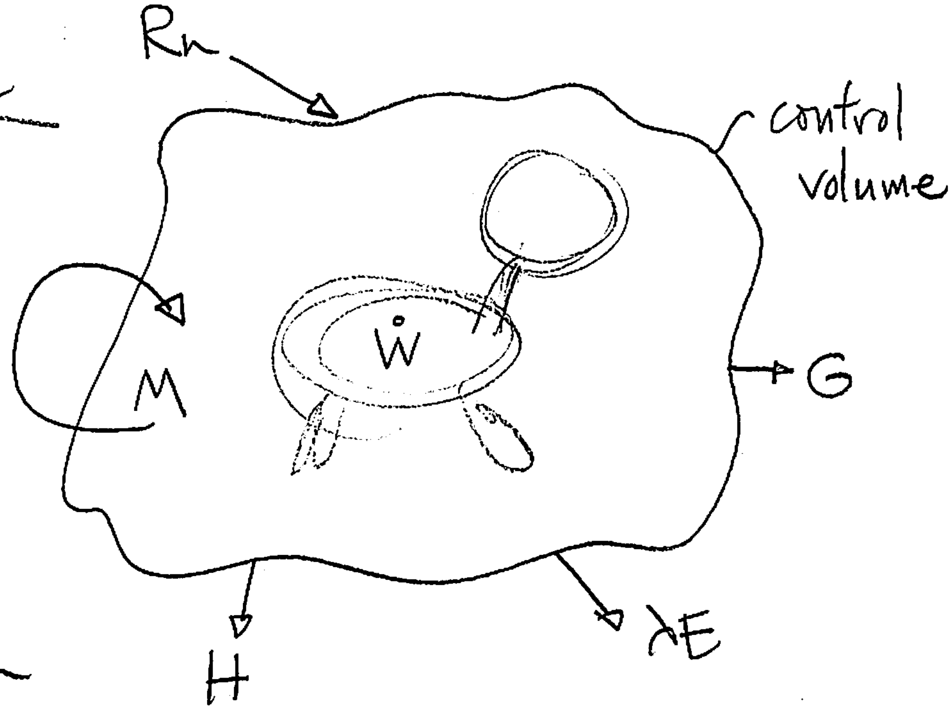
[initials] 1/15/09

Temperature



Importance of temperature

Consider an animal.
We now know that

$$H = g(T_s - T_a)$$ ask

Hence temperature plays an important role in the energy balance of an organism.

energy balance

$$R_n + M = \dot{W} + G + H + \lambda E$$

(inputs) = (storage + outputs)

Other processes also depend on temperature... (ask)

eg biological activity,
saturation water vapor pressure, ...

Definition of Temperature

Temperature is the measure of the average kinetic energy (KE) (ask) of the molecules of a substance. As molecular KE increases, temperature increases.

Measures of Temperature

Temperature is measured in degrees Fahrenheit (°F), degrees Celsius (°C), or kelvin (K).

$$°F = \frac{9}{5}(°C) + 32 \quad , \quad K = (°C) + 273.15$$

(ask for reverse)

1/15/09

Diurnal Variation of Temperature near Earth's Surface

diurnal = variation over the course of a day (ask)

