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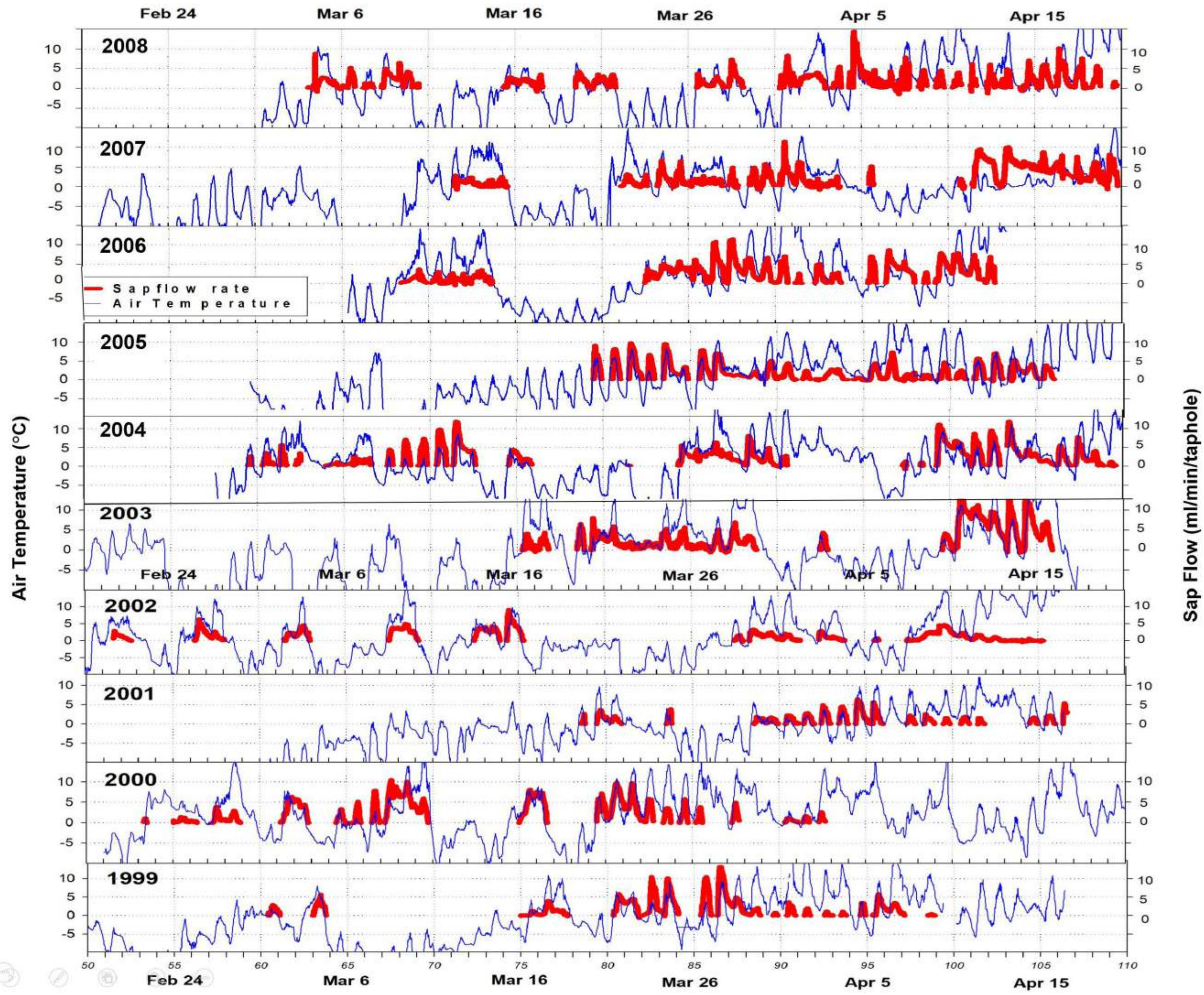
News from the University of Vermont Proctor Maple Research Center



Characterizing maple sap flows

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Individual sap flow events are highly variable and dynamic, ranging from slow, weeping flows that last for days to short bursts of high flow that last for only a few hours. Literature on the process of sap flow identifies several key facts: flow rates tend to decrease over time barring the onset of freezing temperatures, the greatest rates of sap uptake and flow are found when temperatures fluctuate below and above freezing, but flow rates can vary as the temperature changes even without freezing (Tyree 1983).

While we generally think about air temperature, canopy branch temperature is the variable most closely correlated with sap flow (Marvin and Erickson 1956). Each sap flow season is made up of a varying number of such flows, with each season playing out with its own unique nature.

Therefore characterizing (and measuring) sap flow is a challenge, but can be useful in designing sap collection systems to operate at peak sap flow in order to capture the maximum amount of sap during all types of events. Understanding the nature of sap flows also allows producers to build fail-safes and redundancy into the system to prevent losses of sap due to equipment problems.

