Lab 3: Convection

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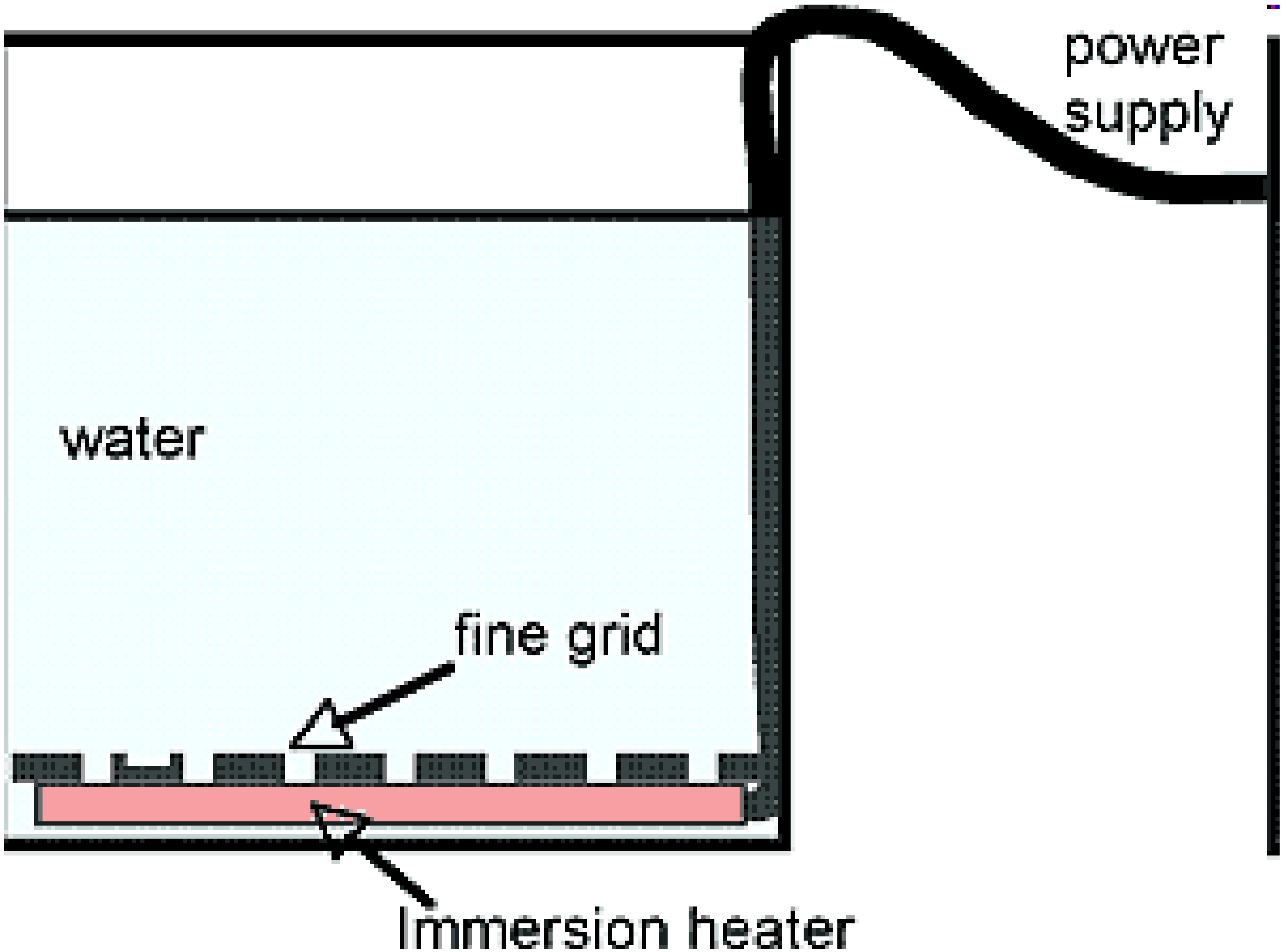
12.307 Weather & Climate Laboratory

