Temperature Measurements in a Milagro Outrigger Detector

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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

Outrigger detector ... **Details & Dimensions**

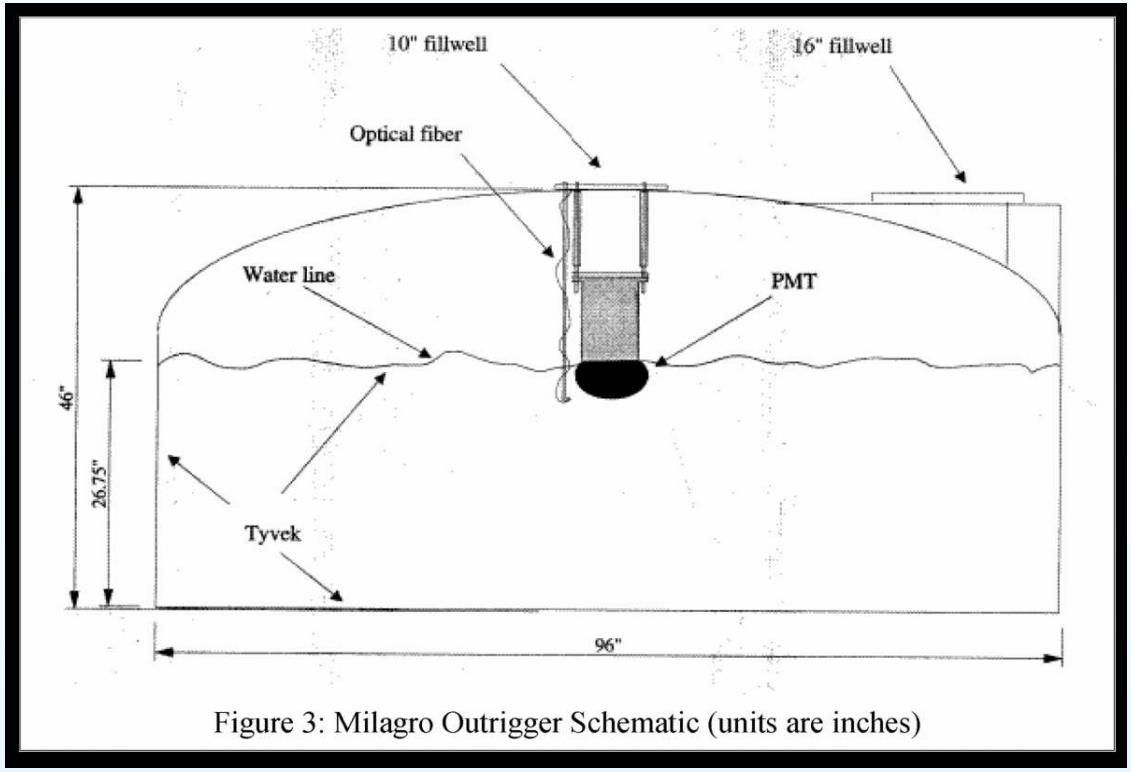

Figure 3: Milagro Outrigger Schematic (units are inches)

