Thesis Equations:

Chapter 3 Equations:

$\mathrm{r}_p = R_p \alpha_p$

Where;

$r_p = [r(1) r(2) ... r(p)]$

$\mathrm{R}_p = \begin{pmatrix} r(0) & r(1) & \dots & r(p-1) \\ r(1) & r(0) & \dots & r(p-2) \\ \\ r(p-1) & r(p-2) & \dots & r(0) \end{pmatrix}$

$\alpha_p = [\alpha(1) \alpha(2) ... \alpha(p)]$

$r(1) = \frac{\widehat{\gamma}(1)}{\widehat{\gamma}(0)}$; Auto-Correlation at Lag 1

$\widehat{\gamma}(h) = \frac{1}{n} \sum_{t=1}^{n-h} \left(X_t - \bar{X} \right) \left(X_{t+h} - \bar{X} \right)$; Auto-Covariance at Lag h

The AR parameters are obtained from the following equation;

$\alpha_p = R_p^{-1} r_p$

$\mathrm{R}_p = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{d1} & x_{d2} & \dots & x_{dn} \end{bmatrix}$

$\mathrm{R}_p = \begin{bmatrix} r(0) & r(1) & \dots & r(p-1) \\ r(1) & r(0) & \dots & r(p-2) \\ \vdots & \vdots & \ddots & \vdots \\ r(p-1) & r(p-2) & \dots & r(0) \end{bmatrix}$

$$E_\lambda = \frac{3.74 \times 10^8}{\lambda^5 \left[\exp\left(\frac{14{,}400}{\lambda T} \right) - 1 \right]} \tag{-8}$$

$$E = A \sigma T^4 \tag{-7}$$

$$\lambda_{max}(\mu m) = \frac{2898}{T(K)} \tag{-6}$$

$$I_d = I_0 (e^{q V_d / kT} - 1) \tag{-5}$$

$$I = I_{SC} - I_d \tag{-4}$$

$$I = I_{SC} - I_0 \left(e^{qV/kT} - 1 \right) \tag{-3}$$

$$V_{OC} = \frac{kT}{q} \ln \left(\frac{I_{SC}}{I_0} + 1 \right) \tag{-2}$$

$$I = I_{SC} - I_0 \left(e^{38.9V} - 1 \right) \tag{-1}$$

$$V_{OC} = 0.0257 \ln \left(\frac{I_{SC}}{I_0} + 1 \right) \tag{0}$$

$$I = (I_{SC} - I_d) - \frac{V}{R_P} \tag{1}$$

$$V_d = V + I.R_S \tag{2}$$

$$I = I_{SC} - I_0 \left\{ \exp \left[\frac{q(V + I.R_S)}{kT} \right] - 1 \right\} \tag{3}$$

$$I = I_{SC} - I_0 \left\{ \exp \left[\frac{q(V + I.R_S)}{kT} \right] - 1 \right\} - \left(\frac{V + I.R_S}{R_P} \right) \tag{4}$$

$$I_{SC} = I + I_d + I_P \tag{5}$$

$$V = V_d - IR_S \tag{6}$$

$$V_{module} = n(V_d - IR_S) \tag{7}$$

$$I_{module} = p(I_{SC} - I_d - I_P) \tag{8}$$

$$T_{cell} = T_{amb} + \left(\frac{NOCT - 20^\circ}{0.8} \right) .\ S \tag{9}$$

$$V_{SH} = V_{n-1} - I(R_P + R_S) \tag{10}$$

$$V_{n-1} = \left(\frac{n-1}{n} \right) V \tag{11}$$

$$V_{SH} = \left(\frac{n-1}{n} \right) V - I(R_P + R_S) \tag{12}$$

$$\nabla V = \frac{V}{n} - I(R_P + R_S) \tag{13}$$

Chapter 4 Equations:

$$\text{Air Mass Ratio} \quad m = \frac{h_2}{h_1} = \frac{1}{\sin \beta} \tag{14}$$

$$d = 1.5 \times 10^8 \left\{ \ 1 + 0.017 \sin \left[\frac{360(n - 93)}{365} \right] \right\} \ \text{km} \tag{15}$$

$$\delta = 23.45 \sin\left[\frac{360}{365}(n-81)\right] \tag{16}$$

$$\beta_N = 90^\circ - L + \delta \tag{17}$$

$$\text{Tilt} = 90^\circ - \beta_N \tag{18}$$

$$\sin(\beta) = \cos(L)\cos(\delta)cos(H) + \sin(L)\sin(\delta) \tag{19}$$

$$\sin(\phi_S) = \frac{\cos(\delta)\sin(H)}{\cos(\beta)} \tag{20}$$

$$\text{Hour Angle } H = \left(\frac{15^\circ}{\text{hour}}\right).\text{(hours before solar noon)} \tag{21}$$