Experimental Setup



http://paoc.mit.edu/labguide/images_new/convec1.gif

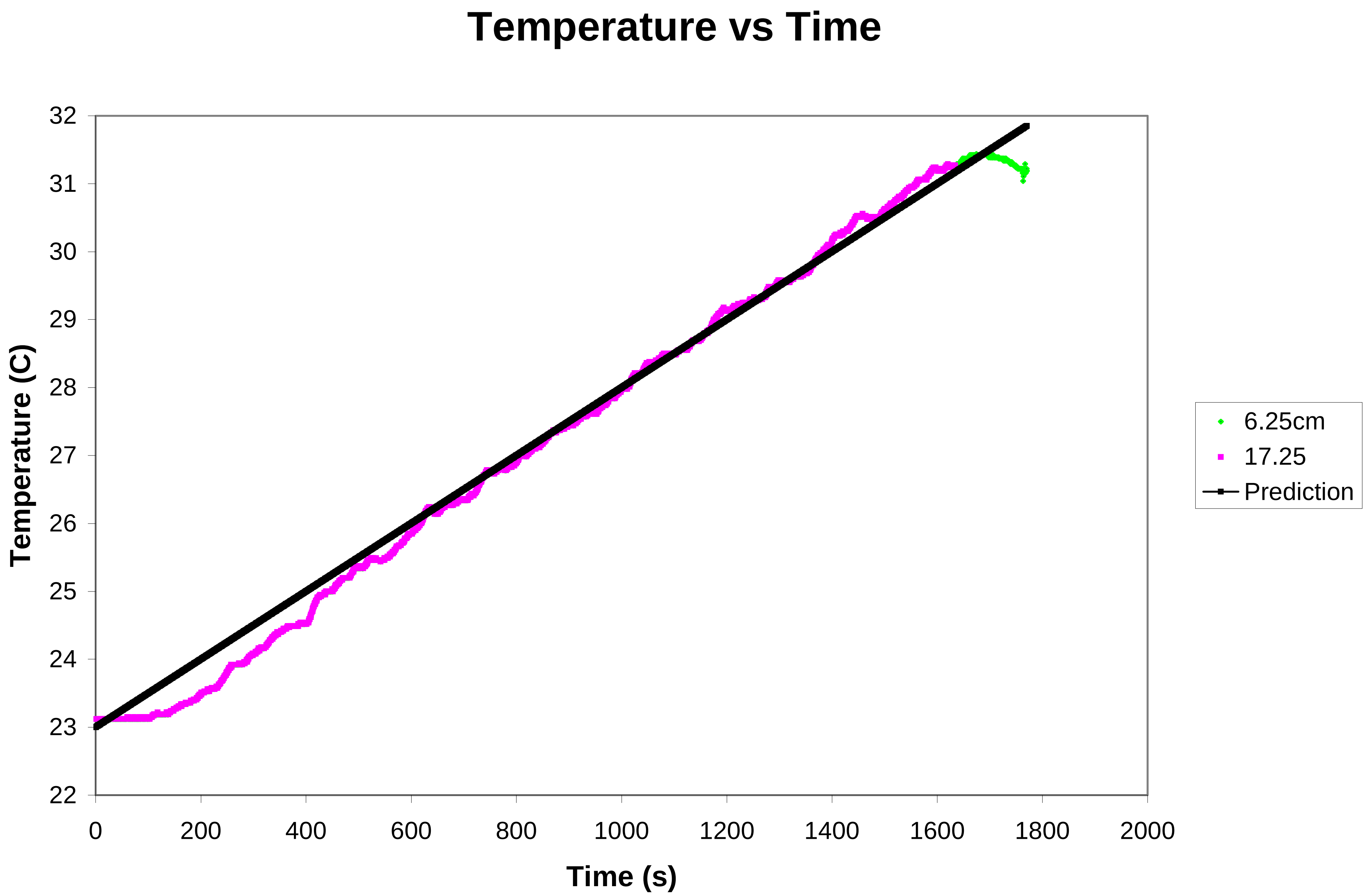
Homogeneous Fluid At Constant Depth

- H: Power per unit area
- ρ: density of water
- C_w: heat capacity of water
- h: depth of fluid
- Thermodynamic Balance: $$\rho c_w \frac{dT}{dt} = \frac{H}{h}$$
- Predicted Temperature: $$T = \frac{H}{h\rho c_w} t$$

Our Experiment

- Power = 500 watts
- Area = .062025 m^2
- ρ= .997 g/cm^3
- C_w: 4.18 J/g/K
- h: 35 cm

- Predicted Temperature: $T = .005t$


Temperature vs Time
Temperature (C)
32
31
30
29
28
27
26
25
24
23
22
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Time (s)
6.25cm
17.25
Prediction

Linearly-Stratified Layer

- H, ρ, C_w
- T_z: slope of temperature
- $h = T_z * T$
- Thermodynamic Balance: $\rho c_w \frac{dT}{dt} = \frac{H}{h}$

