

The Science Behind Measuring Depletions

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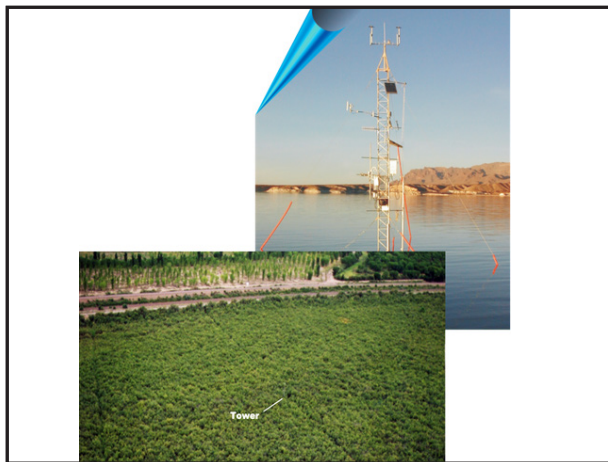
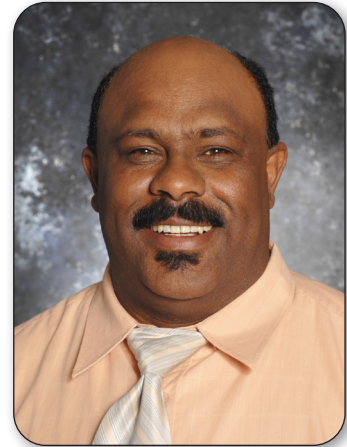


Figure 1. Measuring depletions.

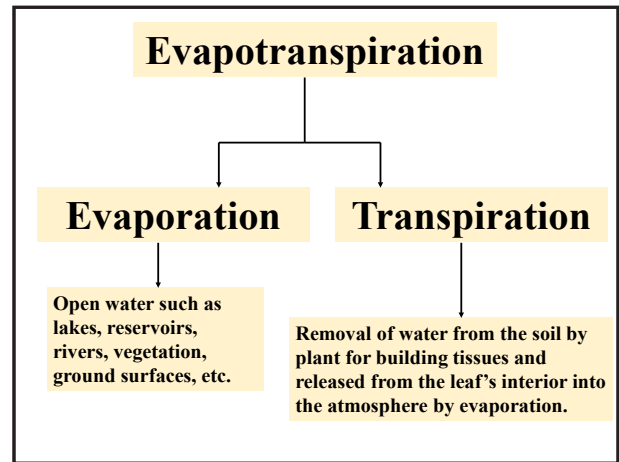


Figure 2. Evaporation and transpiration.

- **Major component of hydrologic cycle**
- **Considered as a loss in Hydrologic Budget**
- **ET information is used for:**
 - Hydrologic and water resources planning
 - Water management and allocation especially in water-scarce regions (e.g. NM)
 - Water resources operation models
 - Weather and climate change forecasting models
 - Negotiating compacts and treaties involving water
 - etc.

Figure 3. Why evapotranspiration (ET)?

