Appendix E. Open Water Evaporation around the DR/GR Area

This appendix contains a few comparisons between the spatially distributed ET data available from the USGS (http://hdwp.er.usgs.gov/) and the ET data from other sources. The objective is to find the best ET data to be applied as evaporation in open water bodies located in the DR/GR Area.

The spatially distributed ET data from USGS was obtained by using solar radiation obtained from Geostationary Operational Environmental Satellites (GOES) [Jacobs et al., 2008]. Reference ET (RET) and a potential ET (PET) were estimated at a 2 km spatial scale and a daily time scale from 1995 to 2004 for the entire state of Florida. The PET calculation used the Priestley-Taylor model that requires incoming solar radiation, air temperature and relative humidity data. Two different constant albedo values are used for land (0.149) and for water (0.062). Inland pixels were identified as water if 75% or more of the pixel contained water. RET calculation is based on the Penman-Monteith equation [Allen et al., 1998], considering short crop or grass reference on a daily basis. Besides incoming solar radiation, air temperature and relative humidity, this method also requires the wind speed.

The ET data from station FPWX (DBHYDRO key OH520) is compared to the USGS data. This station is located in Lee County, in the western boundary of the DR/GR area, and covers most of the DR/GR model domain area in the Thiessen polygon approach used in the previous model version. The ET rate calculation is based on total radiation multiplied by a constant coefficient established by W. Abtew at SFWMD [W. Qinglong, SFWMD, personal communication]. This simple method has been recommended when limited data is available, but it has been found less accurate than the Penman-Monteith method [Abtew, 1996]. **Figure E1** shows the location of this station regarding the distributed ET grid.

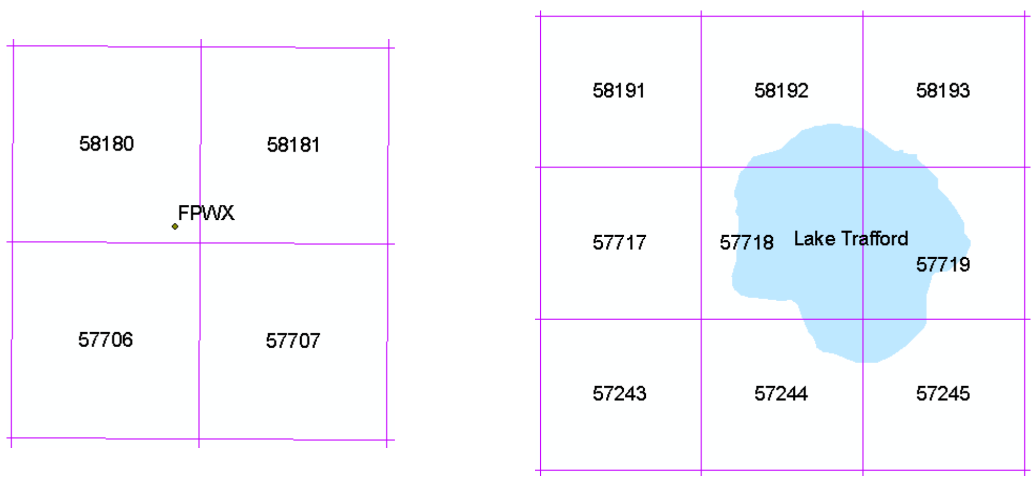

Figure E1. Distributed ET grid around station FPWX and Lake Trafford.

The pan evaporation data from station BCBNAPLE_E (DBHYDRO key DJ227) is used also in the comparison. According to R. Woods [SFWMD, personal communication], this station uses a standard NWS Class A evaporation pan, which is made of unpainted galvanized steel or stainless steel, is 4 feet in diameter by 10 inches deep, and sits on a raised wood frame exposed beneath to let air circulate. The pan is filled to a depth of 8 inches, and is refilled when the depth falls to 7 inches. Water surface level is measured daily with a hook gauge in a stilling well. Evaporation is computed as the difference between observed levels, adjusted for any precipitation measured in a standard rain gauge. Alternatively, water is added each day to bring the level up to a fixed point in the stilling well. This method assures proper water level at all times. Depending on the water level measurement method and how water is supplied to the pan, the measurement accuracy can be varied. The ET data reported is the raw ET data measured at the pan, and there is no (pan) coefficient involved to convert to lake evaporation (LE). This coefficient usually varies between 0.6 and 0.8. A pan coefficient of 0.75 has been used for the estimation of Lake Okeechobee evaporation [Chandra Pathak, SFWMD, personal communication].