- **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 detector ... **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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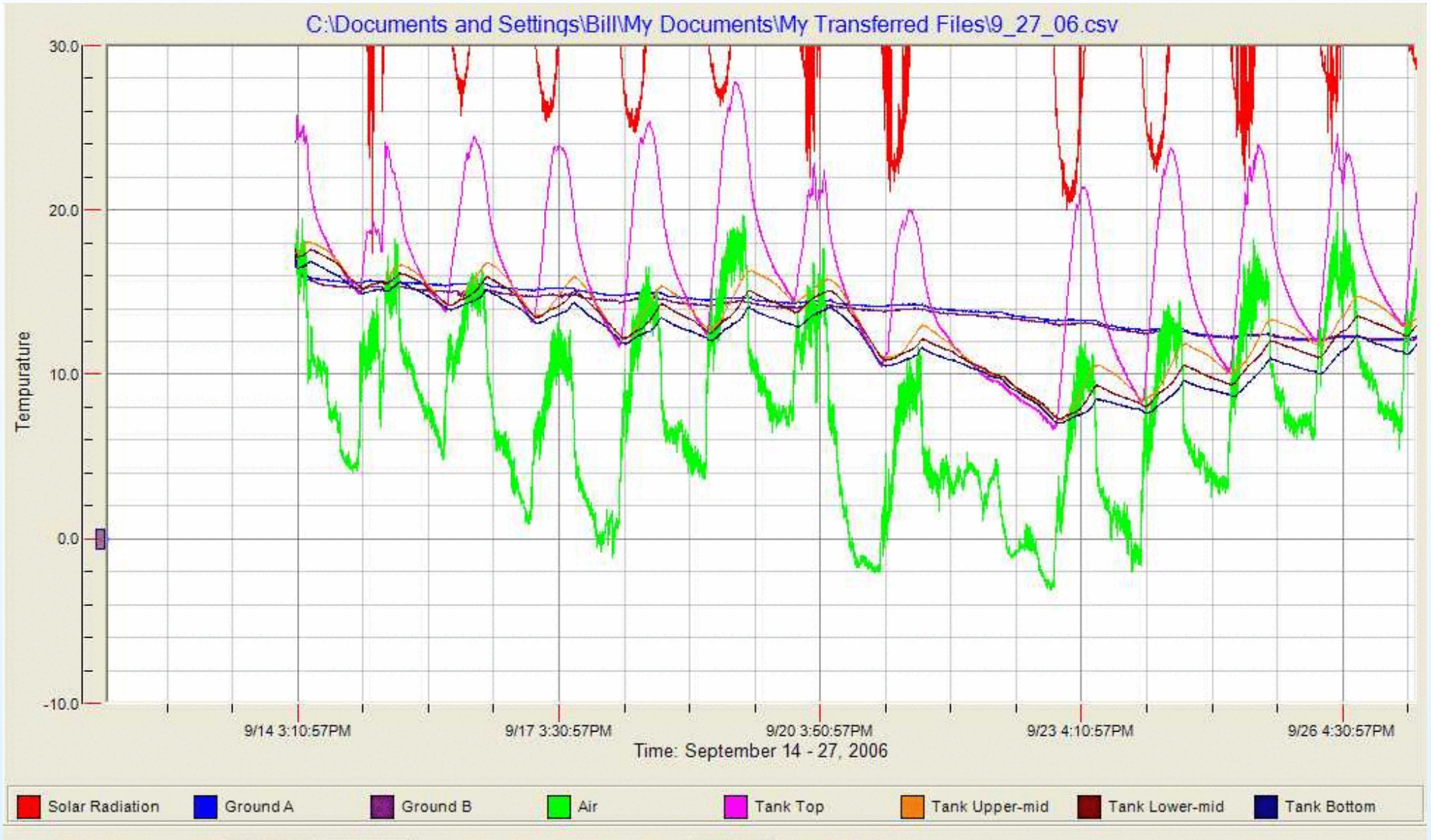
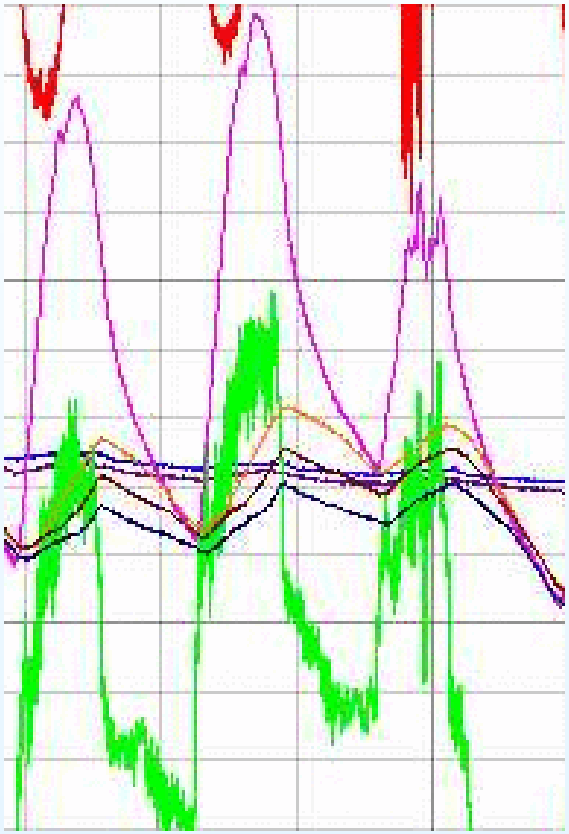
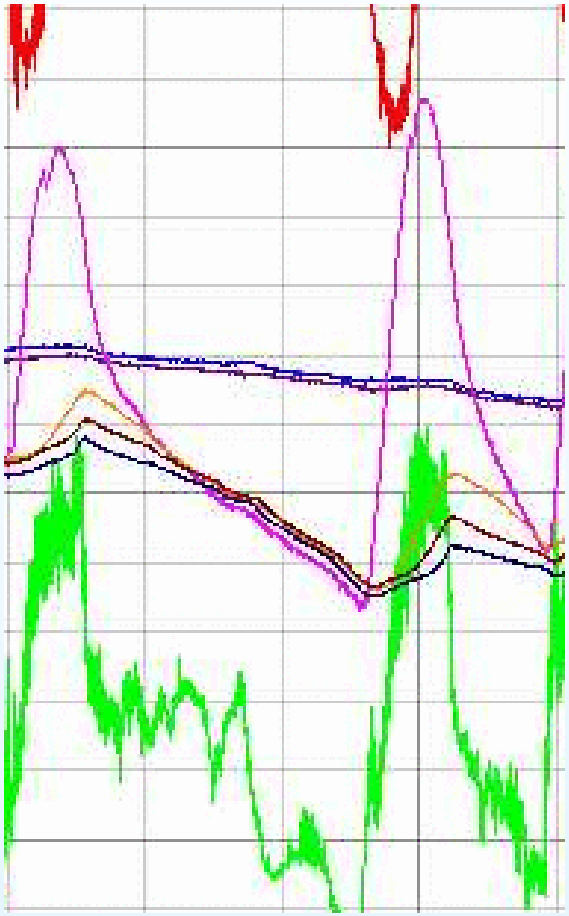
Sample at 1/minute ... **mid to end Sept 2006**



