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Alternate methodologies for computing evapotranspiration at a 2-kilometer resolution for Florida

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

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

Outline

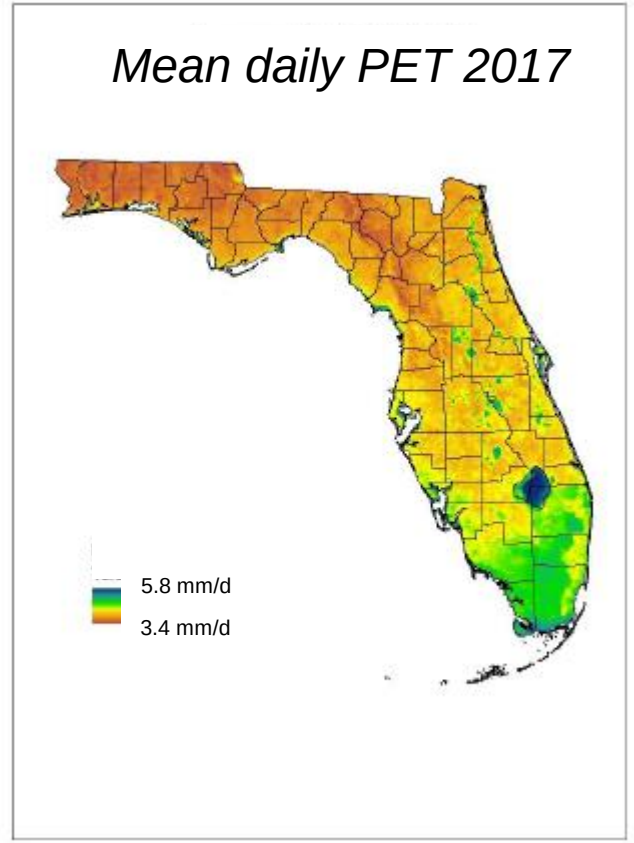
- *USGS gridded evapotranspiration products*
- *Alternate methodologies*
- *Bias analysis at station locations*

Contributing researchers

- *David Sumner, USGS Caribbean-Florida Water Science Center*
- *Barclay Shoemaker, USGS Caribbean-Florida Water Science Center*
- *John Mecikalski, University of Alabama in Huntsville*
- *Qinglong (Gary) Wu, South Florida Water Management District*

Gridded evapotranspiration products

- Potential and Reference Evapotranspiration
  - ~2-kilometer spatial resolution
    - grid is identical to NEXRAD grid
    - extent of Florida
    - includes water bodies
  - Daily time step
    - 1985-present

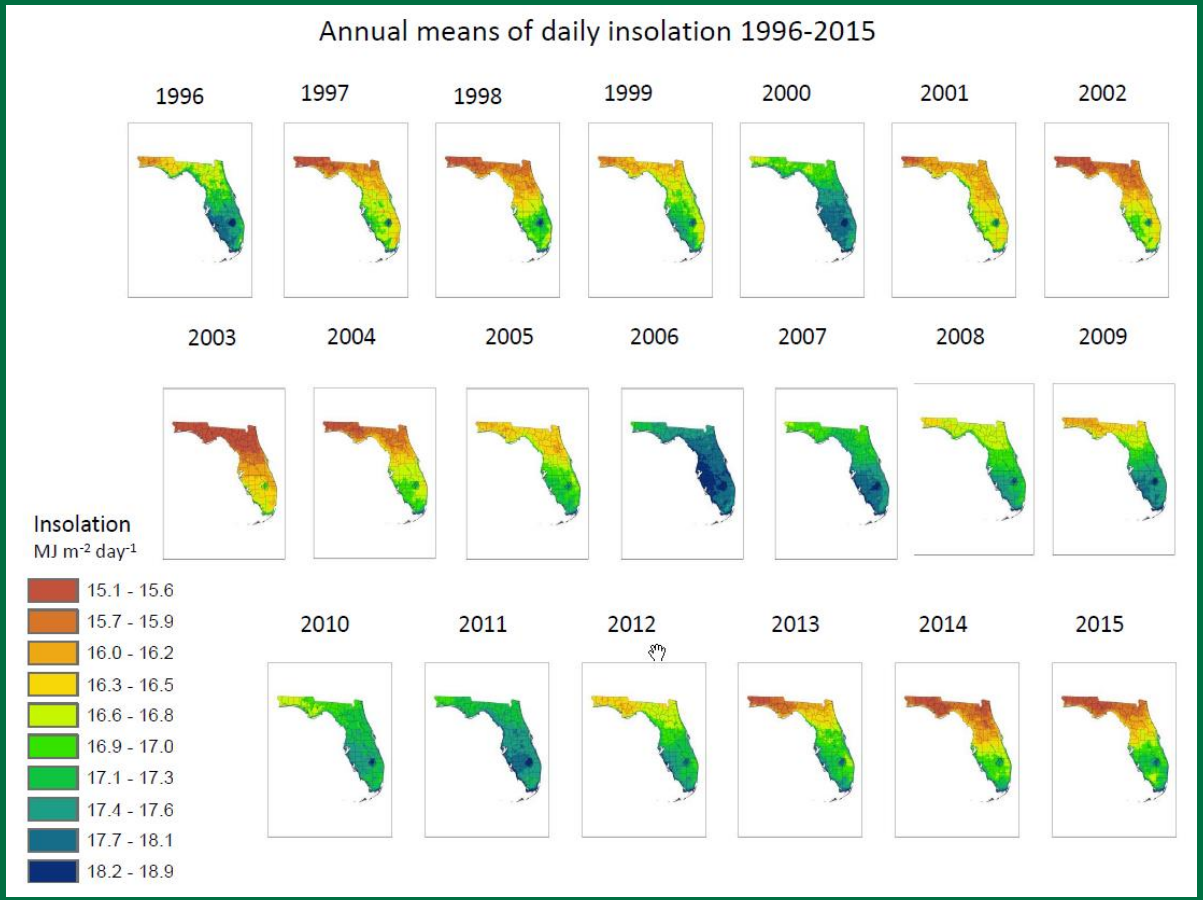


Gridded evapotranspiration products

- *Potential evapotranspiration*
  - *Priestley-Taylor equation*
  - *f (Rs, Tmax,Tmin, RHmax, Rhmin)*
    - *Albedo constant value for land and for water*
- *Reference evapotranspiration*
  - *Penman-Monteith equation*
  - *f (Rs, Tmax,Tmin, RHmax, RHmin, Wind)*
    - *Albedo is constant value (grass)*

Gridded evapotranspiration products, continued

- *Input Solar Radiation*
  - *Geostationary Operational Environmental Satellite (GOES)*



USGS

Gridded evapotranspiration products, continued

- *Input Meteorological variables:*
  - *1985-1995: North American Regional Reanalysis*

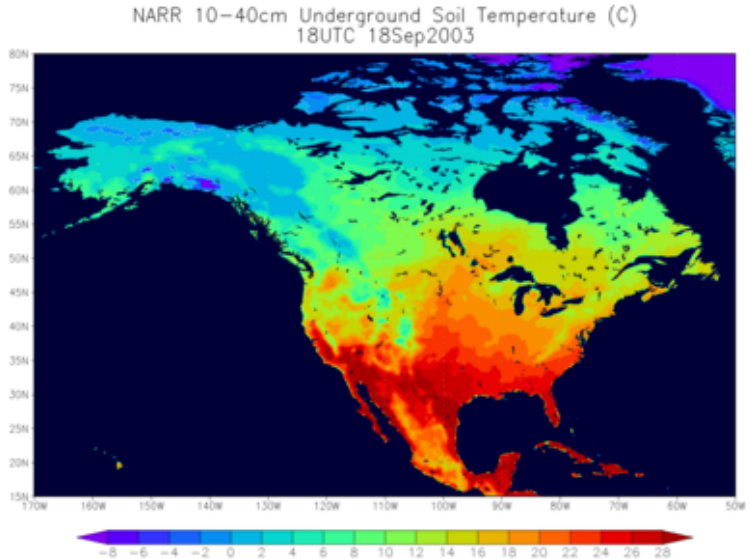
North American Regional Reanalysis

- *NOAA model used in support of weather forecasting*
- *32 km spatial resolution*
  - *Interpolated using Radial Basis Function (RBF)*
- *3 hour time step*
  - *Min and max of atmospheric variables based on 8 daily values*

Quick Links
Land-Based Station
Satellite
Radar
Model
Datasets
AEC
CFS
CM2.X
CMIP5
GDAS
GEFS
GFS
HYCOM
NAM
NARR

North American Regional Reanalysis (NARR)

The North American Regional Reanalysis (NARR) is a regional reanalysis of North America containing temperatures, winds, moisture, soil data, and dozens of other parameters. Produced by the National Centers for Environmental Prediction (NCEP), the NARR model takes in, or assimilates, a great amount of observational data to produce a long-term picture of weather over North America. The data that are assimilated in order to initialize the model to real-world conditions are temperatures, winds, and moisture from radiosondes as well as pressure data from surface observations. Also included in this dataset are dropsondes, pibals, aircraft temperatures and winds, satellite radiance (a measure of heat) from polar (orbiting Earth) satellites, and cloud drift winds from geostationary (fixed at one location viewing Earth) satellites.



