Milagro Tank Temperature Study:

w/ and w/o Tank Insulation

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Tank Temperature Study for Northern Auger

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- Auger North site (Colorado) is colder than Auger South.
- **Sept 2006:** instrument Milargo outrigger tank to study *freezing* issues (**Left** photo) (Milagro experiment is about 1.5 hours drive from UNM)
- Milagro tank, ground and air instrumented with 7 temperature sensors and recorded every minute
- **June 2007:** tank fully insulated with R13 insulation to mimic new Auger North tank design (**Right** photo)
- **Feb 2008:** now 2-years data in winter conditions ...

Where is **Milagro?**

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The Milagro TeV γ-ray detector is at:

- Latitude 35.8 degrees, Longitude +106.67 west
- Elevation: 8650ft / 2650m

Milagro Outrigger tanks: **Details & Dimensions**

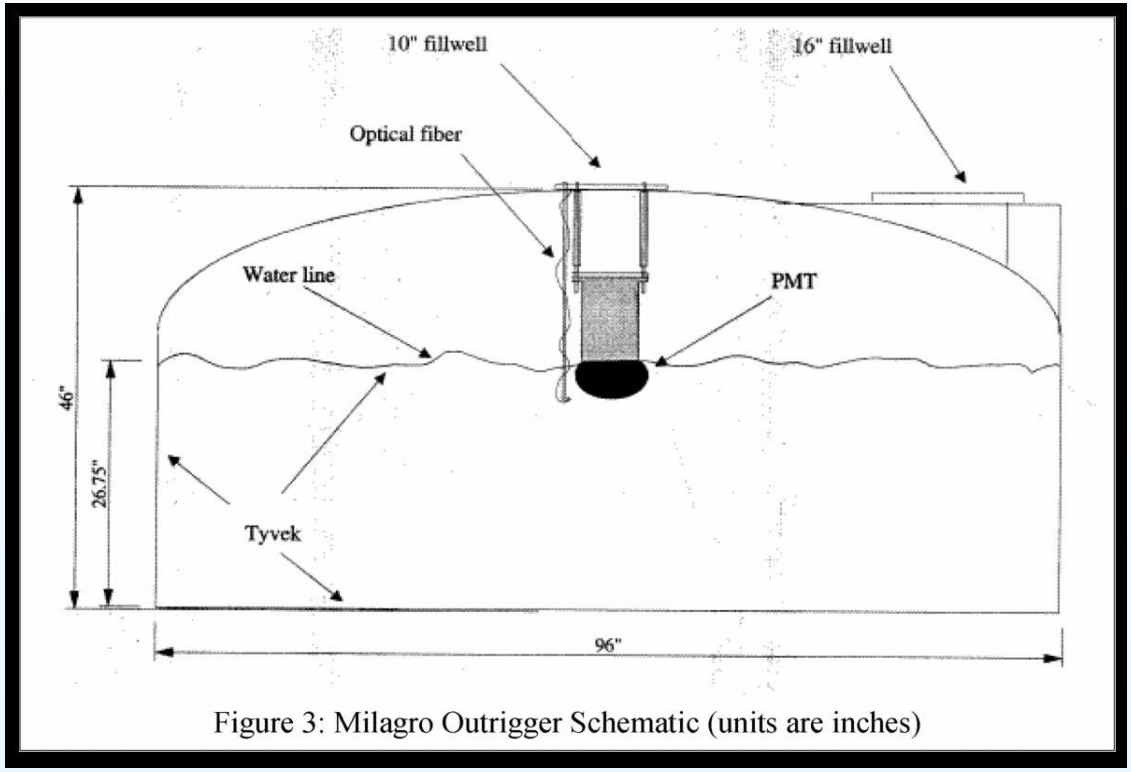


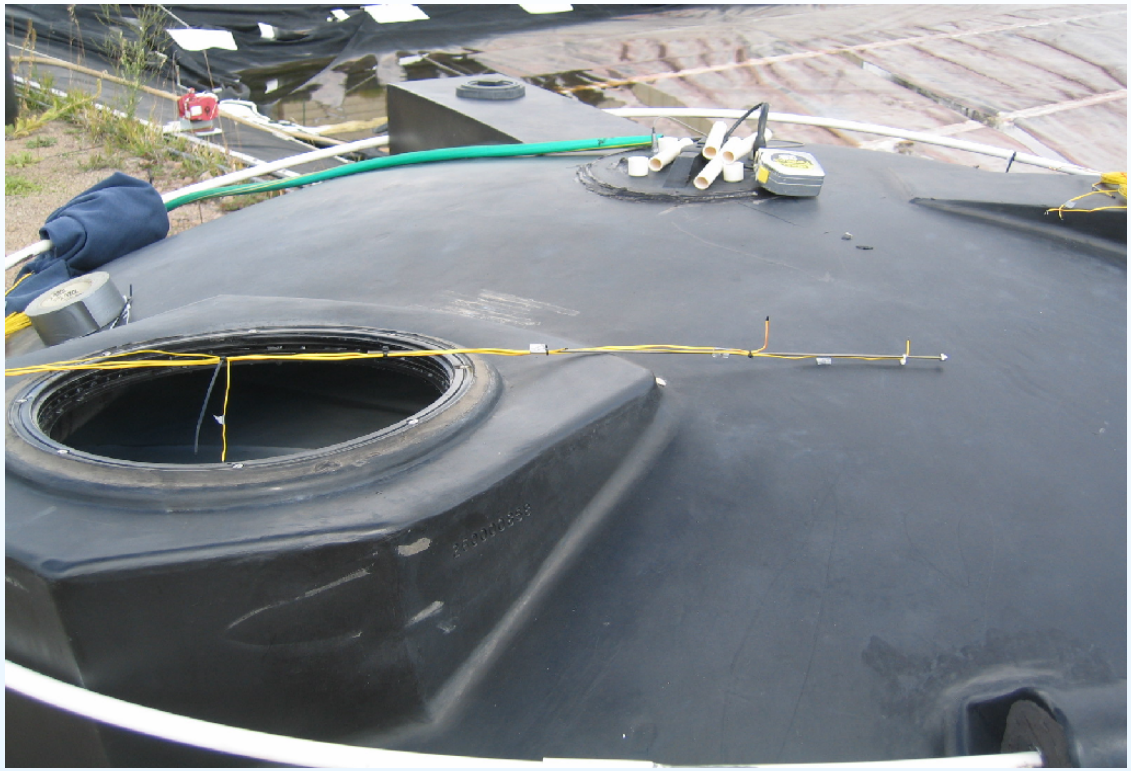
Figure 3: Milagro Outrigger Schematic (units are inches)

- **One** central PMT, enclosure $\sim$ 1/2-immersed, **only electronics: PMT-***base*
- Water depth *typically* $\sim$30-inches (*i.e.* deeper than drawn)
- Smaller water volume and colder winter temperatures (than Auger South)
- In winter often "several inches of ice on water top surface/sides
  ... but never close to freezing solid!"

