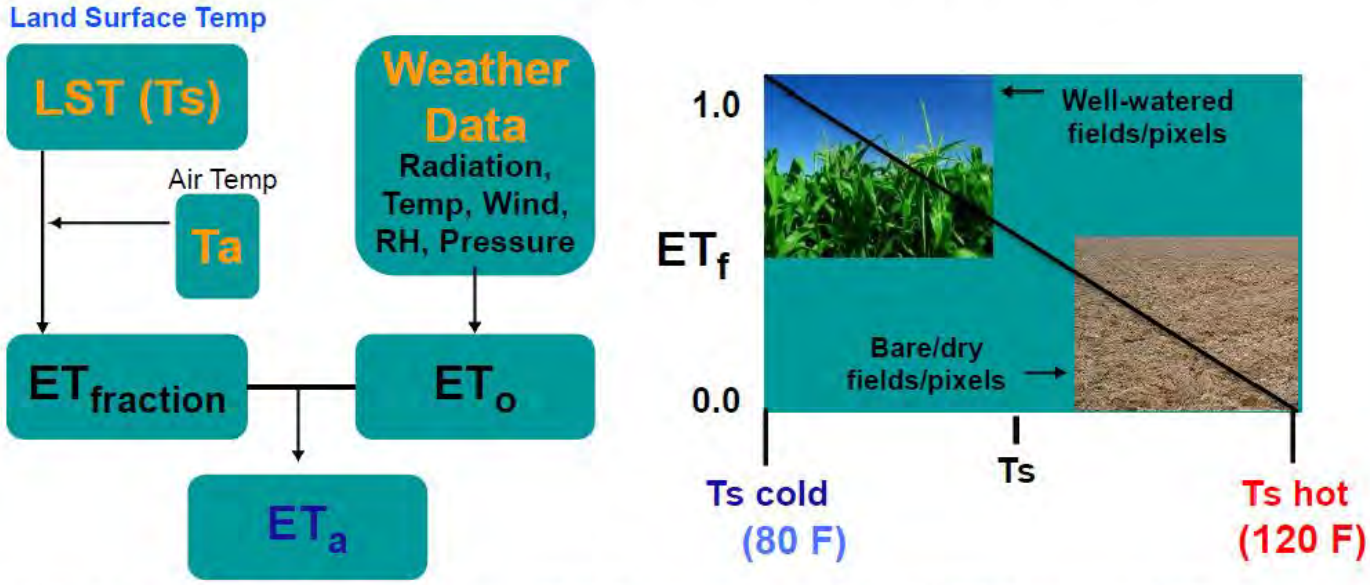


Other USGS resources

- Gabriel Senay, USGS Fort Collins
  - Operational Simplified Surface Energy Balance (SSEBop)
    - Moderate Resolution Imaging Spectrometer (MODIS)
    - Monthly actual ET (ETa)
    - 1-km grid, global
    - urban settings, over water
      - Alternative to MOD16

