Surface and Upper Weather Pre-processor for i-Tree Eco and Hydro

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1   Introduction

US Forest Service's i-Tree tools utilizes field-surveyed urban forest information, location specific data, weather data, and air pollutant measurements to quantify urban forest structure and numerous forest-related effects such as carbon sequestration, energy savings, and pollution removals. Key input is weather data; hourly global surface weather data (NCDC 2013a) and upper air data (NOAA 2013b). This document describes the methods to process hourly weather parameters required to run i-Tree tools.

2   Materials

Surface weather data contain measurements at a single weather station for a year in the Integrated Surface Hourly (ISH) format. Upper air data contain measurements in the morning and afternoon at a single site for a year in the FSL format. Both can be downloaded from Internet or extracted from archive DVDs (NOAA 2013a, 2013b). Tables 1 and 2 summarize the parameter contained in these input data and created and stored in output MS-Access database.

Table 1 Surface weather variables

Input		Output	
Variables	Units/Values	Variables	Units/Values
Wind speed	[miles/h]	Sind speed	[Knot, m/s, miles/h]
Could ceiling height	[100ft]	Cloud ceiling height	[100ft]
Sky cover	[clear]	Total cloud cover	[0/3.75/7.5/10]
	[scattered]	Opaque cloud cover	[0/3.75/5/7.5/10]
	[broken]	Translucent cloud	[0/2.5/3.75/5/7.5/10]
	[overcast]	cover	
	[obscured]		
	[partial obscuration]		
Temperature	[F]	Temperature	[F]/[C]/[K]
Dew point	[F]	Dew point	[F]/[C]
temperature		temperature	
Station altimeter	[in]		
setting			
Station pressure	[mb]	Station pressure	[in]/[kPa]/[mb]
1-hour liquid	[in]	1-hour liquid	[in]/[m]
precipitation		precipitation	
		Solar zenith angle	[deg]
		Air mass	[kg/m^2]
		Direct normal solar	[W/m^2]
		radiation	
		Diffuse horizontal	[W/m^2]
		solar radiation	
		Global horizontal solar	[W/m^2]
		radiation	
		Photosynthetically	[W/m^2]/[uE/m^2/s]
		active radiation (PAR)	
		Net radiation	[W/m^2]
		Relative humidity	
		Vapor pressure	[kPa]
		Saturated vapor	[kPa]

	pressure		
	Potential evaporation from tree	[m/h]	
	Potential evaporation from ground	[m/h]	
	Potential evaporation from snow on tree	[m/h]	
	Potential evaporation from snow on ground	[m/h]	
	Potential evapotranspiration from tree	[m/h]	

Table 2 Upper air variables

Input		Output	
Variables	Units/Values	Variables	Units/Values
Height	[m]	Rural mixing height	[m]
Pressure	[0.1 mb]	Urban mixing height	[m]
Temperature	[0.1 C]		

3   Methods

3.1   Solar Zenith Angle

Solar position is calculated based on algorithms reported by Iqbal (1983). Solar zenith angle, θ_z [deg] is calculated as:

$$cos\,\theta_z = sin\,\delta\,sin\,\phi + cos\,\delta\,cos\,\phi\,cos\,\omega \tag{1}$$

δ [deg] is the solar declination, which is the angle between a line joining the centers of the sun and the earth to the earth's equatorial plane and given by:

$$\delta = (0.006918 - 0.399912\,cos\,\psi + 0.070257\,sin\,\psi - 0.006758\,cos\,2\psi +$$
$$0.000907\,sin\,2\psi - 0.002697\,cos\,3\psi + 0.00148\,sin\,3\psi)(180/\pi) \tag{2}$$

ψ [deg] is the day angle:

$$\psi = \frac{360(d-1)}{365} \qquad (3)$$

d is the day number of a year (1 to 365, assuming no leap year).