The lake evaporation was measured previously in Florida by energy budget methods [Sacks et al., 1994], [Lee and Swancar, 1997], [Swancar et al., 2000]. Here, the lake evaporation reported by Swancar et al. [2000] at Lake Starr (Polk County, FL) and the lake evaporation data at Reedy Lake (Orange County, FL) delivered by D. Sumner at USGS are also compared to the USGS data. **Figure E2** shows the positions of those two lakes regarding the distributed ET grid.

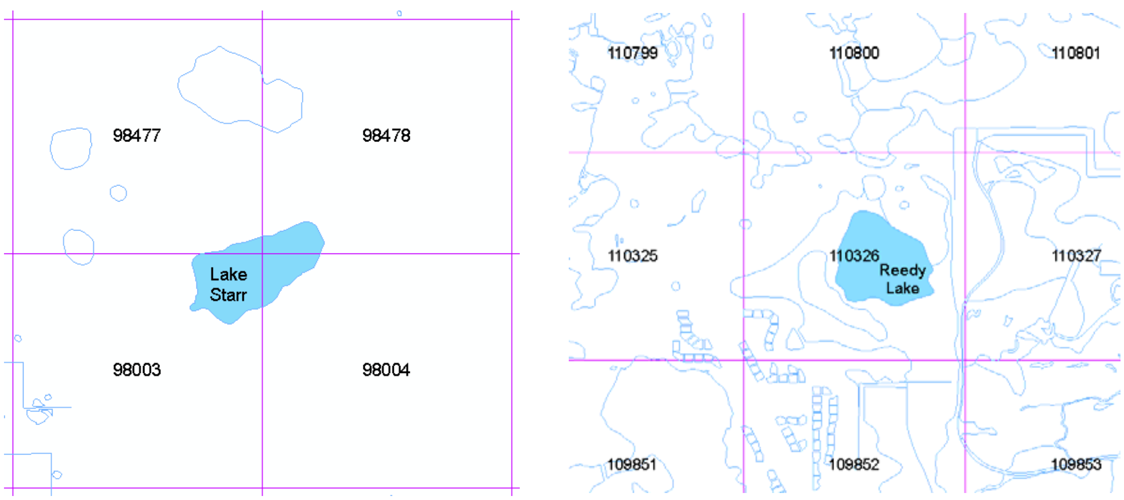

Figure E2. Distributed ET grid around Lake Starr and Reedy Lake.

Finally, a comparison between the PET estimated by the USGS in grid cells marked as "water" and the PET in grid cells marked as "land" and the RET is conducted. Unfortunately, there were not any grid cells marked as water in the model domain or close to it. Lake Trafford, located close to the east boundary of the model domain, was excluded by a slight distance (see Figure E1) from the water classification that required 75% water coverage

[Jacobs et al., 2008]. Thus, three grid cells marked as water west to Lake Okeechobee and shown in **Figure E3** are selected for this comparison.

