Comparing the Energy Requirements of Hot Water Circulation System Control Strategies:
Preliminary Results

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Learning Objectives

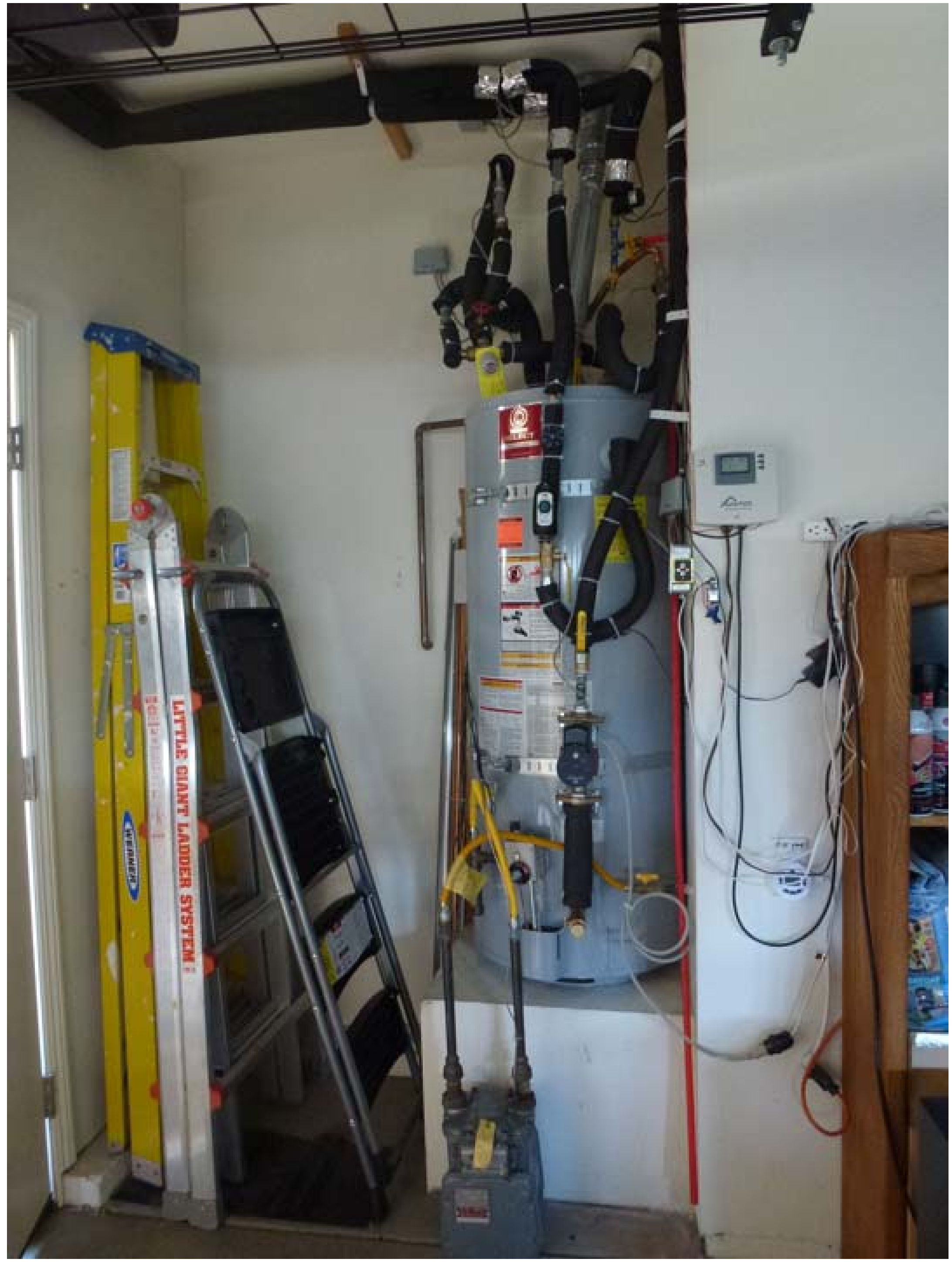
1. Understand the control strategies for hot water circulation systems
2. Learn about a test setup that is being used to compare the water, energy and time performance of the control strategies.
3. Examine the patterns in the data coming from this test.
4. Begin the comparison of the energy performance of several of the control strategies.

The Test House – 2-story, 3,200 sf

Water Heater, Circulation Pump and Controls – as installed

Circulation Pump and Controls – as Installed

Water Heater, Circulation Pump and Controls – as of April 2014



Test Stand for Circulation Pumps and Control Strategies

The Theory

Hot Water Circulation Systems

There are six types of circulation systems:

- Thermosyphon (gravity convection with no pump),
- Continuously pumped systems,
- Timer controlled,
- Temperature controlled,
- Time and temperature controlled, and
- Demand controlled.

Given the same plumbing layout,
all of these systems will waste the same amount
of water at the beginning of a hot water event.

The difference in these systems
is in the ***energy*** it takes to keep the trunk line
primed with hot water.

Operating Costs of Circulation Loops

- Pump
- Heat loss in the loop
- Maintenance
  - Failure of the pump
  - Incorrect control settings
  - Pipe leaks
- What percent of the energy costs are due to the pump? To the losses in the loop?

Determination of Heat Loss in Circulation Loops

- You could measure the pipe lengths, diameters, insulation and environmental conditions and calculate the heat loss, if you can get to all of it!

- Or you could measure flow rate and the difference in temperature between the water leaving from, and returning to the water heater.

Heat Loss in Circulation Loops –

Calculation for Loop Losses Only

Sample Calculation: 1 gpm and 1^{o}F temperature drop

- Energy = m* c_p* (T_{hot}-T_{return})=Btu
- 1 gpm * 8.33 pounds per gallon * 1 * 60 minutes per hour * 1^{o}F = 500 Btu/hour/^{o}F

Natural Gas Water Heater

- 500 ÷ 0.75 efficiency = 667 Btu/hour/^{o}F
- 667 ÷ 100,000 Btu/Therm = 0.00667 Therm/hour/^{o}F
- 0.00667 * $1.00/Therm = $0.00667/hour/^{o}F

Electric Water Heater

- 500 ÷ 0.98 efficiency = 510 Btu/hour/^{o}F
- 510 ÷ 3,412 Btu/kWh = 0.15 kWh/hour/^{o}F
- 0.15 * $0.10/kWh = $0.015/hour/^{o}F

Annual Energy Use for a Circulation System Attached to a Gas Water Heater (Therms)

Continuous Pumping at 1 Gallon Per Minute				
	Temperature Drop in ^{o}F			
Days	**1**	**5**	**10**	**20**
1	0.16	0.80	1.60	3.20
30	5	24	48	96
365	58	292	584	1,168
Pump Flow Rate in Gallons Per Minute				
1	58	292	584	1,168
5	292	1,460	2,920	5,840
10	584	2,920	5,840	11,680
Steady state heat transfer efficiency is assumed to be 75%.				

Electrical energy to operate the pump is additional

Annual Energy Use for a Circulation System Attached to an Electric Water Heater (kWh)

Continuous Pumping at 1 Gallon Per Minute				
	Temperature Drop in ^{o}F			
Days	**1**	**5**	**10**	**20**
1	3.60	18.00	36.00	72.00
30	105	525	1,050	2,100
365	1,278	6,388	12,775	25,550
Pump Flow Rate in Gallons Per Minute				
1	1,278	6,388	12,775	25,550
5	6,388	31,938	63,875	127,750
10	12,775	63,875	127,750	255,500
Steady state heat transfer efficiency is assumed to be 98%.				

Electrical energy to operate the pump is additional

When Do You Not Want to Operate a Hot Water Circulation Pump?

- When you don’t need hot water
  - When you aren’t there
  - When you are sleeping or doing something else
- When you are using hot water

The only time you want to operate the pump is just before you need hot water.

Use Demand Controlled Circulation

- The pump will run less than ½ hour per day
- The most energy efficient option.