Outrigger tank: **Instrumented Sept. 2006**

- Top fill port: 4 temperature sensors
- Hole *under* detector $\sim$ 22”-deep with 2 temperature sensors: one $\sim$18”-(in) from tank edge [Ch 1] and one $\sim$12”-(in) from tank edge [Ch 2]

In-tank: **string of 4 sensors**



Thermocouple string:

- ~ 13” in from the edge of the tank
- depths (below the surface of the water) of <1" (*i.e.* "at the surface") [Ch 4], 14" below the surface [Ch 5], 22" below the surface [Ch 6] and 28.5" below the surface (*i.e.* about 1.5" above the bottom) [Ch 7]

Ambient T [Ch 3] **and Solar Sensors** [Ch 0]

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2007 changes: **stages of tank insulation**

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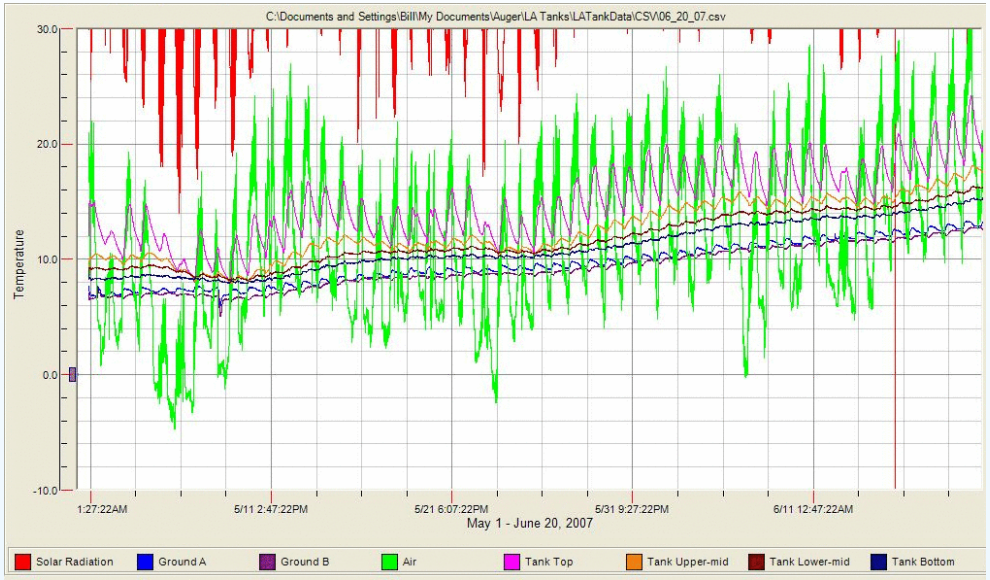
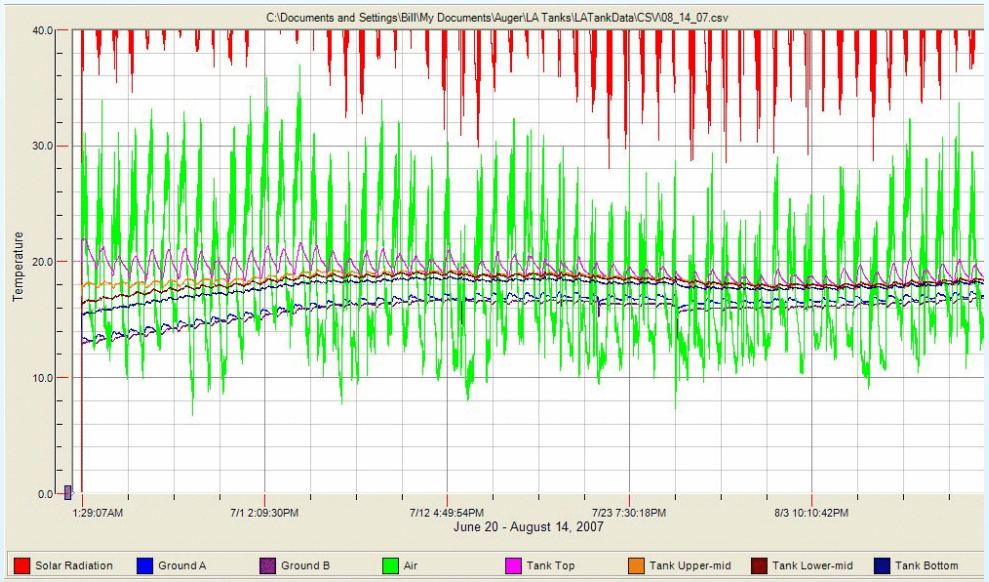
- **Sept 2006:** instrument Milargo outrigger tank to study *freezing* issues
- **April 2007:** add *neutral*-color tarp (not shown)
- **May 2007:** add R13 insulation to cover $\sim 1/2$ the tank (**Left** photo)
- **June 2007:** tank is fully covered with R13 insulation (**Right** photo)

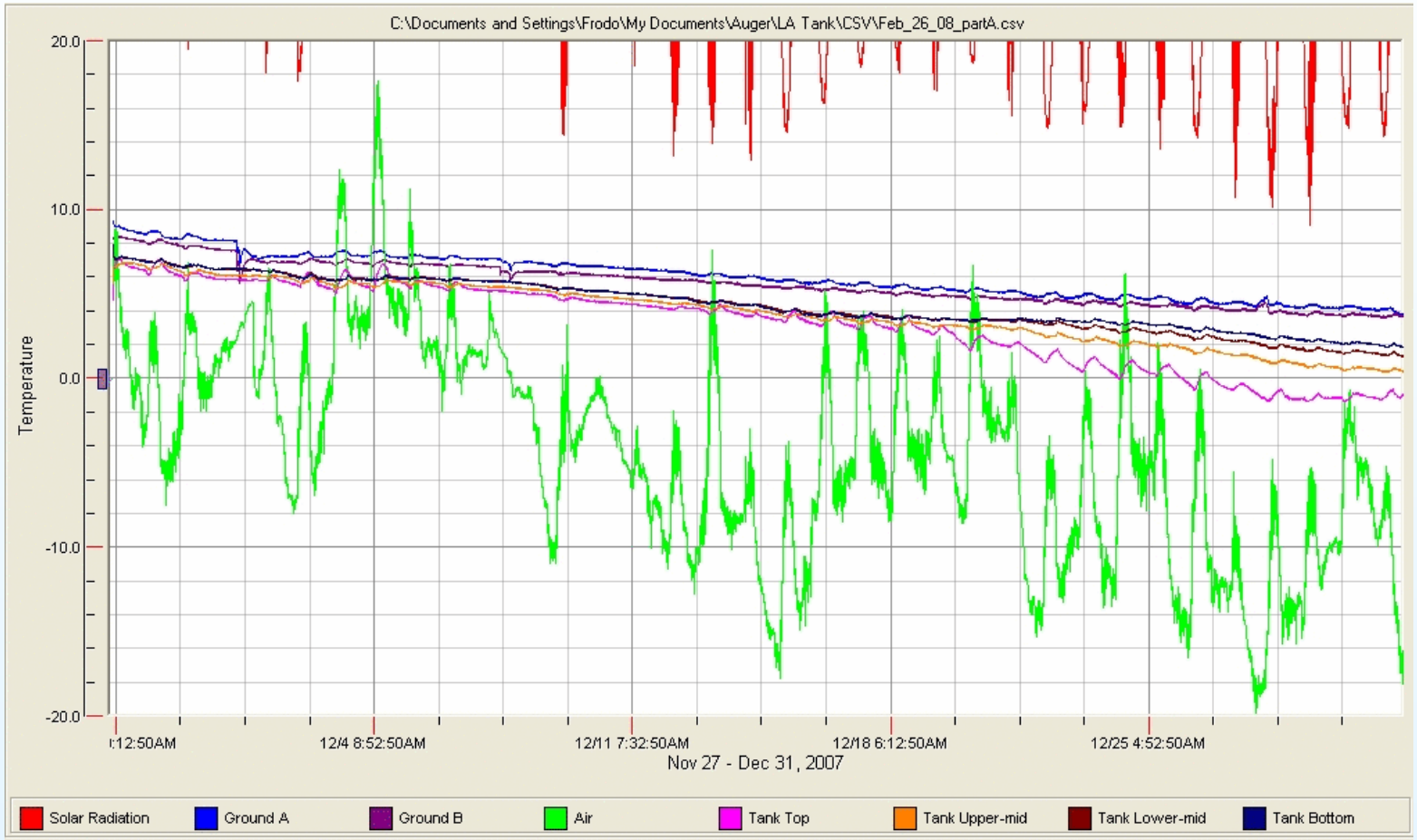
1/2 and full covering with R13 insulation