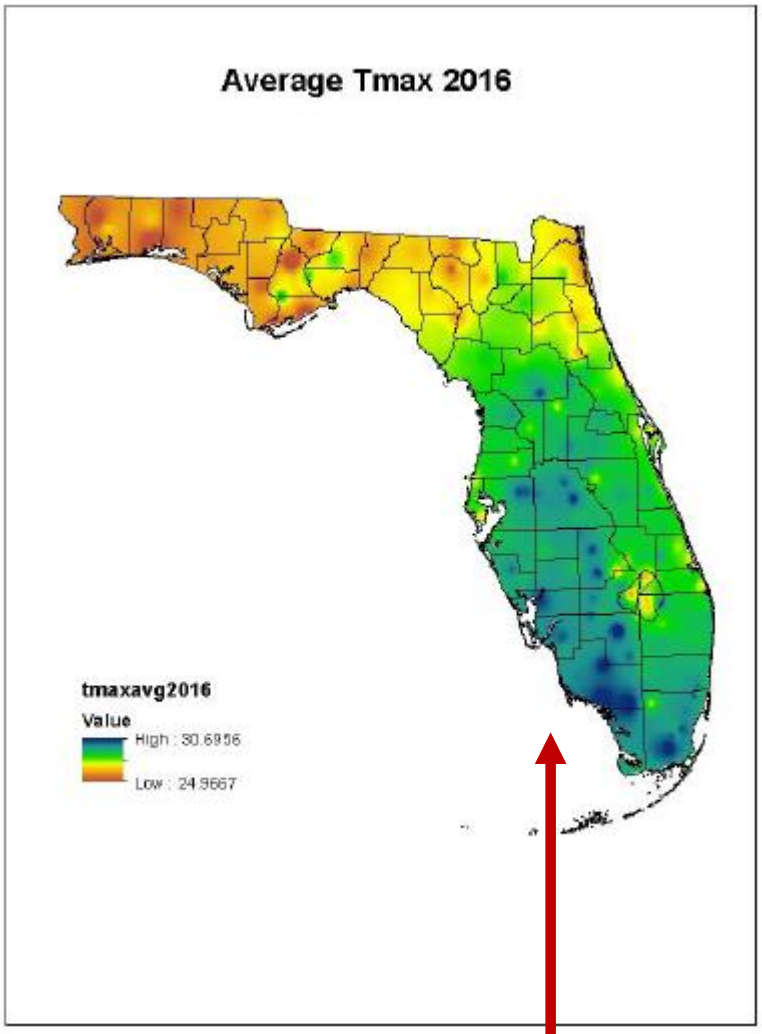
A sub-region plot of NARR underground soil temperature (a layer from 10 cm to 40 cm below ground) at 18 UTC on September 18, 2003. This image was produced by downloading one file of NARR data through NOMADS and visualizing with the Grid Analysis and Display System (GrADS).

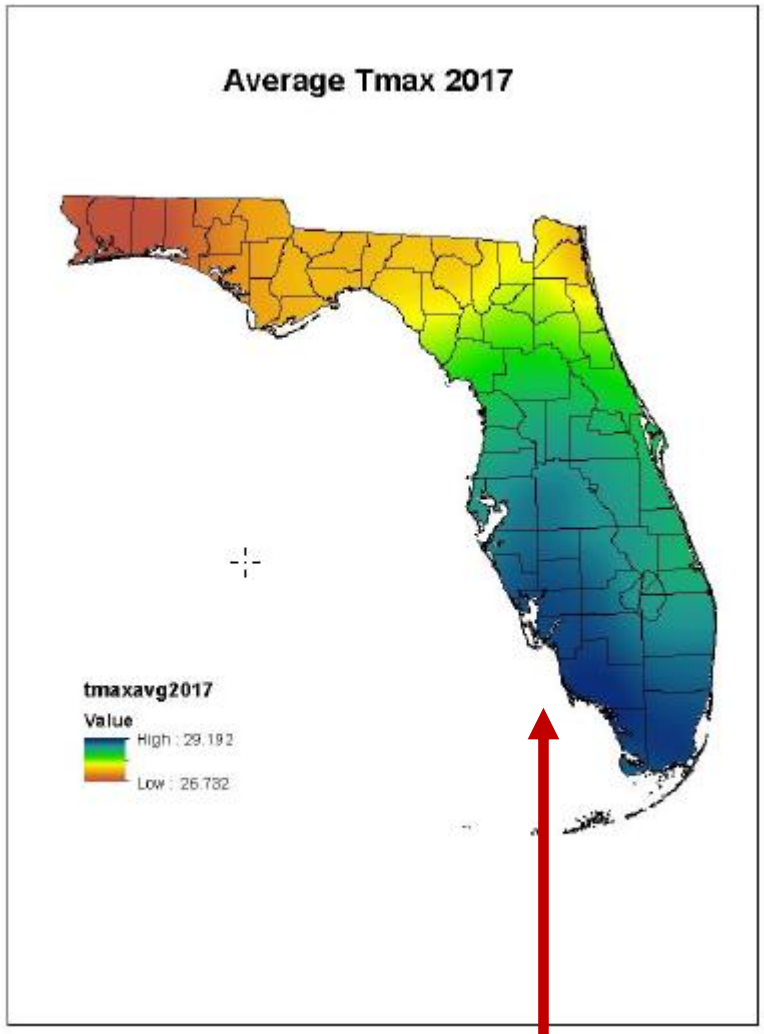
Gridded evapotranspiration products, continued

- *Input Meteorological variables:*
  - *1985-1995: North American Regional Reanalysis*

Gridded evapotranspiration products, continued

- *Input Meteorological variables:*
  - *1985-1995: North American Regional Reanalysis*
  - *1996-2017: interpolated from weather station data*
    - *FAWN, DBHYDRO, NOAA weather station data*
    - *1996-2016: Inverse-Distance Weighted (IDW) interpolation*
    - *2017: RBF interpolation*





IDW

RBF

USGS

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

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
Dade_2016	13,269,070	Holmes_2016	3,039,802	Okeechobee_2016	6,017,924	Volusia_2016	8,200,274
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:

Column	Definition
1	Date (Year Month Day as yyyymmdd))
2	Quality Code (A value of 1, 2, 3, or 4) Based on the quality of Solar data for that day (1 = Good quality, 2 = Usable data, 3 = Uncertain or unverifiable quality, 4 = Unusable or missing)

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

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12 Wind Speed (meters/second)

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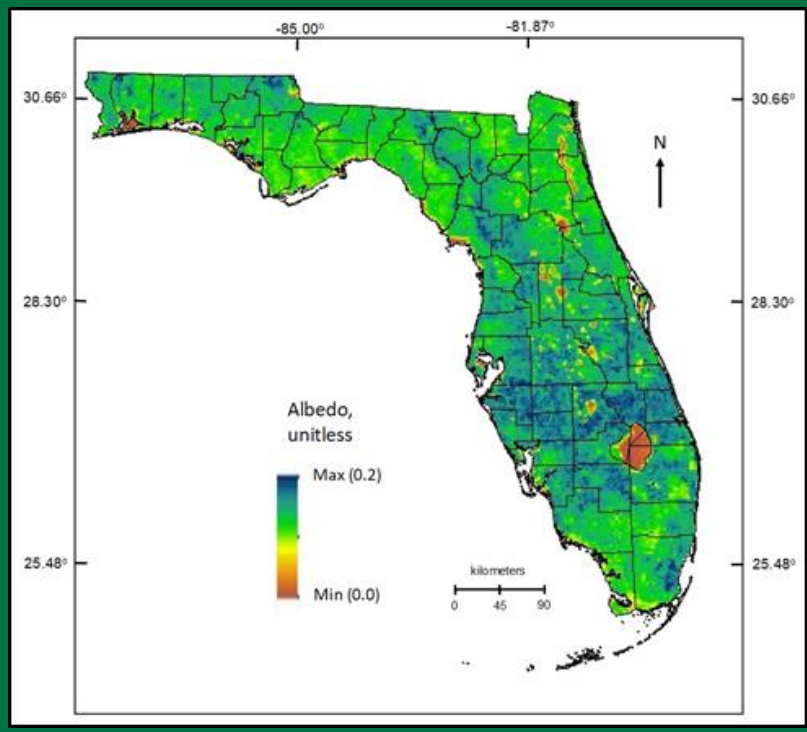
Alternative methodologies

- *"Blue sky" albedo from Moderate Resolution Imaging Spectroradiometer (MODIS) on the NASA Terra satellite*
  - *5 year averages of daily values*
  - *2011-15*
  - *Product unavailable in 2017*
- *PET calculations*

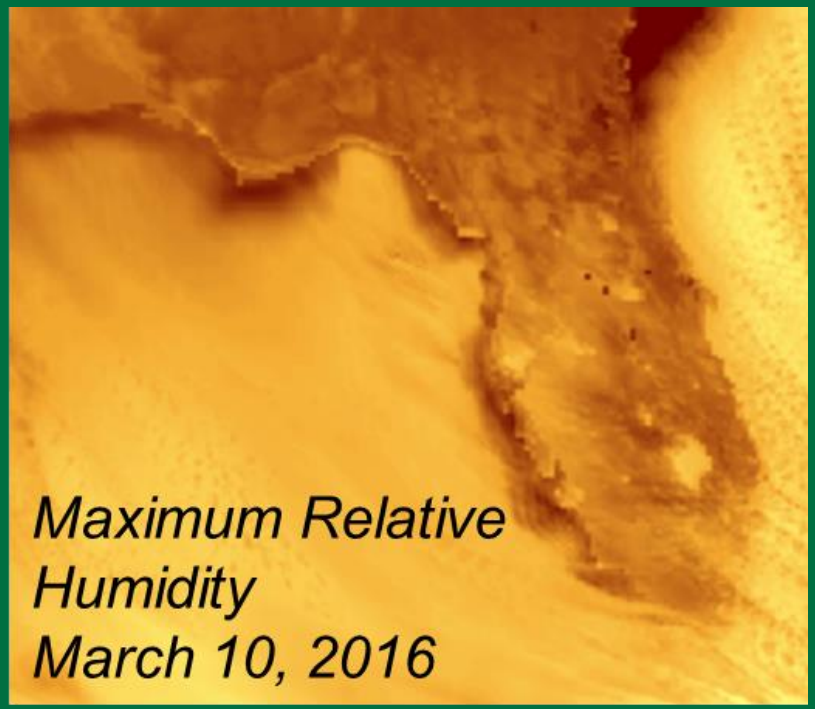


Alternative methodologies, continued

- *Meteorological data from:*
  1. *FAWN, DBHYDRO and NOAA weather station data*
  2. *North American Regional Reanalysis*
  3. *Weather Research and Forecasting Model*

