# Evapotranspiration

Presented by: Danielle Lyons-Morancy

# Presentation Overview

- **Evapotranspiration**
  - **In south Florida & in SFWMM**
  - **Data sources**
    - **v5.4 compared to v7.0**
  - **Estimation methods**
    - **v5.4 compared to v7.0**
  - **Interpolation to 2 mile x 2 mile grid**
    - **v5.4 compared to v7.0**

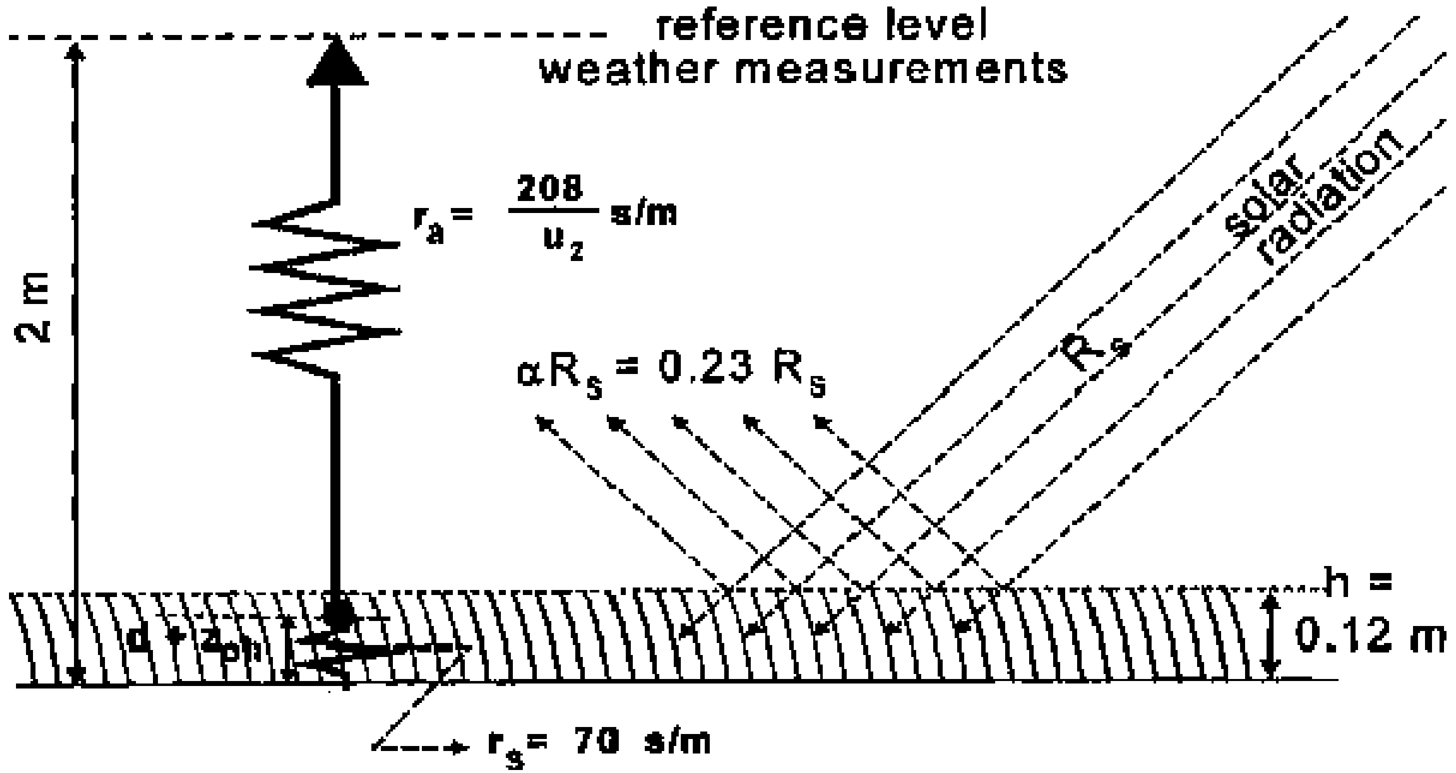
# ET in South Florida

- A main hydrologic variable
- Nearly equal to rainfall
- Water Management

# Potential & Reference ET

- **Potential Evapotranspiration (ETp) is:**
  - **The amount of water transpired in a given time by a short green crop, completely shading the ground, of uniform height, and with adequate water**
- **Reference Evapotranspiration (ETo)**
  - **The rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m a fixed surface resistance 70 s $m^{-1}$, and an albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, well-watered, and completely shading the ground**

# Standard Crop Evapotranspiration



# ET Calculation Process in the SFWMM

**Same for v5.4 & v7.0**

**Reference ET / Potential ET**

**Spatially and temporally variant time series dataset (for ONE defined landscape)**

**Apply Kc for each landscape →**

**Adjusted by landscape → PET for that Landscape**

**Actual ET depends on water available**

# Overview

## THE BIG PICTURE

| | v5.4 | v7.0 |
|---|---|---|
| Data Source | NOAA<br>•COOP<br>•SAMSON | NARR & Hydro51 |
| Estimation Method | Simple | Penman-Monteith |
| Interpolation Method | TIN | MULTIQUAD |
| Reference Landscape | Wet Marsh | Short Grass |