- **Top:** tank 1/2-covered with insulation
  - significant daily internal temperature variations
- **Bottom:** tank fully-covered with insulation
  - **only sensor at water/air interface shows daily temperature variations**
  - temperature sensors in the tank take ~ 10 days to come to new equilibrium ... *i.e.* **the tank is now in slow motion!**
  - tank and ground temperatures now show a strong correlation!

First surface freezing: **late December 2007**



- Ignoring winter to winter differences, the insulation has delayed the time to the first tank freezing (*i.e.* previous year first freezing was in mid-November 2006)

Winter data access: **late February 2008 (I)**

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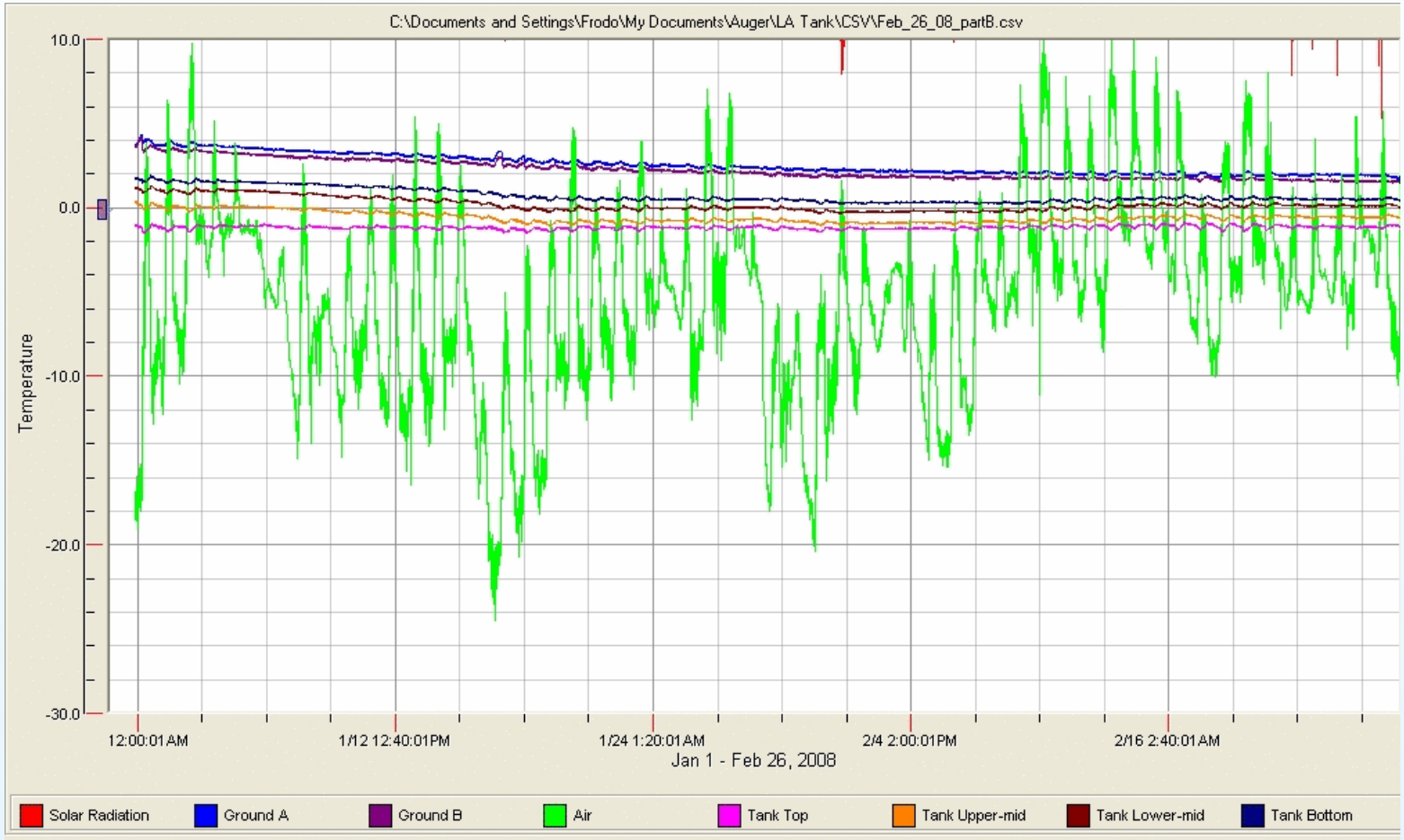
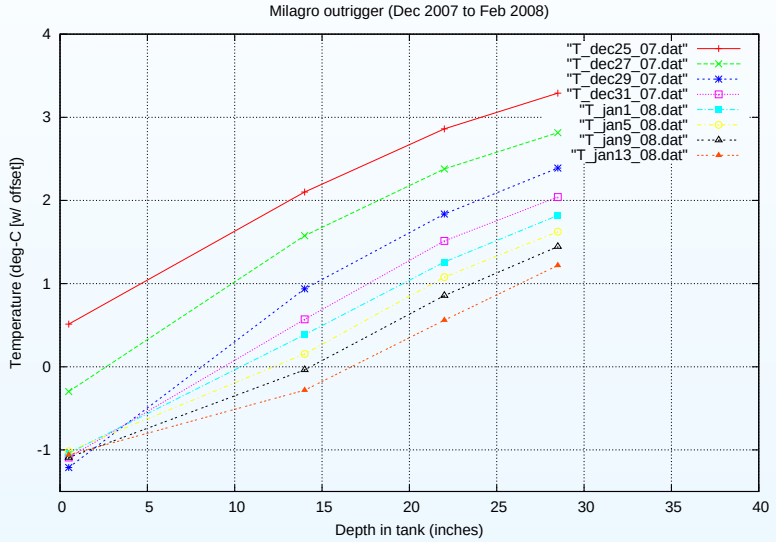
- Insulated tank includes *neutral*-color tarp and R13 insulation
- For comparison several Milagro (uninsulated, black) tanks can be seen
- Wind and sun carve the snow from around every tank down to bare dirt.

