

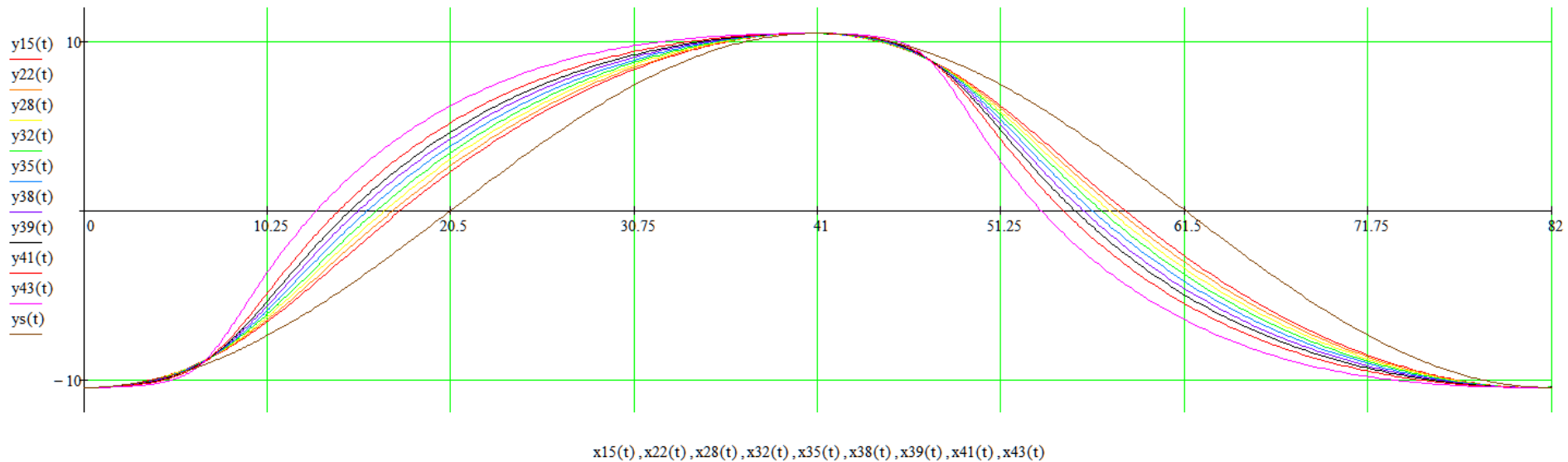
Possible & Impossible Lines

The paths, speeds, and forces of
three different ski strategies

the next step

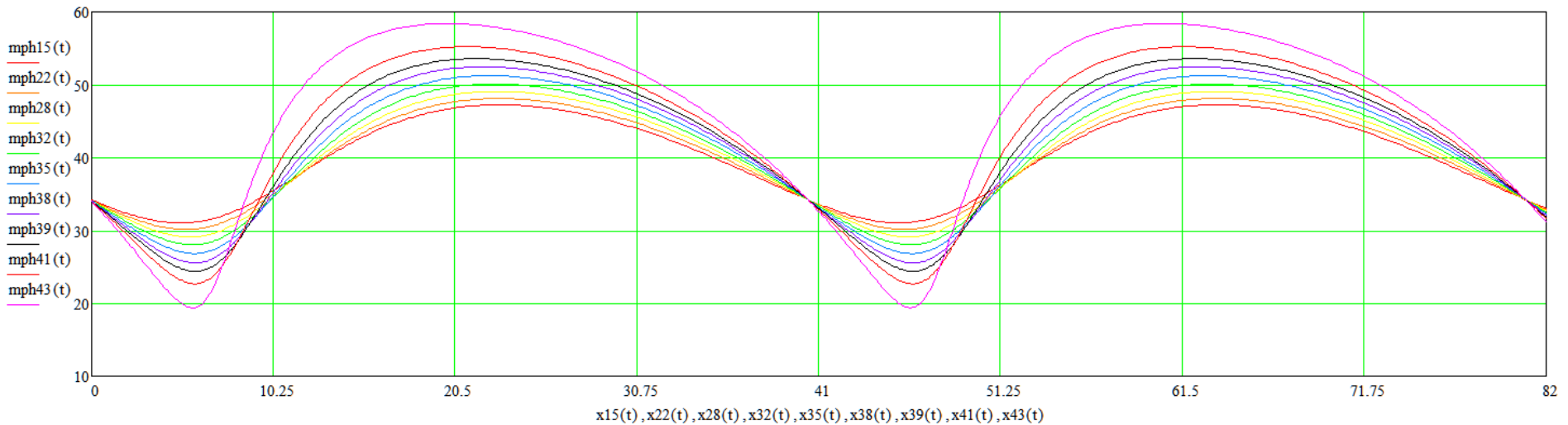
- in 2006 I used physics and math to analyze measured data from pro skiers
 - the results were impossible to argue with, being measured from high quality video taken from the boat, but as the strategies I proposed for skiing the way the pro's ski was very counter intuitive and contrary to accepted dogma, most skiers rejected them. Some of these strategies had been proposed earlier by Schnitz & others, but they too had been rejected by most.
 - over the years as people have thought more about it, I've seen ideas about paths and ski strategies move closer to the 'efficient' path and strategy myself and others had proposed
- in 2009 Chris Rossi wrote about not trying to ski the 'impossible line', which is the line most skiers are trying to ski. The possible line the pro's ski through 41off is pretty close to my efficient path & strategy in many important ways. Although what Chris said and proposed was not new, he'd explained things so well it reshaped our intuition and debates began anew about 'efficiency' and what it was.
- I recently completed a purely theoretical analysis of skiing using differential calculus and Newton's laws of motion. By changing a few variables in my analysis I can create paths for any ski strategy, with 'wide-early' and 'efficient' being the two extremes. Then I can plot the path, the speed, and the forces involved. From that info you can learn a lot about what limits us to whatever line length we fail at. The good news is this theoretical data matches measured data very well – that's the acid test of whether a theory is correct/useful or not.