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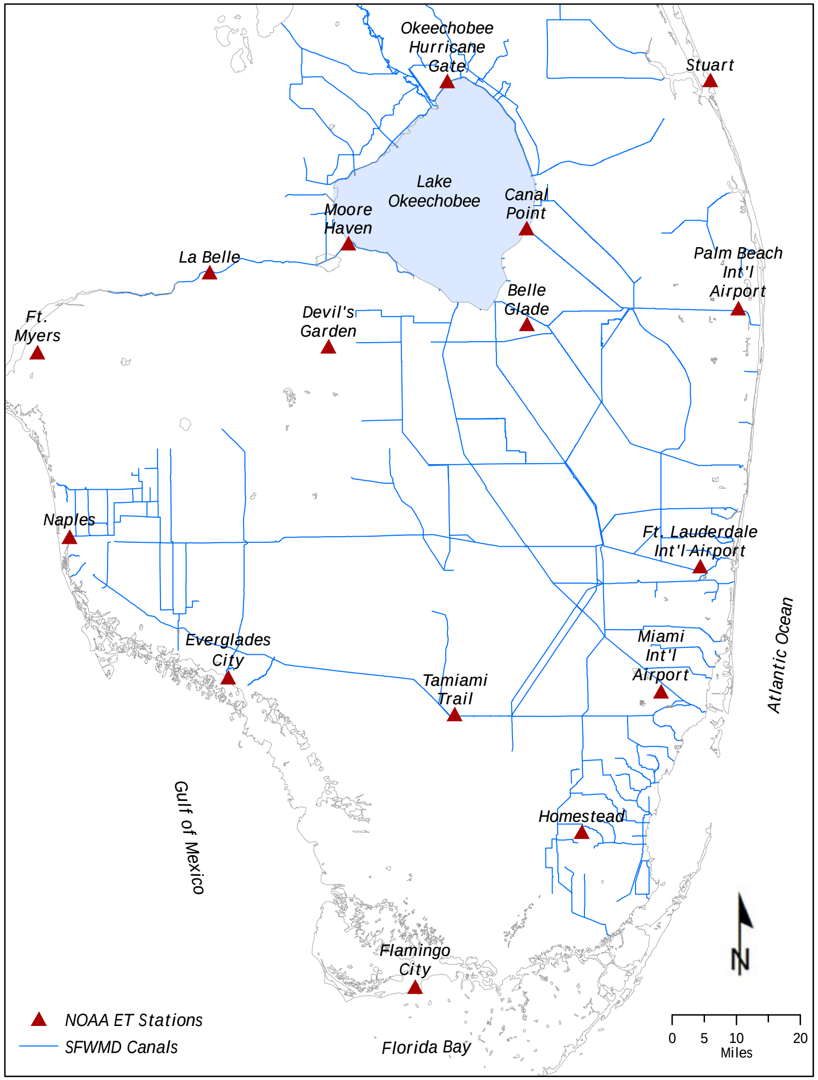
# Data Source for v5.4

- **NOAA –** National Oceanographic & Atmospheric Administration
  - **Cooperative Data**
  - **SAMSON –** Solar & Meteorological Surface Observational Network
- **Observed Data**
- **17 NOAA Stations**

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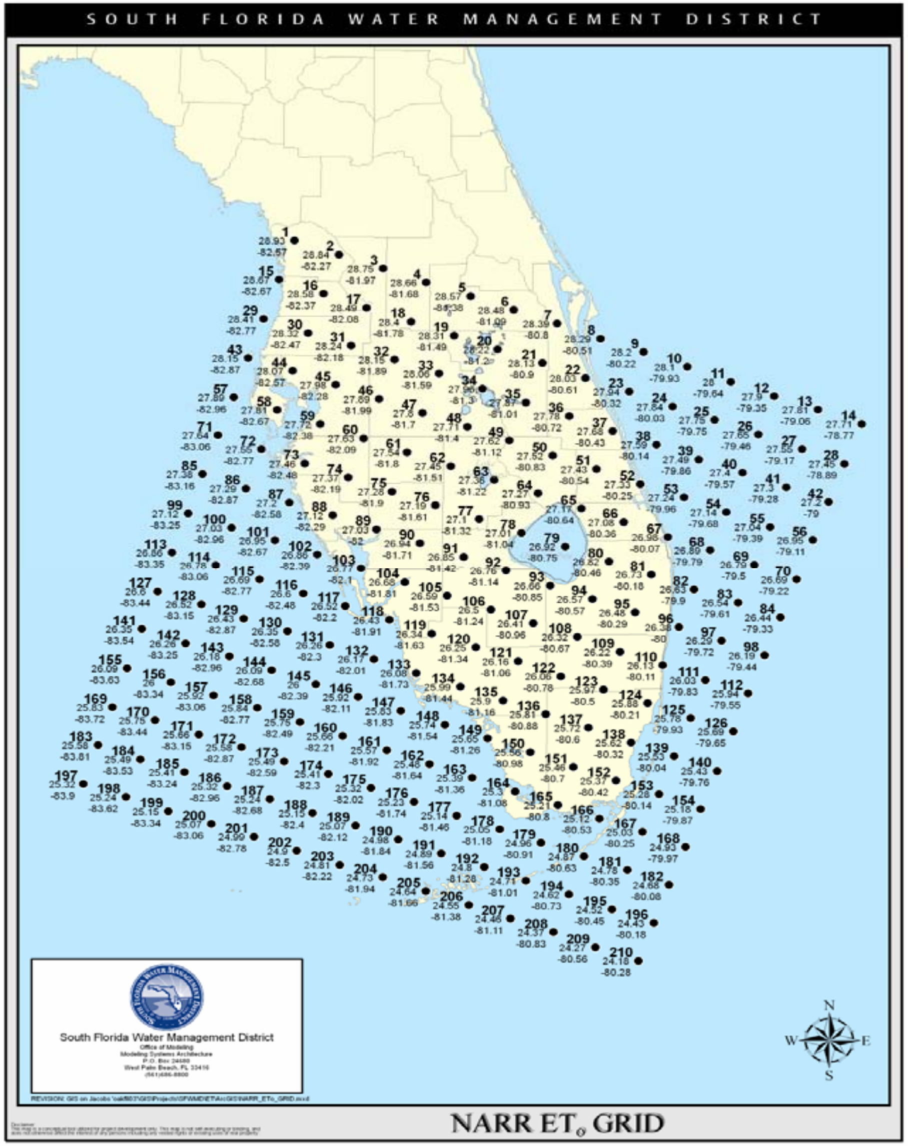
# Data Source for v7.0