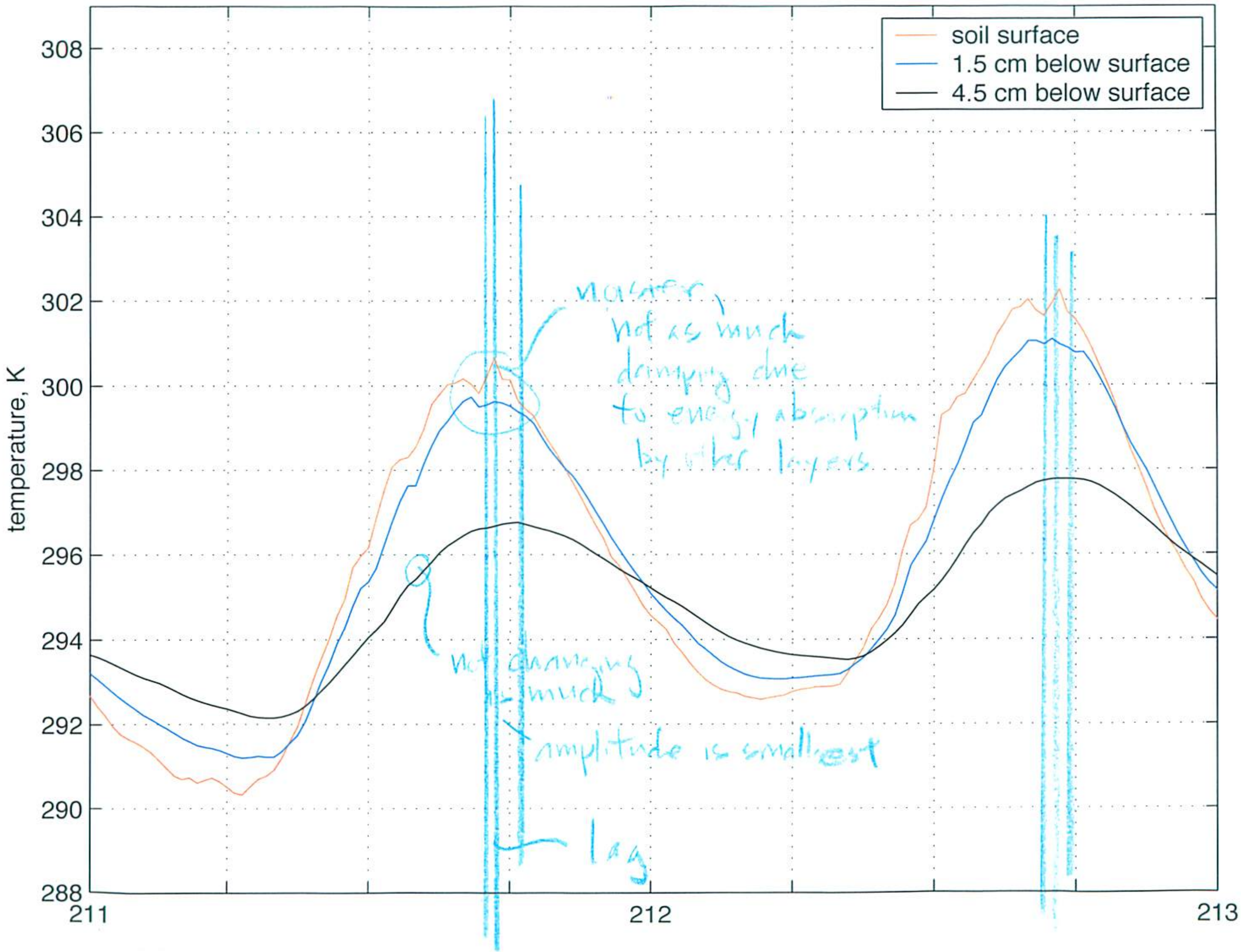
Have students in groups of 2 or 3 examine figures. Students list as many features as possible, and attempt to explain why features exist, or what causes them.