Tank temperature ... **September 2006 details**





- **[left plot]** tank T-sensors show T-gradient: coolest (bottom=**black**) to warmest (top=**violet**) … *large daily temperature variations* … **not a good thing!**
- **[right plot]** but NO T-gradient on cloudy days!

Upgrade ... **solar panel + fix storm damage**

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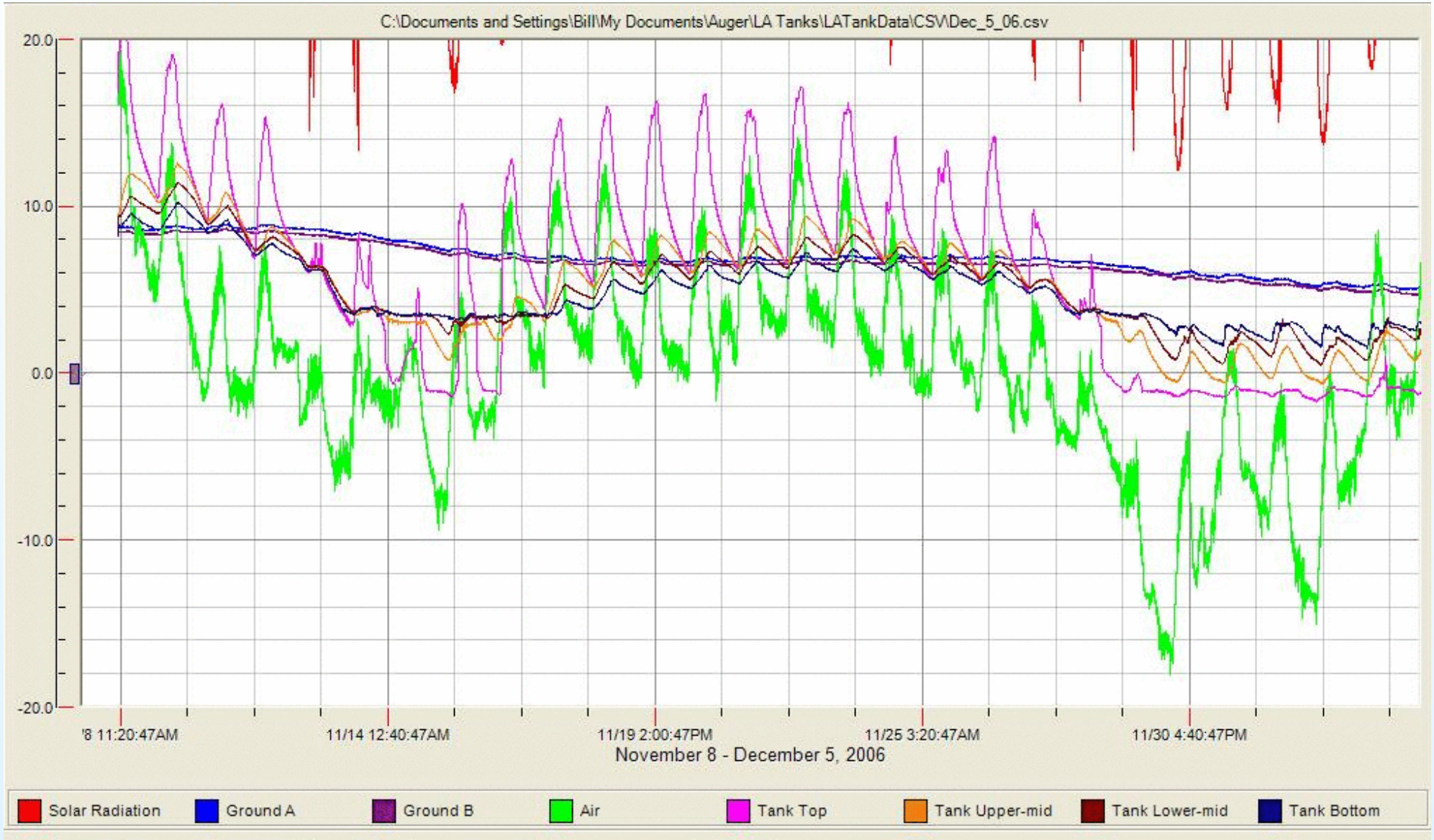
Finally surface freezing ... **in middle and late Nov**