- **NARR –** North America Regional Reanalysis
- **Hydro51 –** U.S. Hydrological Reanalysis by the NOAH Land data Assimilation System
- **Reanalysis Data**
  - Datasets that are simulated based on well QA/QC'd observational data
- **85 NARR data locations**



# v5.4 Estimation Method

- **Simple Method**

$$ET_p = \frac{K_1 * R_s}{\lambda}$$

$$R_s = \tau R_a = K_r (T_{max} - T_{min})^{0.5} R_a$$

- **$K_1$ is the coefficient for wet marsh**
  - **Max Air Temperature**
  - **Min Air Temperature**

- **$K_r$ is an empirical coefficient related to the solar radiation received at land surface**

- **$K_r$ values were not obtained but instead were selected to match an expected north to south gradient**

# v7.0 Estimation Method

- **Penman-Monteith Method**

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

- **Where:**
  - **ETo reference evapotranspiration [mm day-1]**
  - **Rn net radiation at the crop surface [MJ m-2 day-1]**
  - **G soil heat flux density [MJ m-2 day-1]**
  - **T mean daily air temperature at 2 m height [°C]**
  - **u2 wind speed at 2 m height [m s-1]**
  - **es saturation vapor pressure [kPa]**
  - **ea actual vapor pressure [kPa]**
  - **ea saturation vapor pressure deficit [kPa]**
  - **D slope vapor pressure curve [kPa °C-1]**
  - **g psychrometric constant [kPa °C-1].**

# Interpolation Method

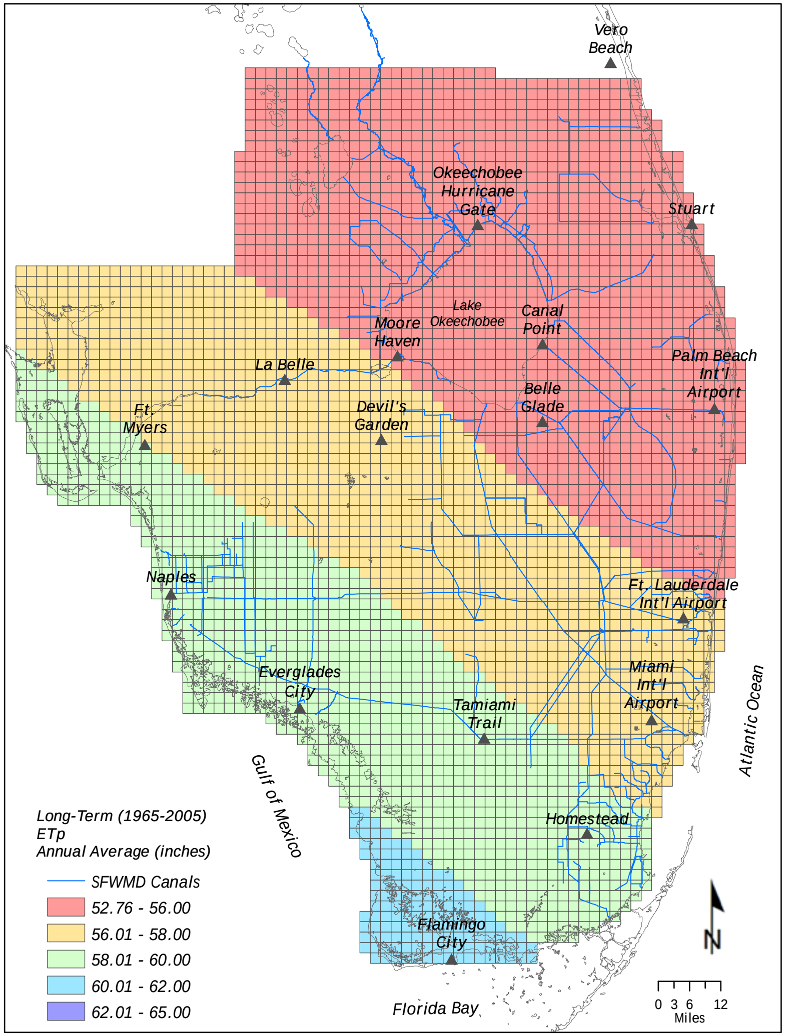
**Method used to interpolate across 2 mile x 2 mile grid:**

- **TIN (v5.4) – Triangulated Irregular Network**
  - **This is a simple method of using the 3 closest station in or around a single cell.**
  - **These values are weighted according to their relevance and added together.**
- **MULTIQUAD (v7.0)**
  - **This method utilizes the full dataset of locations and allows each location to affect the current point by weighting the distance to the relevant location.**
  - **The weights are obtained from quadric surfaces centered at each location.**