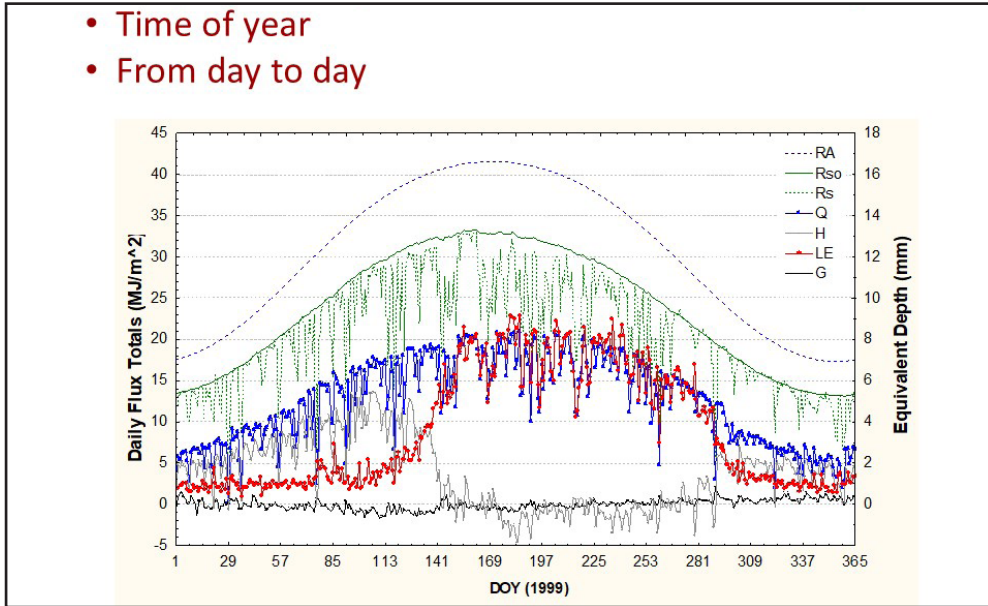




Figure 4. Daily flux varies widely.

Measured crop Climate Station – Reference Crop

$$Kc = ET/ETr$$

$$ETr = \frac{0.408\Delta(Q - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}$$

ASCE Standardized Equation

Figure 5. Traditional method of estimating evapotranspiration (ET).

- **Light Detection And Ranging - LIDAR (Raman Water-Vapor Lidar)**
- **Heat Pulse Technique (Transpiration)**
- **Lysimetry – Lysimeters (extensively used to provide baseline information for other ET methods) – Error 5 to 40%**
- **Measure the change in soil water over a period of time**

Figure 6. Alternative ET methods.

- **Micrometeorological methods (Bowen Ratio Energy Balance, Eddy Covariance..)** $LE = (Rn-G)/(1+\beta)$; H/LE
- **Scintillometers – Measures small fluctuations in the refractive index of air caused by temperature, humidity, and pressure induced variations in density (Optical Transmitter and receiver) – Measures sensible heat flux only;**
 - **Error 10 to 50%**
- **Remote Sensing**
- **Gas Exchange – Stomata Conductance**
- **Class A Pan**

Figure 7. Alternative ET Methods (cont.).



Figure 8. LiDAR (Raman Water-Vapor Lidar) on a trailer (in the back).



Figure 9. Transpiration measurement using heat pulse technique.

ET is determined by measuring change in soil water over a period of time (gravimetric, electromagnetic devices based on dielectric and capacitance, time domain reflectometry, etc.)

- Needs Calibration
- Works well in course soil

ERROR 10% – 30% for person working outside their specialty area can be as high as 70%

Figure 10. Evapotranspiration based on measurement of soil moisture.

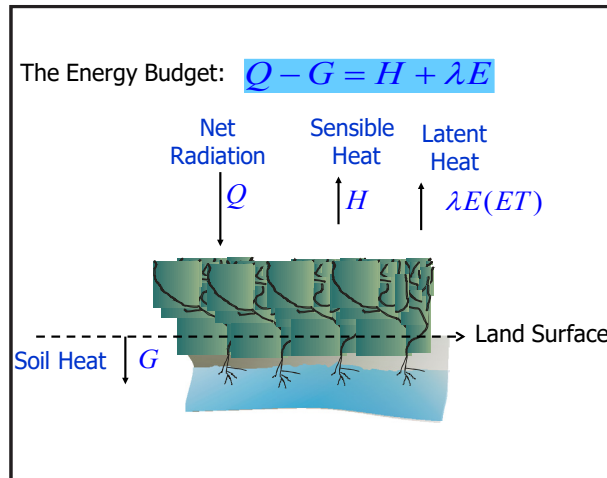


Figure 11. The Energy Budget equation.

Satellite-based ET data are best estimates of an aerodynamic and radiative processes viewed from space.

Not Measurement

- Some use inverse calibration modeling at extreme conditions (dry – wet)
- Others use ground measured values
- Some use vegetation indices (use crop coefficient as a function of NDVI)

ERROR 10% – 40%

- Lag time (e.g. Landsat every 16 days) – precipitation effects, irrigation; bias in seasonal estimates
- Potential bias in albedo and surface temperature- calibration is needed
- Satellite have a view angle that is directly overhead (nearly nadir)
- Aerodynamic exchanges in narrow vegetation systems

Figure 12. Satellite-based ET.