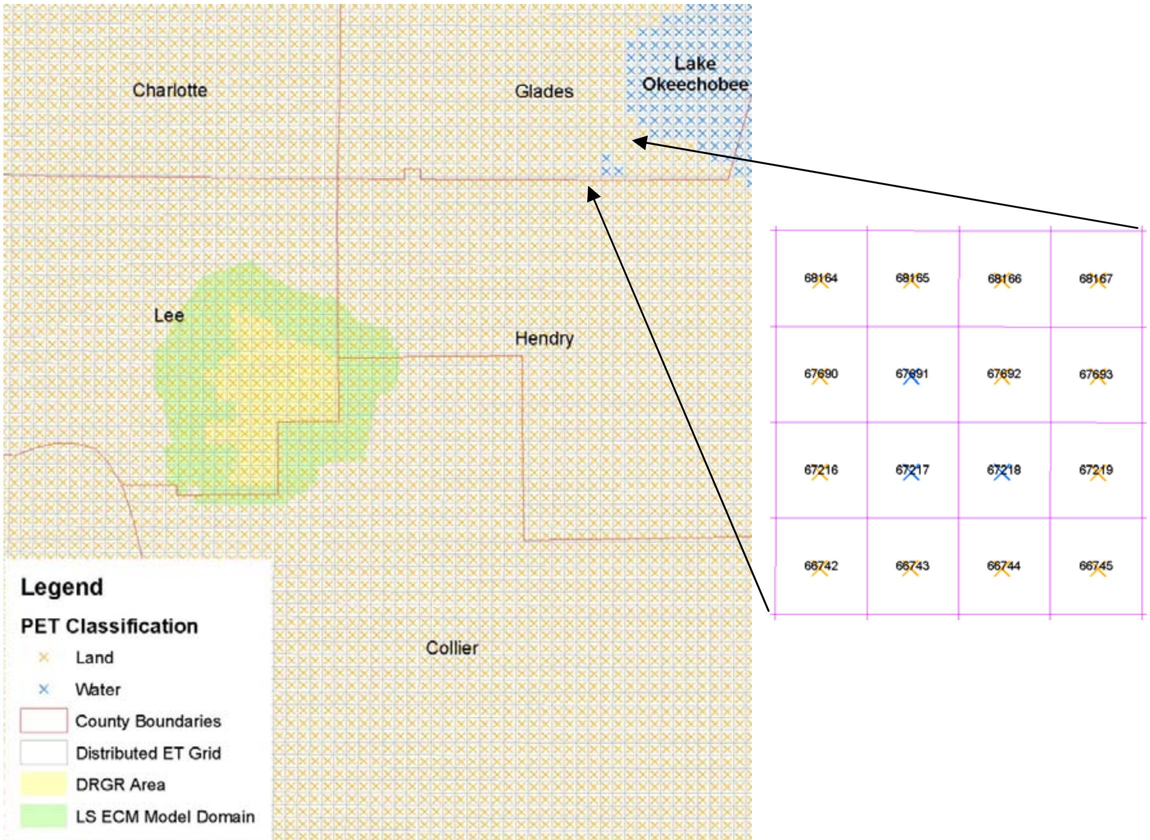

Figure E3. Distributed ET grid around the model domain showing the cells classified as "water" and as "Land". The zoom-in view shows three "water" grid cells used in the ET comparison (see text for details).

The annual ET rates from alternative data and the corresponding RET and PET rates from the USGS are compared in **Table E1**. Comparative plots of the daily ET rates are presented in **Figure E4**. A map with all the site locations is shown in **Figure E5**.

In the four locations compared, PET data from the USGS for grid cells marked as land has higher seasonal amplitude than the corresponding RET data from the USGS. PET is higher during the middle of the year and lower at the end / beginning of the year. In annual averaged magnitudes, PET is lower than RET in a range from 0.2 to 3.1 inches (0.4% to 5.3% of RET).

At station FPWX, the simple method used to estimate ET from solar radiation produced daily ET values closer to the RET values from the USGS. The PET seasonal oscillation has higher amplitude than the one from the station and the RET. In annual averaged magnitudes, that ET estimation underpredicts both PET and RET by about 3%.

The daily pan evaporation measured at the Naples station behaves closer to the RET data during the minimum ET period and closer to the PET (land) data during the maximum ET period (mid-year). In annual averaged magnitudes, the pan evaporation rate exceeds PET by 11.5% and RET by 8.0%. This is surprising since a coefficient to convert from pan evaporation to PET or RET would be of 0.90 or 0.93, respectively, which are above the range of 0.6 to 0.8 suggested for the pan coefficient that converts into lake evaporation. A pan evaporation of 0.9, for instance, would give a lake evaporation equal to 55.0 inches/year (RET- 2.8%). Possible lower values of measured pan evaporation than expected might be a consequence of the algae coverage existing in the pan water surface at the Naples station and also to a building nearby that may reduce the wind and produce some shadow late in the afternoon.