- the 'intuitive' ski strategy, and the one most people use skiing, is what I call 'wide-early'. It's also the 'impossible line' Chris was describing. It works great at 15 and 22off, and it becomes the basis of our 'intuition'. When we start having trouble at shortline, we rarely question that our intuition may be wrong. From the plots you'll see why skiers are bound to fail with that approach long before they get through 39off.
- Despite the progress Chris made debunking the 'wide-early' approach, the 'efficient' ski strategy is still too counter intuitive, and actually not that easy to ski, based on my experience
- After looking again at the way pros typically ski, I realized they ski closer to a 'combination' strategy, that takes the best from from wide-early and efficient strategies. On the next 9 pages I'll show the results for all three strategies, and mention a few positives & negatives.

max wide-early style: path



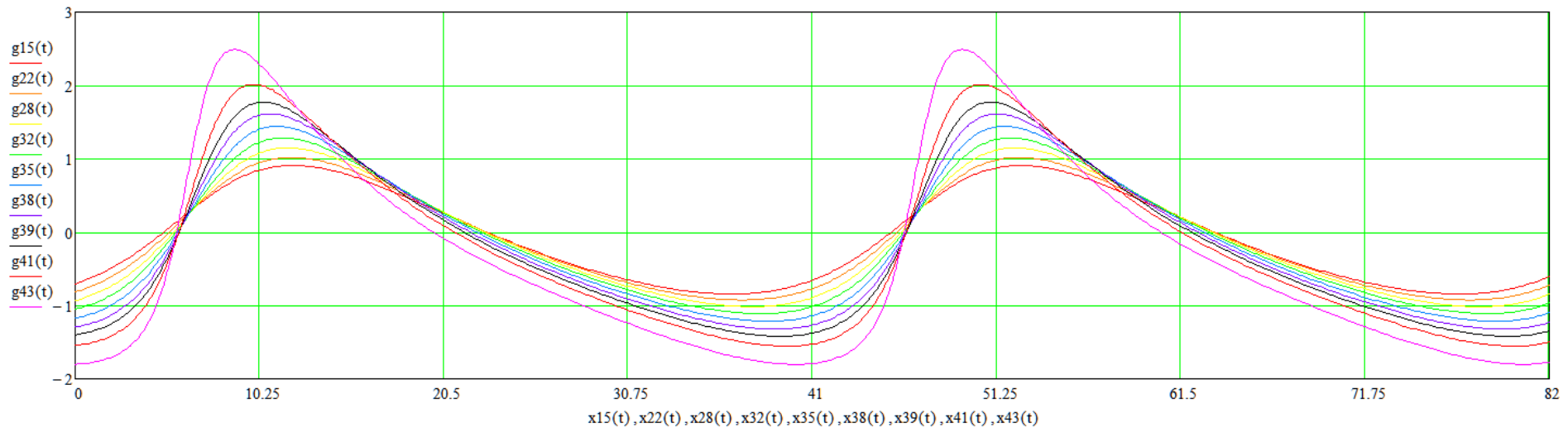
- brown line is path of sine wave, red line is 15off, orange 22off, etc., pink is 43off. The horizontal axis is the course position in meters.
- strategy: skier starts loading line 5 meters past buoy at 90% of max at all line lengths (5 meters is 0.26 seconds from buoy, about equal to skier reaction time)
- as line shortens and rope angle increases, skier gets big assist from the centerline directed force vector powered by the boat through the rope
 - overall acceleration increases
 - skier crosses centerline further upcourse as line shortens, because he's still loading at 90% and the assist from the boat helps him get even earlier