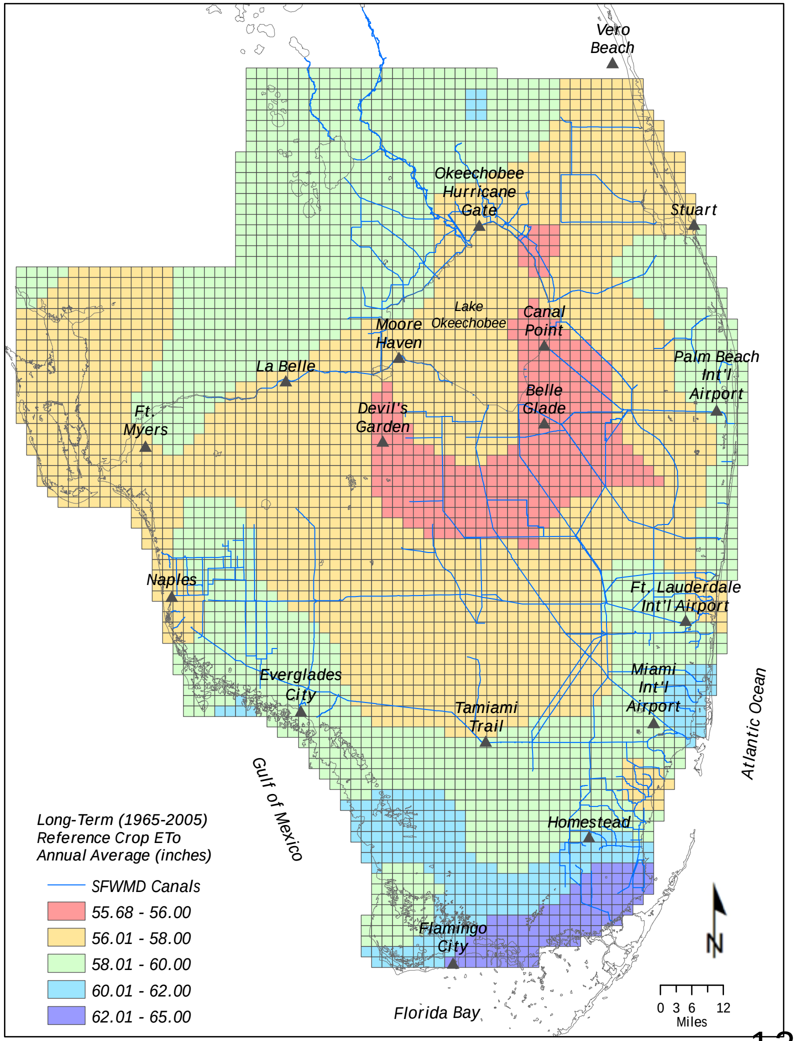
# Comparison of v5.4 to v7.0

## Annual Average ET (1965-2005) (in/yr)

**v5.4**




**v7.0**

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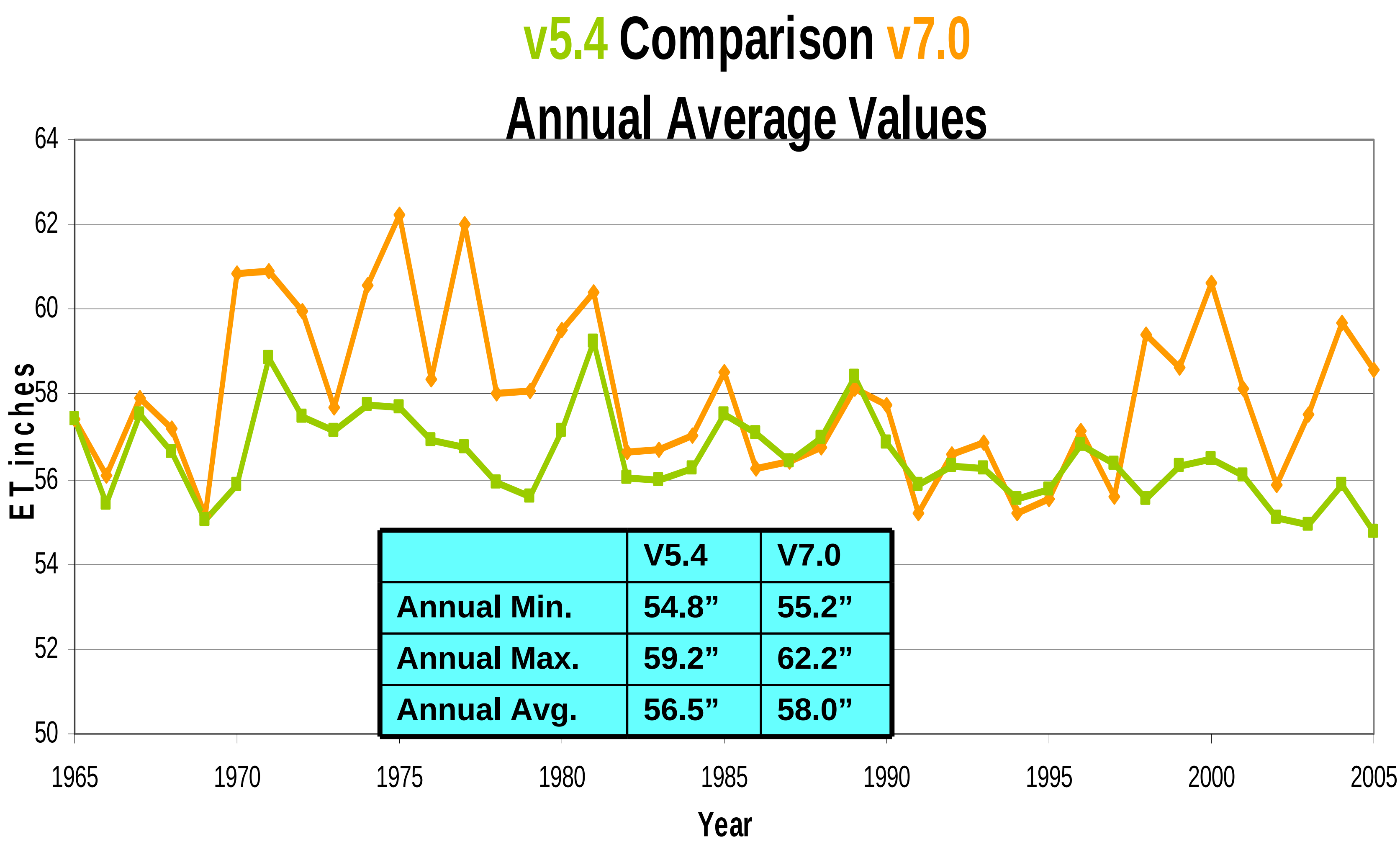
# Comparison of v5.4 and v7.0