Energy to Operate a Circulation Loop

	Recirculation						Demand Controlled Priming
	Daily Hours of Operation						
	24	12	8	6	4	2	0.25
Loop Heat Losses							
Natural Gas (therms)	292	146	97	73	49	24	3
Electric (kWh)	6,388	3,194	2,129	1,597	1,065	532	67
Pump Energy(kWh)	438	219	146	110	73	37	8

Loop is assumed to be 100 feet long.

 50 feet supply, 50 feet return

Recirculation:

 Flow rate is 1 gpm

 Temperature drop is 5F

 50 watt pump

Demand Controlled Priming:

 85 watt pump

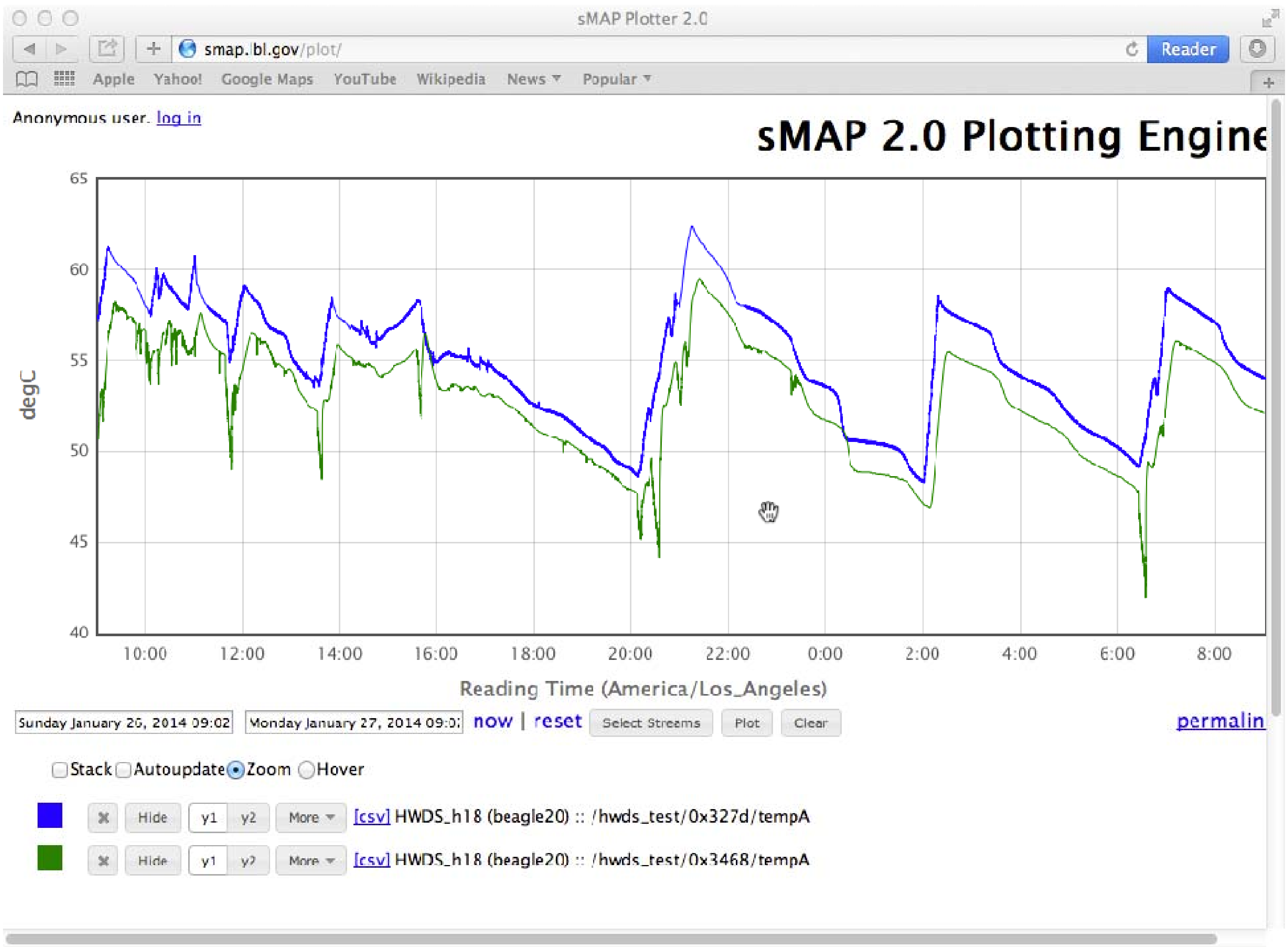
The Practice

Control Strategies Being Tested

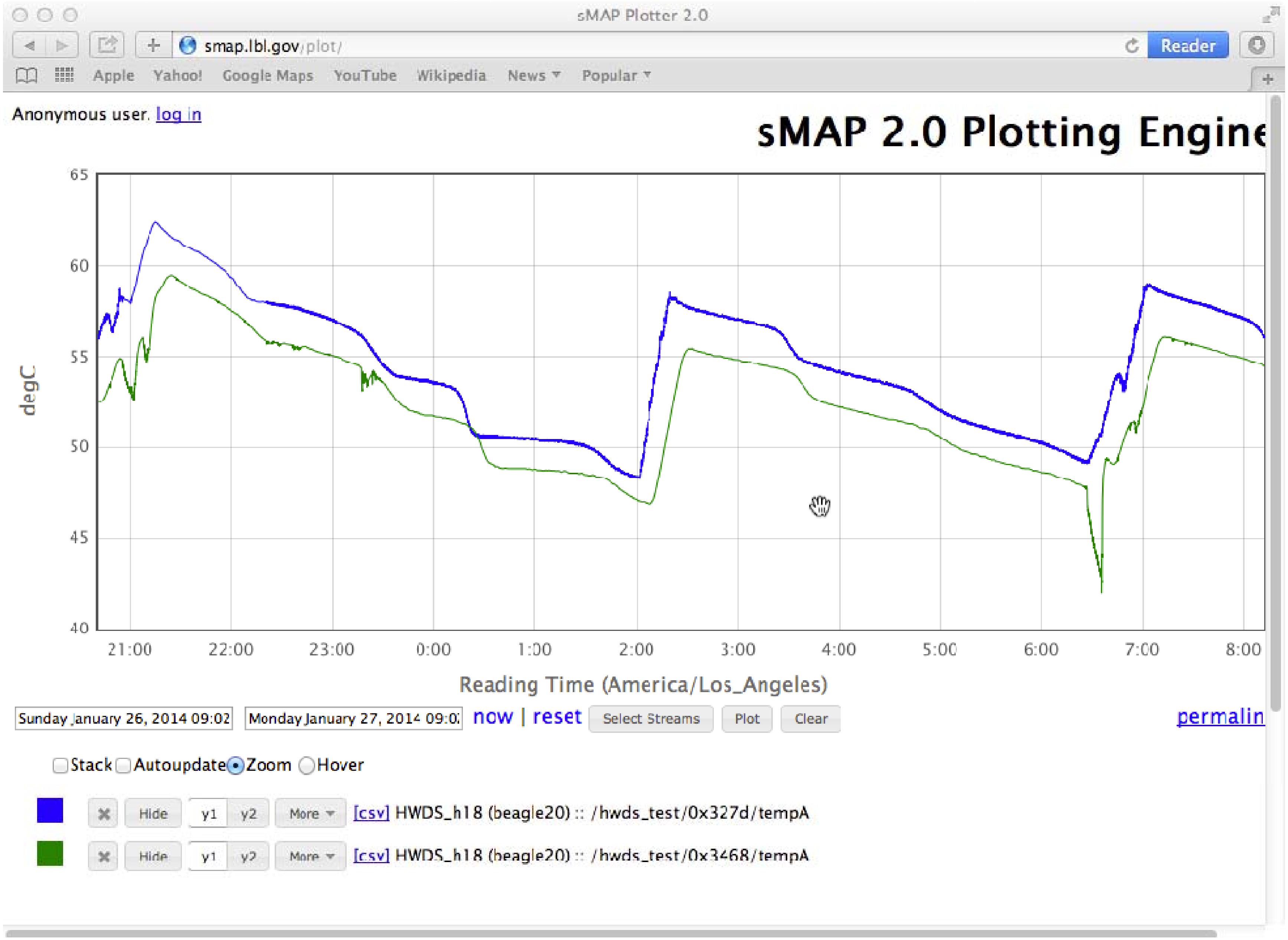
The intent is to determine the energy it takes to provide hot water quickly anywhere, anytime, regardless of changing schedules