Tank temperature ... **November 2006 details**

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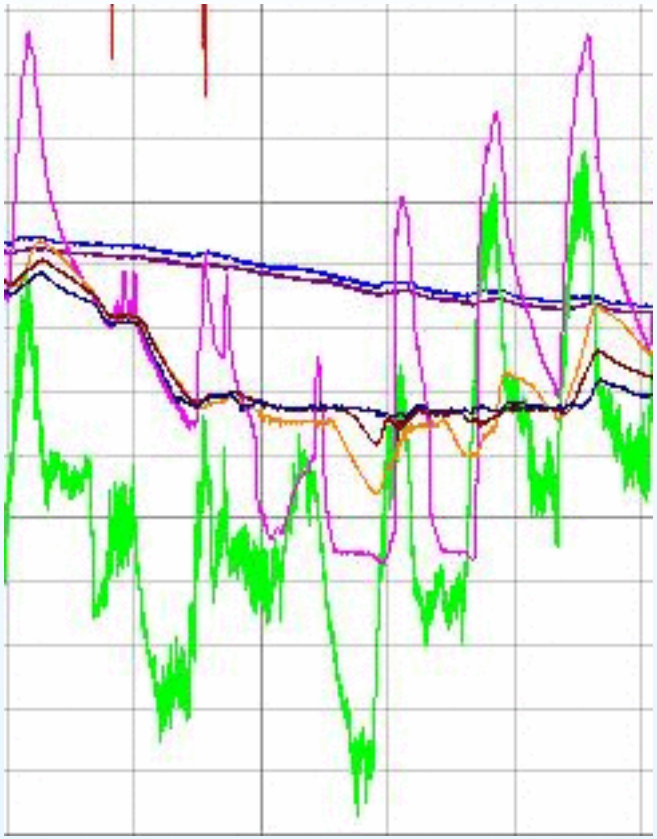