Eddy Covariance

- Energy budget :-**

$$R_n - G = H + LE$$

Where:
 R_n = Net radiation (MJ/m^2)
 G = Soil heat flux (MJ/m^2)
 H = Sensible heat flux (MJ/m^2)
 LE = Latent heat flux (MJ/m^2)

- Eddy Covariance :-**

sensible heat flux, $H = \rho c_p cov [wT]$
 latent heat flux, $LE = \lambda cov [wq]$

Where:
 ρ = density of moist air in (g/m^3)
 c_p = heat capacity of air at constant pressure ($J/g/^\circ C$)
 cov = covariance between w and T or q
 w = vertical air velocity in m/s
 T = air temperature ($^\circ C$)
 q = density of water vapor (g/m^3)
 λ = Latent heat of vaporization of water (J/g)

Figure 13. Energy Budget and Eddy Covariance.

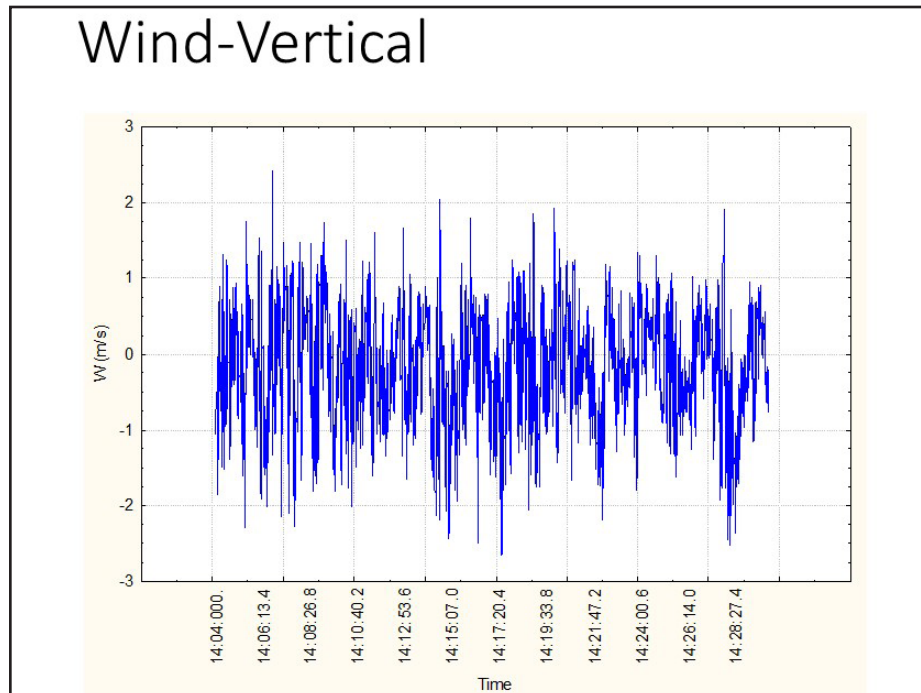


Figure 14. Vertical wind speed measured at high frequency.