- Continuous Circulation
- Aquastat – Low, Medium and High Speed
  - 85-105F, 105-115F
- Intermittent Pulsed Timer
- Demand Controlled
- Other – Aquastat and Timer, Memory

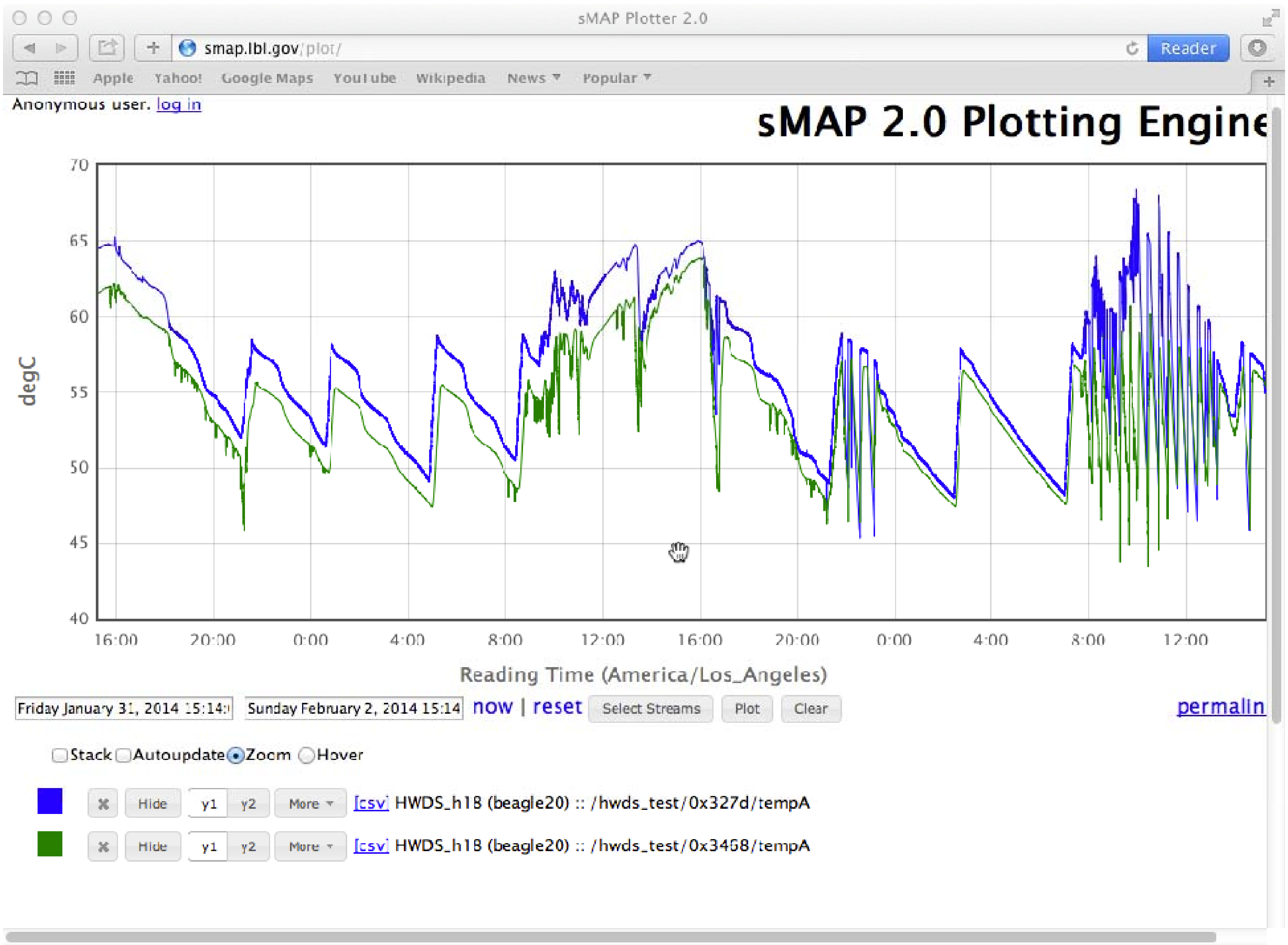
Continuous Circulation: Low Speed



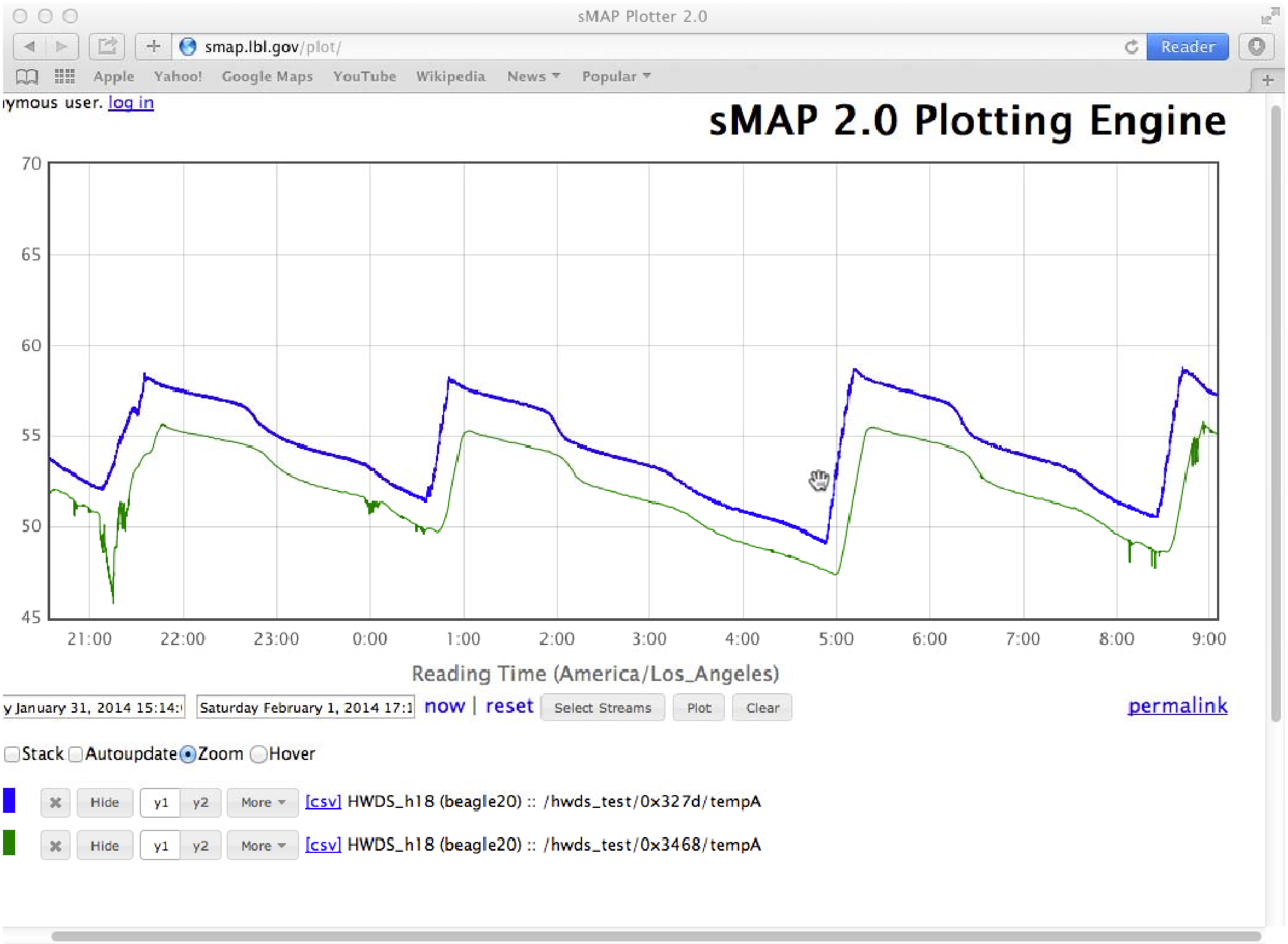
Continuous Circulation: Low Speed



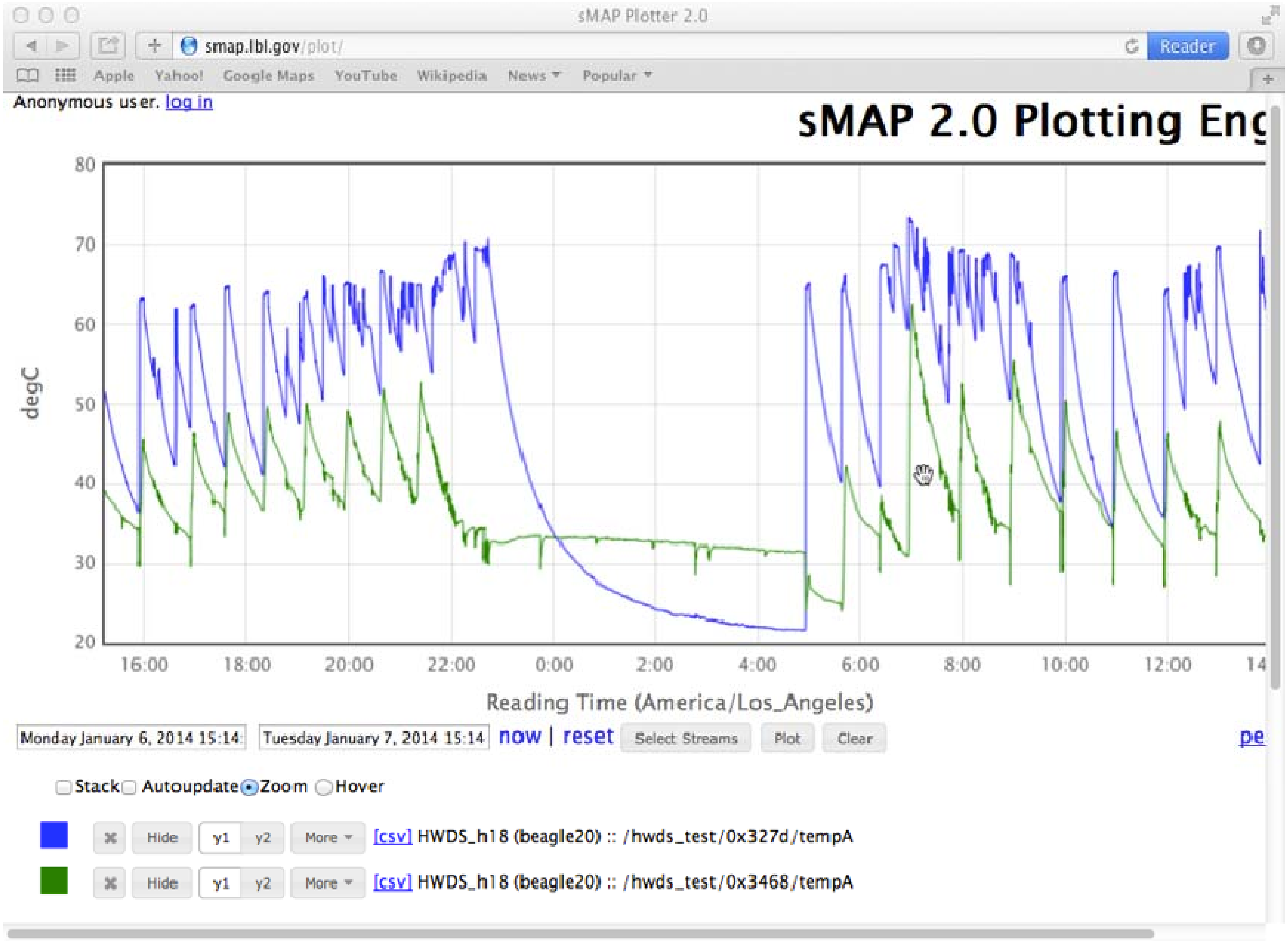
