Reference ET

Critical Zone Science
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More about Evaporation: Penman-Monteith Eq.

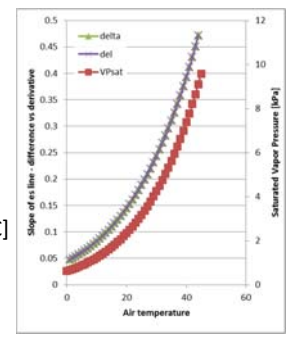
- $\lambda E \quad = \frac{\Delta(R_n - G) + \rho C_p\,(e_s - e_a)/r_a}{\Delta + \gamma(1 + r_s/r_a)}\ [\frac{MJ}{m^2 s}]$
- $r_a \sim \frac{208}{u_2}\,[\frac{s}{m}]$; $r_s \sim 70\,[\frac{s}{m}]$; $\frac{r_s}{r_a} = 0.3365 * u_2 \sim 0.34 u_2$ for short grass;
- for num. $C_p = \frac{\gamma \varepsilon \lambda}{P}$, which eventually gives the γC_n factor (see FAO)
- $\lambda ET_{os} = \frac{\Delta(R_n - G) + \gamma C_n u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}\ [\frac{MJ}{m^2 d}]$

Some Constants & Units

- Latent Heat of Vaporization of water, λ = 2.45 $[\frac{MJ}{Kg}]$;
- Specific Heat of Air, C_p = 0.001013 $[\frac{MJ}{Kg\,^oC}]$;
- Psychrometric constant, $\gamma = \frac{C_p}{0.622\lambda} P\ [\frac{kPa}{^oC}]$
- $\gamma = \frac{0.001013}{0.622 * 2.45} P = 0.000665 * P =$~ .0674 (possible adjust.: 1 mb=0.1 kPa)
- Density of water, ρ = 1 $[\frac{g}{cm^3}]$ = 1000 $[\frac{kg}{m^3}]$
- Watt = Joule/sec

Slope of Vapor Pressure vs. Temp (Δ)

- Fundamental property of air & water
- best fit equation:
- $e_s = 0.6108 e^{\frac{17.27 T_a}{T_a + 237.3}}$
- $\Delta = 4098 * e_s/(T_a + 237.3)^2$ [kPa/°C]
- note 4098*0.6108 = 2503



Reference ET – mm/d

- $ET_{os} = \frac{0.4082 \Delta R_n / 11.6 + \gamma \frac{900}{Ta + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}\ [\frac{mm}{d}]$ eq.2
- *where Rn is in W/m²*
- *to convert, multiply by 2.45 MJ/m²/mm per mm/d, which includes λ (2.45 MJ) and ρ_w (1000 kg/m³)*
- $\frac{MJ}{m^2 d} = \frac{mm}{d} * [\frac{2.45\,MJ}{kg} * \frac{1000\,kg}{m^3} * \frac{m}{1000\,mm}]$
- *it turns out that 2.45 * 0.4082 = 1.0*

Reference ET – MJ/m²/d

- $\lambda ET_{os} = \frac{\Delta R_n / 11.6 + \gamma \frac{2205}{Ta + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}\ [\frac{MJ}{m^2 d}]$ (eq.3)
- *where Rn is in W/m²*
- *to convert to W/m², multiply by 11.57 W-d/MJ per MJ/m²/d (eq.4)*
- $\frac{W}{m^2} = \frac{J}{s - m^2} = \frac{MJ}{m^2 d} * [\frac{h}{3600\,s} * \frac{d}{24\,h} * \frac{1{,}000{,}000\,J}{MJ}]$

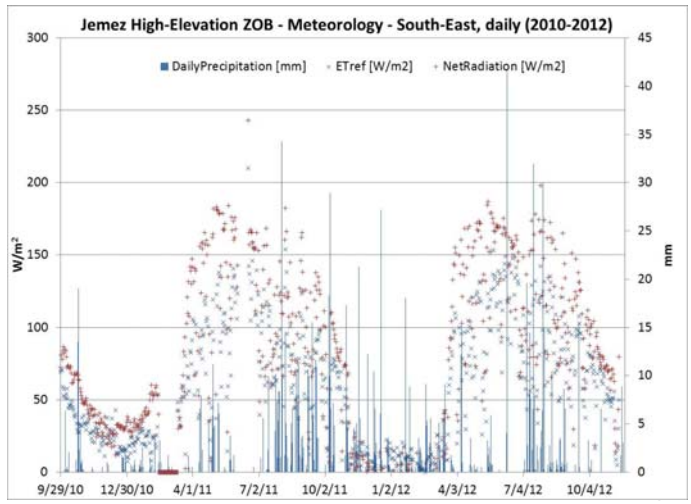
Reference ET – W/m^2

- $\lambda ET_{os} = \frac{\Delta R_n + \gamma \frac{25520}{Ta+273} u_2 (e_s - e_a)}{\Delta + \gamma(1+0.34u_2)}$ $[\frac{W}{m^2}]$ daily (eq.4)