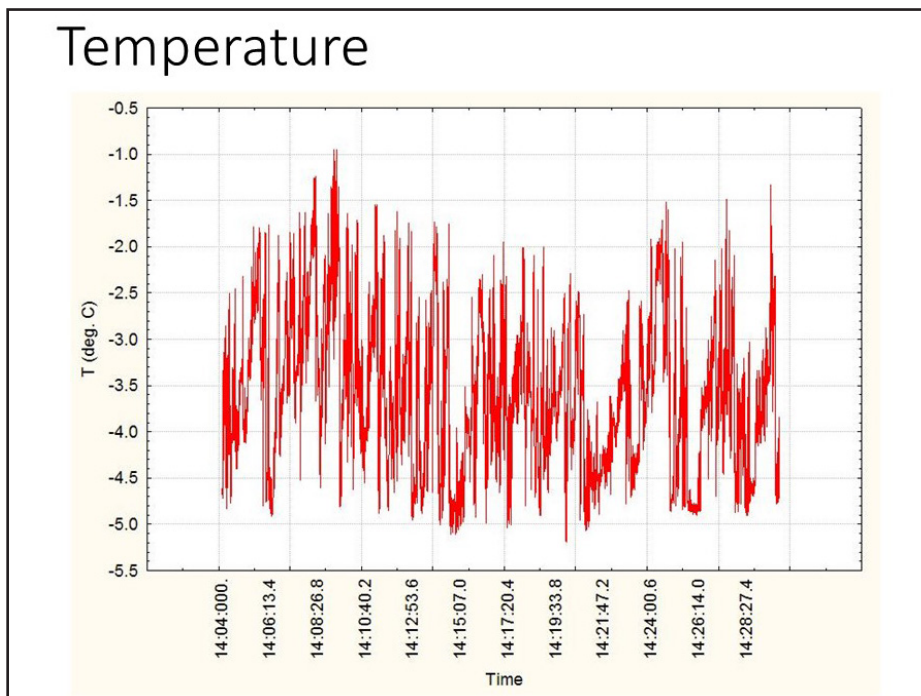


Figure 15. Ambient temperature measured at high frequency.