Continuous Circulation: Medium Speed



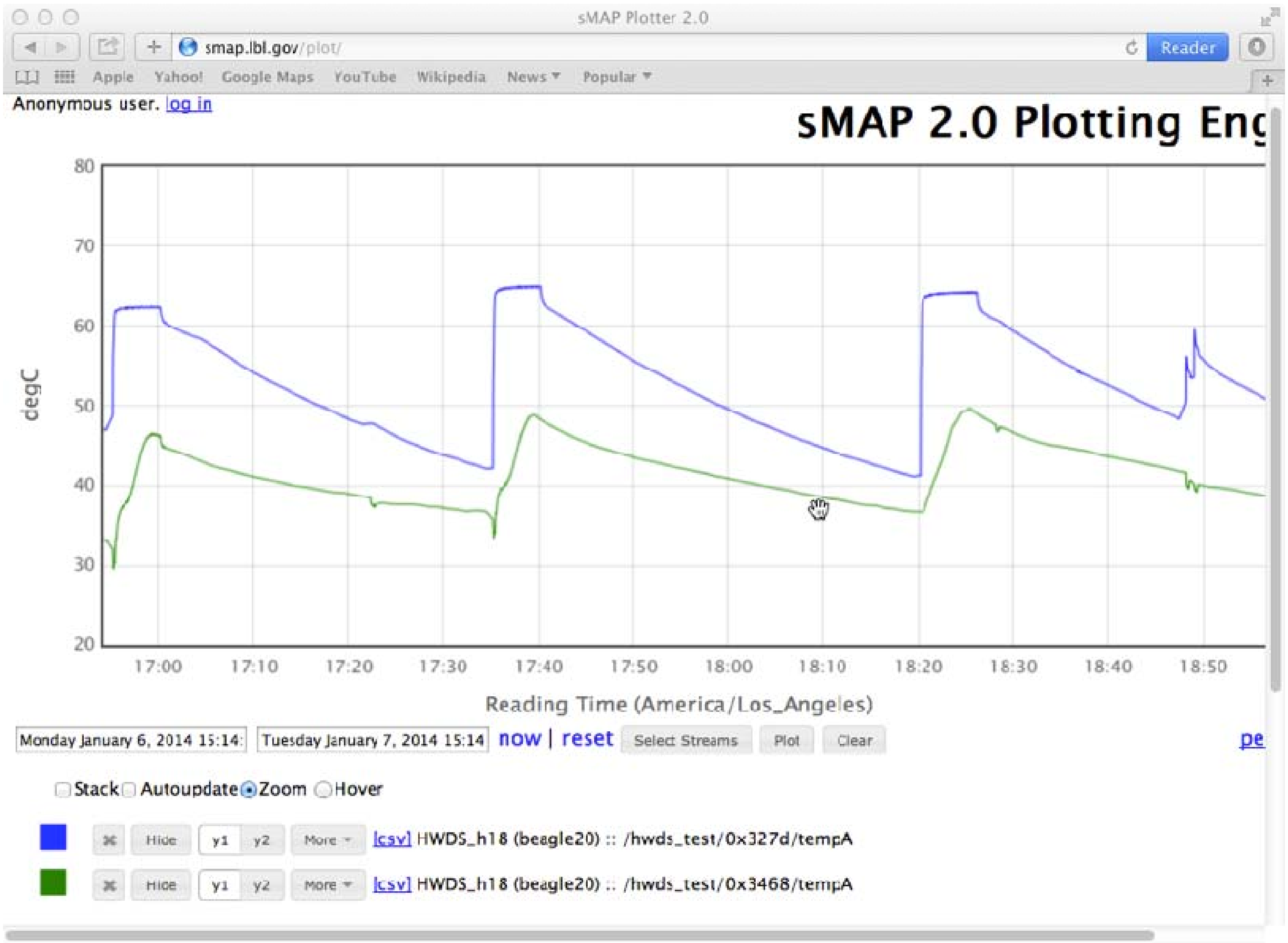
Continuous Circulation: Medium Speed



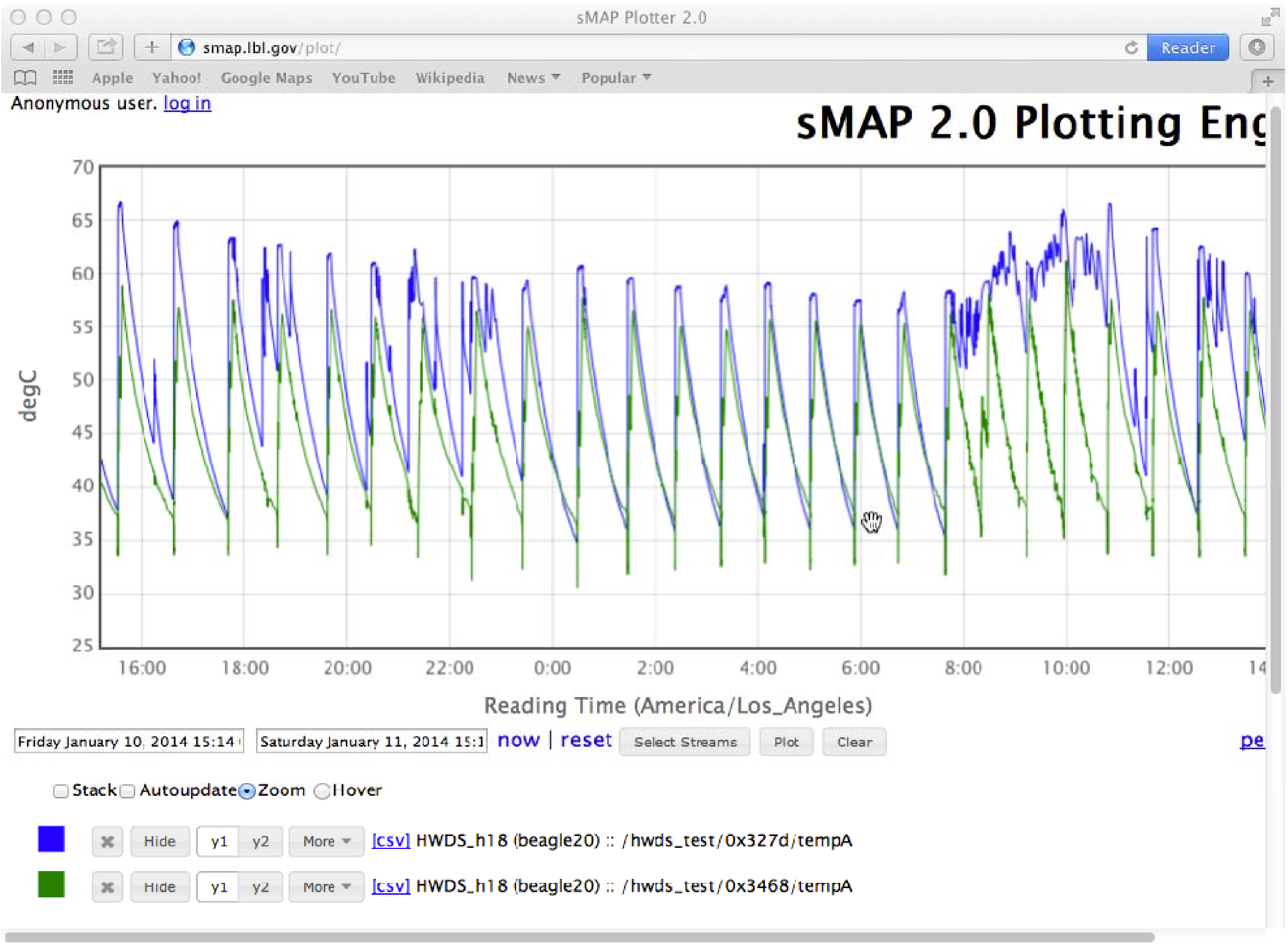
Intermittent Pulsed Timer