USGS

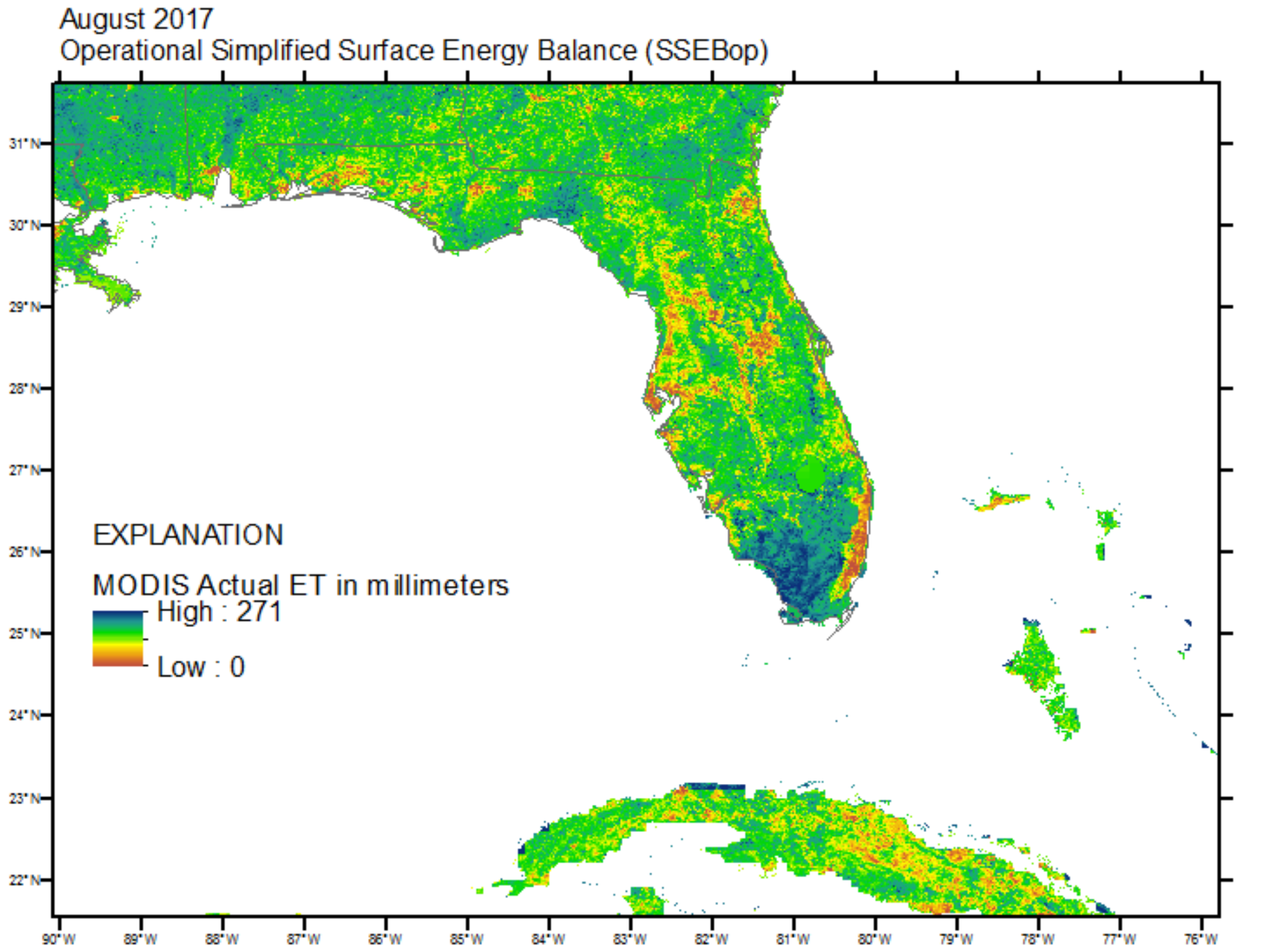
Operational Simplified Surface Energy Balance (SSEBop) Modeling Approach



Adapted the "hot" and "cold" pixel concept from SEBAL (Bastiaanssen et al., 1998) and METRIC (Allen et al., 2007) to calculate ET fraction and combine it with ETo.

SSEB: Senay, et al., 2007 sensors; 2011 AWM; SSEBop: 2013 JAWRA.

USGS


August 2017
Operational Simplified Surface Energy Balance (SSEBop)
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
22°N
90°W
89°W
88°W
87°W
86°W
85°W
84°W
83°W
82°W
81°W
80°W
79°W
78°W
77°W
76°W
EXPLANATION
MODIS Actual ET in millimeters
High : 271
Low : 0

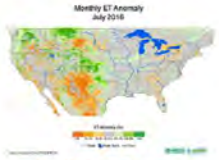
https://earlywarning.usgs.gov/useta

US SSEBop Evapotranspiration

Products

Seasonal Cumulative ETa Anomaly

End of Season ETa Anomaly



Monthly ETa Anomaly

Yearly ETa Anomaly

Documentation

- SSEBop ET product description
- Symbology files

Related Links

- USGS Geo Data Portal

USGS

Future research

- *Effects of hurricanes on evapotranspiration and carbon flux*
  - *Loss of leaf area*
- *Calibration and validation of MODIS ETa for Florida*
- *Meeting in Orlando on October 19th to discuss future research*

USGS

USGS