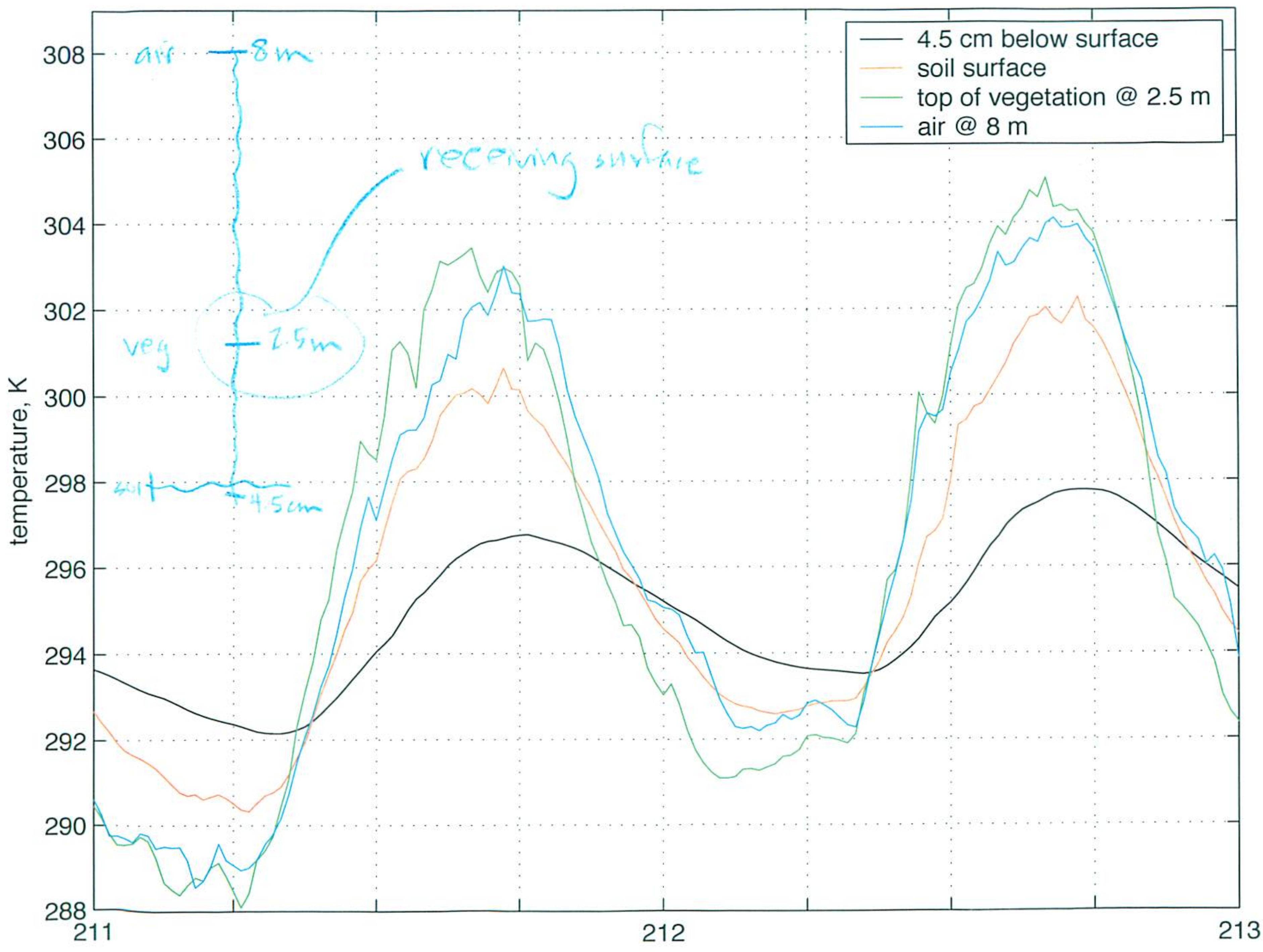
First explain/describe instruments that recorded data. Bring IVS temp sensors and air temp/rh probe, IR thermometer.

R8x	R8x
soil surface	air temp
1.5 cm below	veg temp
4.5 cm below	soil surface
	4.5 cm below

Some observations

- largest extremes at receiving surface for solar radiation
- diurnal change due to solar angle
- smooth curve for soil temp (damping), jagged
- change in amplitude and lag w/ distance away from receiving surface due to storage of energy and resistance to energy transfer (or finite conductance)
- change in amplitude occurs more quickly in soil → conduction in soil vs. conduction + convection in atmosphere
- amplitude decreases, lag increases as you move away from receiving surface


soil surface
1.5 cm below surface
4.5 cm below surface
temperature, K
308
306
304
302
300
298
296
294
292
290
288
211
212
213
warmer, not as much damping due to energy absorption by other layers
not changing as much
amplitude is smallest
lag



4.5 cm below surface
soil surface
top of vegetation @ 2.5 m
air @ 8 m
temperature, K
308
306
304
302
300
298
296
294
292
290
288
211
212
213
air
8 m
veg
2.5 m
soil
4.5 cm
recevirg surfae

1/15/09

Diurnal Variation of Temperature: Important Observations

* amplitude of diurnal temperature change decreases as the distance from the surface receiving energy increases