- *<u>where Rn is in W/m^2</u>*
- *divide Σ hourly by 24 to get equivalent daily*

- $\lambda ET_{os} = \frac{\frac{\Delta}{\gamma} R_n + \frac{25520}{Ta+273} u_2 (e_s - e_a)}{\frac{\Delta}{\gamma} + (1+0.34u_2)}$ $[\frac{W}{m^2}]$ daily

- debugging: Δ & γ should be similar; LH & RH should be similar



Data derived from http://criticalzone.org/catalina-jemez/data/dataset/2475/

=(J3*F3+K3*25520/H3*E3*(I3-L3))/(J3+K3*(1+0.34*E3))

M3 =(J3*F3+K3*25520/H3*E3*(I3-L3))/(J3+K3*(1+0.34*E3))

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	DateTime	AvgAirPre:	AvgAirTem	AvgRelativ	AvgWindS	NetRadiat	Tair1	Tair	VPsat	delta	gamma	VPa	ETref
2	[MST]	[kPa]	[degC]	[%]	[m/s]	[W/m2]	[deg C]	[degK]	[kPa]	kPa/degC	kPa/degC	[kPa]	[W/m2]
3	09/27/10	79.5932	13.028	42.364	0.558	83.1647	250.328	286.128	1.50052	0.09813	0.00529	0.63568	80.3312
4	09/28/10	715.425	14.147	33.391	0.67	77.9345	251.447	287.247	1.61392	0.10461	0.04758	0.5389	68.6839
5	09/29/10	713.088	15.4	26.003	0.675	72.6117	252.7	288.5	1.74976	0.11229	0.04742	0.45499	69.2853
6	09/30/10	715.435	13.756	43.882	0.914	80.7046	251.056	286.856	1.57347	0.1023	0.04758	0.69047	70.8854
7	10/01/10	716.685	14.277	39.977	0.854	77.9289	251.577	287.377	1.62757	0.10538	0.04766	0.65065	70.3696
8	10/02/10	716.453	9.641	61.262	0.769	83.8466	246.941	282.741	1.19873	0.08056	0.04764	0.73437	58.9378
9	10/03/10	715.32	7.654	77.332	0.624	86.5226	244.954	280.754	1.04775	0.07156	0.04757	0.81025	52.8731
10	10/04/10	713.678	8.996	63.465	0.921	82.1337	246.296	282.096	1.14775	0.07754	0.04746	0.72842	57.3905
11	10/05/10	714.667	7.777	79.369	0.977	84.8855	245.077	280.877	1.05658	0.07209	0.04753	0.8386	51.9858
12	10/06/10	716.927	7.741	79.419	0.687	83.7869	245.041	280.841	1.05399	0.07193	0.04768	0.83707	51.036
13	10/07/10	715.888	8.319	67.038	0.934	79.6674	245.619	281.419	1.0963	0.07447	0.04761	0.73494	53.8644
14	10/08/10	713.133	7.475	45.995	1.169	72.2441	244.775	280.575	1.03501	0.07079	0.04742	0.47605	57.8764
15	10/09/10	712.63	5.186	51.075	0.961	72.793	242.486	278.286	0.8837	0.06159	0.04739	0.45135	50.5283
16	10/10/10	710.069	3.665	58.632	0.567	73.7024	240.965	276.765	0.79428	0.05606	0.04722	0.4657	43.9826
17	10/11/10	710.244	5.031	55.763	0.647	71.8599	242.331	278.131	0.8742	0.061	0.04723	0.48748	46.0956
18	10/12/10	714.496	5.243	60.11	0.737	71.8813	242.543	278.343	0.88722	0.06181	0.04751	0.53331	46.0211

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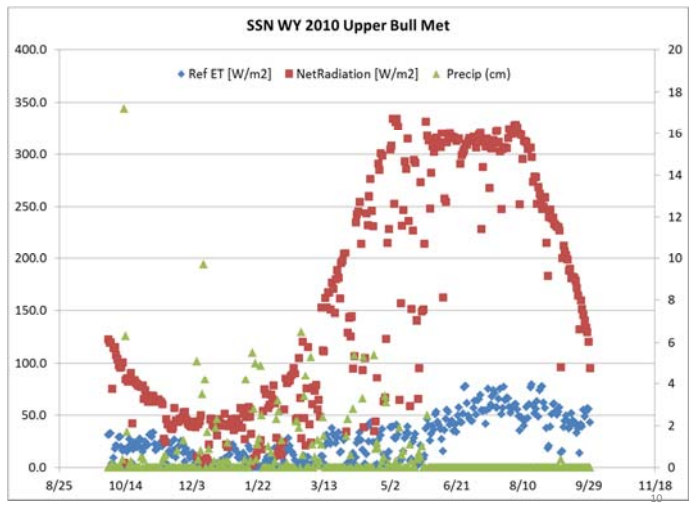

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