Weather Research and Forecasting Model

- *2 km spatial resolution*
  - *Grid aligns with PET, RET, NEXRAD grids*
- *1 hour temporal resolution*



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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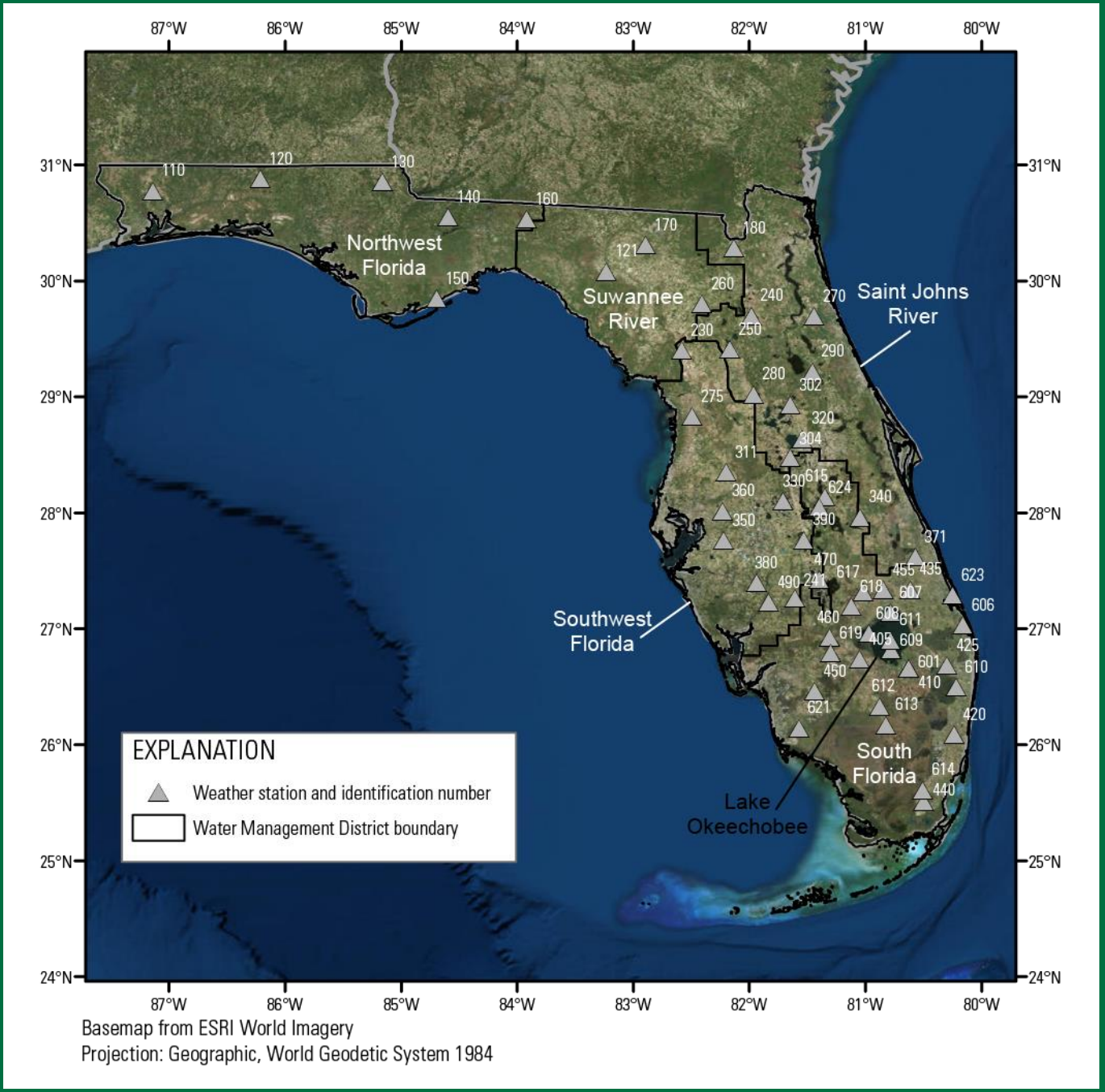
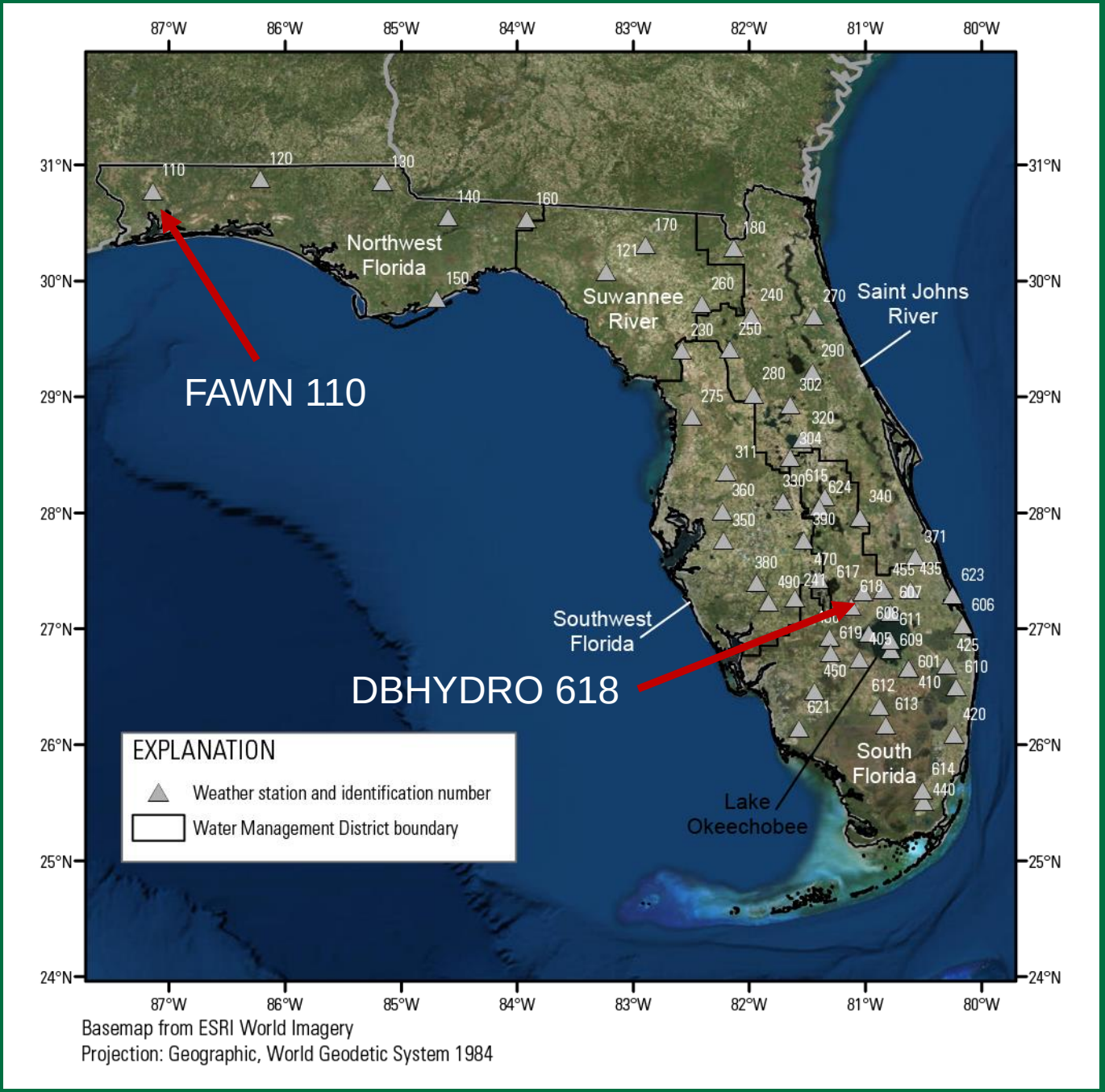
Bias analysis at weather station locations