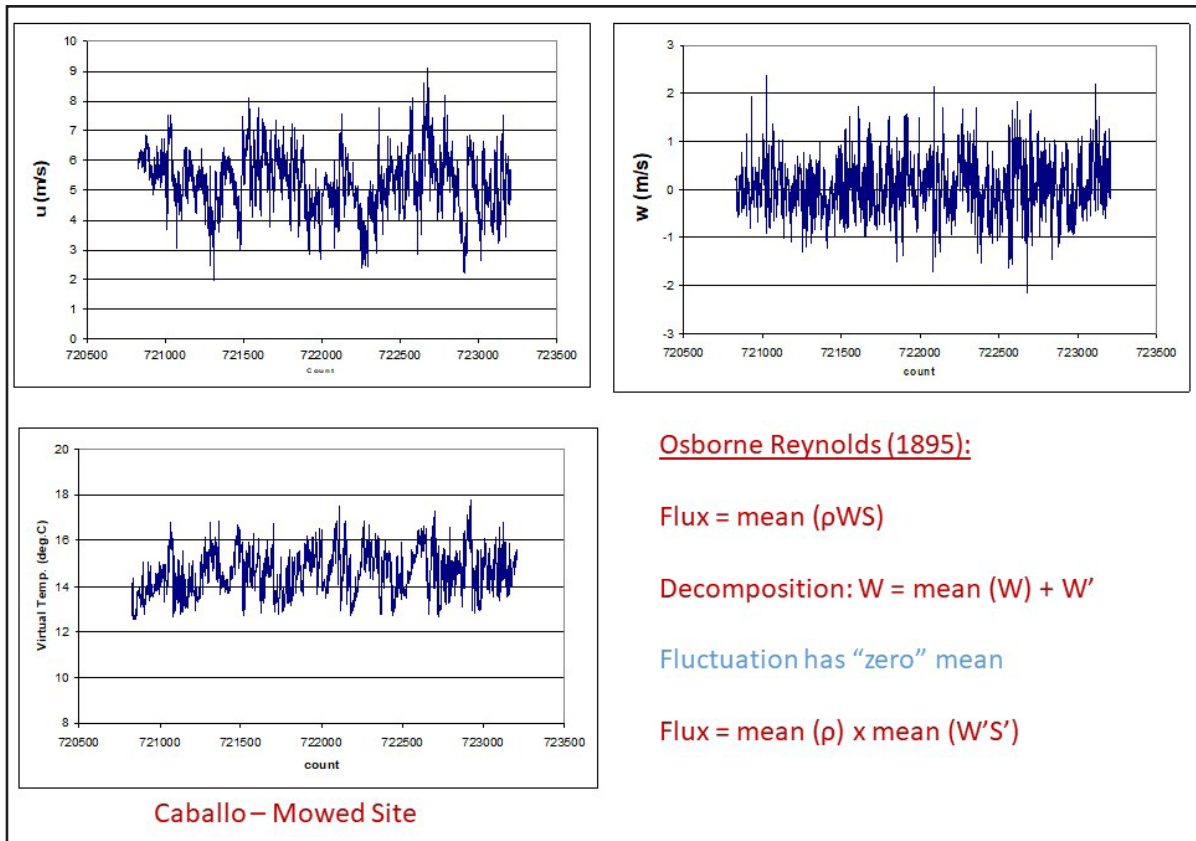


Figure 16. Basic derivation and formulas.

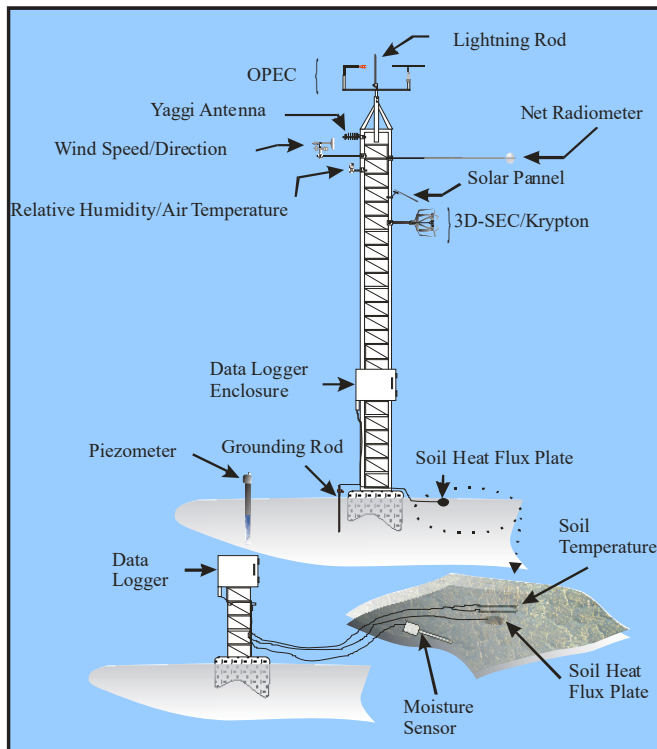


Figure 17. Instrumentation setup for evapotranspiration studies.

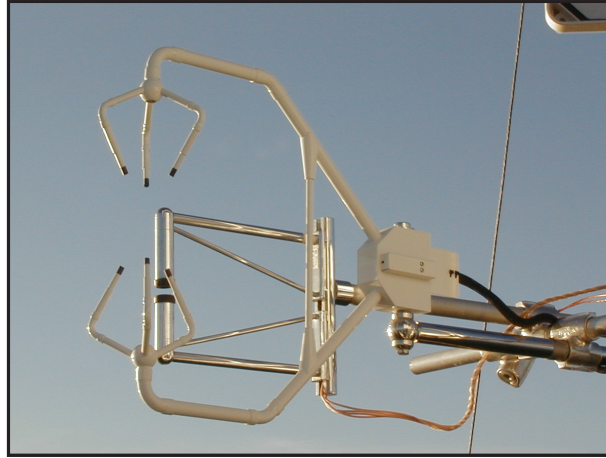


Figure 18. 3-D Sonic Anemometer and Krypton Hygrometer.



Figure 19. One Propeller Eddy Covariance (OPEC) system.

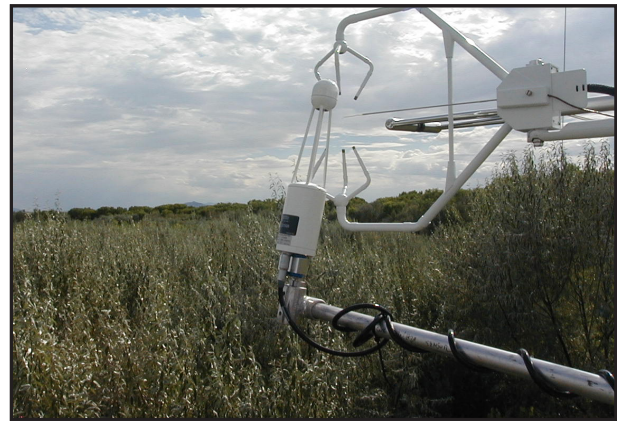


Figure 20. LI-7500 and Krypton Hygrometers with 3-D Sonic Anemometer.