ϕ [deg] is the geographic latitude (north positive)
ω [deg] is the hour angle:

$$\omega = 15TST - 180 \qquad (4)$$

TST is the true solar time:

$$TST = LST + 4(|L_s| - |L_e|) + E_t \qquad (5)$$

L_s [deg] is the standard meridian, occurring every $15°$ of longitudinal displacement from the prime meridian that runs through Greenwich, England:

$$L_s = 15T_z \qquad (6)$$

T_z is the time difference in hour from Greenwich to a certain location (east positive). L_e [deg] is the local longitude (east positive), 4 [min] is the longitude correction for every degree of difference between L_s and L_e, and E_t [min] is the equation of time, variation in length of a solar day (the duration of the sun to complete one cycle about a stationary observer on earth) throughout a year:

$$E_t = (0.000075 + 0.001868 \cos\psi - 0.032077 \sin\psi - 0.014615 \cos 2\psi -$$
$$0.040849 \sin 2\psi)(229.18) \qquad (7)$$

Atmosphere-corrected solar zenith angle (θ_z') is calculated as:

$$\theta_z' = \theta_z - C_r \qquad (8)$$

C_r is the refraction correction on the solar elevation angle ($\alpha=90- \theta_z$), and calculated as (Astronomical Almanac 1992): if $-1 \le \alpha < 15$

$$C_r = \frac{P_a}{T_a} \cdot \frac{0.1594 + 0.0196\alpha + 0.00002\alpha^2}{1 + 0.505\alpha + 0.0845\alpha^2} \qquad (9)$$

if $15 \leq \alpha < 90$

$$C_r = \frac{0.00452\frac{Pa}{Ta}}{\tan \alpha} \tag{10}$$

P_a is the absolute pressure (=1013.25 mb) and T_a is the absolute temperature (=288.15 K).

3.2 Solar Radiation

Accounting for extraterrestrial, and direct and diffuse components for clear and cloudy, solar radiation parameters (direct normal solar radiation, diffuse horizontal solar radiation, global horizontal solar radiation, PAR, and net radiation) are calculated based on National Renewable Energy Laboratory's METSTAT (Maxwell 1998, NSRDB 1995) and the Bird Clear Sky model (Bird & Hulstrom 1981).

The extraterrestrial global horizontal radiation, ETR [Wm^{-2}] is calculated as (Maxwell 1998):

$$ETR = I_o cos\theta_z \tag{11}$$

I_o [Wm^{-2}] is the extraterrestrial normal radiation (i.e. solar radiation on a plane normal to the solar beam) (Maxwell 1998):

$$I_o = e_o I_c \tag{12}$$

I_c is the solar constant, 1367 [Wm^{-2}] (Fröhlich and Brusa 1981). e_o is the eccentricity of the Earth's orbit (Spencer 1971; Bird and Riordan 1986; Iqbal 1983):

$$e_o = (r_o/r)^2 = 1.00011 + 0.034221cos\psi + 0.00128sin\psi$$

$$+0.000719cos2\psi + 0.000077sin2\psi \tag{13}$$

r is the sun-earth distance and r_o is the mean sun-earth distance.

Molecules of the air, ozone, uniformly mixed gas, water vapors, aerosols, translucent and opaque clouds impact the direct component through scattering and absorption. The direct normal solar radiation after passing through the Earth's atmosphere, S_n [Wm^{-2}] is calculated as:

$$S_n = K_n I_o \tag{14}$$

K_n is the transmission value (Maxwell 1998):

$$K_n = 0.9751 T_R T_O T_{UM} T_W T_A T_{OPQ} T_{TRN} \tag{15}$$

T_R is the Rayleigh scattering transmittance (Bird and Hulstrom 1981):

$$T_R = exp\{-0.0903(M')^{0.84}[1 + M' - (M')^{1.01}]\} \tag{16}$$

M' [kg m^{-2}] is the pressure-corrected relative optical air mass (Bird and Riordan 1986):

$$M' = M\frac{P}{P_o} \tag{17}$$

M [kg m^{-2}] is relative optical air mass, which is a measure of the length of the path through the atmosphere to sea level traversed by light rays from a celestial body, expressed as a multiple of the path length for a light source at the zenith. P [mb] is measured surface pressure and P_o=1013mb. Optical air mass is calculated as (Kasten and Young 1989):

$$M = [sin\,\gamma + 0.50572(\gamma + 6.07995°)^{-1.6364}]^{-1} \tag{18}$$

T_O is the ozone absorption transmittance (Bird and Hulstrom 1981):

$$T_o = 1 - 0.1611 X_o (1 + 139.48 X_o)^{-0.3035} - 0.002715 X_o/(1 + 0.044 X_o + 0.0003 X_o^2) \tag{19}$$