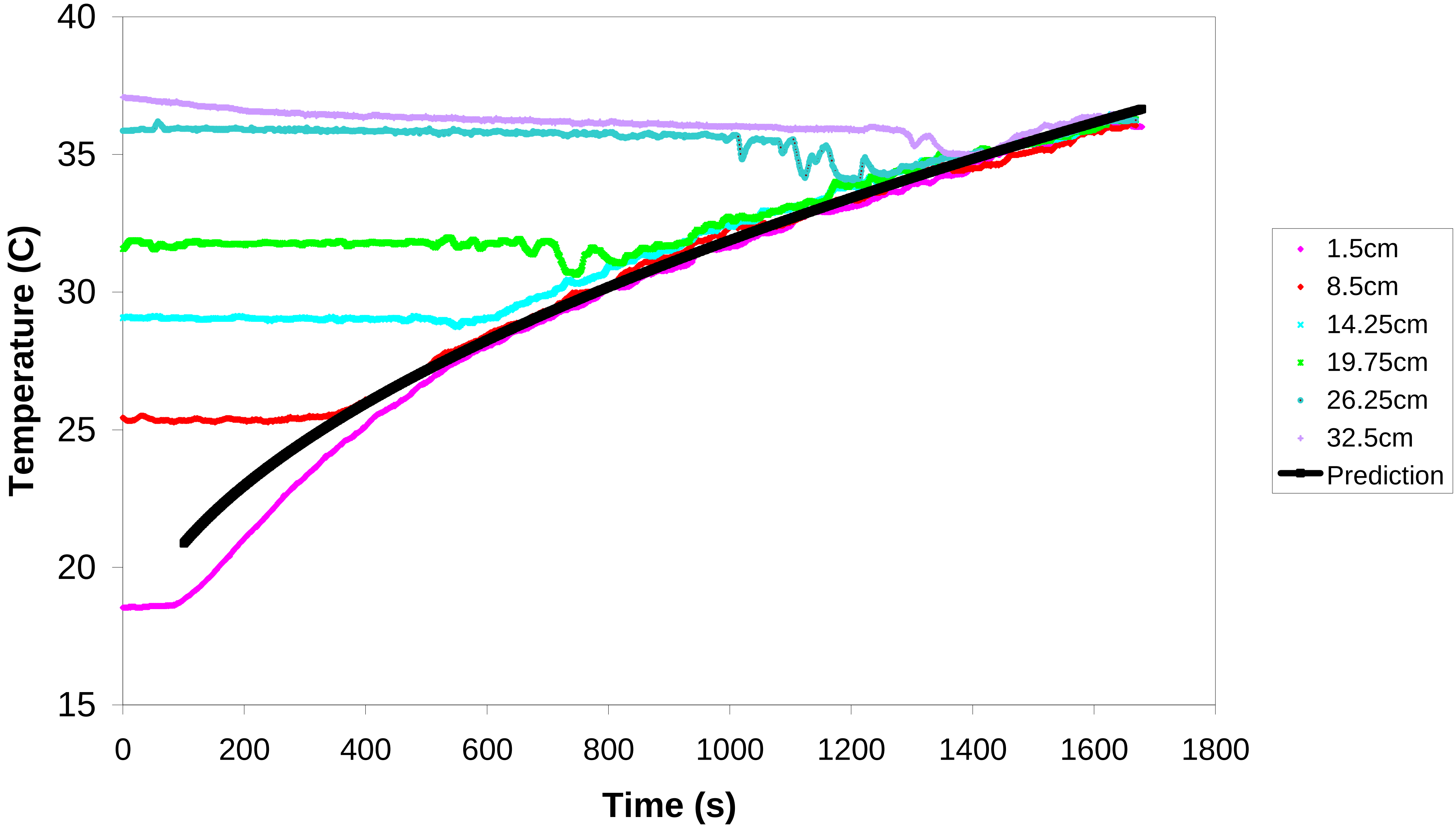
- Predicted Temperature: $T = \sqrt{\frac{2HT_z}{\rho c_w} t}$