| | V5.4 | V7.0 |
|---|---|---|
| Annual Min. | 54.8” | 55.2” |
| Annual Max. | 59.2” | 62.2” |
| Annual Avg. | 56.5” | 58.0” |

# ETo Development and Usage

- **Utilization of ETo in the SFWMM and application of the Crop Coefficient Kc**

# Penman-Monteith Crop Coefficient Kc

**Presented by: Daniel J. Kriesant**

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# Overview of Presentation

- **Overview**
  - **What the Water Management Model has used historically**
  - **Kc critical concerns and how it is used to account for crop differences**
  - **Literature Review to develop v7.0 Kc values**
  - **How we apply Kc in v7.0 Methods**
  - **Presentation of v7.0 and v3.5 values**
  - **Future developments and conclusions**

# Historical Modeling Application of Evapotranspiration

- **Historical Evapotranspiration Application**
  - **Several methods have previously been applied such as:**
    - **SFWMM v3.5 utilized a form of the Penman-Monteith Equation which is very similar to our current effort**
    - **SFWMM v5.4 utilized a form of temperature-based calculation which did not account for the variance in crop conditions to the extent that the Penman-Monteith method does**
  - **In comparing datasets to previous work only v3.5 is usable because of the difference between crop-based and temperature-based methods**

# Crop Coefficient (Kc) Relationship

- **The previous equation has been transformed to allow for calculation based on the following:**

$$ETc = Kc * ETo$$

- **Where:**
  - **ETc crop evapotranspiration [mm d-1]**
  - **Kc crop coefficient [dimensionless]**
  - **ETo reference crop evapotranspiration [mm d-1]**

# Critical Crop Coefficient (Kc) Concerns

- **Kc is the ratio of the crop ETc to the reference ETo and it represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass. These characteristics are:**
  - **Crop Height**. The crop height influences the aerodynamic resistance term, $r_a$, of the FAO Penman-Monteith equation and the turbulent transfer of vapor from the crop into the atmosphere.
  - **Albedo** (reflectance) of the crop-soil surface
    - The albedo is affected by the fraction of ground covered by vegetation and by the soil surface wetness
    - The albedo of the crop-soil surface influences the net radiation of the surface, Rn, which is the primary source of the energy exchange for the evaporation process
  - **Canopy Resistance**. The resistance of the crop to vapor transfer is affected by leaf area (number of stomata), leaf age and condition, and the degree of stomatal control
  - **Evaporation** from soil, especially exposed soil

# Penman-Monteith Literature Review

- **Differences in modeling techniques between v3.5, v5.4, and v7.0 required a current literature review to acquire updated values**
- **Critical information was provided from the St. Johns River Water Management District and their recent work concerning the updating and development of a crop coefficient Kc database**
- **Additional sources were required to complete the task of updating all the utilized land forms**