X_O [cm] is the total amount of ozone in a slanted path (Bird and Hulstrom 1981):

$$X_O = U_O M \tag{20}$$

U_O [cm] is the amount of ozone in a vertical column from surface.
T_{UM} is the uniformly mixed gas absorption transmittance (Bird and Hulstrom 1981):

$$T_{UM} = exp[-0.0127(M')^{0.26}] \tag{21}$$

T_W is the water vapor absorption transmittance and calculated as (Maxwell 1998):

$$T_W = 1.0 - 1.668 X_W/[(1.0 + 54.6 X_W)^{0.637} + 4.042 X_W] \tag{22}$$

X_W [cm] is the precipitable water vapor in a slant path through the atmosphere (NSRDB 1995):

$$X_W = U_W M \tag{23}$$

T_A is the aerosol absorption and scattering transmittance (Maxwell 1998):

$$T_A = exp(-\tau_A M) \tag{24}$$

τ_A is the broadband aerosol optical depth in a vertical path from the surface (broadband turbidity) (Maxwell 1998):

$$\tau_A = a\ sin[(360d/365) - b] + c \tag{25}$$

Coefficients, a, b, and c for a study site are provided by CoeffA, CoeffPHI and CoeffC, respectively in the i-Tree's location database.

T_{OPQ} is the opaque cloud cover transmittance (Maxwell 1998):

$$T_{OPQ} = [10.0 - (OPQ + N)]/10.0 \tag{26}$$

OPQ represents observed opaque cloud cover (0 -10 tenths). N is added to obtain effective opaque cloud cover (Maxwell 1998):

$$N = A_1\ sin(18.0 OPQ) + B_1 sin(36.0 OPQ) \tag{27}$$

The coefficients A_1 and B_1 were determined empirically as (NSRDB 1995):

$$A_1 = 4.955[1.0 - exp(-0.454M)] - 3.4 \tag{28}$$

$$B_1 = -0.2A_1\ if\ A_1 \leq 0.0\ or$$

$$= 0.1A_1\ if\ A_1 > 0.0 \tag{29}$$

T_{TRN} is the translucent cloud transmittance (NSRDB 1995).

$$T_{TRN} = A_{TRN} - B_{TRN}M \tag{30}$$

Coefficients A_{TRN} and B_{TRN} can be determined empirically using measurements (NSRDB 1995).

Molecules of the air, aerosols, opaque and translucent clouds impact the diffuse component through scattering and reflection. The diffuse solar radiation on a horizontal plane after passing through the Earth's atmosphere, S_d is calculated as:

$$S_d = K_d ETR \tag{31}$$

K_d is the transmission value (Maxwell 1998):

$$K_d = K_{d0} + K_{S_{GRF}} \tag{32}$$

where

$$K_{d0} = \left[f(M)(K_{S_R} + K_{S_A}) + K_{S_{OPQ}} + K_{S_{TRN}} \right] PSW \tag{33}$$

$f(M)$ is the empirical air mass function accounting for an air mass dependency of K_{S_R} and K_{S_A}(NSRDB 1995):

$$f(M) = 0.38 + 0.925 exp(-0.851M) \tag{34}$$

$K_{S_R}$is the diffuse radiation from Rayleigh scattering (NSRDB 1995):

$$K_{S_R} = 0.5(1.0 - T_R)T_O T_{UM} T_{AA} \tag{35}$$

T_{AA} is aerosol absorption transmittance (Bird and Hulstrom 1981):

$$T_{AA} = 1.0 - K_1(1.0 - M + M^{1.06})(1.0 - T_A) \tag{36}$$

The coefficient K_1=0.10. $K_{S_A}$is the diffuse radiation from aerosol scattering (NSRDB 1995):

$$K_{S_A} = B_A(1.0 - T_A)T_O T_{UM} T_{AA} \tag{37}$$

The coefficient B_A=0.84.
$K_{S_{OPQ}}$is the diffuse radiation from opaque cloud scattering (NSRDB 1995):

$$K_{S_{OPQ}} = -0.06 + B_2 T_A + C_2 T_A^2 \tag{38}$$

$$B_2 = 0.0953 + 0.137OPQD - 0.0409OPQD^2 + 0.00579OPQD^3$$
$$- 0.000328OPQD^4$$

$$\tag{39}$$

$$C_2 = -0.109 - 0.02OPQD + 0.011OPQD^2 - 0.00156OPQD^3 + 0.000121OPQD^4$$

$$\tag{40}$$

$$OPQD = OPQ + D \tag{41}$$

D is used to adjust the observed OPQ data for calculating the diffuse radiation from clouds