Finally, understanding the wide range of sap flows permits a better assessment of sap storage and processing requirements.

Tim Wilmot of the University of Vermont Extension Maple Program collected data on sap flow from a group of trees at the Proctor Maple Research Center in Underhill, Vermont, for the ten-year period from 1999-2008.

These data were displayed on the internet in real-time for maple producers and were used by scientists to understand the relationships between temperature, stem pressure, and sap flow within and exudation from maple stems (Wilmot 2006, Stockie et al. 2022). However, we can also use the information gleaned to get a better understanding of the number and types of flows that occur within and across seasons.

Air temperature and sap flow rates collected by Wilmot from 1999-2008 are shown in Figure 1. The black lines represent temperature (in degrees Celsius along the left-axis) and periods of sap flow are depicted by the thick red line (milliliters/min per tap hole on the right-axis, 1 ml/min = 0.016 gph). It doesn't take long to recognize that seasons are quite different. Some seasons (example 2001, 2003) are quite short while others are very long and drawn-out (example 2002).

Over this ten-year period, there were 5-18 sap runs per season, with an average of 11.9 discrete flow events per year. The distribution of the number of sap flows per season was relatively flat (Figure 2), meaning that the likelihood of a low, intermediate, or high number of runs per year is roughly equal.

Duration of sap flows is depicted in Figure 2. Individual runs were characterized as either short (<24 hrs) or extended (>24 hrs). Sap runs (gravity) lasting longer than 24 hrs accounted for 62% of the total number of flows over the 10 yr period. Short runs of less than 24 hrs made up 38% of the total flows.

There was a moderate negative relationship (r^2=0.45) between the number of runs in a season and the duration of runs. Seasons with fewer sap flow periods tended to have a higher proportion of longer duration runs and seasons that had more flow periods tended to have a more equal distribution of short and extended sap flow durations. This is most likely due to a low number of freeze periods resulting in tree recharge in seasons with predominantly long runs.

Sap flow rate from trees is highly variable.

In general, flow rates are highest early in the flow period if the tree thaw rate is adequate. In some instances, thawing occurs very slowly so that a high sap flow rate occurs later in a run. Over 50% of the sap runs from tapholes under gravity collection tend to be slow, with peak flow rates remaining under 0.08 gph from each taphole (Figure 2).

Just under 40% of sap runs have moderate flow rates from 0.08-0.16 gph per tap, while only 10.1% of sap runs have flow rates exceeding 0.16 gph. Peak flow rates from tapholes under gravity only rarely reach 0.2 gph or more, with the maximum observed sap flow rate from gravity tapholes being just slightly above that level.

These data were collected under gravity conditions. While it is probable that there are some differences in flow characteristics between gravity and vacuum collection, the number of flow periods between the two methods are likely quite similar. Vacuum can undeniably induce sap to flow under conditions that are too marginal for gravity flow, and undoubtedly lengthens the duration of sap flows during extended thaw periods.

One key difference in flow characteristics between gravity and vacuum flow is in peak sap flow rates. Under vacuum, sap flow from tapholes can reach 0.4 gph or more per tap due to the higher driving force (the differential in pressure from the inside of the tree to the inside of the tubing system under vacuum).

Vacuum can also pull sap further vertically and horizontally in the stem -- in essence drawing from a larger sap reservoir within the tree. During extended thaws with tapholes under high vacuum, sap can be pulled upward from areas well below the taphole, and can even induce water flow from the soil into the roots, up the stem and out of the taphole, explaining why sap sugar concentration decreases under such conditions.

Understanding sap flow rates is important because it helps in the design of collection systems that are adequate to deal with anticipated sap volumes within a period of time. Recognizing the amount of sap that can fill a bucket between collection periods helps to avoid overflows.

Knowing sap flow rates through tubing systems is critical in designing and building lateral lines and mainlines that will capture peak flows while maintaining high vacuum (by removing air from the system) to drive the flows to as high a level as possible.