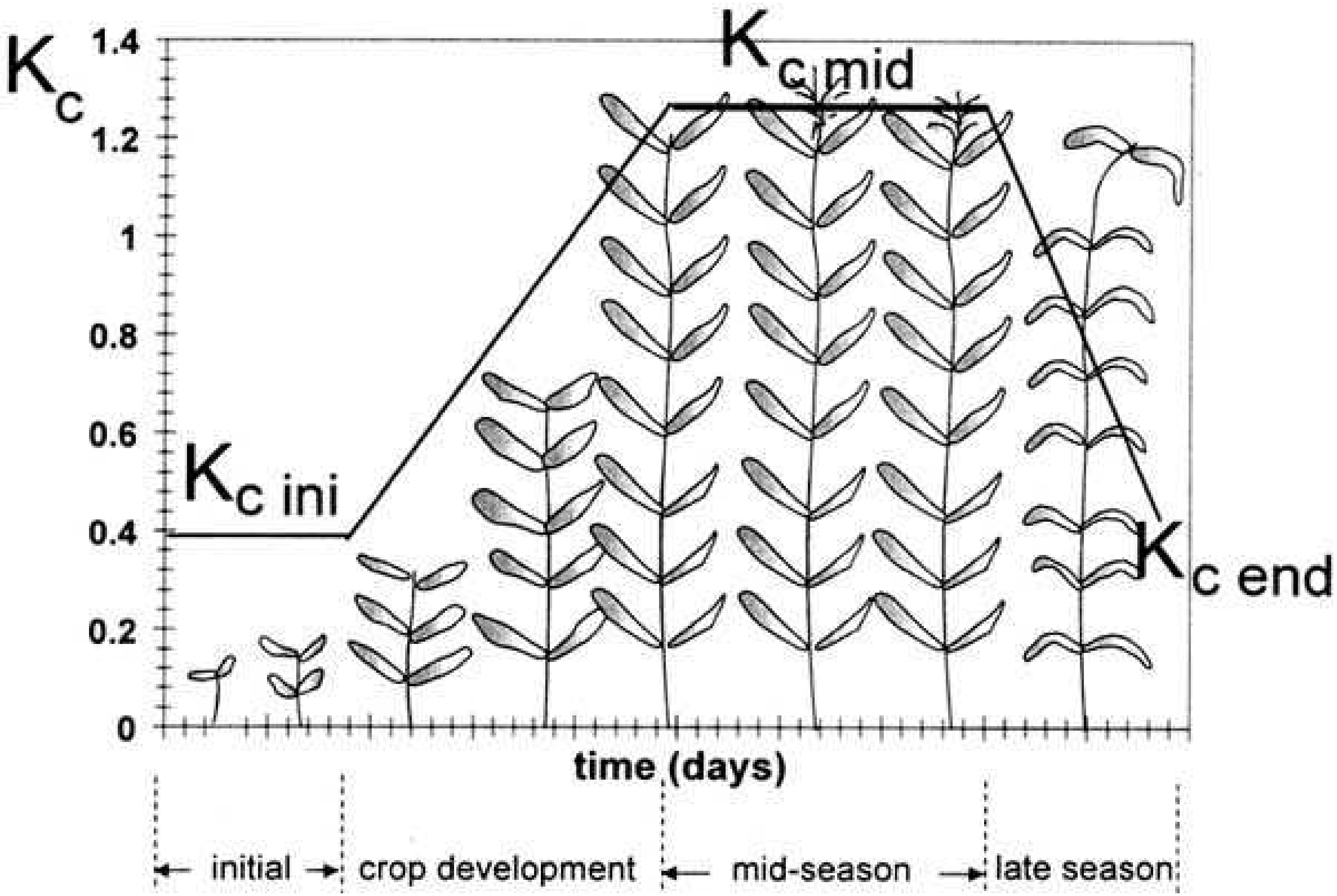
# Penman-Monteith Literature Sources

- Crop co-efficients published by Beede, RH and David A. Goldhammer. 1994.
- "Chapter 11, Olive Irrigation Management" *Olive Production Manual,* Louise F. Ferguson, GS Sibbett, and GC Martin. California: University of California.
- FAO Irrigation and Drainage Paper, 56, Food and Agriculture Organization of the United Nations, Rome
- Crop coefficients are suitable for use with evapotranspiration (ETo) calculated according to FAO56
- Kc values are derived from crop factors published by Benzioni, A., 1997
- *New Crop Factsheet: Jojoba.* West Lafayette, Indiana: Centre for New Crops and Plant Products, Purdue University
- Kc values derived from crop factors published by Burke, K. and Parlevliet, G. 2001.
- *Irrigation of Native Cut Flowers in Western Australia,* Department of Agriculture Farmnote No. 03/2002, Department of Agriculture, Perth, Western Australia.
- AGDEX 280/560.
- Kc values are derived from crop factors provided by McCarthy, M., 2000, Pers. Comm.
- Kc values are derived from crop factors published by Mitchell, P.D. and I. Goodwin, 1996.
- *Micro-Irrigation of Vines and Fruit Trees,* Agmedia, East Melbourne. Victoria.
- Co-efficients arranged according to crop calendars provided by irrigators in the South East of South Australia.