The lake evaporation at Lake Starr and Reedy Lake estimated from energy budget also behaves closer to the RET data during the minimum ET period and closer to the PET (land) data during the maximum ET period (middle of the year). In annual averaged magnitudes, the lake evaporation rate exceeds PET by 9.4% and 19.6%, and exceeds RET by 5.3% and 11.2%, respectively. Notice that Reedy Lake is located north of Lake Starr and the annual average PET and RET values decrease toward the north, as expected. The annual average lake evaporation estimation, however, increases unexpectedly by about 3 inches from Lake Starr to Reedy Lake.

Table E1. Annual ET rates obtained from USGS distributed data (PET and RET) and from alternative data (labeled as ET).

Alternative Data for ET	Pixels for PET and RET	period	ET (in/y)	PET (in/y)	RET (in/y)	ET-PET (% PET)	ET-RET (% RET)	PET-RET (% RET)
FPWX	57706, 57707, 58180, 58181	1/1/2002 12/31/2006	52.4	53.8	54.0	-2.7	-3.1	-0.4
BCBNAPLE_E	52488	1/1/2002 12/31/2006	61.1	54.8	56.6	11.5	8.0	-3.2
Lake Starr	98477, 98478, 98003, 98004	7/20/1996 7/19/1998	56.7	51.8	53.9	9.4	5.3	-3.8
Reedy Lake	110326	1/1/2002 12/31/2006	59.6	49.8	53.5	19.6	11.2	-7.0
Water pixels at 67217, 67218 and 67691	66743, 66744, 67216, 67219, 67690, 67692, 68165	1/1/2002 12/31/2006	61.4	53.4	56.5	14.9	8.8	-5.3