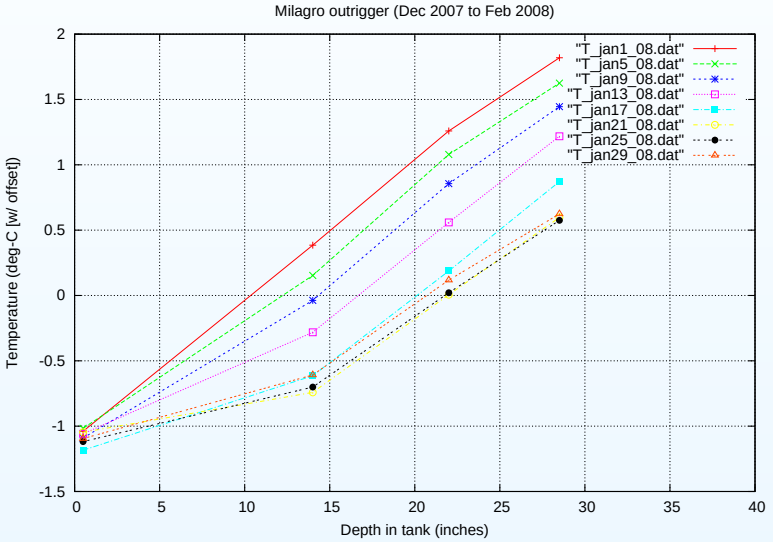
Winter data access: **late February 2008 (II)**

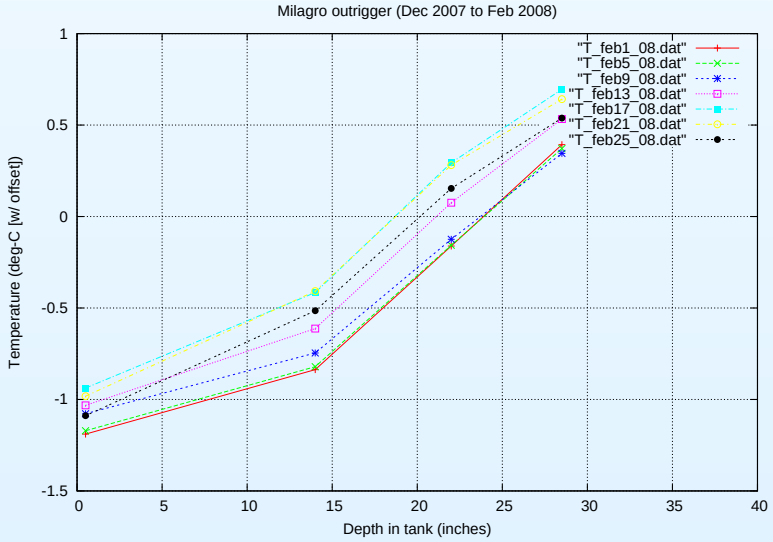


- The reduction of solar daily temperature variations with R13 insulation makes it more difficult to monitor the amount of tank freezing ... (or does it?)