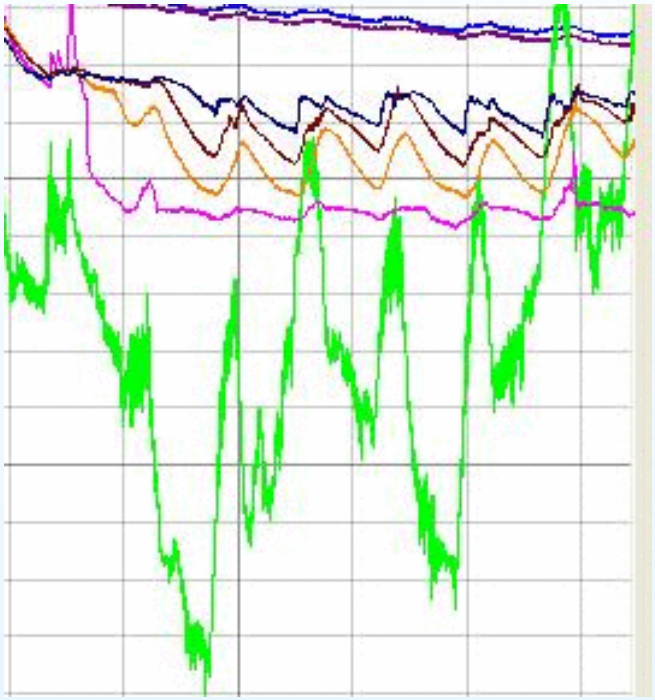

- **[left plot]** tank T-sensors show **inverted** T-gradient: coolest (top) to warmest (bottom) ... with top probably freezing at night and thawing during the day ... **not a good thing!**
- **[right plot]** now the top (**violet**) stays frozen day and night!