Our Experiment

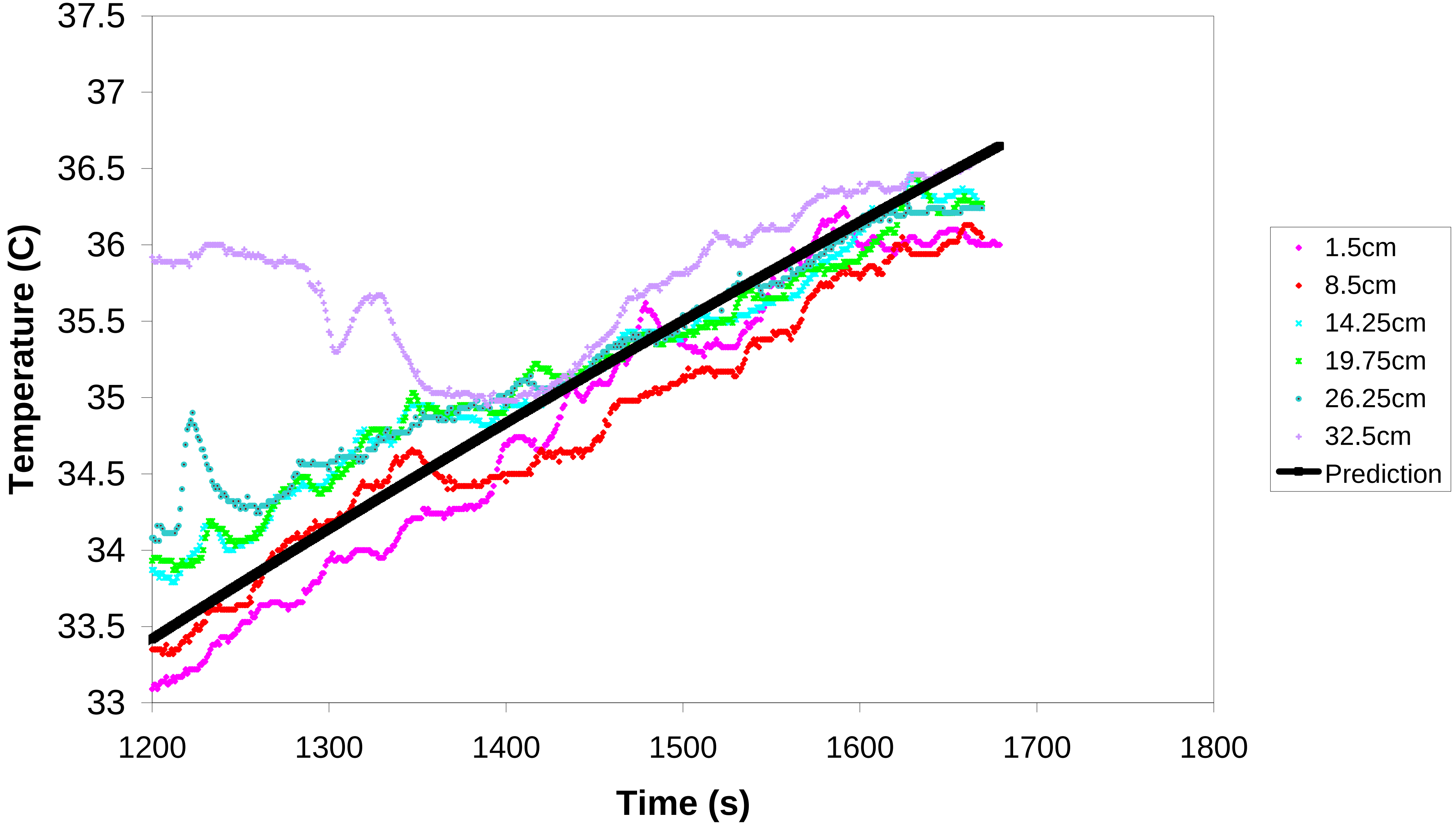
- H = 1620 watts
- Area = .2025 m^2
- ρ= .997 g/cm^3
- C_w: 4.18 J/g/K
- T_z =67 K/m

- Predicted Temperature: $T = .51\sqrt{t}$

Temperature vs. Time



Temperature vs. Time



Atmospheric Data: Dry Convection

- Dry adiabatic lapse rate:

$$\Gamma_d = -g/c_p \sim 10^o K/\text{kilometer}$$

- Stability of temperature profile:

$$\left.\begin{array}{c}\text{UNSTABLE}\\ \text{NEUTRAL}\\ \text{STABLE}\end{array}\right\} \text{ if } \left\{\begin{array}{l}\left(\frac{dT}{dz}\right)_E < -\Gamma_d\\ \left(\frac{dT}{dz}\right)_E = -\Gamma_d\\ \left(\frac{dT}{dz}\right)_E > -\Gamma_d\end{array}\right.$$

Potential temperature

- Temperature of an air parcel if compressed adiabatically to standard pressure

$$\theta = T \left(\frac{p_0}{p} \right)^{\kappa} \qquad k = R/c_p \qquad p_o = 1000mb$$