$$\text{if,} \quad \cos(H) \geq \frac{\tan(\delta)}{\tan(L)}; \qquad \text{then, } |\phi_S| \leq 90^\circ; \qquad \text{otherwise, } |\phi_S| > 90^\circ \tag{22}$$

$$E = 9.87\sin(2B) - 7.53\cos(B) - 1.5\sin(B) \quad \text{minutes} \tag{23}$$

$$B = \frac{360}{364}(n-81) \tag{24}$$

$$\text{Solar Time (ST)} = \text{Clock Time (CT)} + \frac{4\text{ min}}{\text{degree}}(\text{Local Time Meridian} - \text{Local Logitude})^\circ + E(\text{min}) \tag{25}$$

$$\sin(\beta) = \cos(L)\cos(\delta)cos(H) + \sin(L)\sin(\delta) = 0 \tag{26}$$

$$\cos(H) = -\frac{\sin(L)\sin(\delta)}{\cos(L)\cos(\delta)} = -\tan(L)\tan(\delta) \tag{27}$$

$$H_{SR} = \cos^{-1}(-\tan(L)\tan(\delta)) \quad (+ \text{ for sunrise}) \tag{28}$$

$$\text{Sunrise(geometric)} = 12:00 - \frac{H_{SR}}{15^\circ/h} \tag{29}$$

$$Q = \frac{3.467}{\cos(L)\cos(\delta)\sin(H_{SR})} \quad (\text{min}) \tag{30}$$

$$I_0 = \text{SC.}\left[1 + 0.0334\cos\left(\frac{360n}{365}\right)\right] \quad (\text{W/m}^2) \tag{31}$$

$$I_B = Ae^{-km} \tag{32}$$

$$A = 1160 + 75\sin\left[\frac{360}{365}(n-275)\right] \quad (\text{W/m}^2) \tag{33}$$

$$k = 0.174 + 0.035 \sin \left[\frac{360}{365}(n - 100) \right] \tag{34}$$

$$I_{BC} = I_B \cos(\theta) \tag{35}$$

$$I_{BH} = I_B \cos(90^\circ - \beta) = I_B \sin(\beta) \tag{36}$$

$$\cos(\theta) = \cos(\beta)\cos(\phi_S - \phi_C)\sin(\Sigma) + \sin(\beta)\cos(\Sigma) \tag{37}$$

$$I_{DH} = C I_B \tag{38}$$

$$C = 0.095 + 0.04 \sin \left[\frac{360}{365}(n - 100) \right] \tag{39}$$

$$I_{DC} = I_{DH} \left(\frac{1 + \cos(\Sigma)}{2} \right) = C I_B \left(\frac{1 + \cos(\Sigma)}{2} \right) \tag{40}$$

$$I_{RC} = \rho(I_{BH} + I_{DH}) \left(\frac{1 - \cos(\Sigma)}{2} \right) \tag{41}$$

$$I_{RC} = \rho I_B(\sin(\beta) + C) \left(\frac{1 - \cos(\Sigma)}{2} \right) \tag{42}$$

$$I_C = I_{BC} + I_{DC} + I_{RC} \tag{43}$$

$$\begin{aligned} I_C = A e^{-km} \Big[&\cos(\beta)\cos(\phi_S - \phi_C)\sin(\Sigma) \\ &+ \sin(\beta)\cos(\Sigma) + C \left(\frac{1 + \cos(\Sigma)}{2} \right) \\ &+ \rho(\sin(\beta) + C) \left(\frac{1 - \cos(\Sigma)}{2} \right) \Big] \end{aligned} \tag{44}$$

$$I_{BC} = I_B \tag{45}$$

$$I_{DC} = C I_B \left[\frac{1 + \cos(90^\circ - \beta)}{2} \right] \tag{46}$$

$$I_{RC} = \rho(I_{BH} + I_{DH}) \left[\frac{1 - \cos(90^\circ - \beta)}{2} \right] \tag{47}$$

$$\Sigma_{effective} = 90^\circ - \beta + \delta \tag{48}$$

$$I_{BC} = I_B \cos(\delta) \tag{49}$$

$$I_{DC} = CI_B \left[\frac{1 + \cos\left(90^\circ - \beta + \delta\right)}{2} \right] \tag{50}$$

$$I_{RC} = \rho(I_{BH} + I_{DH}) \left[\frac{1 - \cos\left(90^\circ - \beta + \delta\right)}{2} \right] \tag{51}$$