Then endless snows ... **until late Jan 2007**

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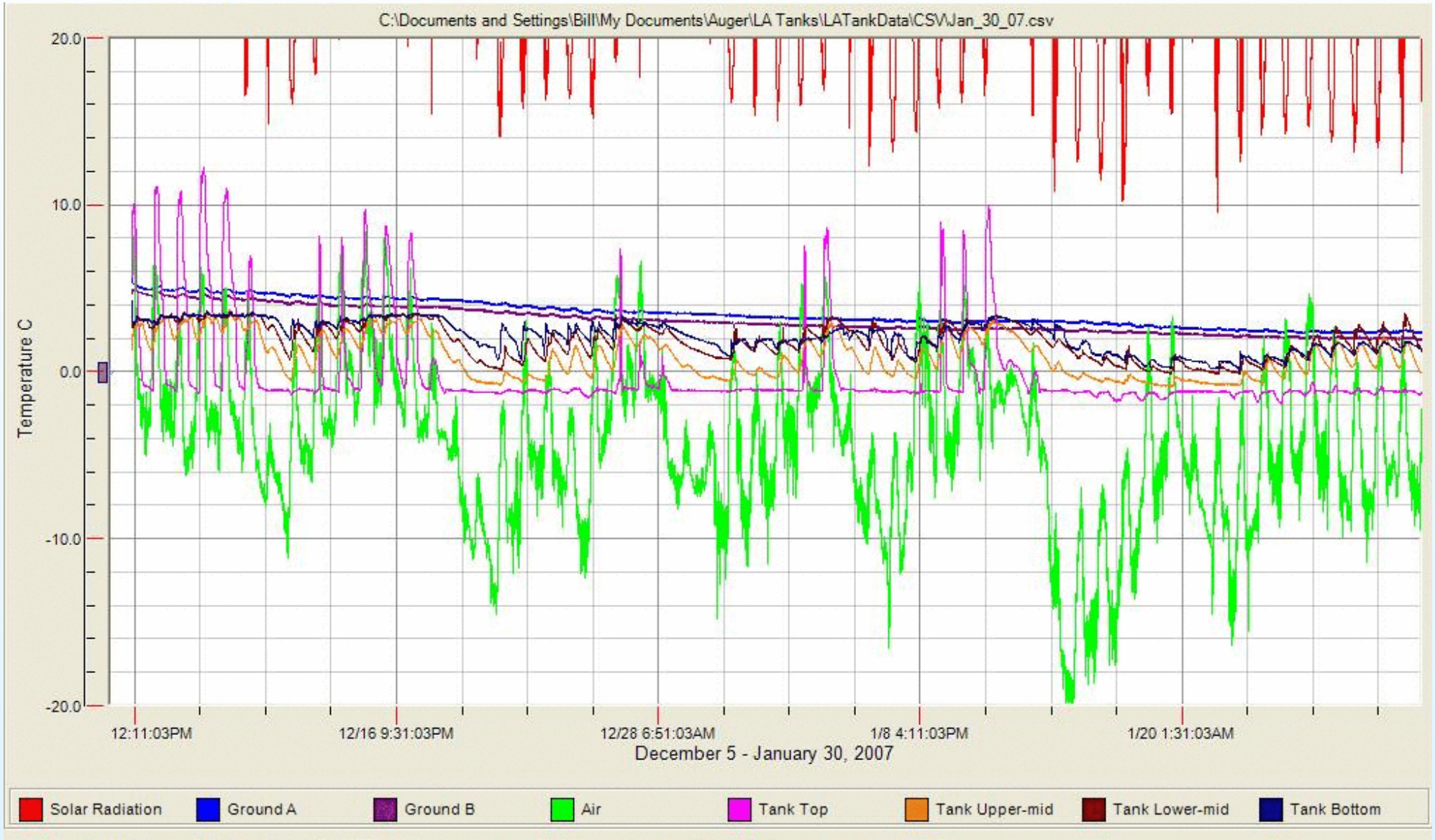
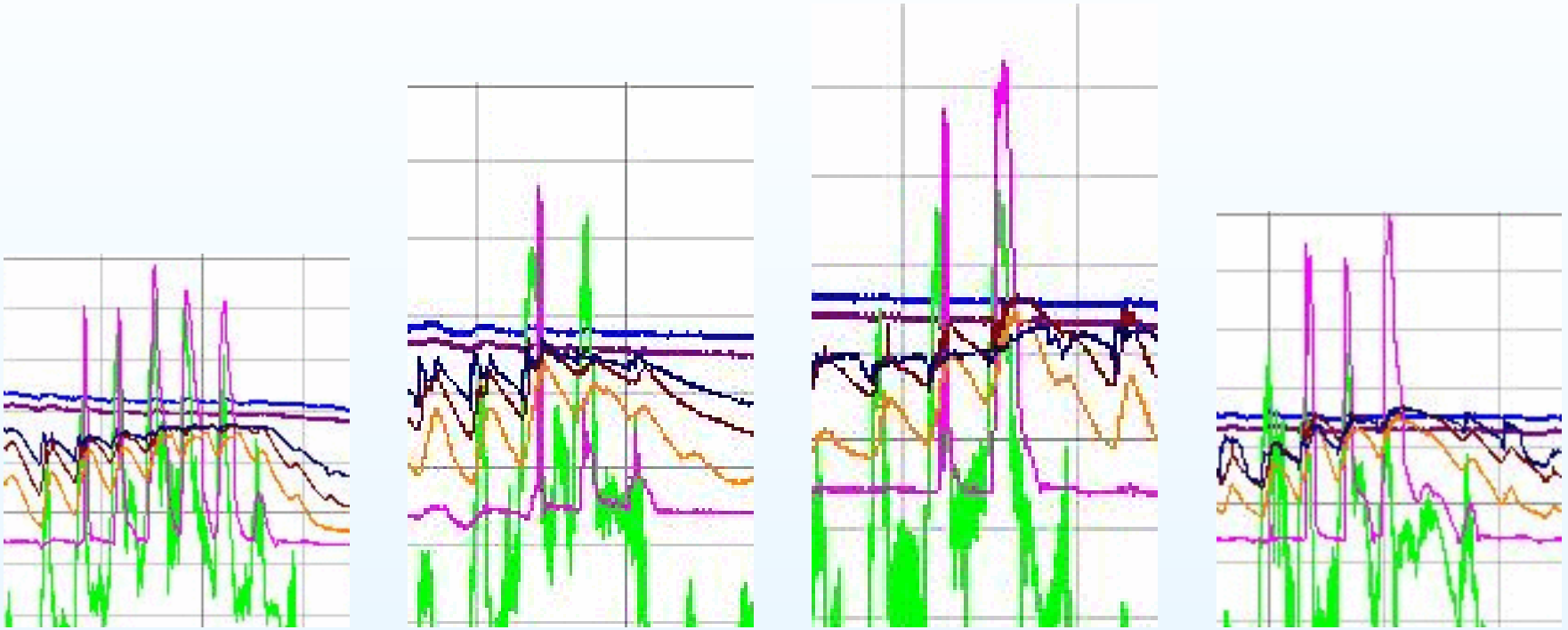
- Milagro experiences significant snow cover during the coldest months.
- Tanks in full sun have least snow (cover).
- Tanks in the shade (not shown) can be totally covered.