- Stability of potential temperature profile:

$$\left.\begin{array}{c} \text{UNSTABLE} \\ \text{NEUTRAL} \\ \text{STABLE} \end{array}\right\} \text{ if } \left\{ \begin{array}{l} \left(\frac{d\theta}{dz}\right)_E < 0 \\ \left(\frac{d\theta}{dz}\right)_E = 0 \\ \left(\frac{d\theta}{dz}\right)_E > 0 \end{array}\right.$$

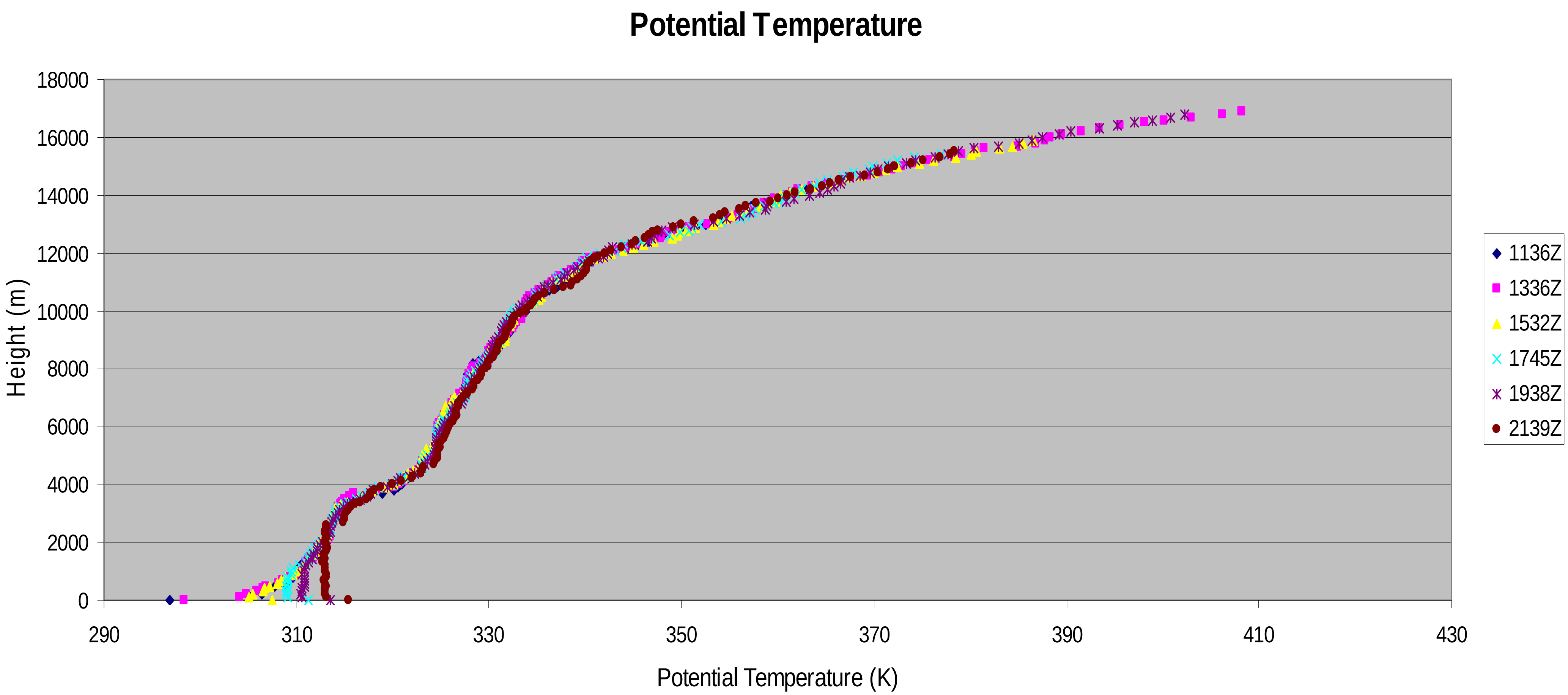