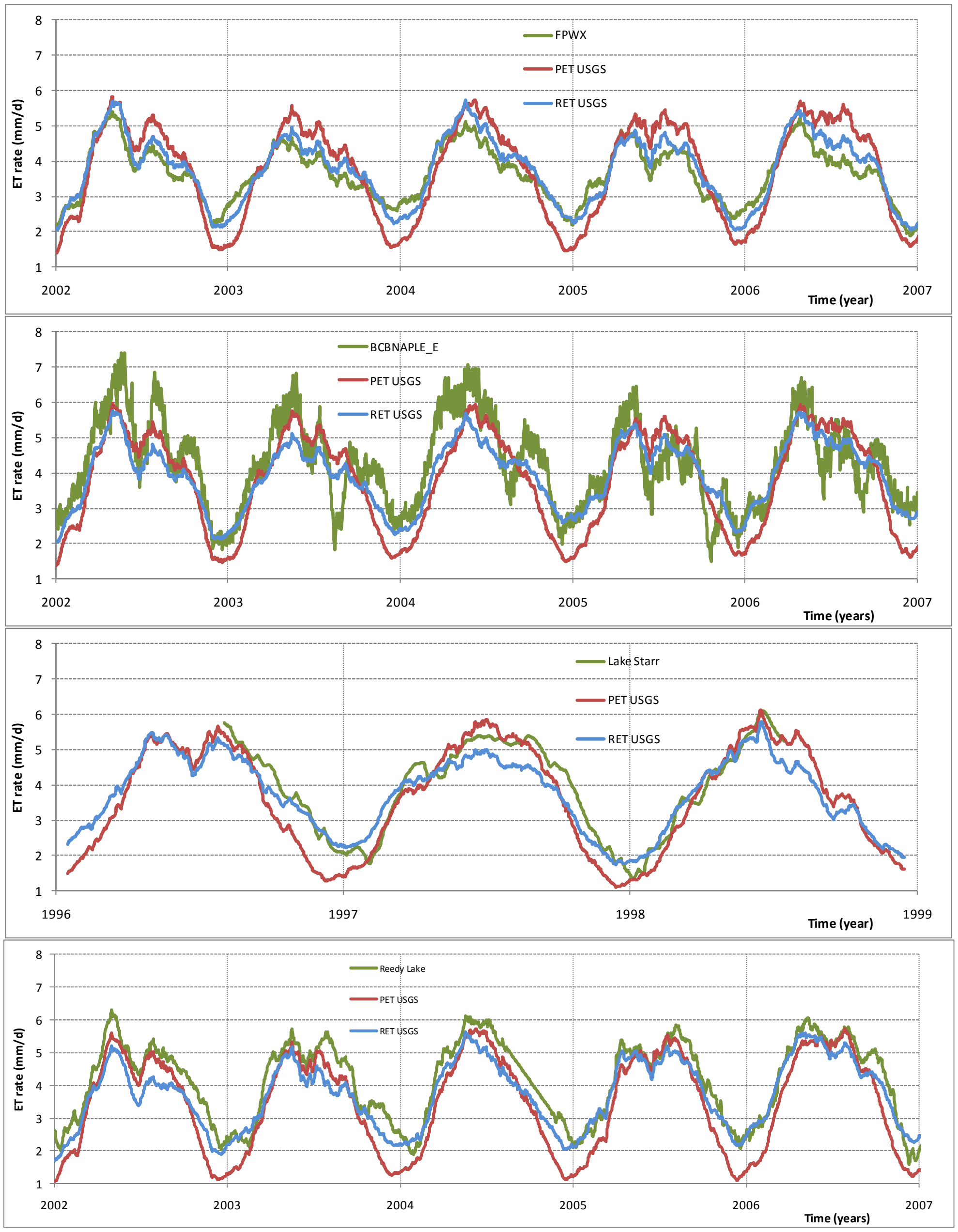

Figure E4. Comparative plot of the daily ET rates, which are running averaged with a 31 days windows. They are presented in the same order as in Table E1.

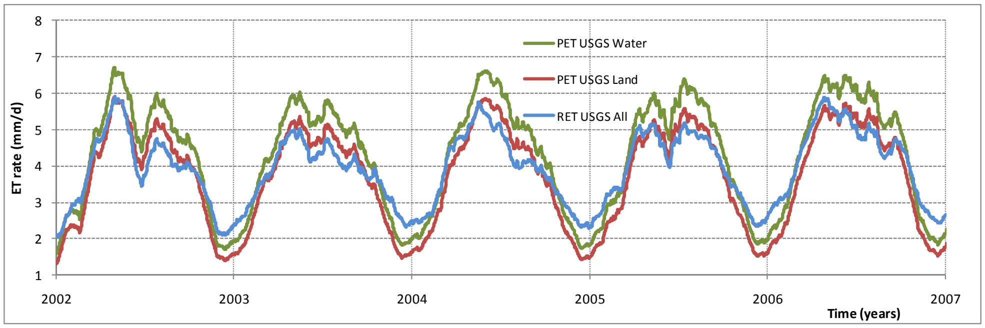

Figure E4. Comparative plot of the daily ET rates, which are running averaged with a 31 days windows. They are presented in the same order as in Table E1. Continuation.

The PET estimated in "water" pixels west of Lake Okeechobee is consistently higher than PET in neighboring "land" pixels through the year. At the same time, RET is higher than both PET estimations during the minimum period and lower during the maximum period (mid-year). In annual averaged magnitudes, the PET estimated in "water" pixels is 14.9% higher than PET in "land" pixels and 8.8% higher than RET. Thus, in this case, the annual PET estimated in water pixels is between the RET + 5.3% estimation at Lake Starr and the RET + 11.2% estimation at Reedy Lake.

In summary, the lake evaporation rates estimated by energy budget methods at Lake Starr and Reedy Lake suggest the use of an increment in the range of 5.3% and 11.2% to convert RET to lake evaporation. This range contains PET at water pixels estimated west of Lake Okeechobee as RET + 8.8%. The pan evaporation of RET + 8.0% measured at Naples seems to be low considering that a pan coefficient between 0.6 and 0.8 is typically applied to convert to lake evaporation. From all these results, the use of RET + 8.2% is recommended as a middle value of lake evaporation, with a possible range of variation of RET + 5.3% to RET + 11.2%.