Intermittent Pulsed Timer



Aquastat: 85-105F, Medium Speed



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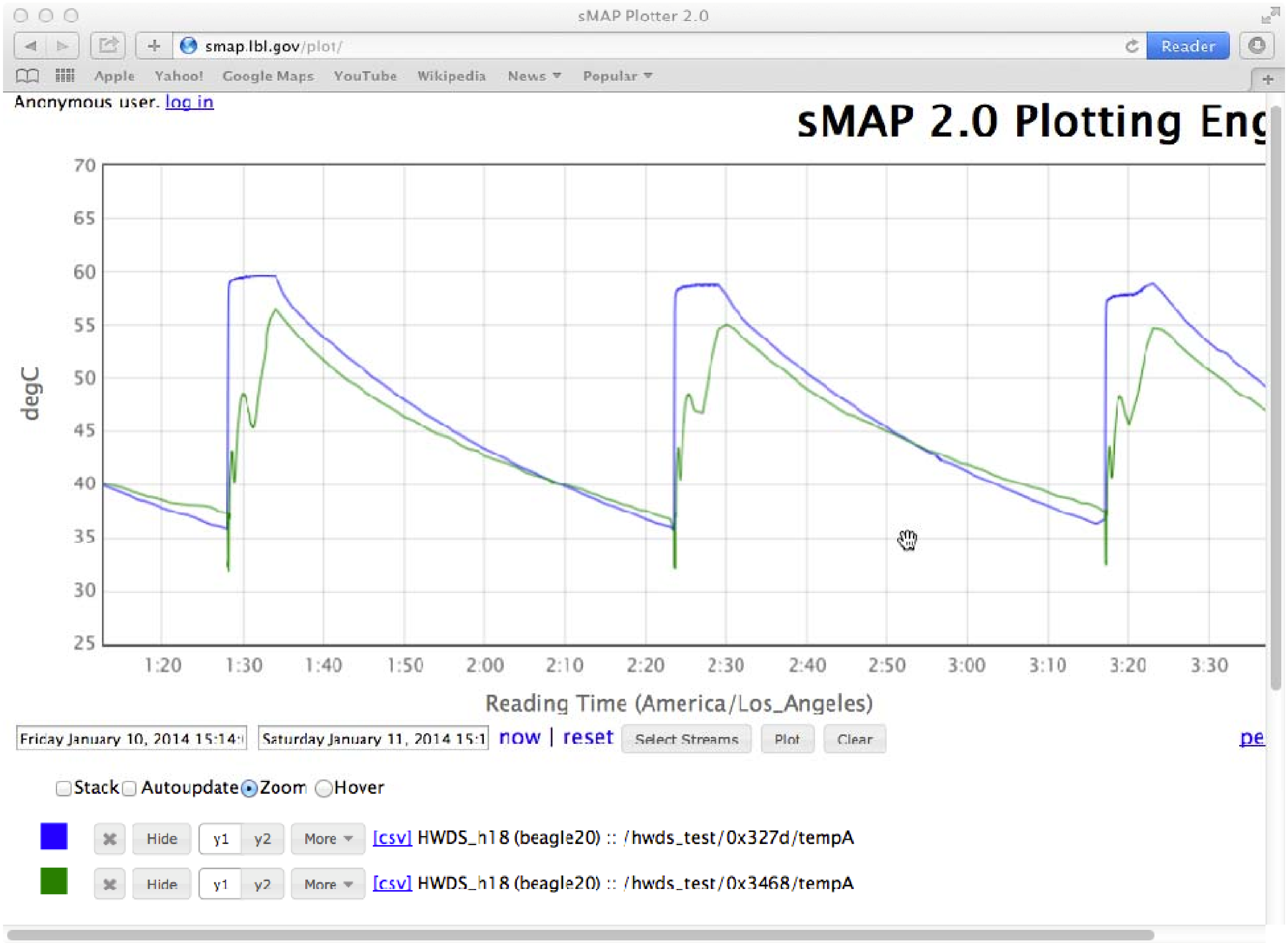
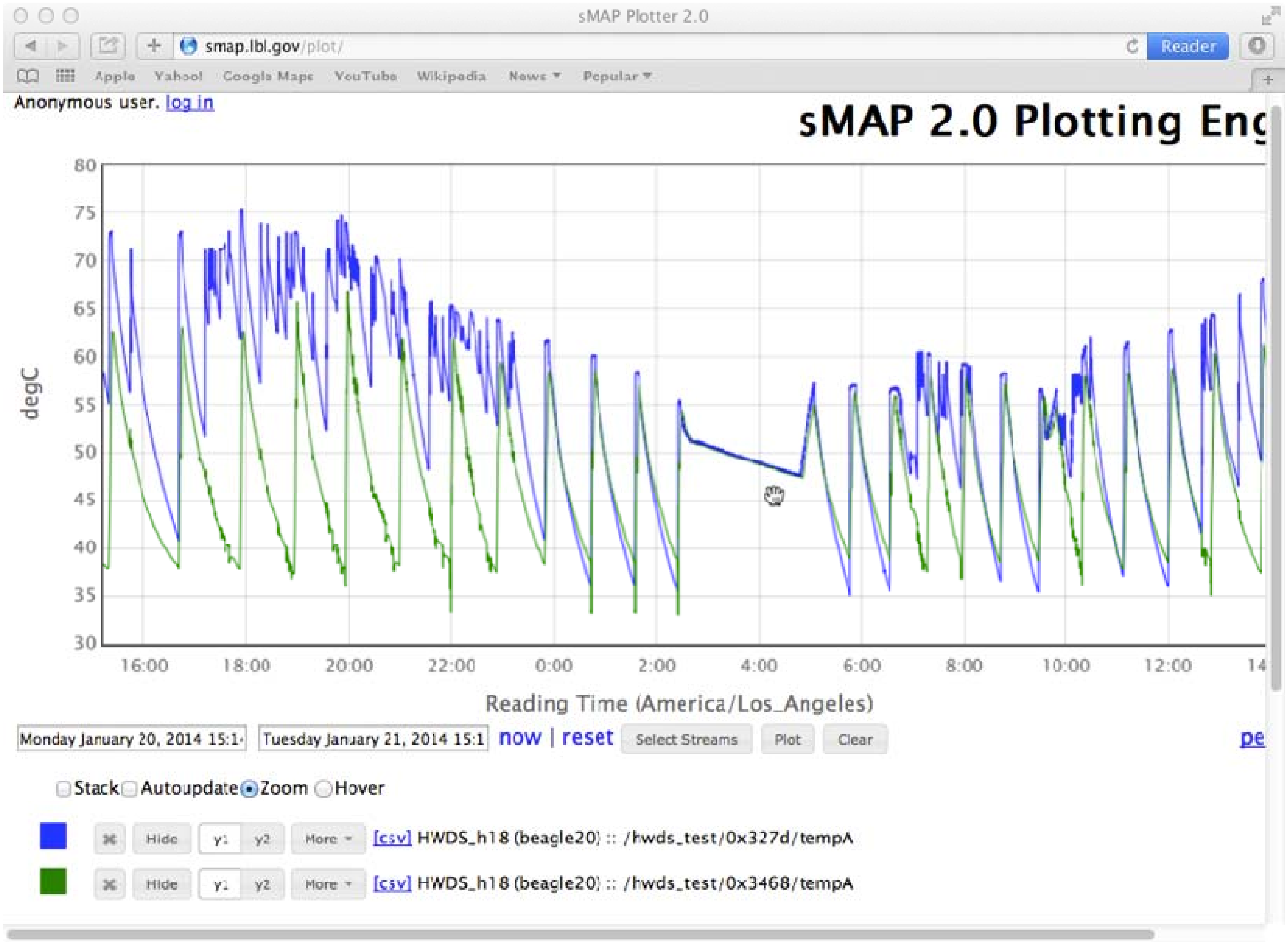