(NSRDB 1995):

$$D = 0.5A_1 \sin(18.0OPQ) \tag{42}$$

$K_{S_{TRN}}$ is the diffuse radiation from translucent cloud scattering (NSRDB 1995):

$$K_{S_{TRN}} = -0.00235 + 0.00689TRN + 0.000209TRN^2 \tag{43}$$

TRN is observed translucent cloud cover (0-10 tenths), calculated as the difference of total cloud cover, $TOTAL$ (0-10 tenths) and OPQ.

$$TRN = TOTAL - OPQ \tag{44}$$

Precipitation switch, PSW=0.06 when OPQ is greater than or equal to 8 tenths and the occurrence of rain is reported. PSW=1.0 otherwise.

$KSGRF$ is diffuse radiation from ground reflectance, and the sum of $KSGRF1$ and $KSGRF2$, normalized diffuse radiation from multiple reflections between surface and clouds, and between surface and the atmosphere, respectively (NSRDB 1995):

$$K_{S_{GRF}} = K_{S_{GRF1}} + K_{S_{GRF2}} \tag{45}$$

$$K_{S_{GRF1}} = (K_n + K_{d0})[R_{CLD}(ALB - 0.2)] \tag{46}$$

$$K_{S_{GRF2}} = (K_n + K_{d0})(R_{ATM}ALB) \tag{47}$$

ALB is the monthly surface albedo defined for a study site.
R_{CLD} is the broadband cloud reflectance (NSRDB 1995):

$$R_{CLD} = 0.06OPQ + 0.02TRN \tag{48}$$

R_{ATM} is the broadband atmospheric reflectance (NSRDB 1995):

$$R_{ATM} = [0.0685 + 0.16(1.0 - T_{AS})][(10 - OPQ)/10] \tag{49}$$

T_{AS} is aerosol scattering transmittance (Bird and Hulstrom 1981):

$$T_{AS} = T_A/T_{AA} \tag{50}$$

The global horizontal solar radiation G [Wm^{-2}] is the sum of the vertical components of the direct solar radiation S_n and the diffuse solar radiation S_d.

$$G = S_n \cos \theta_z + S_d = K_n I_o \cos \theta_z + K_d ETR = (K_n + K_d)ETR \qquad (51)$$

It is assumed that 46% of G [Wm^{-2}] is in the visible portion or PAR (Norman 1982).

$$PAR = 0.46G \qquad (52)$$

Net radiation at Earth's surface R_n [Wm^{-2}] is calculated with the net short and long wave radiations:

$$R_n = S_n + L_n \qquad (53)$$

S_n is the net short wave radiation:

$$S_n = (1 - ALB) \qquad (54)$$

L_n is the net long wave radiation:

$$L_n = E(L_{sky} + L_{cld} - L_{sfc}) \qquad (55)$$

L_{sky} and L_{cld} is the downwelling long wave radiation from the sky and cloud, respectively:

$$L_{sky} = E \frac{1 - TOTAL}{10} \sigma T^4 \qquad (56)$$

$$L_{cld} = E \frac{TOTAL}{10} \sigma T^4 \qquad (57)$$

E is the emissivity of the clear sky:

$$E = 0.741 + 0.0062T \qquad (58)$$

σ is the Stefan-Bolzmann constant (=5.67×10^{-8} W m^{-2} K^{-4}). L_{sfc} is the upwelling long wave radiation from the surface:

$$L_{sfc} = \sigma T^4 \qquad (59)$$

3.3 Potential Evaporation and Evapotranspiration

Potential evaporation, E [m hr^{-1}] is calculated by the modified Penman-Monteith equation (Shuttleworth 1992):

$$E = \frac{1}{\lambda \rho_w} \left[\frac{\Delta R_n + \frac{\rho_a c_p D}{r_a}}{\Delta + \gamma} \right] \times 10^{-3} \tag{60}$$