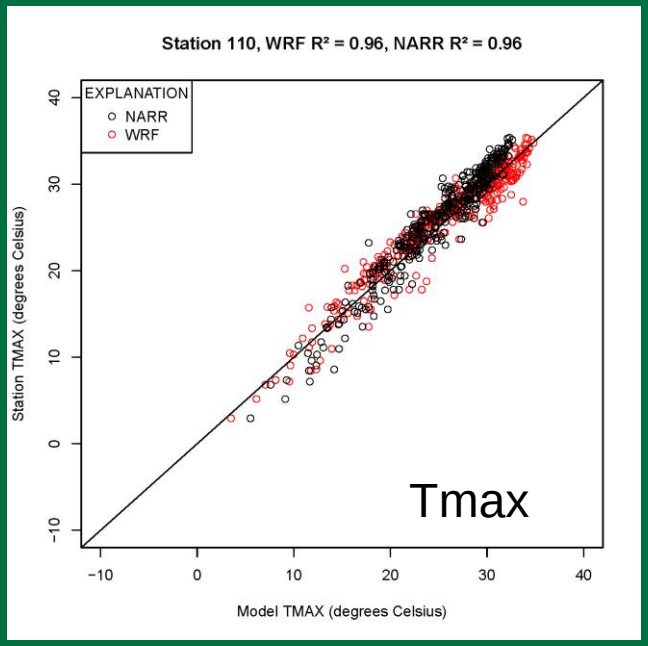
- *Bias in NARR and WRF data as alternative sources of meteorological data*
  - *Calendar year 2017*
  - *57 weather stations*
    - *contained sufficient data to compute RET*
    - *wind was limiting variable that excluded stations*

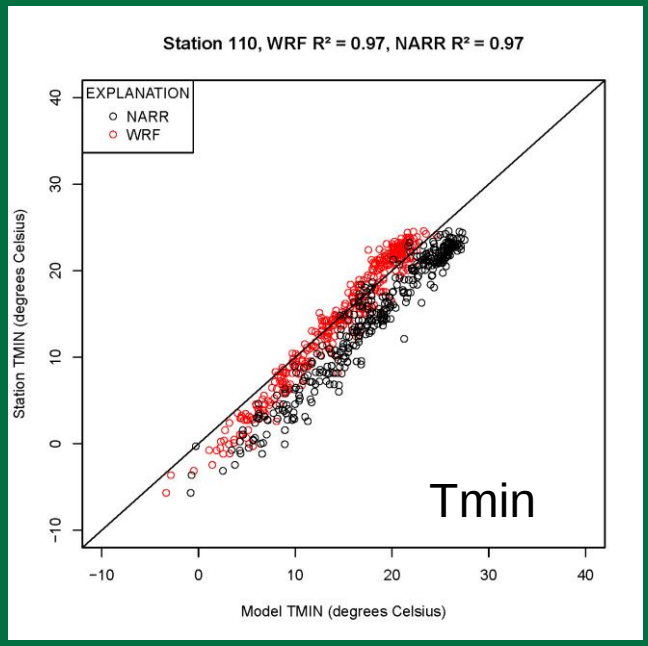


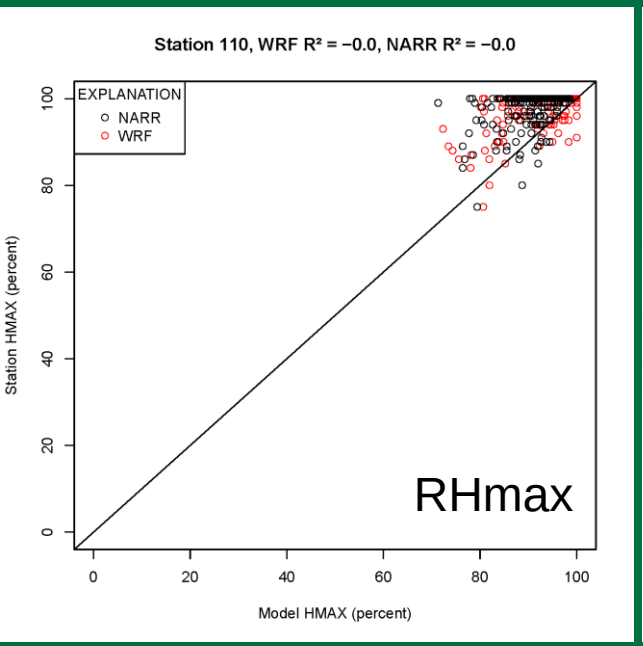


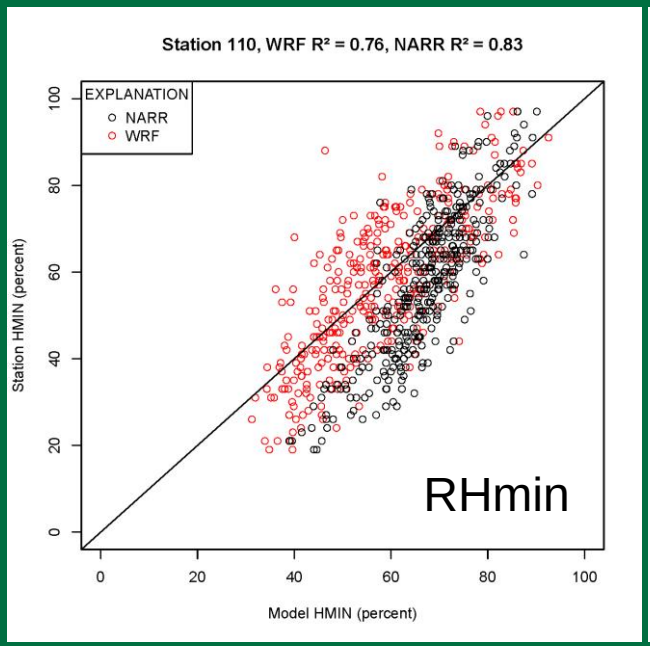
USGS

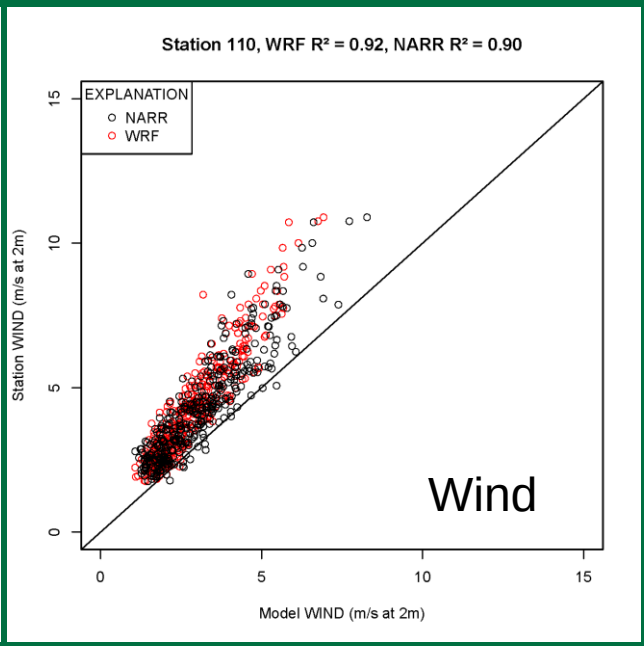
Cross plots for FAWN 110: model (NARR and WRF) on x-axis, observed on y-axis