Winter data access: **late February 2008 (III)**

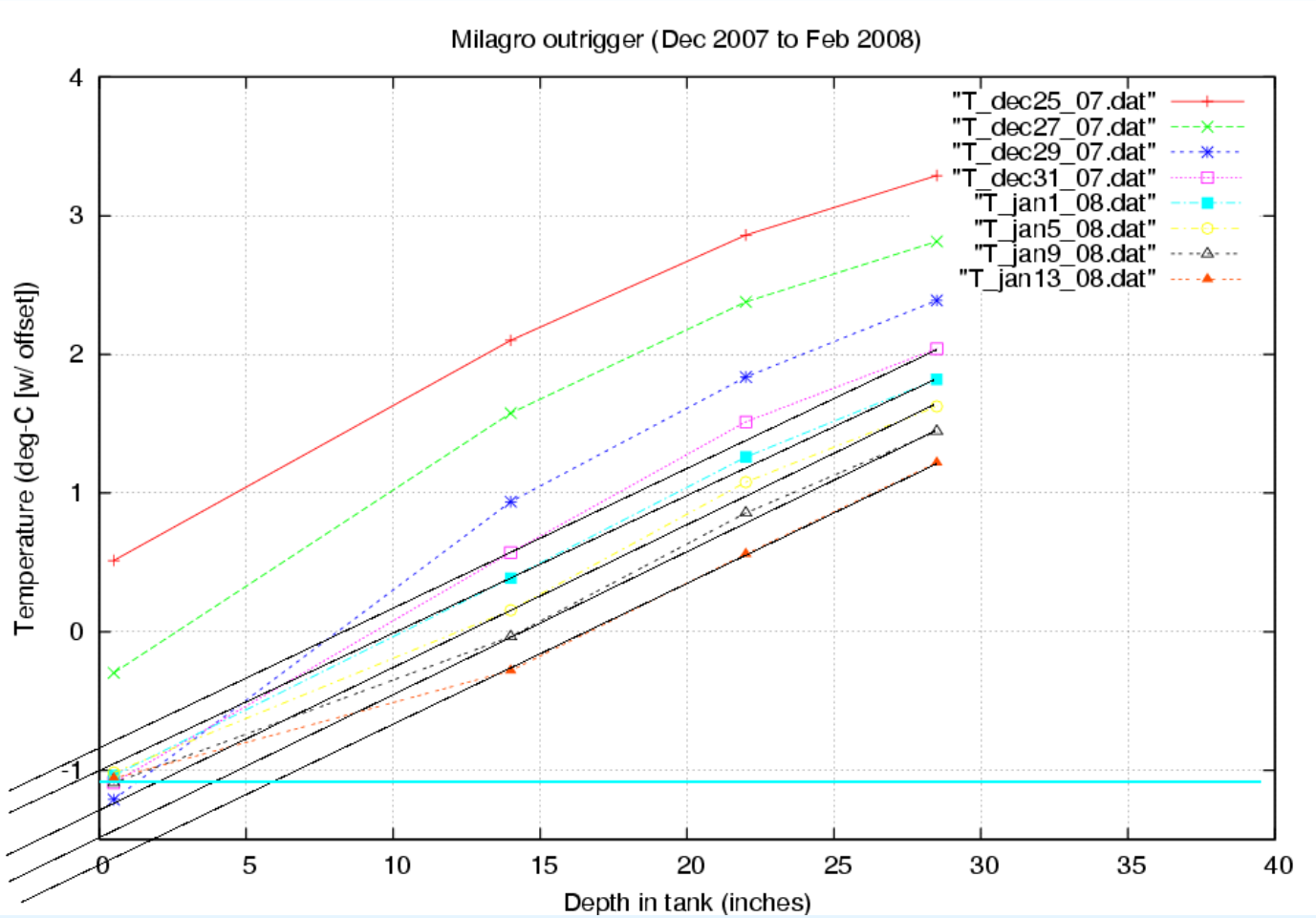






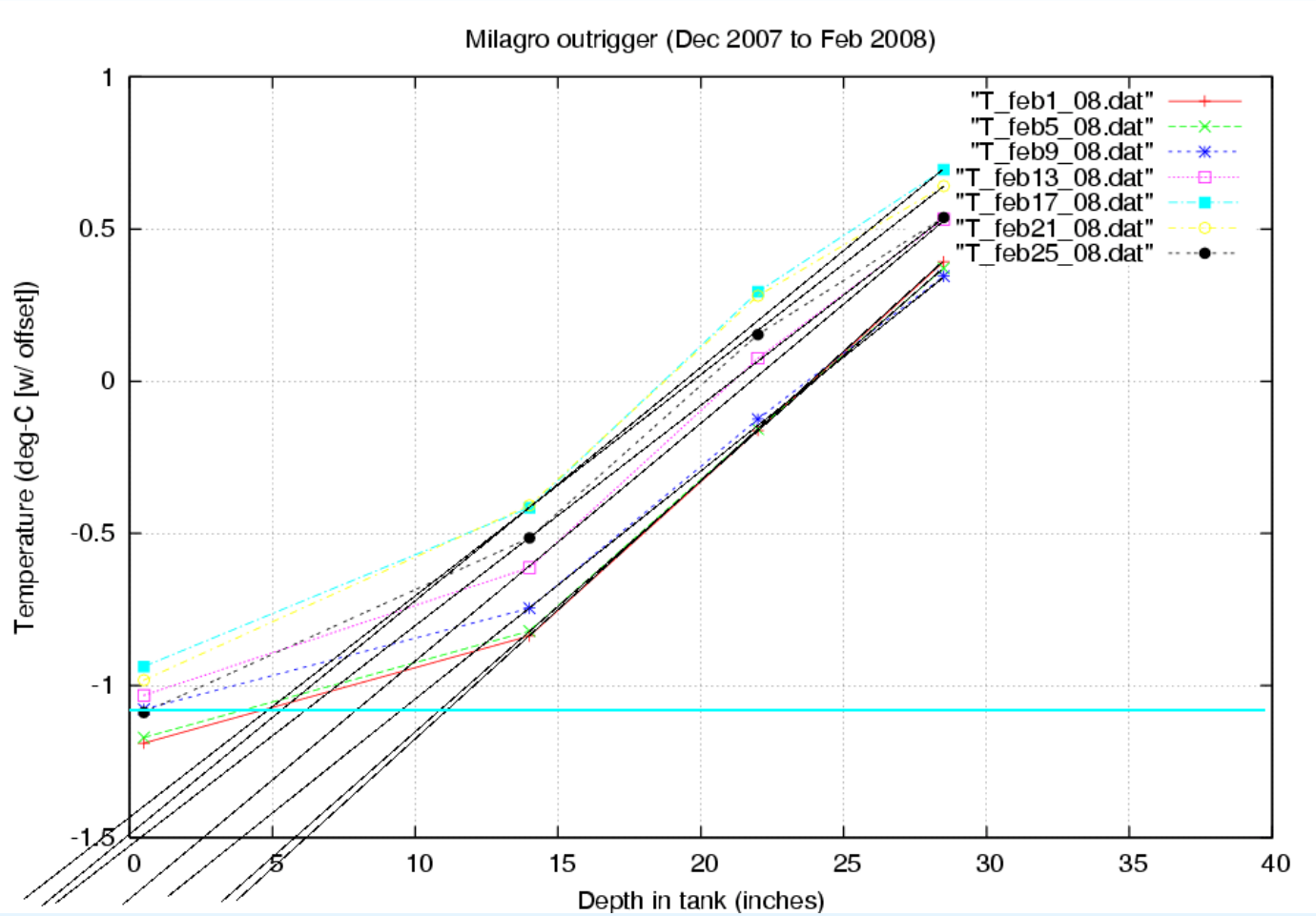
- Once the tank has a layer of ice, the three bottom sensor *temperatures* are approximately linear with *depth in the tank*
- This is consistent with heat transfer by conduction with stable (ice) and (ground) boundaries.

Winter data access: **late February 2008 (IVa)**



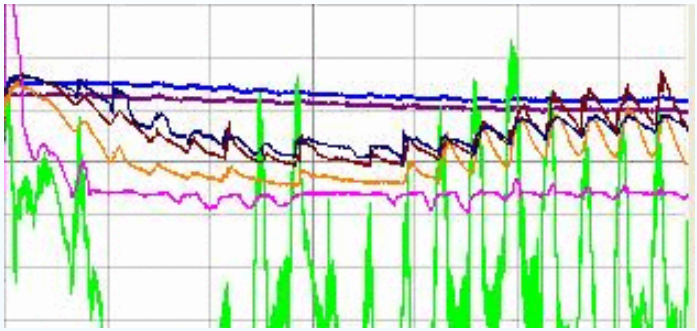
- We extrapolate the *linear* **T** *VS* **depth** to the ($\sim -1^\circ$ offset) temperature of the ice.
- This suggests that a **several inch thick layer of ice** forms on in the tank.

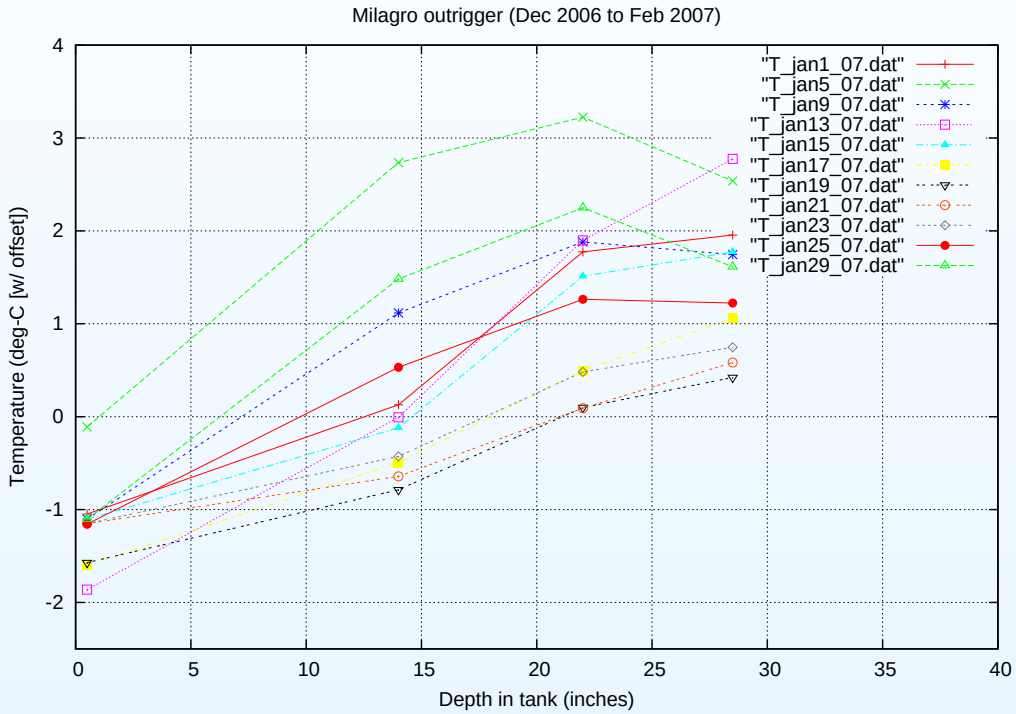
Winter data access: **late February 2008 (IVb)**