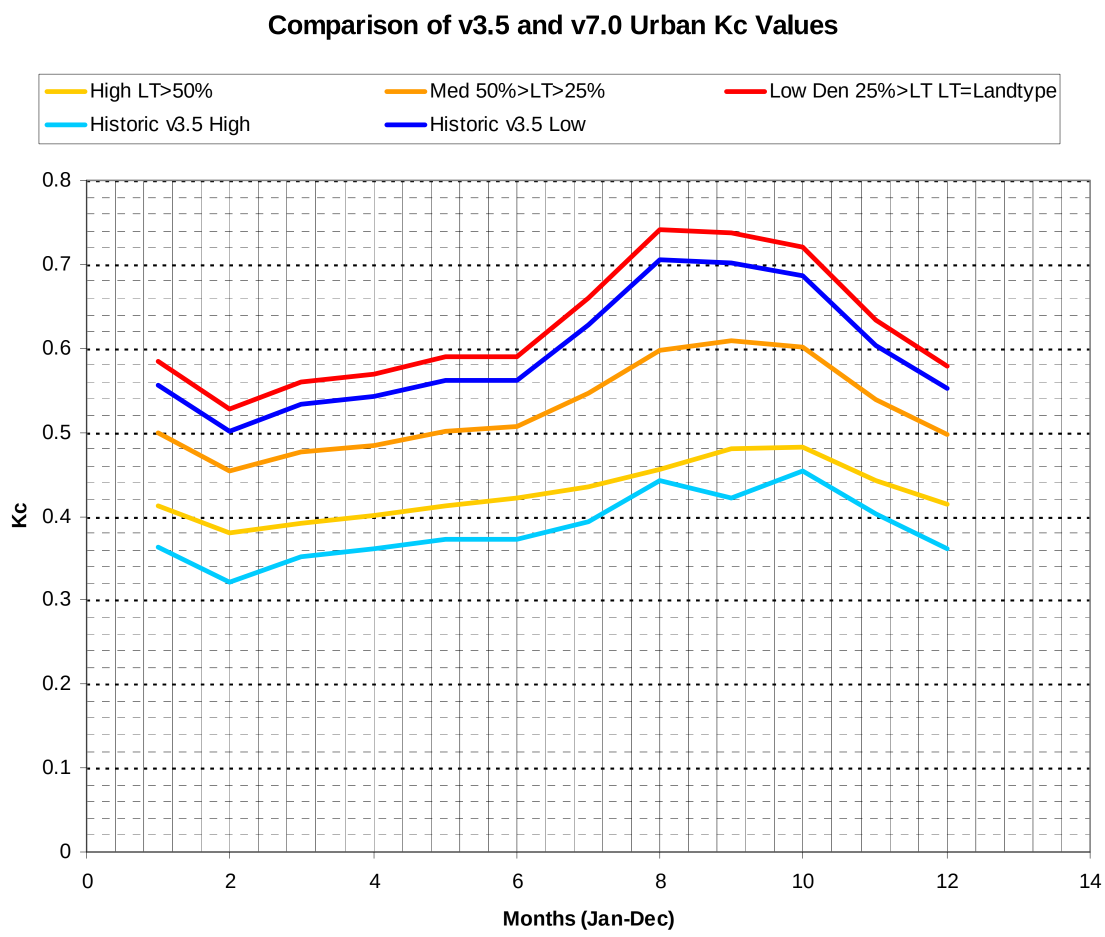
# ETc Determination Procedure

- **The calculation procedure for crop evapotranspiration, ETc, consists of:**
  1. **Identifying the crop growth stages, determining their lengths, and selecting the corresponding Kc coefficients**
  2. **Adjusting the selected Kc coefficients for frequency of wetting or climatic conditions during the stage**
  3. **Constructing the crop coefficient curve (allowing one to determine Kc values for any period during the growing period)**
  4. **Calculating ETc as the product of ETo and Kc**