Aquastat: 85-105F, High Speed



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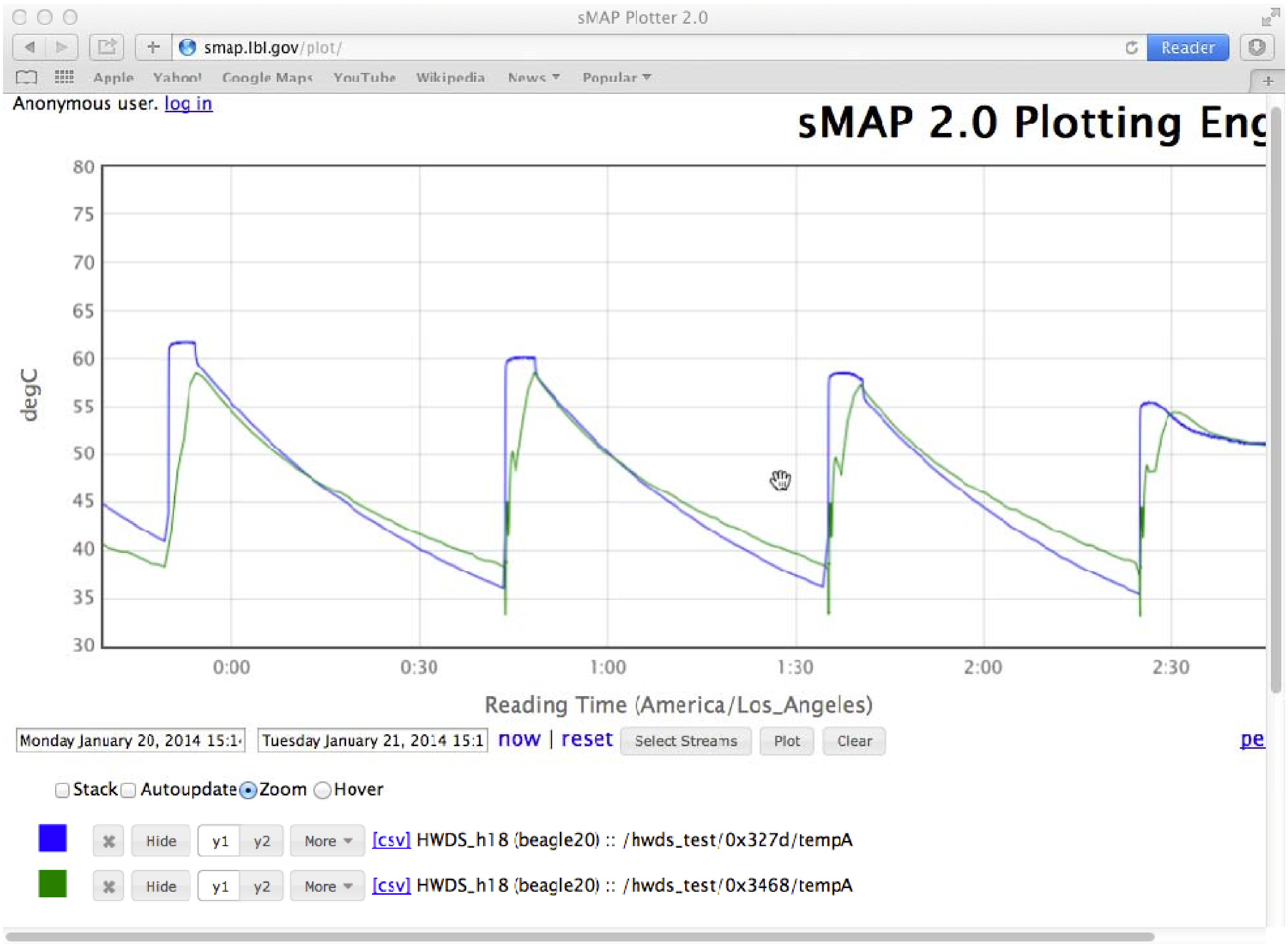
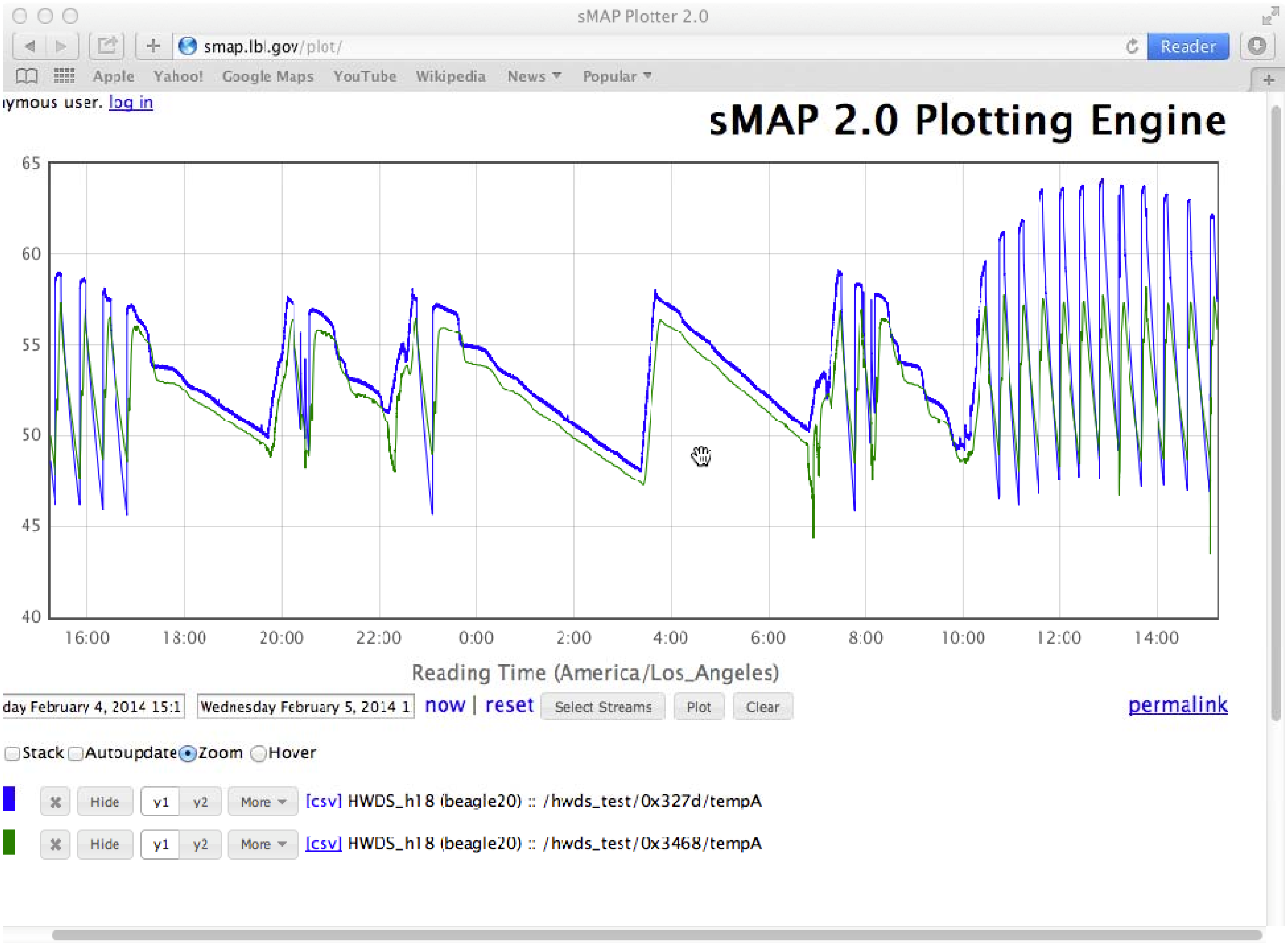
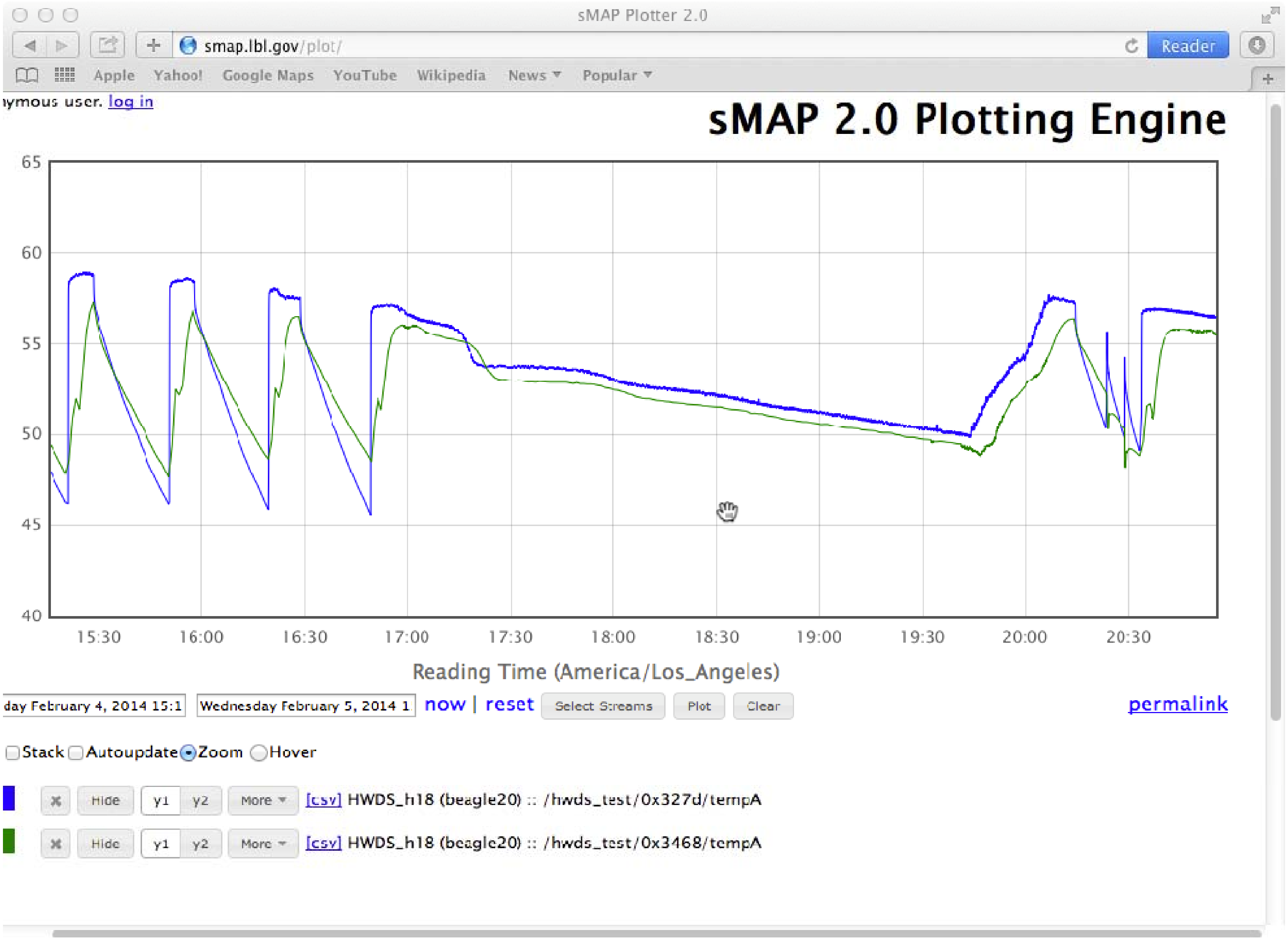