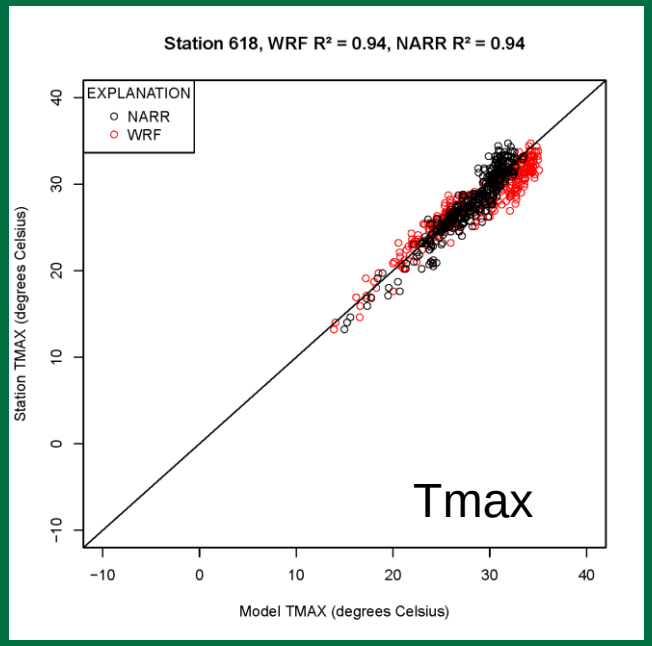


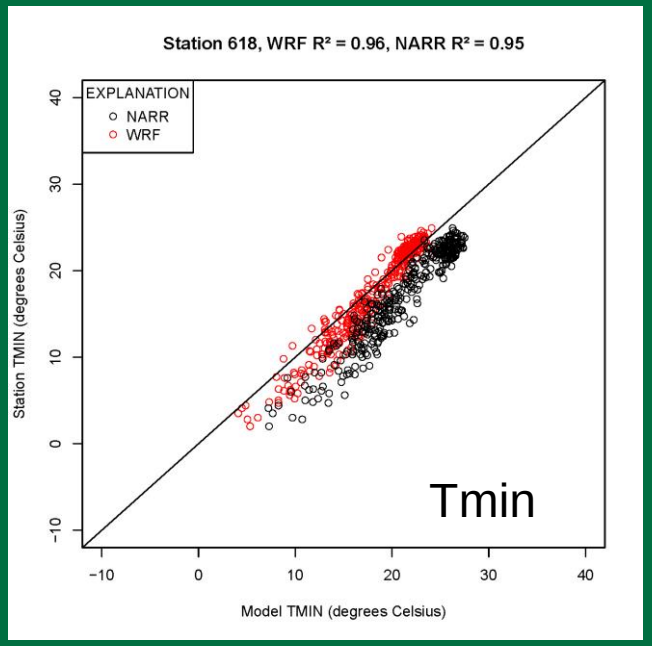


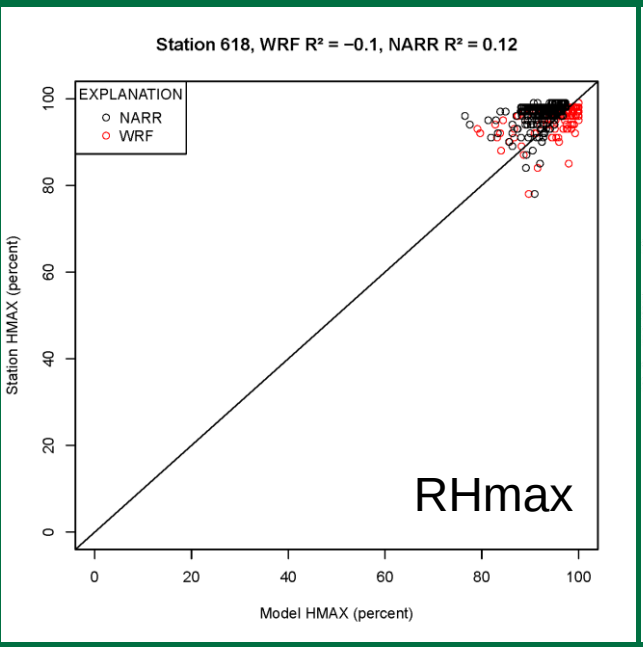


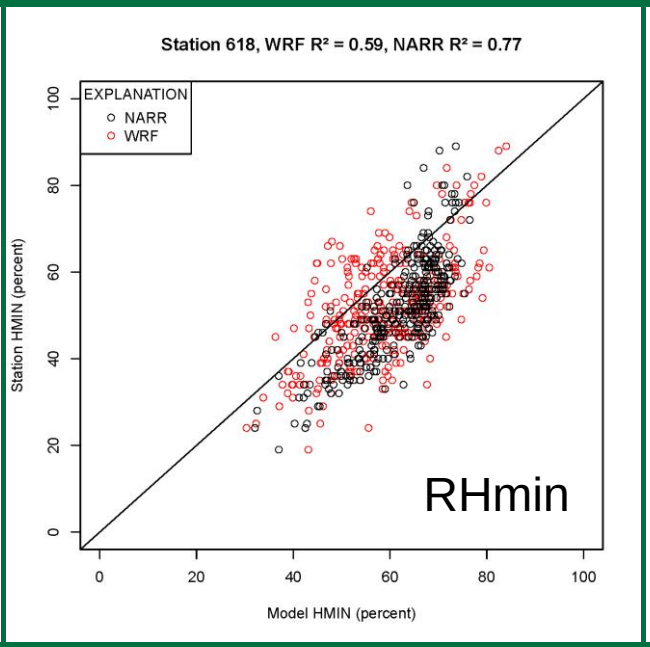


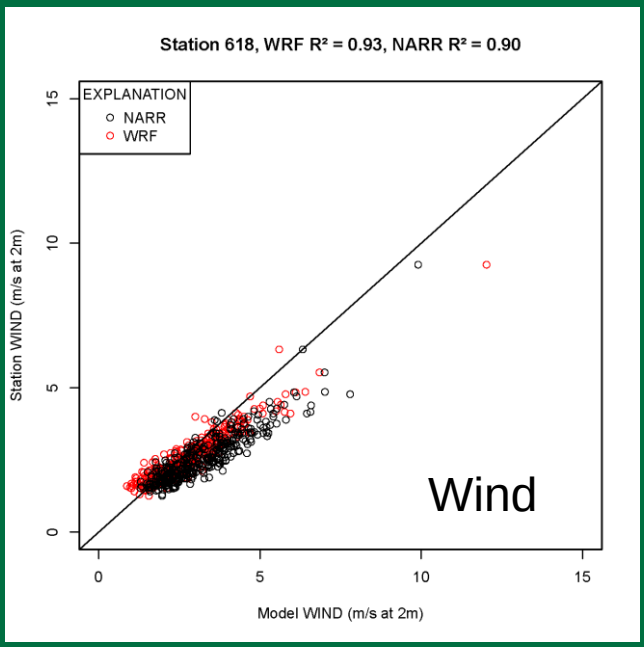
Cross plots for DBHYDRO 618





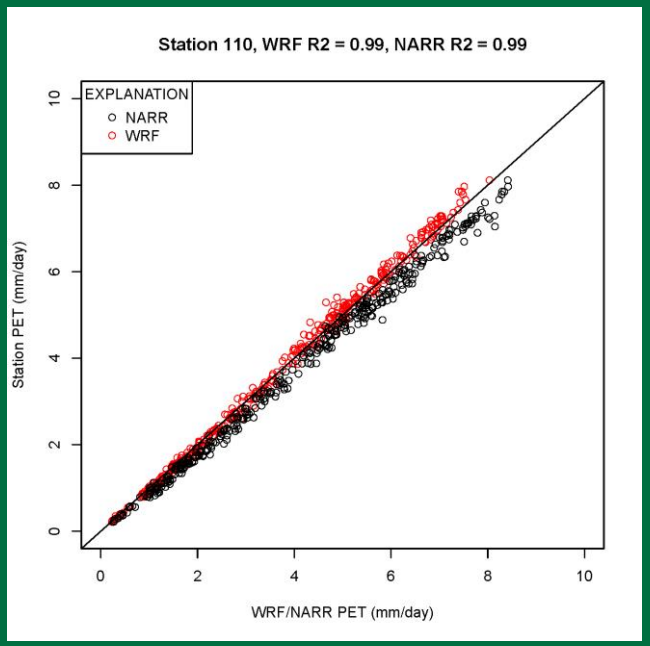


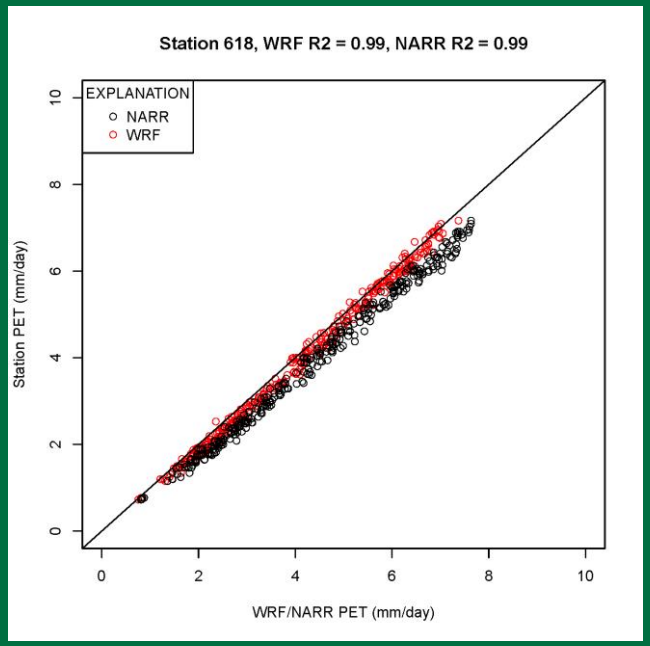




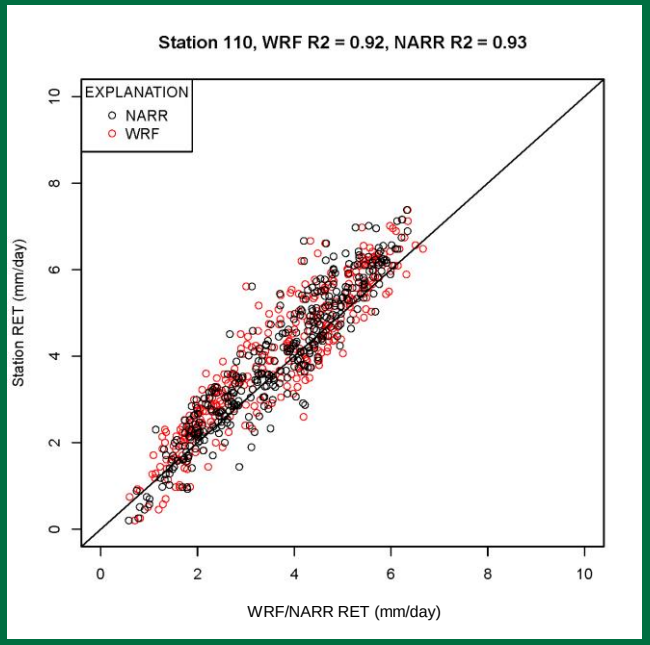
Cross plots for PET and RET

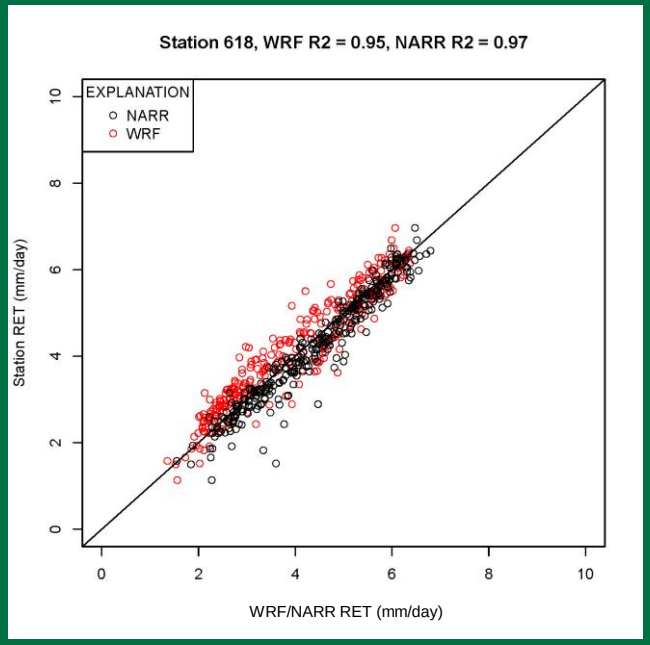
PET





RET





Bias in NARR ET at station locations

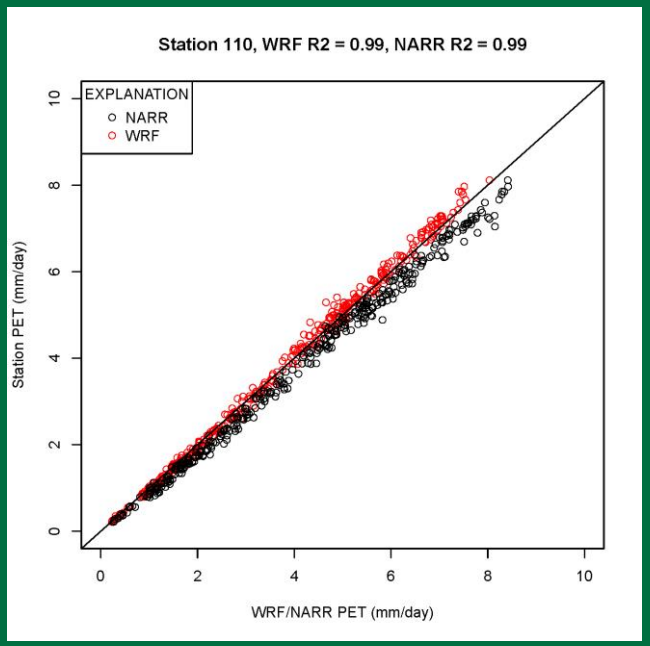
Time Period (2017)	Evapotranspiration based on weather station observations		NARR evapotranspiration		Bias		After bias correction	
	Potential	Reference	Potential	Reference	Potential	Reference	Potential	Reference
	(millimeters)		(millimeters)		(millimeters)		(millimeters)	
Annual	1547	1568	1661	1535	114	-33	-2	-1
January	56	87	64	84	8	-3	1	-4
February	77	98	86	92	9	-6	1	-5
March	118	139	130	130	12	-9	2	-6
April	155	165	166	155	11	-9	1	-5
May	192	190	206	180	13	-10	1	-3