Case Study: Yuma, Arizona

6/18/2007

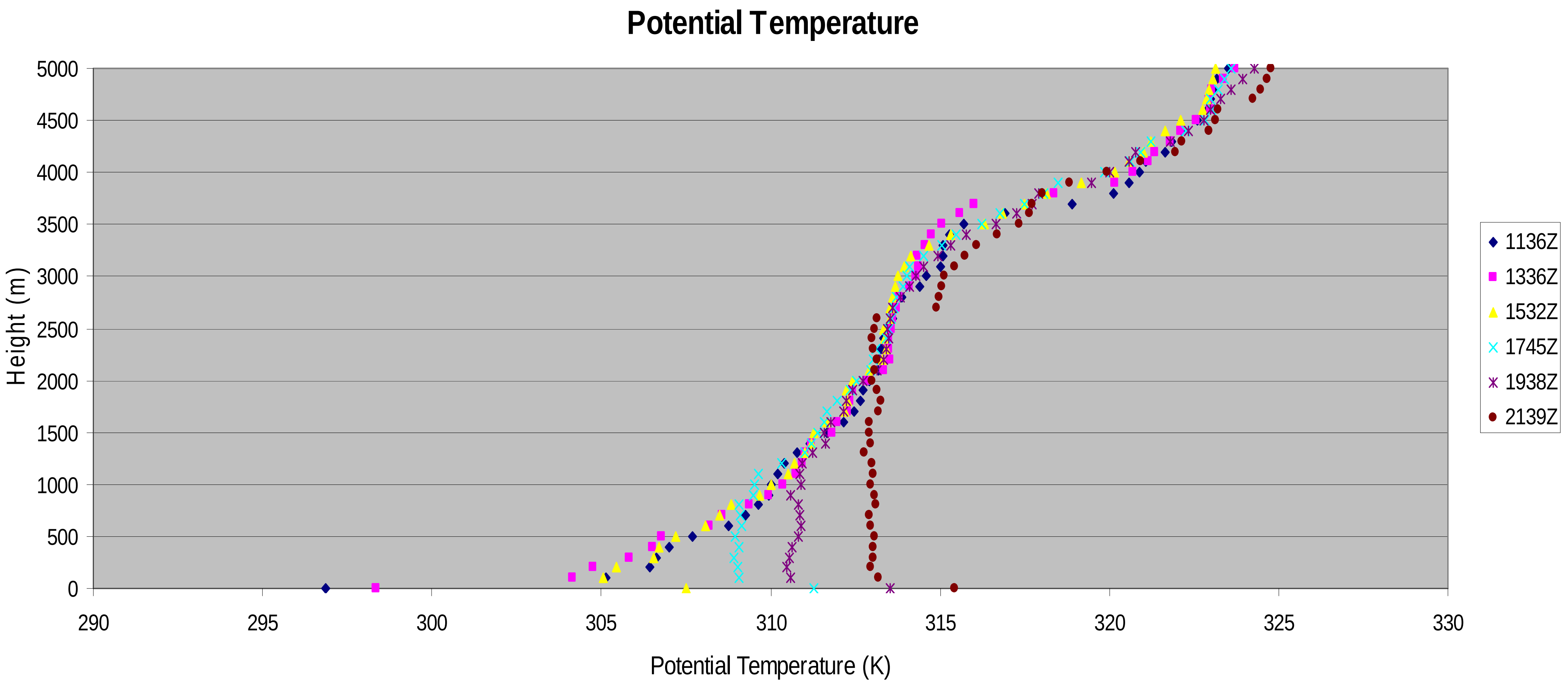
http://maps.google.com/

http://pics4.city-data.com/cpicv/vfiles6272.jpg

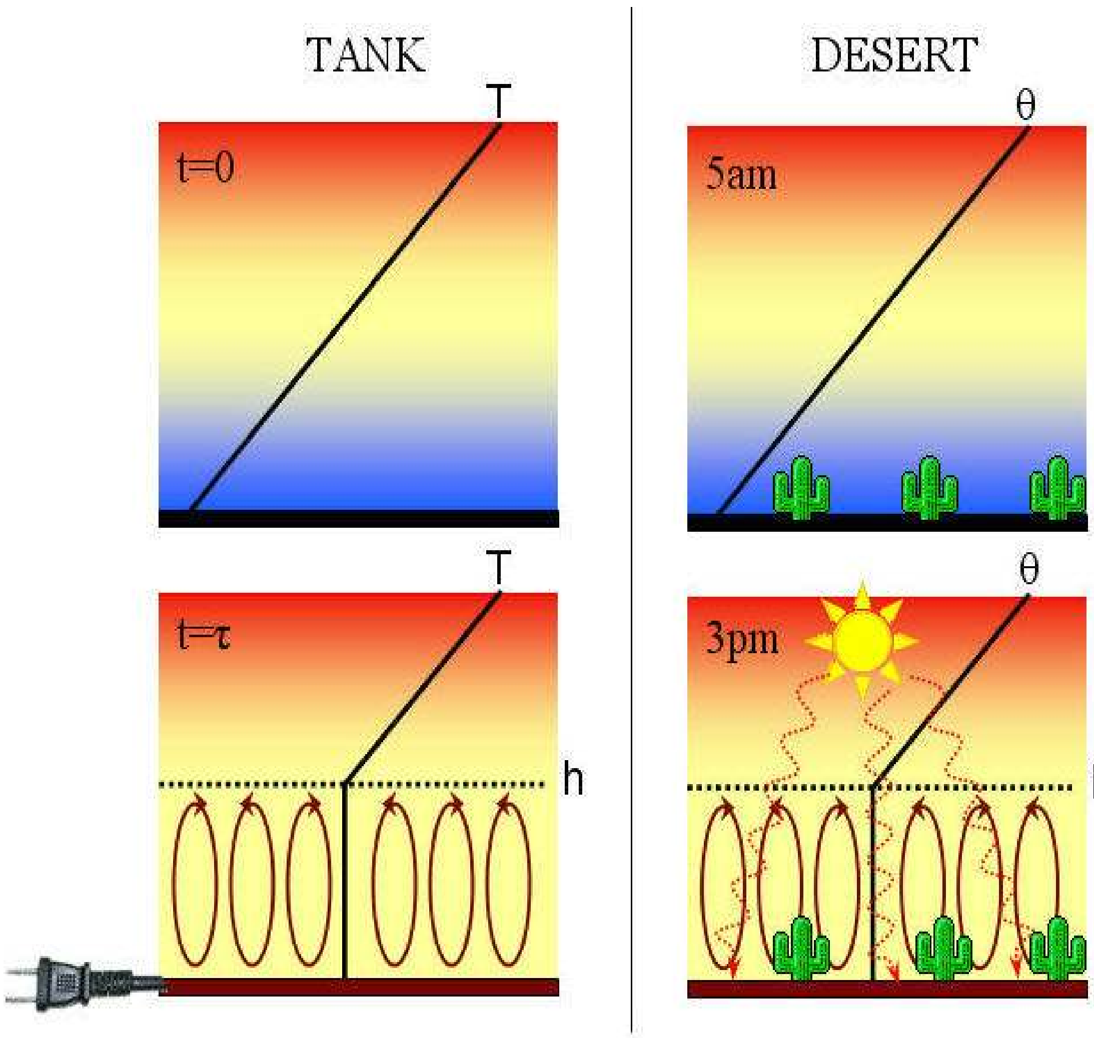
Overall potential temperature profile



Evolution of the convective layer



Making connections



http://paoc.mit.edu/12307/convection/yuma_i4.jpg

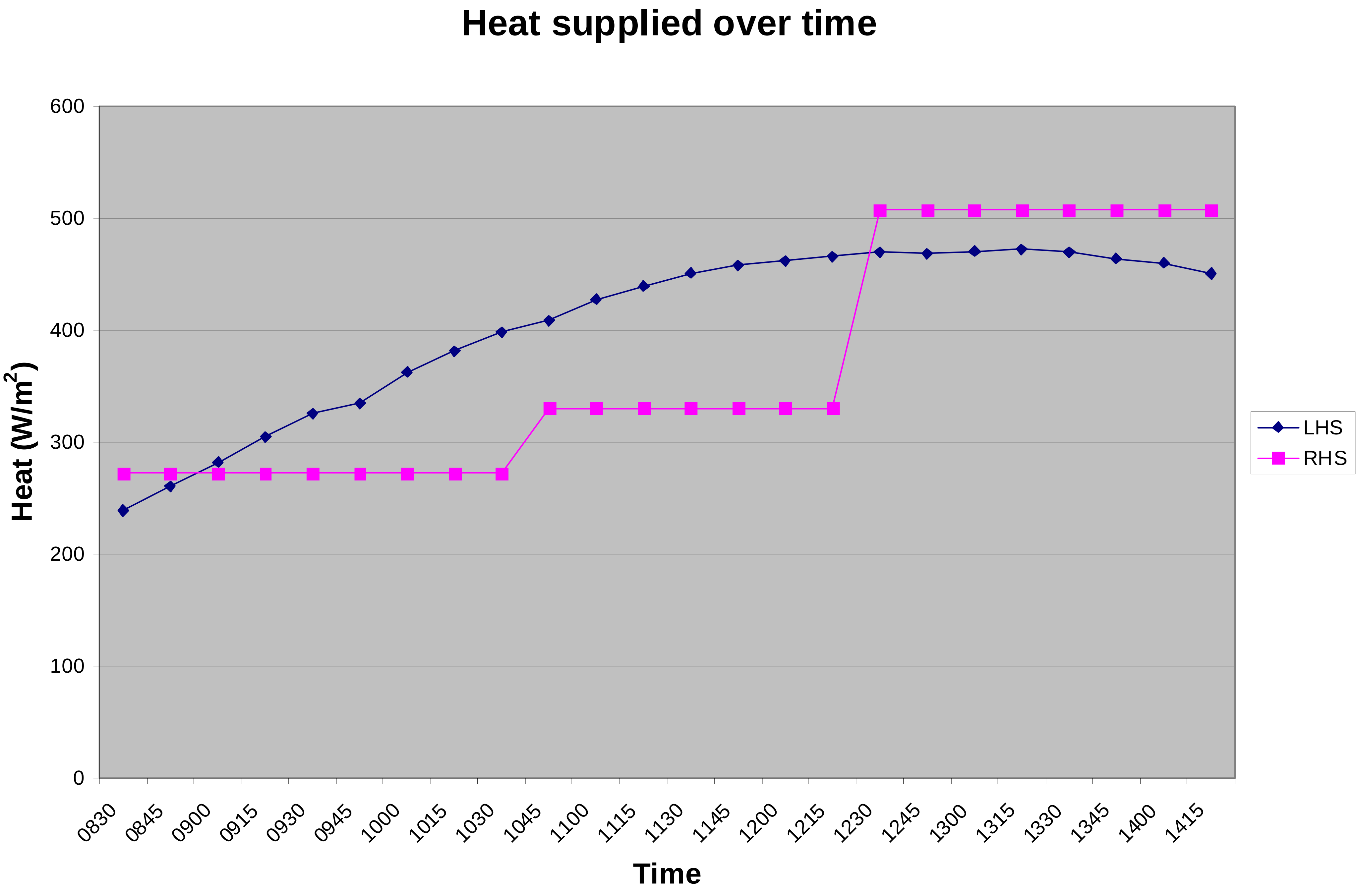