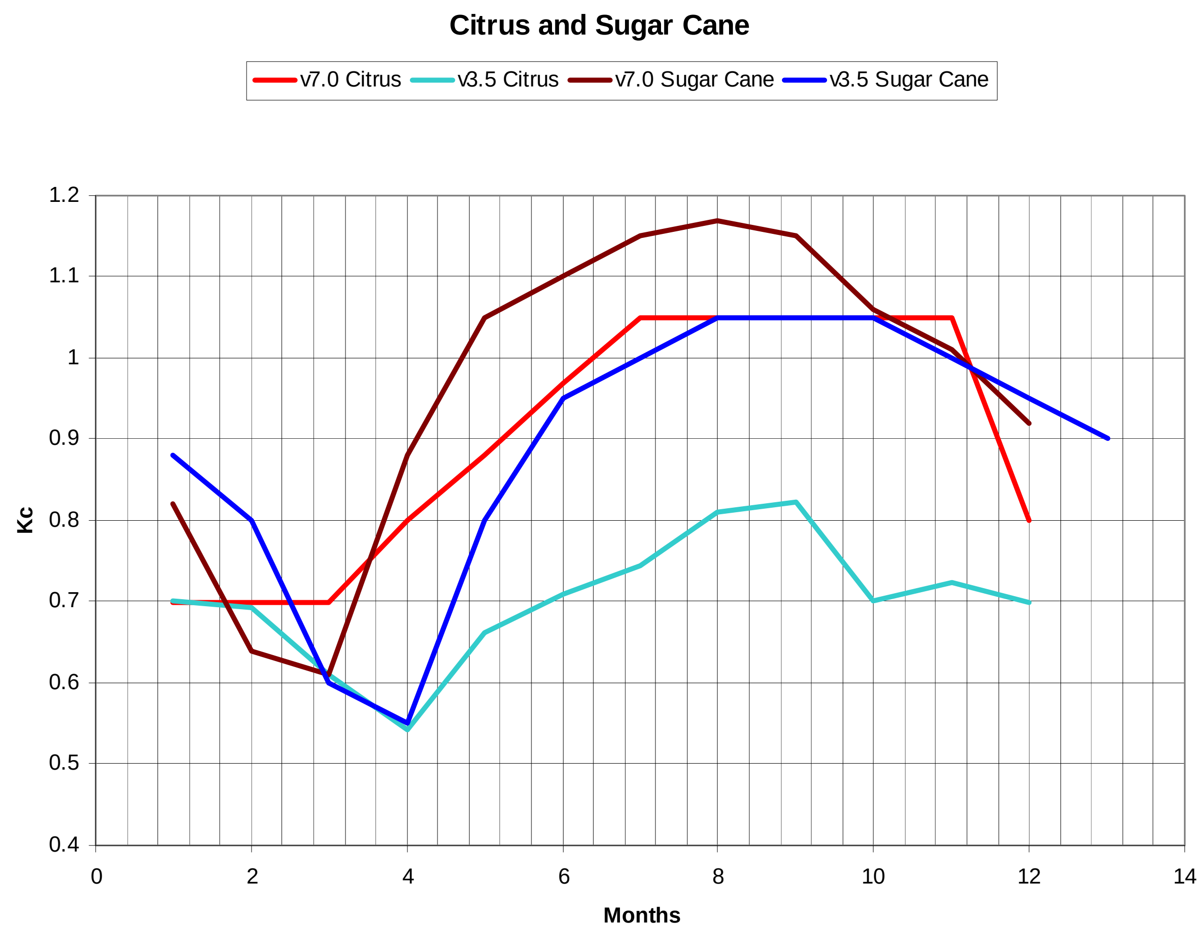
# Variation of Kc over Growing Season



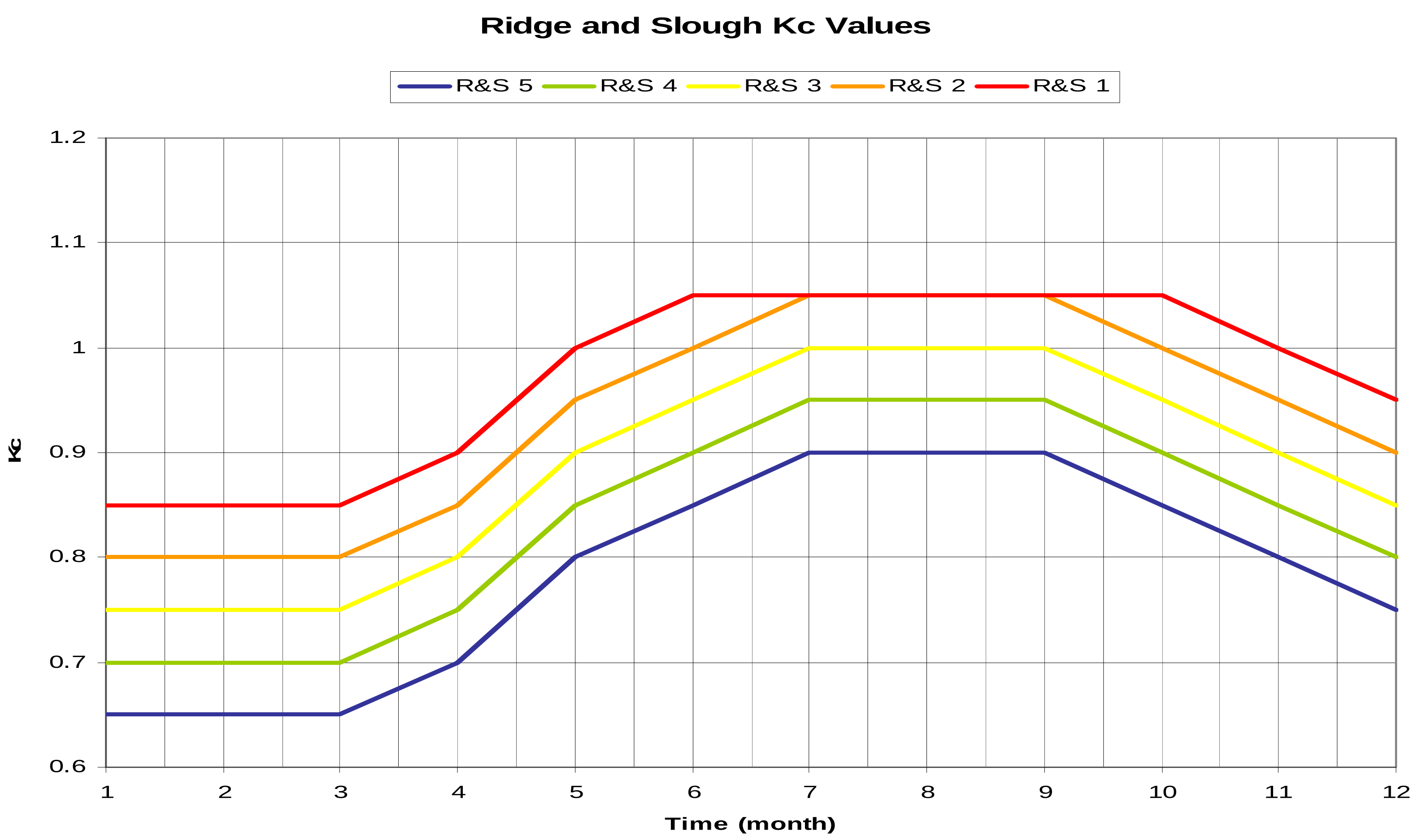
# v3.5 and v7.0 Urban Kc Values



# v3.5 and v7.0 Citrus and Sugar Kc Values



# v7.0 Ridge and Slough Kc Values



# Considerations Regarding Kc

- **The primary task was to develop an ideal Kc value along with acceptable upper and lower bounds**
- **Kc is a calibration parameter and will vary within the bounds in order to calibrate South Florida Water Management Model (SFWMM)**
- **In the final calibration of the SFWMM Kc values within the bounds will be considered acceptable**

| | Citrus January To December | | | | |
|---|---|---|---|---|---|
| Month | v3.5 | v5.4 | min | ideal | max |
| January | 0.701 | 0.701 | 0.525 | 0.70 | 1.155 |
| February | 0.693 | 0.693 | 0.525 | 0.70 | 1.155 |
| March | 0.610 | 0.610 | 0.525 | 0.70 | 1.155 |
| April | 0.542 | 0.542 | 0.525 | 0.80 | 1.155 |
| May | 0.661 | 0.661 | 0.525 | 0.88 | 1.155 |
| June | 0.710 | 0.710 | 0.525 | 0.97 | 1.155 |
| July | 0.744 | 0.744 | 0.525 | 1.05 | 1.155 |
| August | 0.810 | 0.810 | 0.525 | 1.05 | 1.155 |
| September | 0.822 | 0.822 | 0.525 | 1.05 | 1.155 |
| October | 0.702 | 0.772 | 0.525 | 1.05 | 1.155 |
| November | 0.723 | 0.723 | 0.525 | 1.05 | 1.155 |
| December | 0.700 | 0.700 | 0.525 | 0.80 | 1.155 |

# Conclusion

- **Selections of appropriate Kc values within the established boundary are critical to the correct application of the Penman-Monteith Method**
- **South Florida is complex due to the major role that evapotranspiration plays in the water budget**
- **Currently there are advancements being made to run AFSIRS through ArcGIS allowing users to develop unique locations to pull data from and place into their AFSIRS model run**
- **St. Johns River Water Management District is attempting to develop a state-wide database of established and verified Kc values**

# Thanks and Gratitude

- **Special thanks goes out to St. Johns River Water Management District for their help in providing the IMC with updated information regarding several critical land types**
- **Thanks also to the United States Geological Survey for providing the connections to SJRWMD**
- **Comments and questions?**