λ [Mj kg^{-1}] is the latent heat of vaporization:

$$\lambda = 2.501 - 0.002361T \tag{61}$$

ρ_w [kg m^{-3}] is the density of water:

$$\rho_w = -0.0051T^2 + 0.018T + 999.88 \tag{62}$$

Δ [kPa $^\circ$C^{-1}] is the slope of vapor pressure temperature curve:

$$\Delta = \frac{4398 e_s}{(237.3 + T)^2} \tag{63}$$

ρ_a [kg m^{-3}] is the density of air:

$$\rho_a = 3.486 \frac{P}{275 + T} \tag{64}$$

c_p is the specific heat of moist air (=1.013kJ kg^{-1} $^\circ$C^{-1})
D [kPa] is the vapor pressure deficit:

$$D = e_s - e \tag{65}$$

e_s [kPa] is the saturated vapor pressure:

$$e_s = 0.6108 exp \left(\frac{17.27T}{237.3 + T} \right) \tag{66}$$

e [kPa] is vapor pressure:

$$e = 0.6108 exp \left(\frac{17.27DT}{237.3 + DT} \right) \tag{67}$$

DT is the dew point temperature [$^\circ$C].
γ [kPa $^\circ$C^{-1}] is the psychrometric constant:

$$\gamma = \frac{c_p P}{\lambda} \tag{68}$$

P [mb] is the measured surface pressure.

r_a [s m^{-1}] is the aerodynamic resistance. To estimate the potential evaporation from trees, r_a shown below is used in Eqn. 60.

$$r_a = \frac{4.72\left(ln\frac{Z_t}{Z_{ov}d_t}\right)^2}{1+0.536U_t}$$ (69)

Z_t is the wind estimate height for trees (=7m), Z_{ov} [m] is the mass transfer coefficient (=0.0123m), d_t [m] is the roughness height for tree (=0.95m). U_t [m s^{-1}] is the wind speed at the tree top:

$$U_t = U\frac{ln\left(\frac{Z_t}{d_w}\right)}{ln\left(\frac{Z_u}{d_w}\right)}$$ (70)

U is the measured wind speed, d_w is the roughness height for water (=0.00137m), Z_u is the wind measurement height (=2m).

To estimate the potential evaporation from the ground, r_a shown below is used in Eqn. 60.

$$r_a = \frac{4.72\left(ln\frac{Z_u}{Z_{ov}d_w}\right)^2}{1+0.536U_g}$$ (71)

U_g [m s^{-1}] is the wind on the ground:

$$U_g = U\frac{ln\left(\frac{Z_g}{d_w}\right)}{ln\left(\frac{Z_u}{d_w}\right)}$$ (72)

Z_g is the wind estimate height for the ground (=0.1+ d_w).

The potential evaporation from snow on tree canopy [m hr^{-1}] is calculated as (Fassnacht 2004):

$$E = \frac{0.1}{P}\left\{\frac{U_t}{\left[ln\left(\frac{Z_t}{d_w}\right)\right]^2}(611.2 - e)\right\} \times 10^{-3}$$ (73)

The potential evaporation from snow on the ground [m hr⁻¹] is calculated as (Fassnacht 2004):

$$E = \frac{0.1}{P}\left\{\frac{U_g}{\left[ln\left(\frac{z_u}{d_w}\right)\right]^2}(611.2 - e)\right\} \times 10^{-3} \tag{74}$$

Potential evapotranspiration from trees, ET [m hr⁻¹] is calculated by the modified Penman-Monteith equation (Shuttleworth 1992):

$$ET = \frac{1}{\lambda \rho_w}\left[\frac{\Delta R_n + \frac{\rho_a c_p D}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}\right] \times 10^{-3} \tag{75}$$

The aerodynamic resistance, r_a [s m⁻¹] shown below is used in Eqn. 75.

$$r_a = \frac{208}{U_t} \tag{76}$$

r_s [s m⁻¹] is the stomatal resistance:

$$r_s = \frac{200}{L} \tag{77}$$

L is the leaf area index.

3.4 Missing Value Imputation

Surface weather data are typically recorded once per hour but the timestamp is not always at the top-of-hour. During rain events, precipitation (PCP01) and other data tend to be recorded more often. The timestamps in the surface weather data is adjusted to the nearest next top-of-hour. Figure 1 presents an example. After the adjustment, there may be multiple records with the same timestamp. Values found the last in the same timestamp will be used in the later processes for wind speed, cloud ceiling height, sky cover, temperature, dew point temperature, station altimeter setting, and station pressure. For 1-hour liquid precipitation, the largest value will be used.

Missing values in the first and last records for a year are filled with an existing value found

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nearest to the missing values. An existing value is searched in an ascending order for the first records, while in a descending order for the last records. Missing values in the middle of the records are linearly interpolated from values in records existing immediately before and after the record with the missing value.