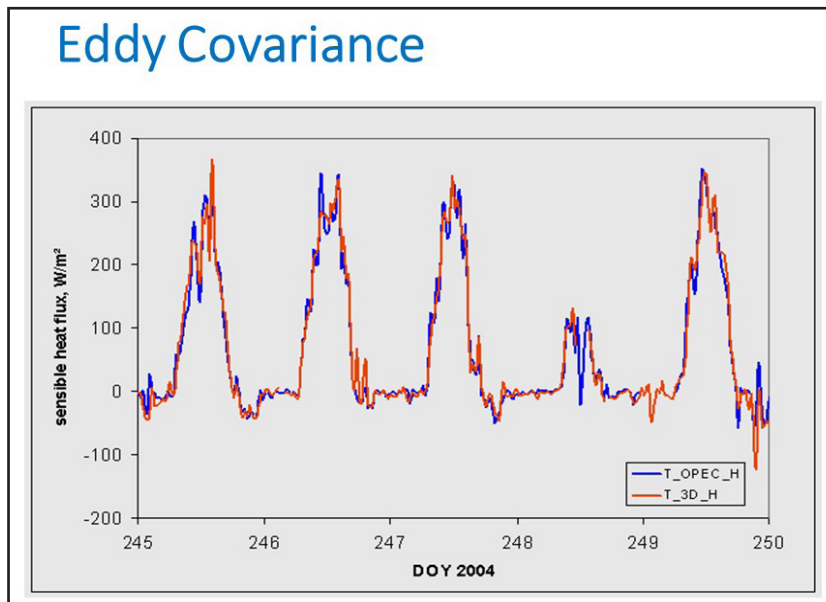


Figure 21. Daily cycle of measured sensible heat.