June	171	144	180	145	9	1	-2	5
July	195	164	206	165	10	1	-2	6
August	191	161	201	164	10	3	-2	8
September	156	139	162	138	7	-1	-4	3
October	113	119	120	121	7	2	-2	4
November	72	88	81	88	8	1	1	1
December	51	74	60	71	8	-2	1	-4

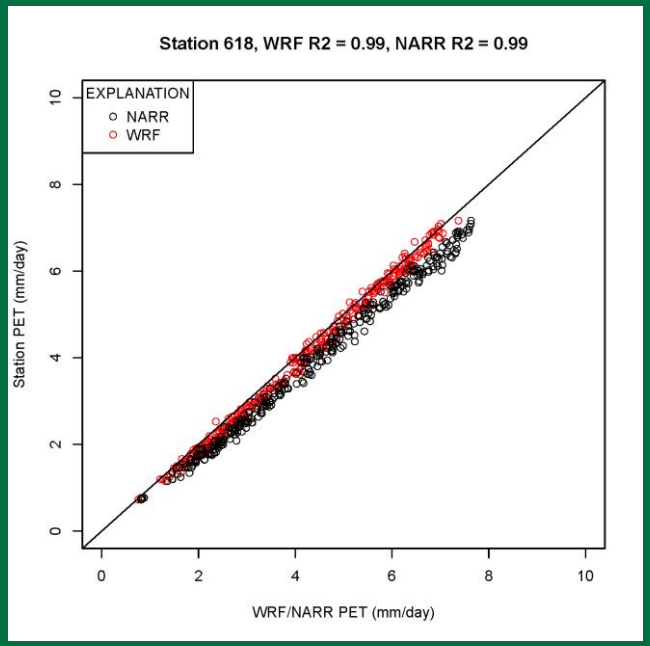
Bias in WRF ET at station locations

Time Period (2017)	Evapotranspiration based on weather station observations		WRF evapotranspiration		Bias		After bias correction	
	Potential	Reference	Potential	Reference	Potential	Reference	Potential	Reference
	(millimeters)		(millimeters)		(millimeters)		(millimeters)	
Annual	1547	1568	1552	1434	5	-133	-2	-1
January	56	87	59	71	3	-16	1	-4
February	77	98	80	80	3	-18	2	-7
March	118	139	121	116	3	-24	3	-12
April	155	165	158	142	3	-23	3	-13
May	192	190	193	170	1	-20	2	-9
June	171	144	170	146	-1	2	-1	12
July	195	164	192	164	-3	0	-2	11
August	191	161	188	160	-3	-1	-2	10
September	156	139	151	134	-5	-5	-5	6
October	113	119	112	111	-1	-8	-2	3
November	72	88	74	76	1	-11	-1	0
December	51	74	53	64	2	-10	0	2