Timestamp before and after adjustment

Before	After
YR--MODAHRMN	YR--MODAHRMN
200501050054	200501050100
200501050154	200501050200
200501050254	200501050300
200501050339	200501050400
200501050354	200501050400
200501050407	200501050500
200501050454	200501050500
200501050515	200501050600
200501050536	200501050600
200501050554	200501050600
200501050600	200501050600
200501050605	200501050700
200501050623	200501050700
200501050654	200501050700
200501050700	200501050700

Figure 1 Timestamp adjustment for surface weather records

3.5 Mixing Height

3.5.1 Twice-Daily Mixing Height

Hourly mixing height is calculated based on US EPA's mixing height program (US EPA 1998) and PCRAMMET (US EPA 1999). Twice-daily (i.e. morning and afternoon) mixing heights are first calculated with surface weather and upper air data, they are then interpolated hourly. The results will be used in i-Tree Eco to quantify the air quality improvements due to air pollutant removal by vegetation.

The twice-daily mixing height is computed as the height where the surface temperature raised at the dry adiabatic lapse rate intersects with the observed 12:00 GMT sounding temperatures. For morning and afternoon mixing height, the minimum surface temperature from 02:00 to 06:00 local standard time (LST) and the maximum from 12:00 to 16:00 LST is used,

respectively. Surface and sounding temperatures are converted to the potential temperature (θ) [K] as:

$$\theta = T \left(\frac{1000}{P}\right)^2 \tag{78}$$

where T is temperature (K) and P is pressure (mb). Five is added to the minimum surface temperature to account for some initial surface heating just after sunrise (Holzwoth 1967). Two heights in the sounding layers can be identified so that θ at the surface is found between θ in the two layers. Based on the two heights identified, the mixing height can be calculated by linear interpolation. When the height is missing for the layer, the mixing height is determined by interpolating from θ to P and then from P to height. When the surface θ is smaller than θ at the first layer, or upper air data are missing for a specific day, it is impossible to calculate the mixing heights. In such cases, twice-daily mixing heights are interpolated from those calculated.
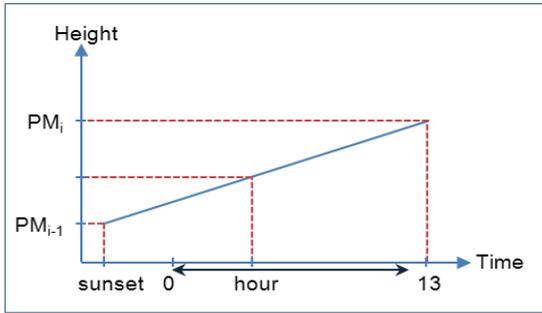
3.5.2 Hourly Mixing Height

Computation of hourly mixing heights requires: 1) morning mixing heights for the computation day (i) and the following day (i+1) and afternoon mixing heights for the days (i-1), (i), and (i+1), 2) sunrise and sunset LST, and 3) hourly stability class (neutral or not neutral). Table 3 presents interpolation methods defined based on hours of estimation, stability (neutral or not), and sites (urban or rural). AM_i and PM_i are mixing heights estimated for the morning and afternoon, respectively on the computation day, i. Letters from (a) to (e) indicate interpolation methods illustrated in Figures 2 (a) to (e).

Table 3 Hourly mixing height interpolation methods for neutral and not neutral stability conditions in urban and rural sites
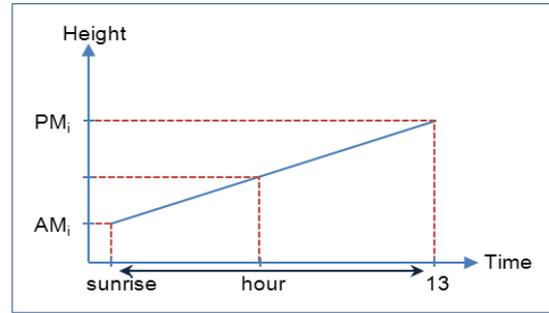
Hours (h)	Urban		Rural	
	Neutral	Not Neutral	Neutral	Not Neutral
$0{:}00 \le h \le \text{sunrise}^A$	(a)	AM_i	(a)	(a)
$\text{sunrise} < h < 13{:}00^B$	(a)	(b)	(a)	(e)
$13{:}00 \le h \le \text{sunset}^B$	PM_i	PM_i	PM_i	PM_i
$\text{sunset} < h \le 23{:}00^B$	(c)	(d)	(c)	(c)