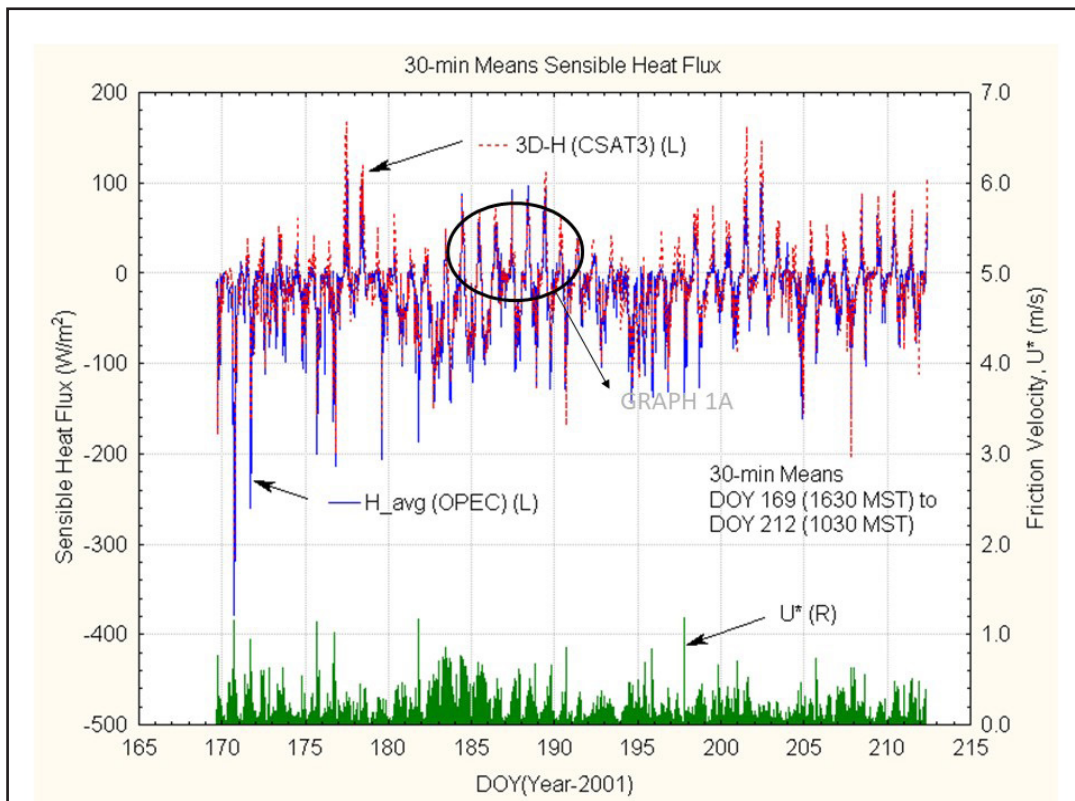


Figure 22. 30-minute Means Sensible Heat Flux.

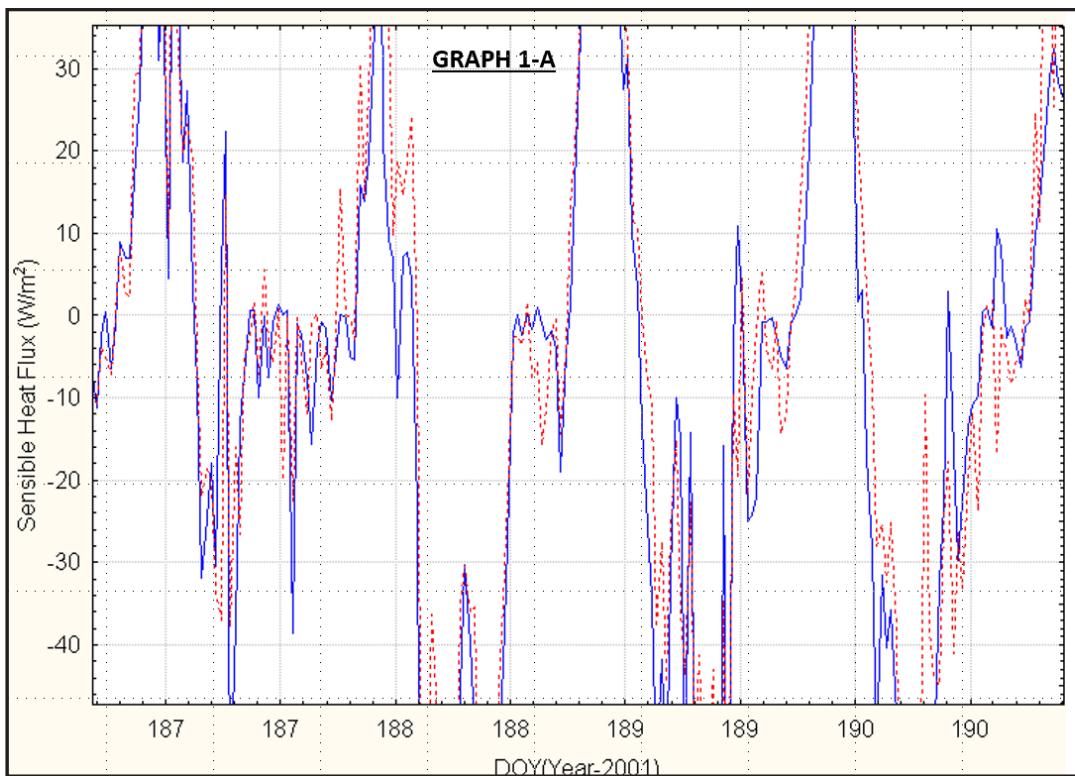


Figure 23. 30-minute Means Sensible Heat Flux-3D Sonic v. OPEC.



Figure 24. Evaporation flux tower at Elephant Butte Reservoir.



Figure 25. Net radiation measurement above dense saltcedar.