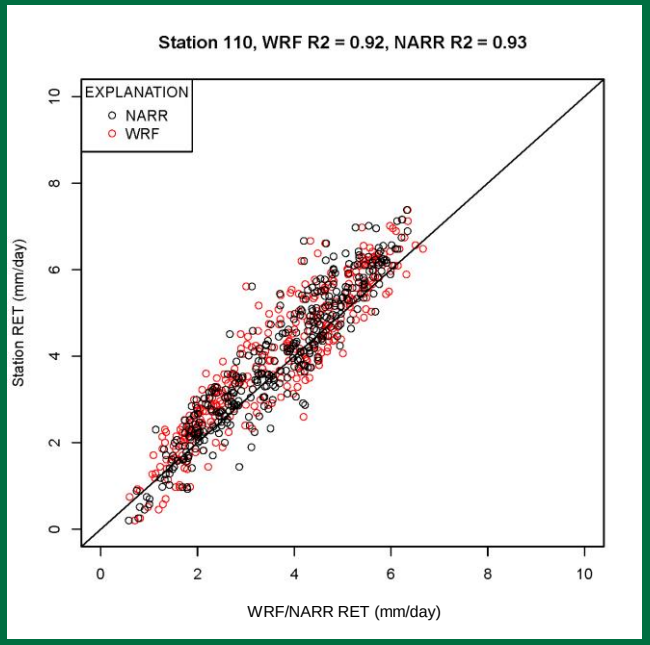
Cross plots for PET and RET

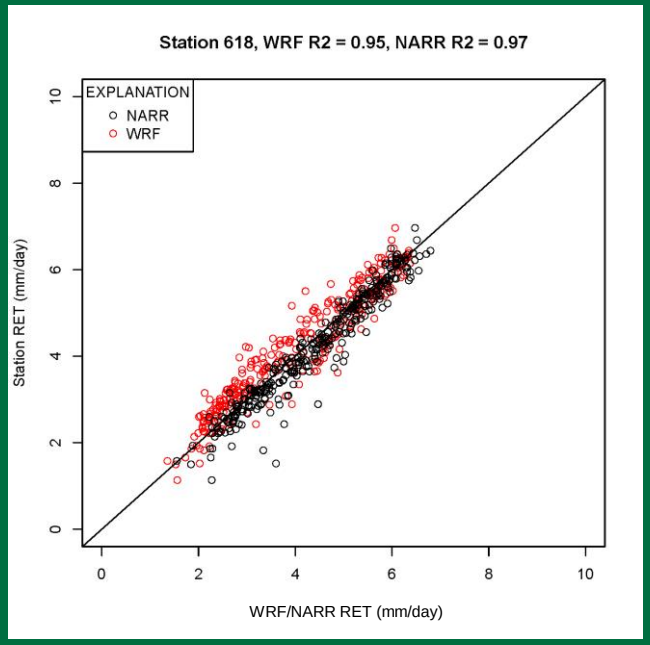
PET





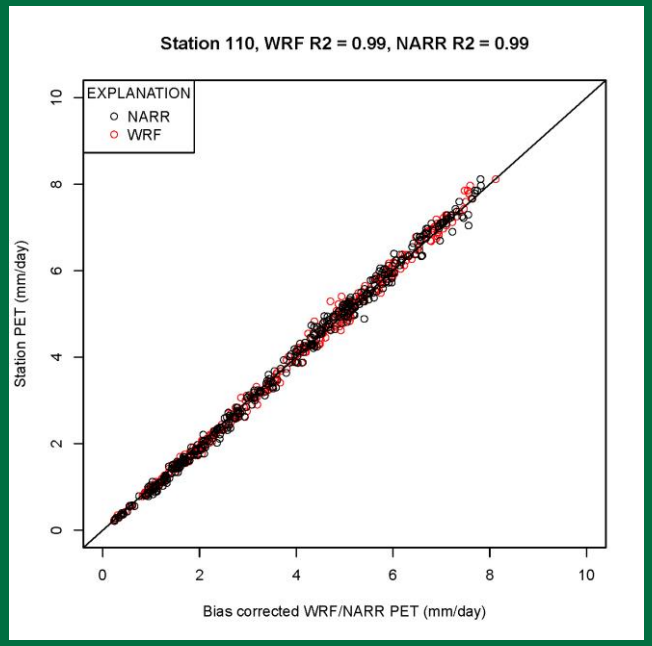
RET

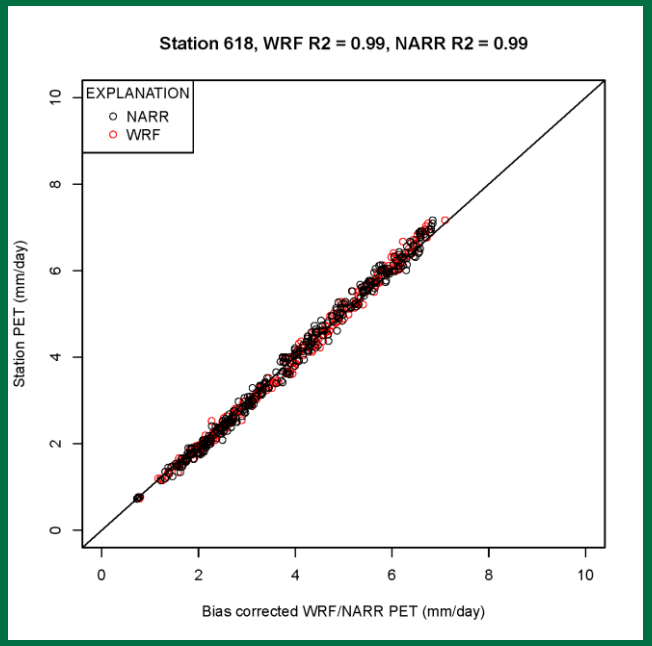




Cross plots for bias corrected PET and RET

PET





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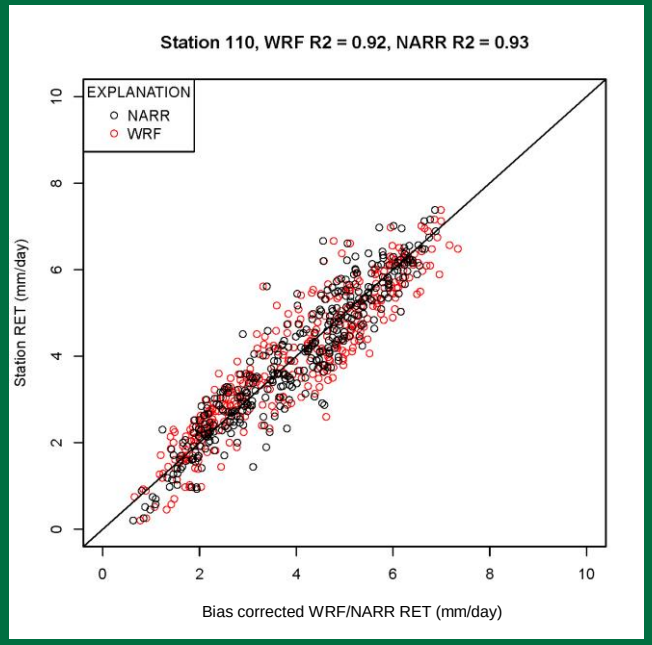
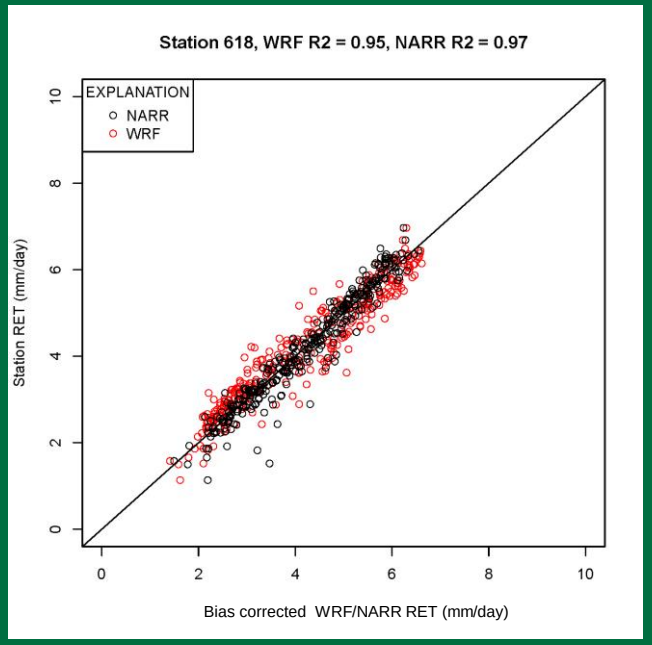
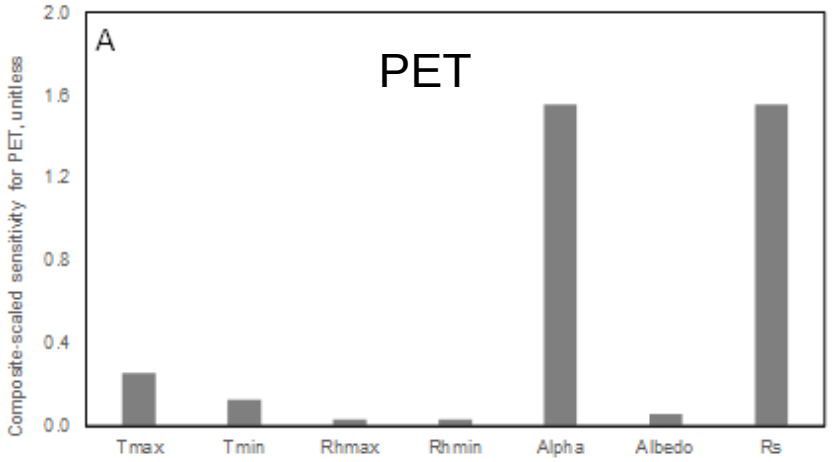
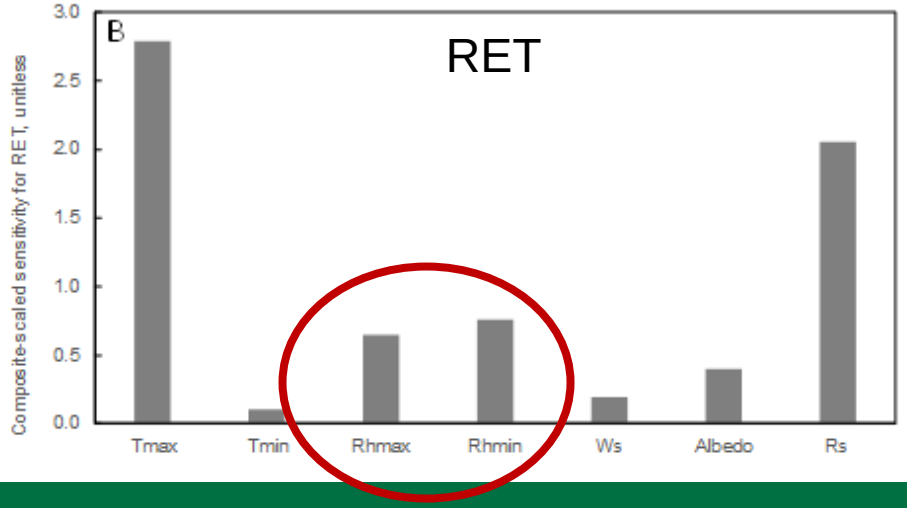




Sensitivity of PET and RET to input meteorological variables

- *Based on methodology of Hill (1998)*
- *Dimensionless index*





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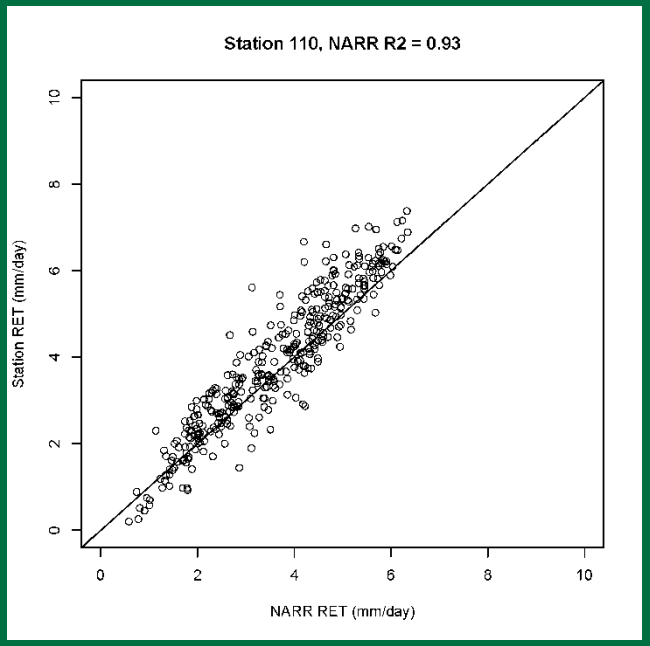
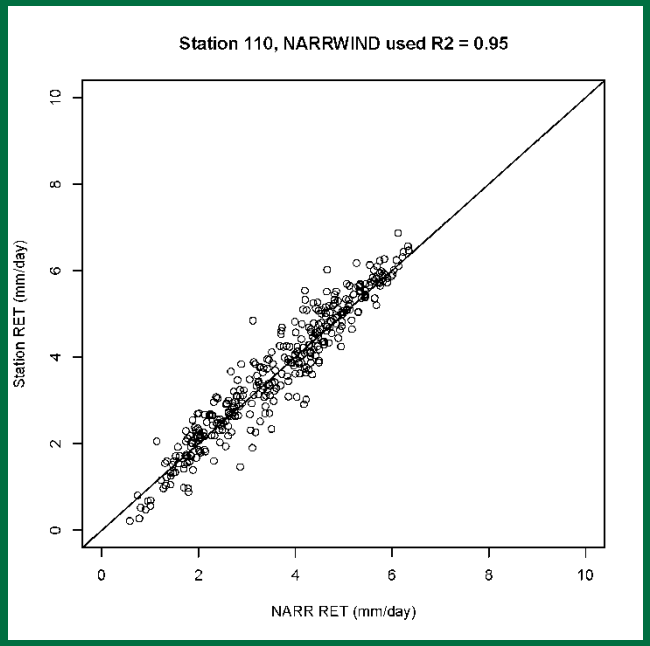
Hill, M.C., 1998, Methods and guidelines for effective model calibration: U.S. Geological Survey Water-Resources Investigations Report 98-4005, 90 p.