- In this model, the ice was thickest (~ 11") February $1 \sim 5$ 2008
- How clear is this ice **and** how does this effect the performance of the tank?

Coldest period previous winter: **late January 2007**





- Only **one** period of sustained freezing of the tank surface (**violet**)
- Middle of the tank (**orange**) close to 0° but probably above freezing
- Linear temperature model (again) suggests $\lesssim 11$" of ice on the tank
- **Ground temperatures remain above freezing** ($\sim 3^\circ$C)

My own ... **impressions!**

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- Without insulation: large temperature variations in the tank ... especially near the top surface. **With R13 insulation the Milagro tank shows little to no daily temperature variations!**
- With (or without) insulation, the ground temperature (under the tank) varies slowly with time and remains a few degrees above freezing. **Note: unlike plans for Northern Auger, our measurements have no insulation on the bottom of the tank!** And there is evidence for heat flow into the tank from the ground.
- With (or without) insulation there is evidence for formation of a substantial ice layer (~ 10" thickness or 1/3 of the tank depth) on the tanks! So we need to be sure that we can run and calibrate the tanks under these conditions!
- Maybe its time to start measuring VEMs with ice in the tank?!

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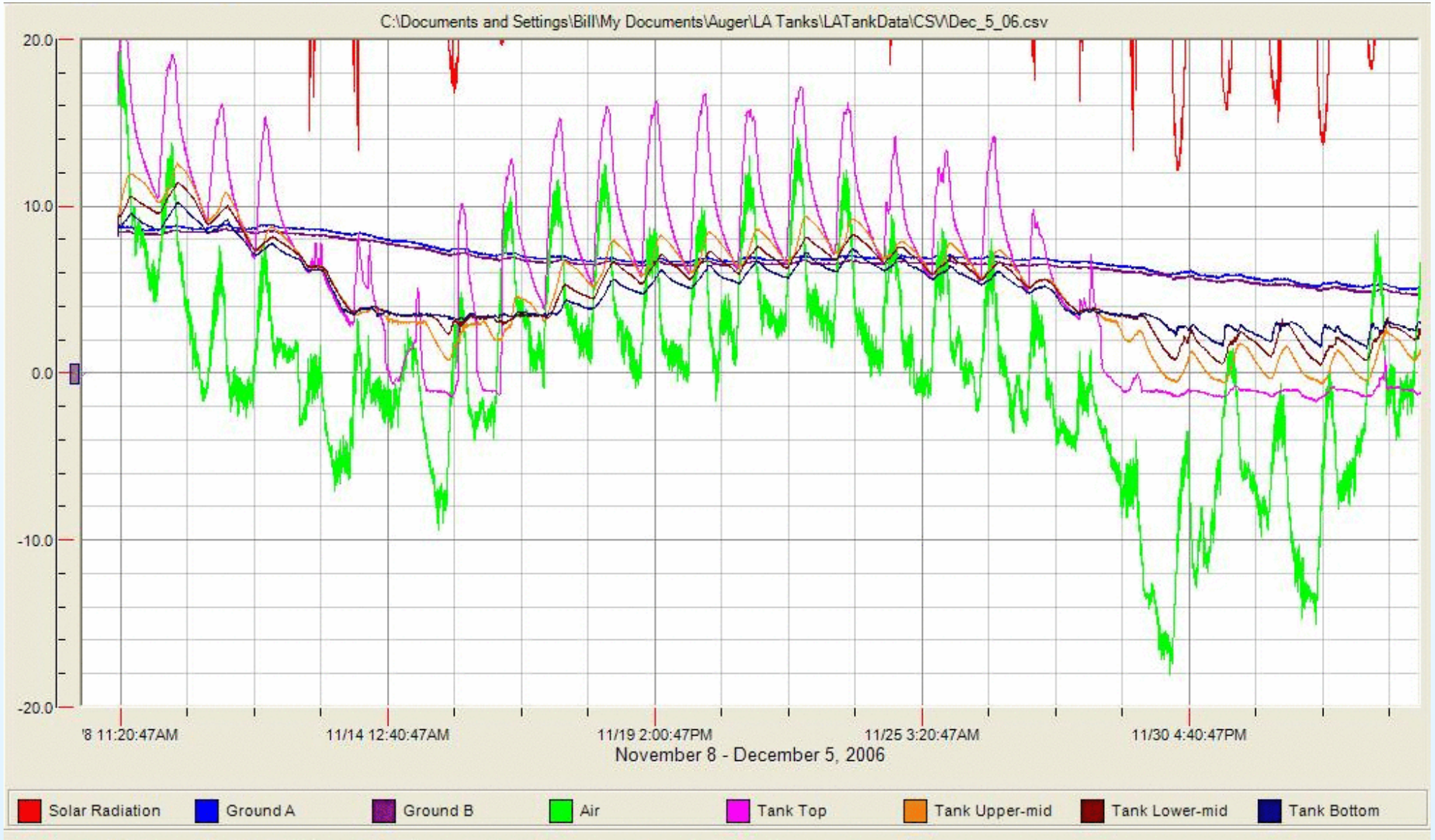
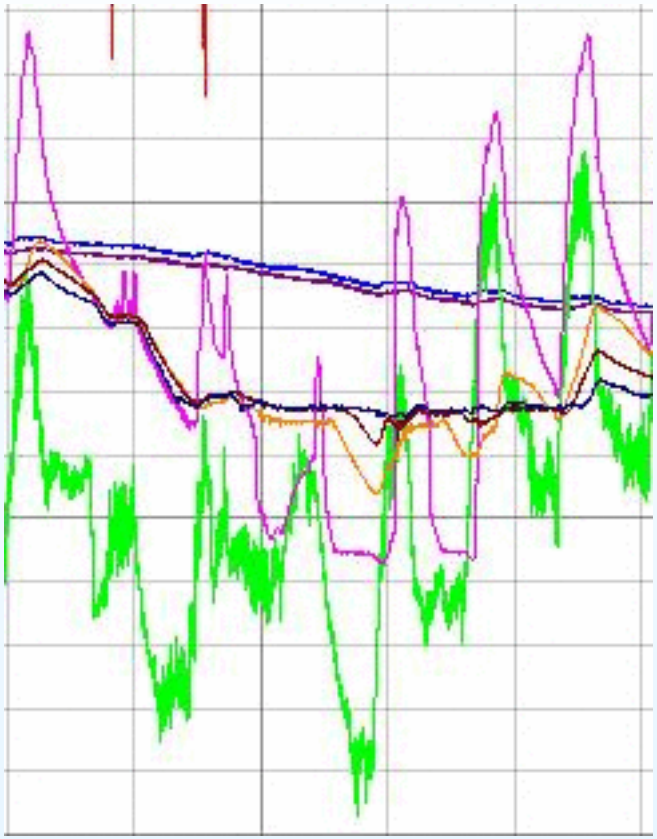
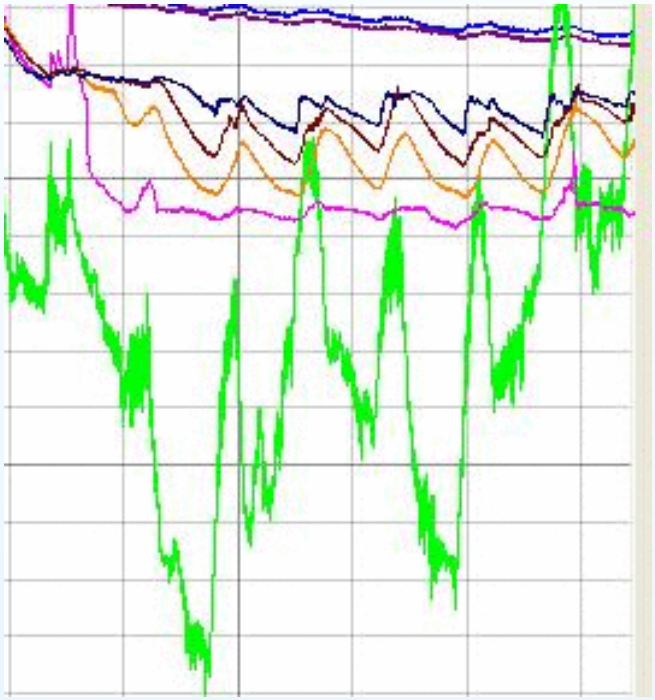
Additional slides