A: Stability class at the sunrise hour is used.
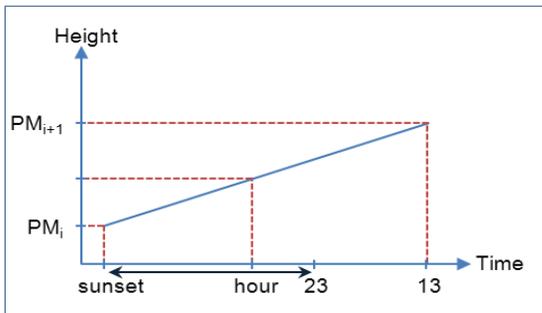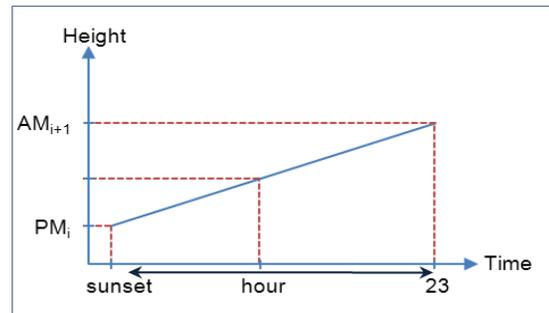B: Stability class at each hour is used.
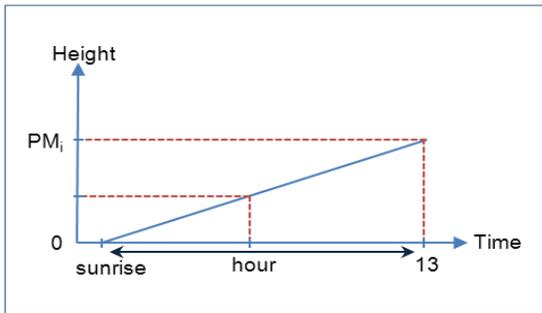
Figure 2 Hourly mixing height interpolation methods (a) interpolate with PM_{i-1} and PM_i for 00:00 to 13:00 LST (b) interpolate with AM_i and PM_i for sunrise to 13:00 LST (c) interpolate with PM_i and PM_{i-1} after sunset to 23:00 LST (d) interpolate with PM_i and AM_{i+1} after sunset to 23:00 LST (e) interpolate with 0 and PM_i after sunrise to 13:00 LST

3.5.3 Sunrise and Sunset LST

Following algorithms implemented in PCRAMMET, this function calculates hourly solar elevation angles as well as sunrise and sunset hours for the location specified with latitude, longitude, and time zone for a Julian day. The PCRAMMET uses known earth-sun relationships (e.g., Sellers (1965)).

3.5.4 Atmospheric stability class

Seven atmospheric stability classes (1 to 7) are determined based upon day/nighttime, wind speed, and insolation classes for daytime. The insolation is classified into five classes (Strong, Moderate, Slight, Weak, and Overcast) by means of the Turner (1964) objective method using solar elevation angle, ceiling height, and cloud cover as indicators (Table 4).

Table 4 Insolation classes as a function of solar elevation angle, ceiling height and cloud cover

Solar Elevation Angle (a)	Ceiling Height (h)	Cloud Cover (c)		
		c ≤ 5/10	5/10 < c < 10/10	c = 10/10
0° < a ≤ 15°	h < 7000 ft	Weak	Weak	Overcast
	7000 ft ≤ h ≤ 16000 ft			Weak
	16000 ft < h			
15° < a ≤ 35°	h < 7000 ft	Slight	Weak	Overcast
	7000 ft ≤ h ≤ 16000 ft			Weak
	16000 ft < h			
35° < a ≤ 60°	h < 7000 ft	Moderate	Weak	Overcast
	7000 ft ≤ h ≤ 16000 ft		Slight	Weak
	16000 ft < h			Slight
60° < a	h < 7000 ft	Strong	Slight	Overcast
	7000 ft ≤ h ≤ 16000 ft		Moderate	Slight
	16000 ft < h			Moderate

The atmospheric stability classes are selected from Table 5 based upon wind speed, day/nighttime, and insolation classes for daytime determined above. Stability smoothing is implemented as standard EPA practice in regulatory dispersion modeling is to restrict temporal changes in stability class to no more than one per hour.

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