Then endless snows ... **until late Jan 2007**



Tank temperature ... **January 2007 details**



- **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

Tank temperature ... **January 2007 details**

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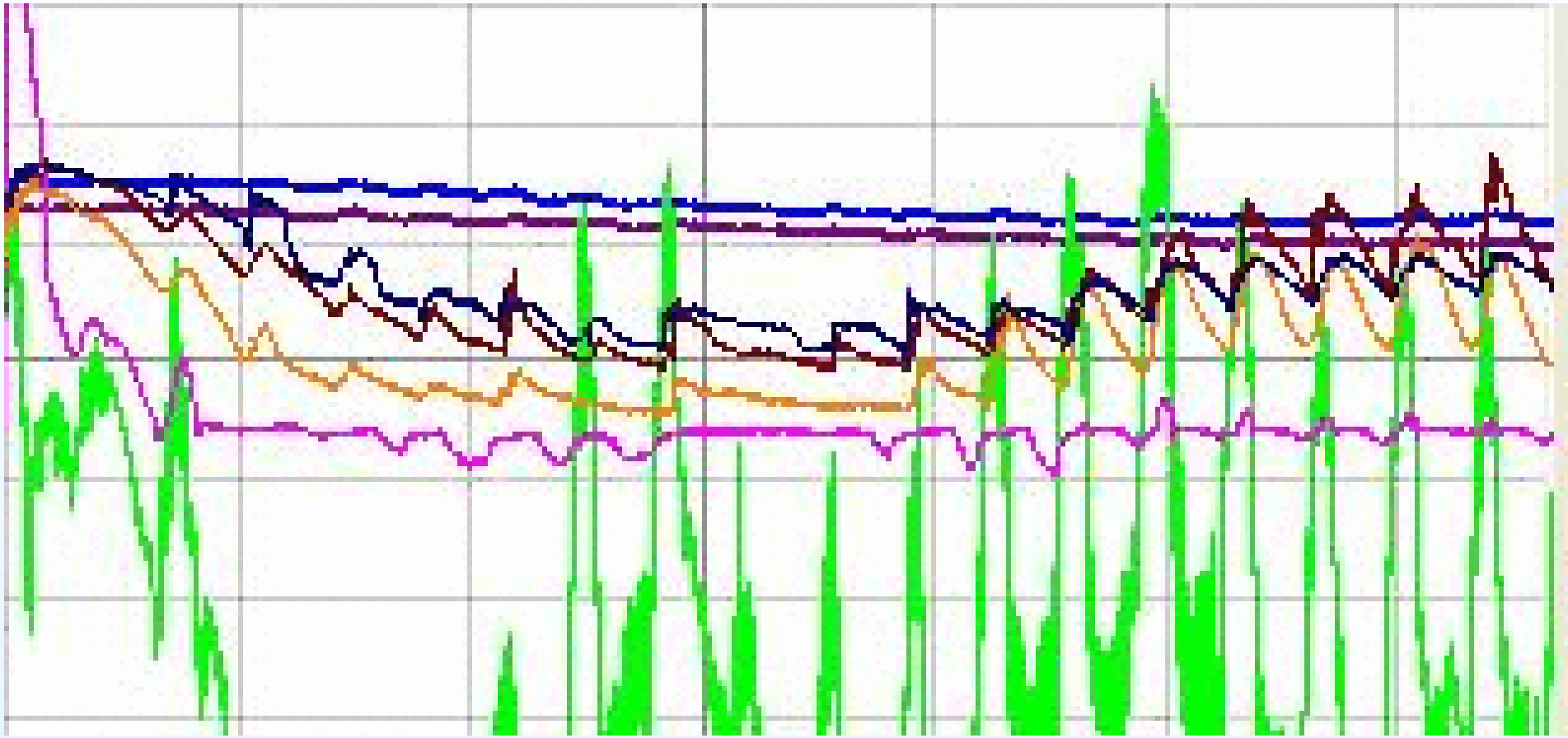
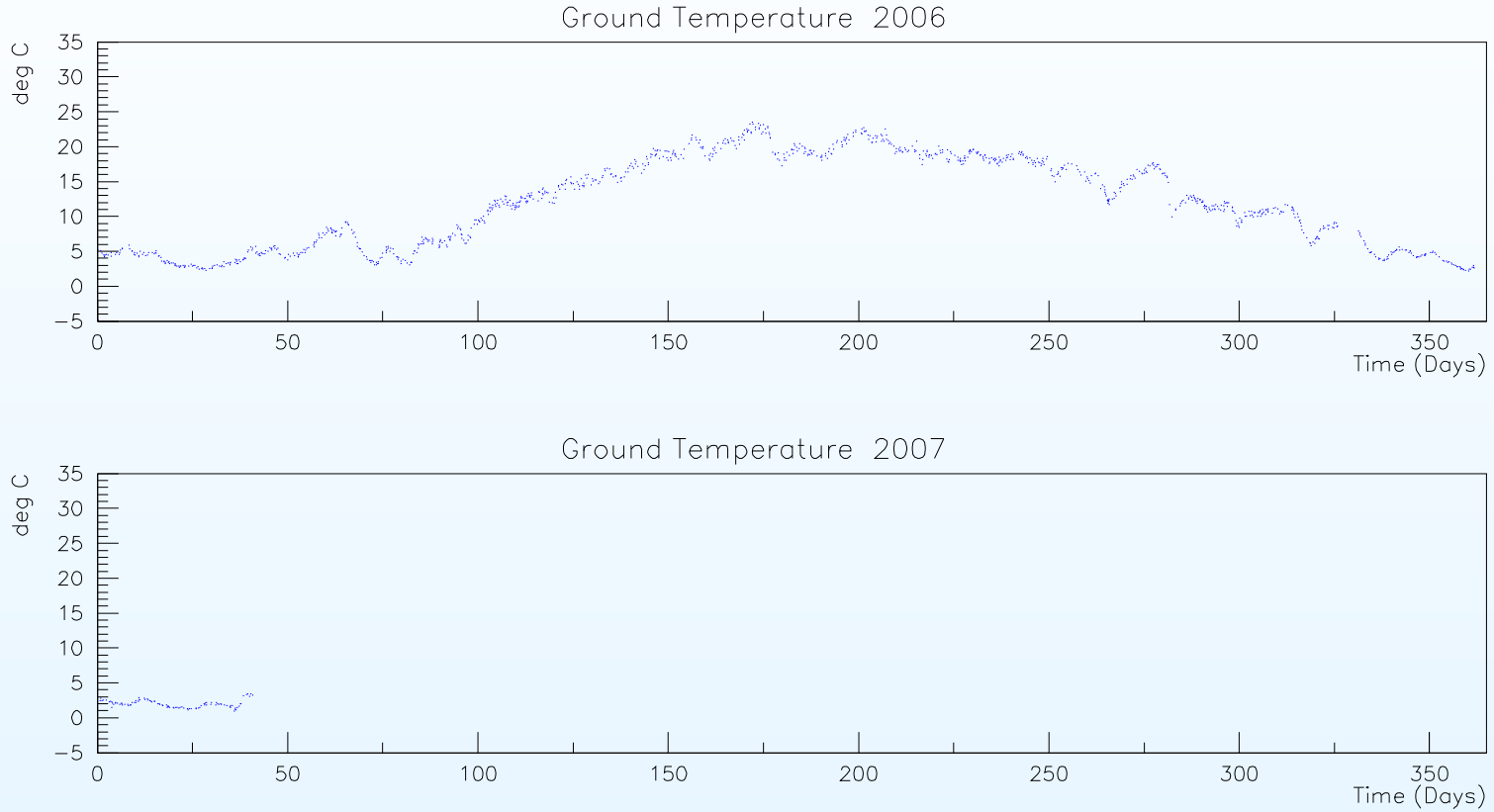


- Only **one** period of sustained freezing of the tank surface (**violet**)
- Middle of the tank (**orange**) close to 0° but probably above freezing
- **Ground temperatures remain above freezing** ($\sim 3^\circ$C)

Milagro ground temperature ... **agree with our data!**



- Milagro temperature sensor ~ 12 inches below the surface ... **not under a tank**
- Temperature record for 2006 **top**, and 2007 **bottom**
- **Ground temperatures remain above freezing: possibly a consequence of *typical* snow cover at Milagro during the coldest months.**

My own ... **impressions!**

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- We observe large temperature variations in the tank ... especially near the top surface. Of these freezing:thawing is probably the most damaging to components in the tank. **Insulation of Auger North tanks should reduce these variations substantially!**
- The ground under the tanks remains *warm* ... and slowly varying in time (*e.g.* through Jan 30, 2007 the ground was warmer than the water!) **This, AND the** *typical* **snow cover at Milagro during the coldest months, may explain why: "***the Milagro tanks are never close to freezing solid!***"**
- Future plans: add insulation to Milagro outrigger tank in *steps*.
- Do we want to do some ground temperature studies in Lamar?