First surface freezing: **in middle and late Nov 2006**



Tank temperature(s): **November 2006 details**



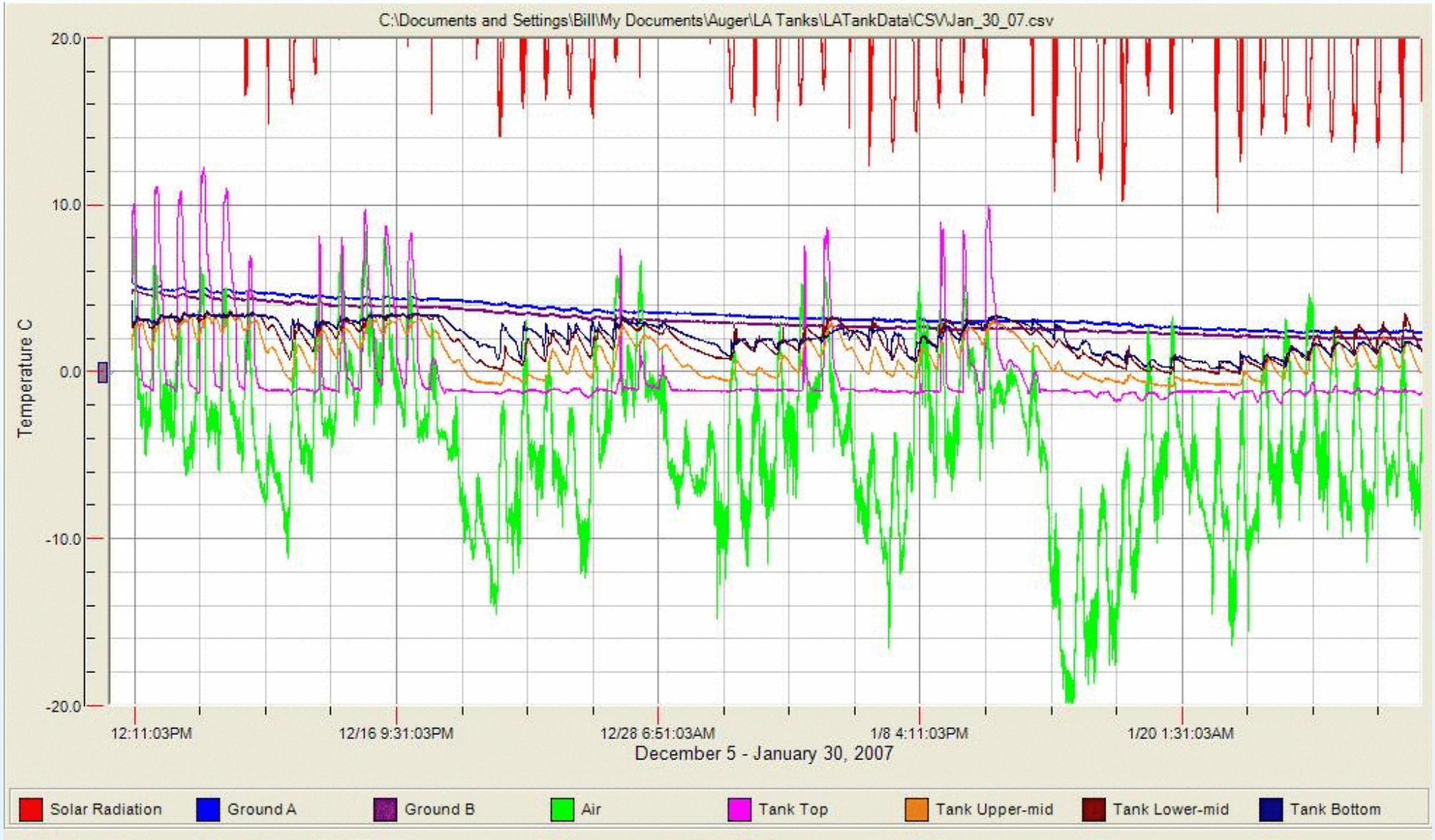


- **[left plot]** tank T-sensors show **inverted** T-gradient: coolest (top) to warmest (bottom) ... with top probably freezing at night and thawing during the day ... **not a good thing!**
- **[right plot]** now the top (**violet**) stays frozen day and night!