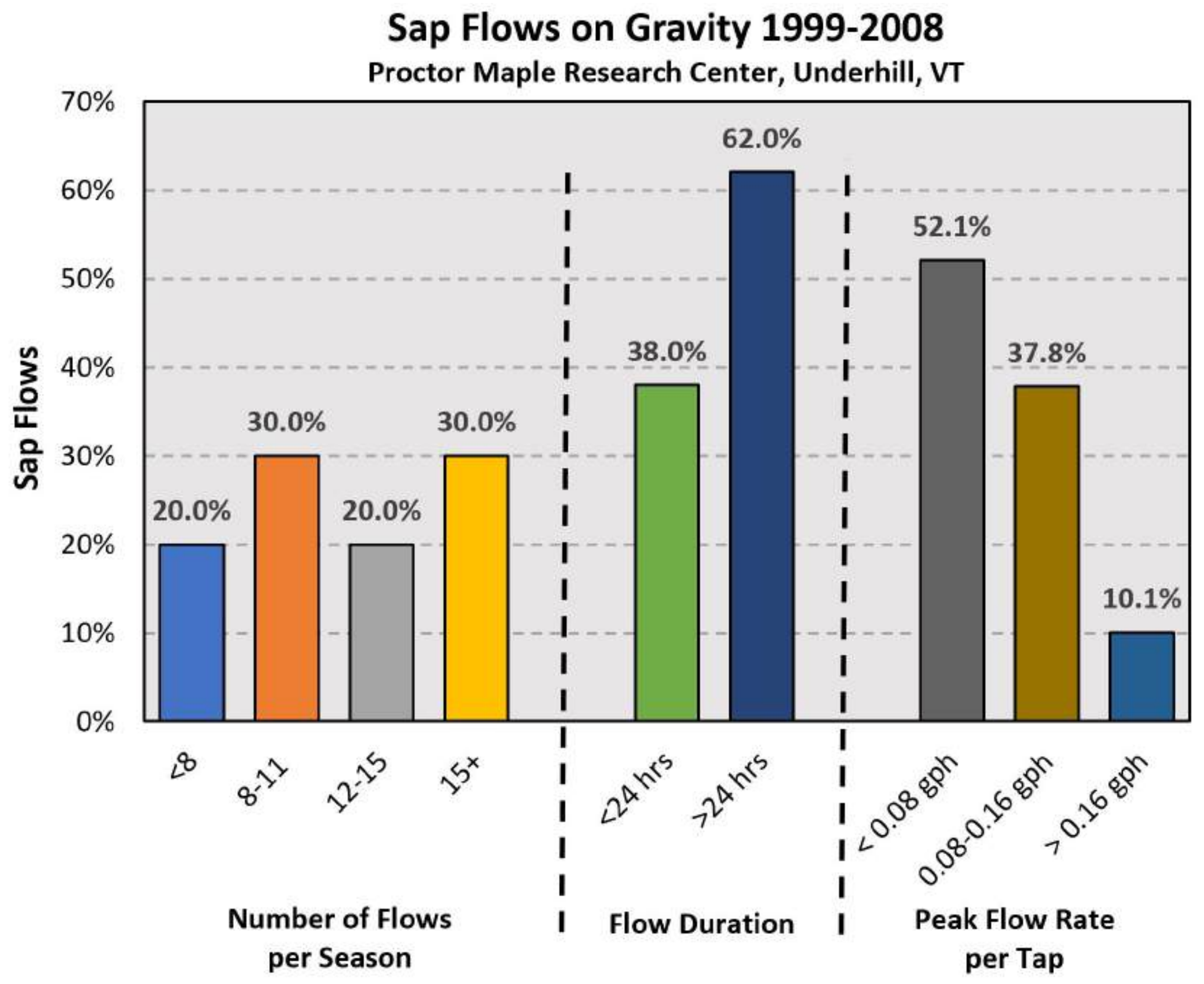
Also, of great importance is recognizing how important each sap run is in terms of its contribution to the season-long yield. In years where only five or six sap runs occur, missing some or all of one run could mean losing 15-20% of the total yield whereas in years with many sap runs missing one or two flow events might result in only a 4-5% loss.

This is all the more reason having tubing and vacuum systems installed and operated properly avoids significant freeze-ups in the lines.

Unfortunately, at present we are unable to parse out the total volumes of flow associated with each type of sap run (long vs short duration or low/moderate/high flow rates) as described above.

However, as with the other variables, the amount of sap collected can vary tremendously from sap run to sap run, with some flow periods resulting in sap amounts barely worth collecting and some flows resulting in yields that are surprisingly high. Flows of 2.5 gal per tap within a 24-hr period (on vacuum) are not unheard of during occasional runs.

These are generally times to celebrate – that is as long as adequate sap storage was available and you don't walk into a sugarhouse with the sap running over the top of the tank and spilling down the drain.



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Literature Cited:

Marvin, J.W. and Erickson, R.O., 1956 A Statistical Evaluation of Some of the Factors Responsible for the Flow of Sap from the Sugar Maple. Plant Physiology 31: 57-61

Tyree, M.T. 1983 Maple Sap Uptake, Exudation and Pressure Changes Correlated with Freezing Exotherms and Thawing Endotherms. Plant Physiology 73: 277-285

Stockie, J.M., van den Berg, A.K., Perkins, T.D., Wilmot, T.R. and Isselhardt, M.L. 2022 Exudation Pressure in Maple Trees: Comparing Simulations with Experiments. Maple Syrup Digest 61(2): 9-17.

Wilmot, T.R. 2006. Temperatures in the Sugarbush. Maple Syrup Digest 18(A)2: 20-23.