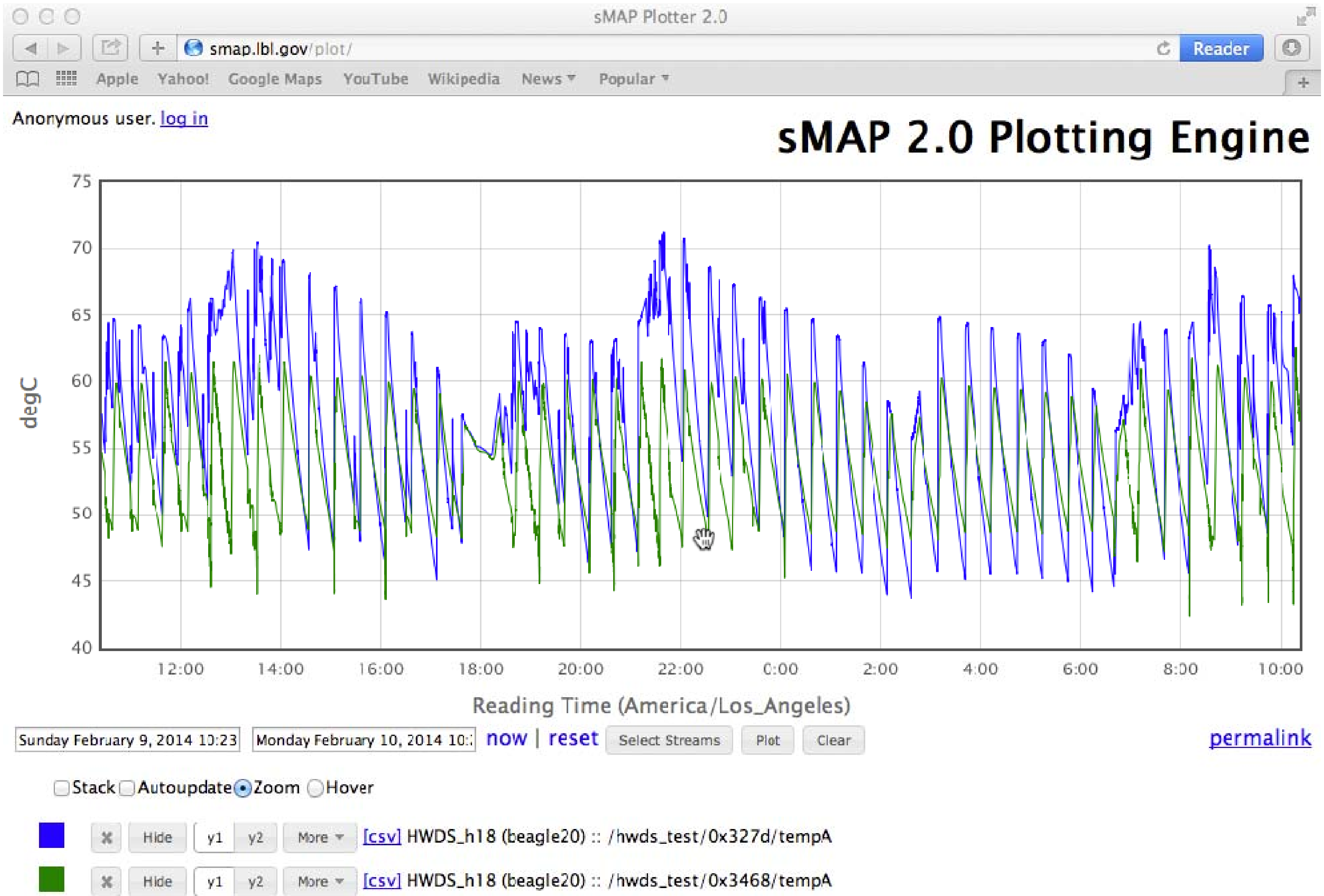
Aquastat: 105-115F, Medium Speed



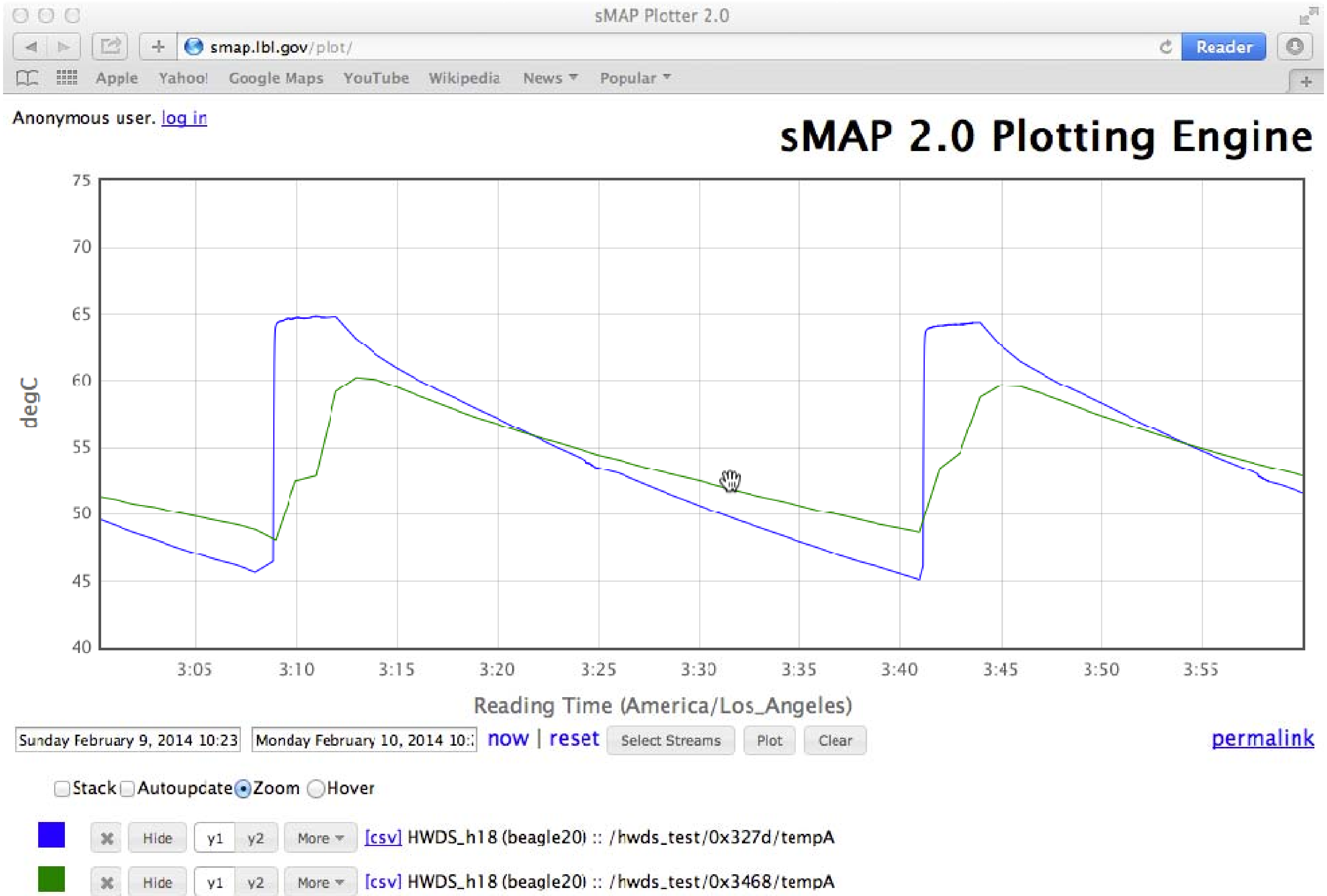
Aquastat: 105-115F, Medium Speed



Aquastat: 105-115F, High Speed



Aquastat: 105-115F, High Speed



Given human nature,
it is our job
to provide the infrastructure
that supports efficient behaviors.

Thank You!

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