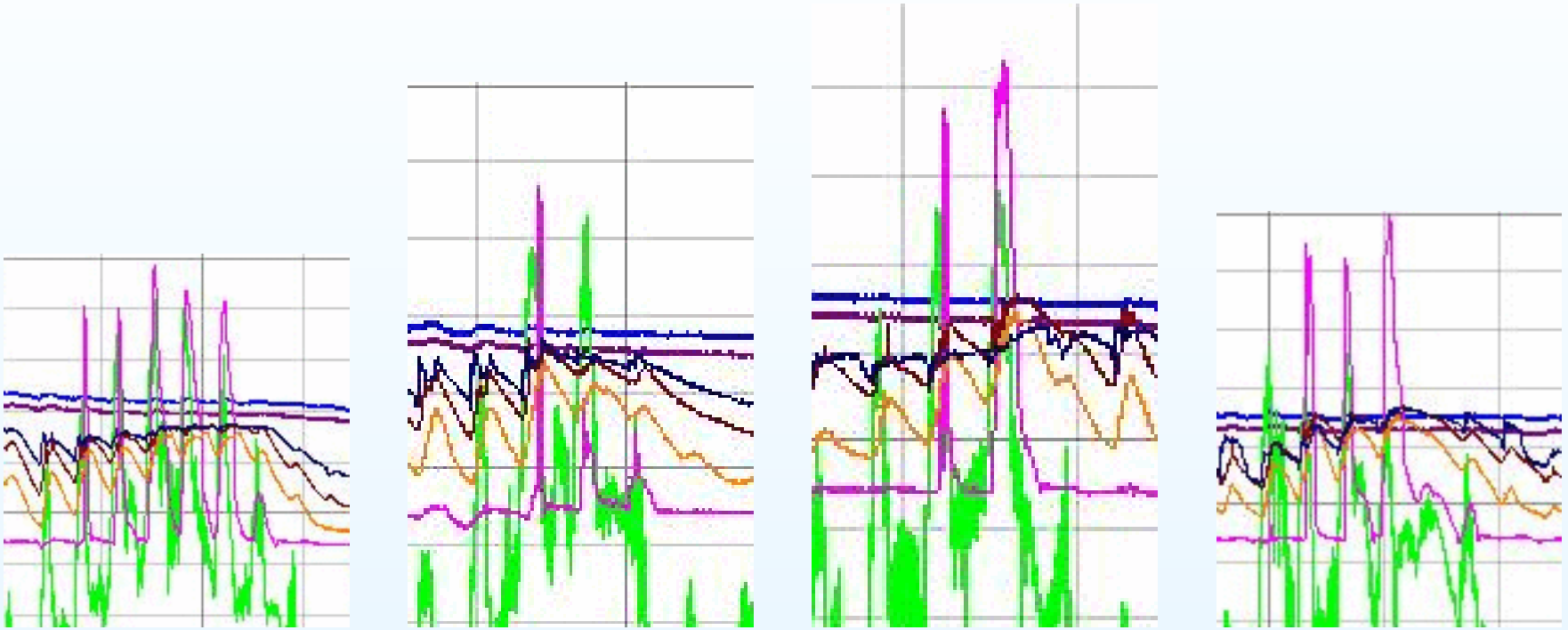
Next data access: **late January 2007 (I)**

- Milagro experiences significant snow cover during the coldest months.
- Tanks in full sun have least snow (cover).
- Tanks in the shade (not shown) can be totally covered.

Next data access: **late January 2007 (II)**



Next data access: **late January 2007 (III)**



- **Note:** likely temperature offset of $\sim 1^{\circ}$ for all sensors
- Many (**more**) examples of tank surface (**violet**) night-time freezing followed by day-time warming
- Other depths in the tank (**orange, brown and black**) above freezing

Next data access: **late January 2007 (IV)**

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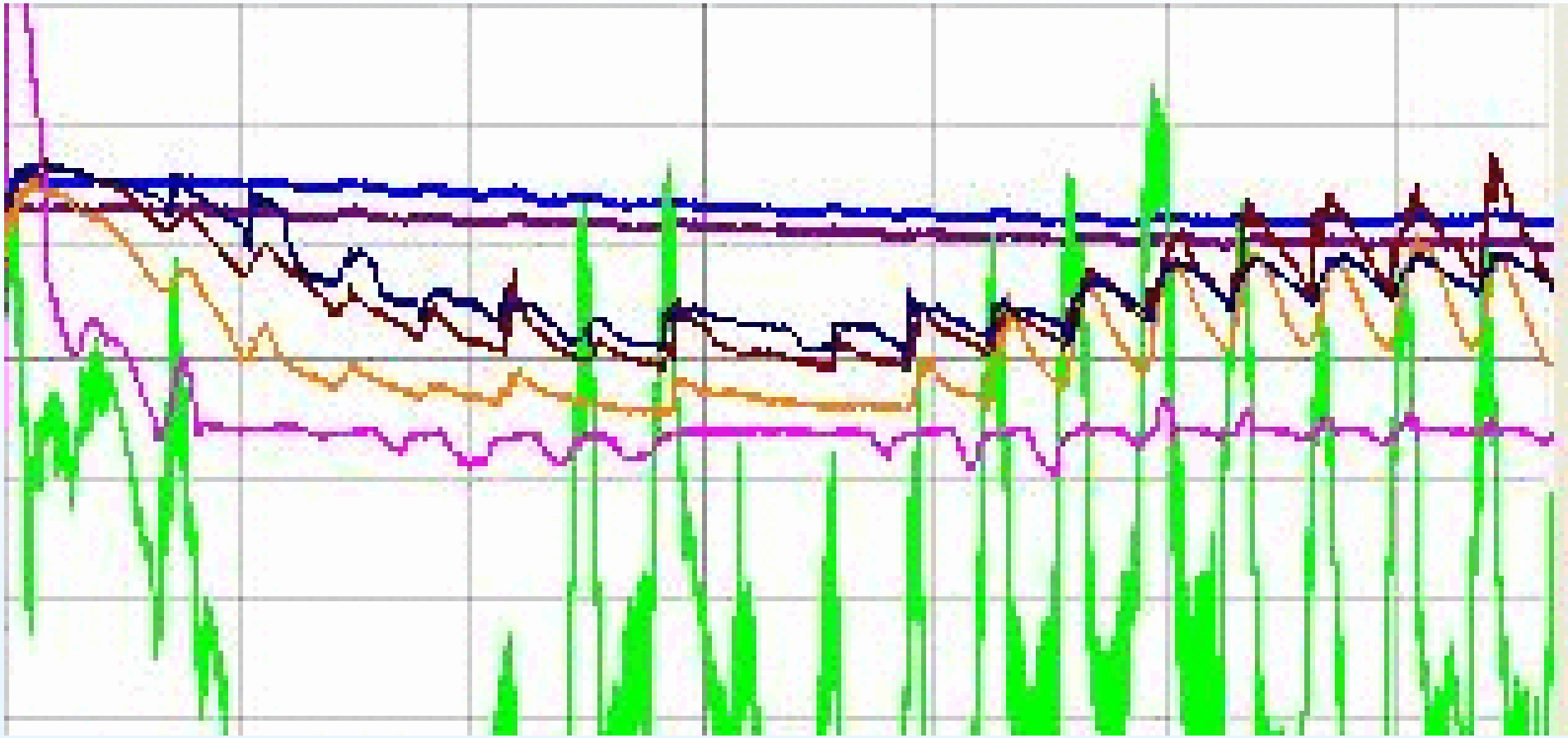

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