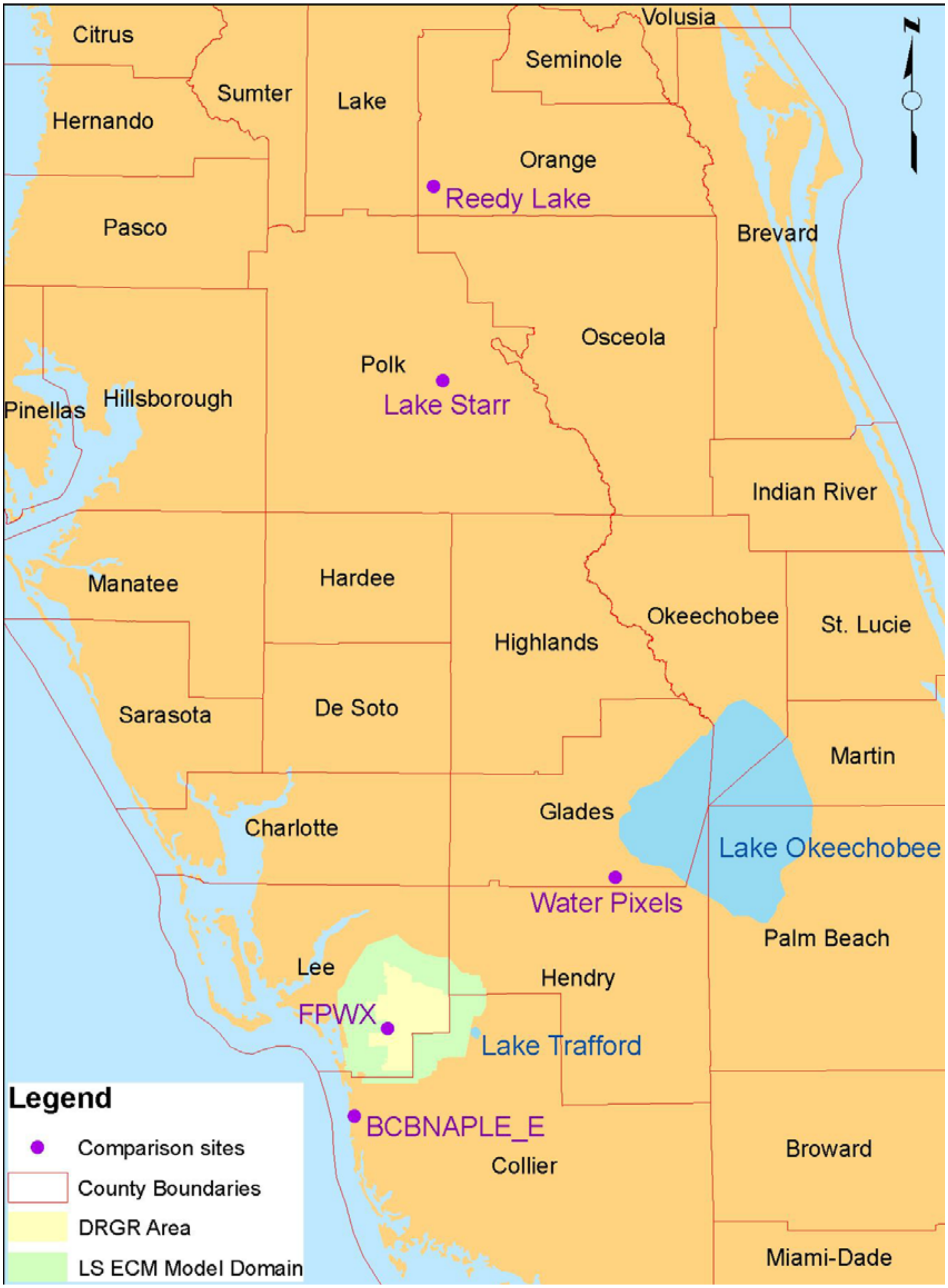

Figure E5. Location of the comparison sites.