Energy Calculations

- Heat supplied = change in internal energy

$$H = \int \rho c_p \frac{\partial T}{\partial t} dz = \frac{c_p}{g} \int_{p_{sfc}}^{p_{BL}} \frac{\partial T}{\partial t} dp$$

- Discretized:

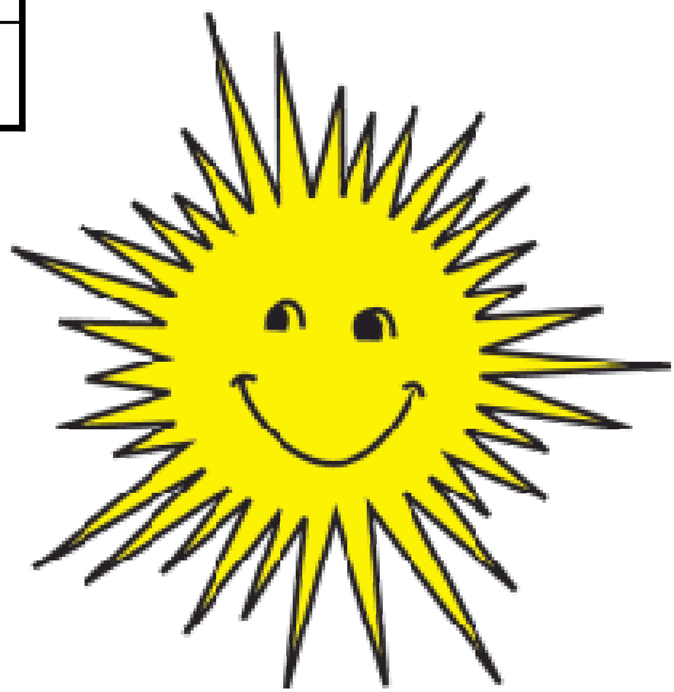
$$H \Delta t = \frac{c_p}{g} \sum_{i=1}^{N} \Delta T_i \delta p_i$$



Heat supplied over time
Heat (W/m²)
600
500
400
300
200
100
0
0830
0845
0900
0915
0930
0945
1000
1015
1030
1045
1100
1115
1130
1145
1200
1215
1230
1245
1300
1315
1330
1345
1400
1415
Time
LHS
RHS

Total heat supplied

Time	RHS	LHS
1532Z-1745Z	2.6×10^6	2.2×10^6
1745Z-1938Z	2.8×10^6	2.1×10^6
1938Z-2139Z	3.4×10^6	3.7×10^6



http://fpcknox.org/wp/wp-content/uploads/2007/06/clip-sunshine.gif