Cross plots for PET and RET for FAWN 110 using NARR meteorological data

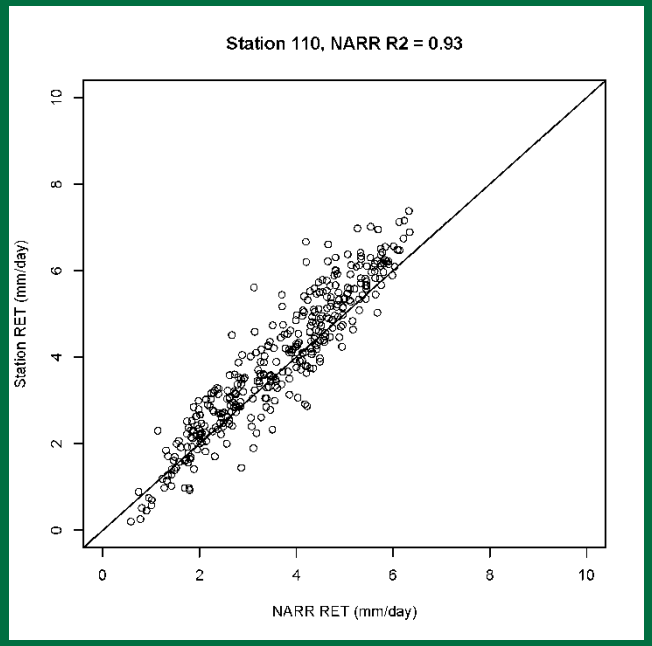
Effect of Wind

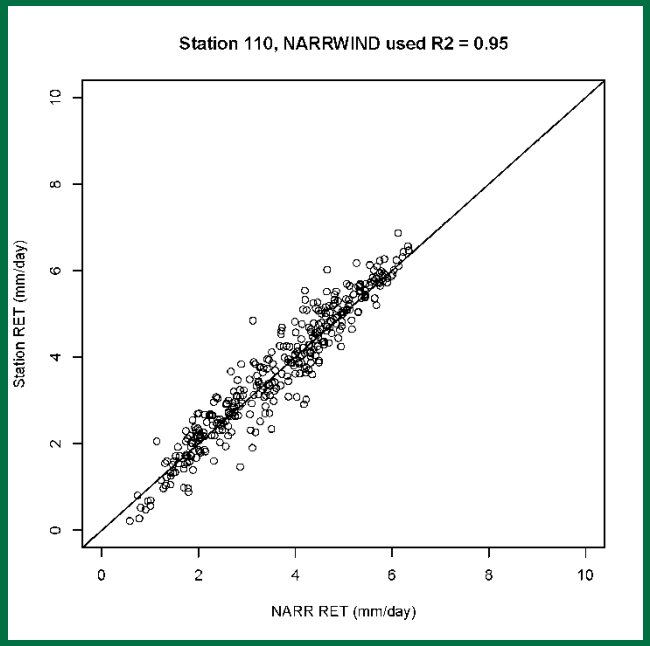




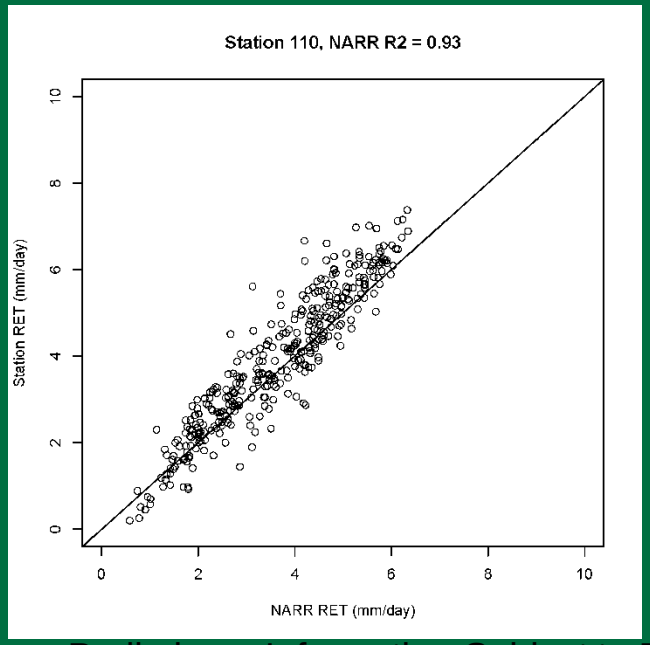
Cross plots for PET and RET for FAWN 110 using NARR meteorological data

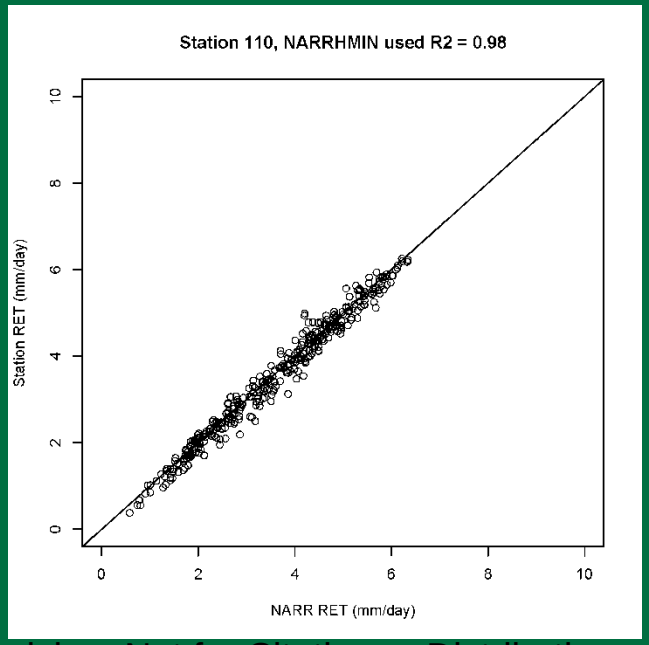
Effect of Wind





Effect of RHmin

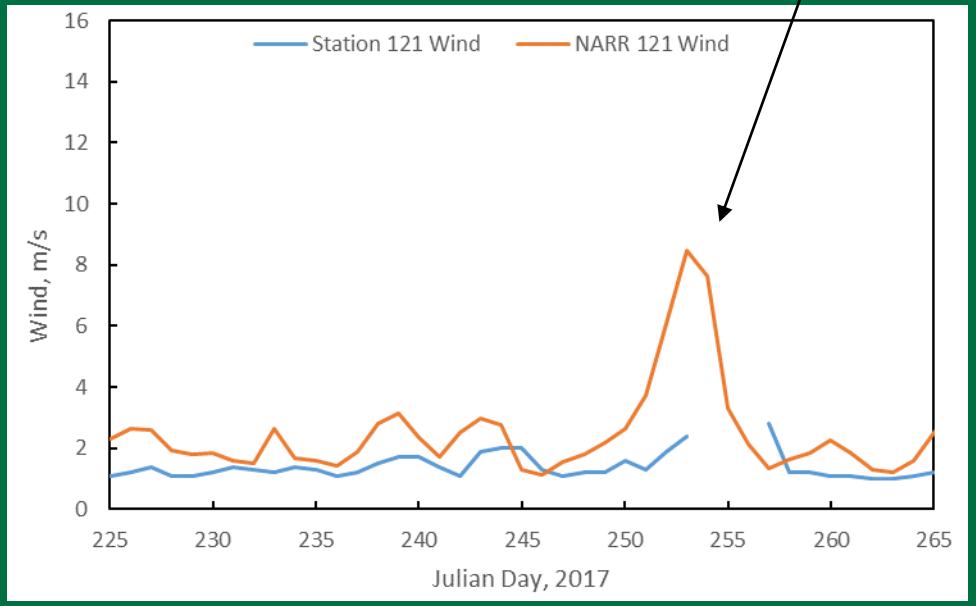




Conclusions

- *MODIS data improves spatial representation of albedo*
- *Radial basis functions improves spatial interpolation*
- *NARR and WRF output are an alternative to weather station data for computing PET*
  - *can be used to fill missing data*

No data at station during Hurricane Irma



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Conclusions

- *Bias in NARR removed by linear model*
  - *Linear bias correction does not fully remove WRF bias*
- *Remaining bias primarily due to variability in minimum relative humidity*
  - *Random scatter, so might be difficult to correct*
  - *How accurate are RH sensors?*
  - *How accurate is RH of weather models?*
  - *Is variability due to sub-grid scale variability?*

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Preliminary Information-
Subject to Revision. Not for
Citation or Distribution.

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