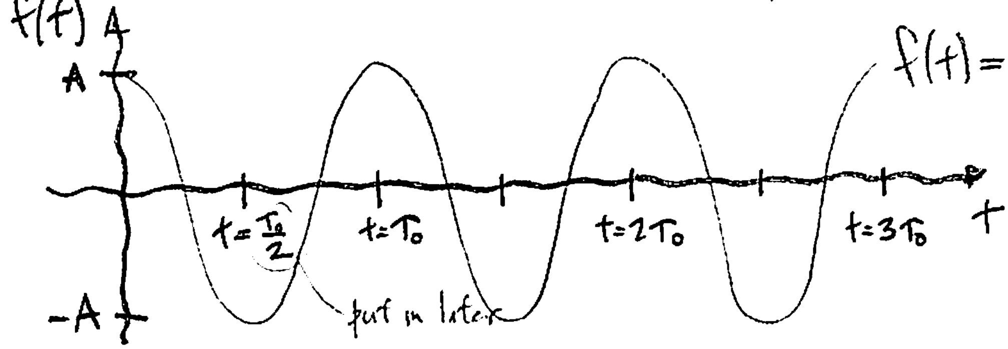
* amplitude of diurnal temperature change decreases faster in the soil than in the atmosphere because the heat capacity of air is ~1000 times smaller than soil heat capacity: less heat is stored by a layer of air between the energy receiving surface and an observation point in the atmosphere than in the layer in the soil, and consequently more of the energy is transferred through the air layer.

* time of maximum temperature at points away from energy-receiving surface lags the time of maximum temperature at the energy-receiving surface, and this lag is not as great in the atmosphere as in the soil because of the greater conductance of energy transfer in the atmosphere due to convective transport as compared to conductance via conduction in the soil.

1/15/09

Sinusoids

We will use sinusoids to model diurnal temperature change.



$$f(t) = A\cos(2\pi f_0 t + \theta) \qquad (1)$$ note

← $\theta = 0$ ask

t = time, $f(t)$ = function of time, A = amplitude,
f_0 = frequency = repititions per second, θ = phase — $360° = 2\pi$ rad (ask)

$[t] = s \qquad [f(t)] = [A] \qquad [f_0] = \frac{1}{s} = Hz \qquad [\theta] = rad$

We know $\cos\phi = \cos(\phi + 2\pi n)$, $n = 0, \pm1, \pm2, \dots$

The quantity $(2\pi f_0 t + \theta)$ changes by 2π when t changes by $\frac{1}{f_0}$.

T_0 = period = $\frac{1}{f_0}$ = time it takes argument of (1) to change by 2π

<u>Note</u>: $f(t) = A\cos(2\pi f_0 t)$ when $\theta = 0$ rad.

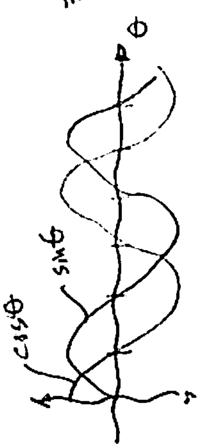
$f(t) = A\cos(2\pi f_0 t - \frac{\pi}{2}) = A\sin(2\pi f_0 t)$ when $\theta = \frac{-\pi}{2}$ rad. — shifts function right, back in time

It is often convenient to use the <u>radian</u> <u>frequency</u>, ω_0.

$\omega_0 = 2\pi f_0$, $[\omega_0] = \frac{rad}{s} = rad \cdot s^{-1}$ — ask

Now (1) becomes $f(t) = A\cos(\omega_0 t + \theta)$

and $T_0 = \frac{1}{f_0} = \frac{1}{\frac{\omega_0}{2\pi}} = \frac{2\pi}{\omega_0}$ — ask



RAF
11/15/09

Annual Variations in Temperature

Use IEM to find daily average temperature for Shenandoah, Ames, and Waukon.

Note: variation with latitude, random variations, amplitude and phase, ...

Temperature Variation Over Short Periods

Diurnal data shown earlier were 20-minute averages of temperature sampled every 10 seconds.

Over short periods of time random temperature variations dominate. These random variations cannot be predicted. Mean temperature and the variance can be modeled.

ask

Fig 1.4
page 19

MATLAB demonstration

Data from IEM in m-file.