max wide-early style: speed



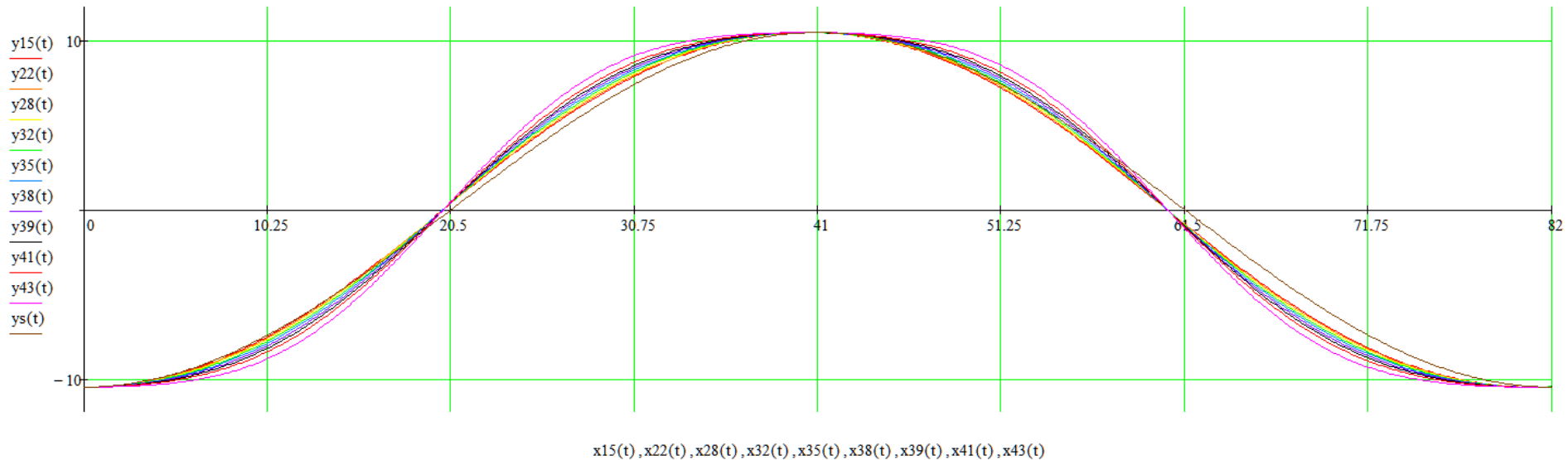
- this plot shows the speed plotted versus course position for each line length
- to keep the rope tight, the speed must continue to drop 5 meters or so past the buoy
 - to avoid rope going slack, the skier must not anticipate and consequently rush the turn
 - notice the skier continues to slow down during the 5 meter setup, more so as the line shortens
- as the skier loads the rope, speed increases rapidly, peaking near mid course

max wide-early style: G force



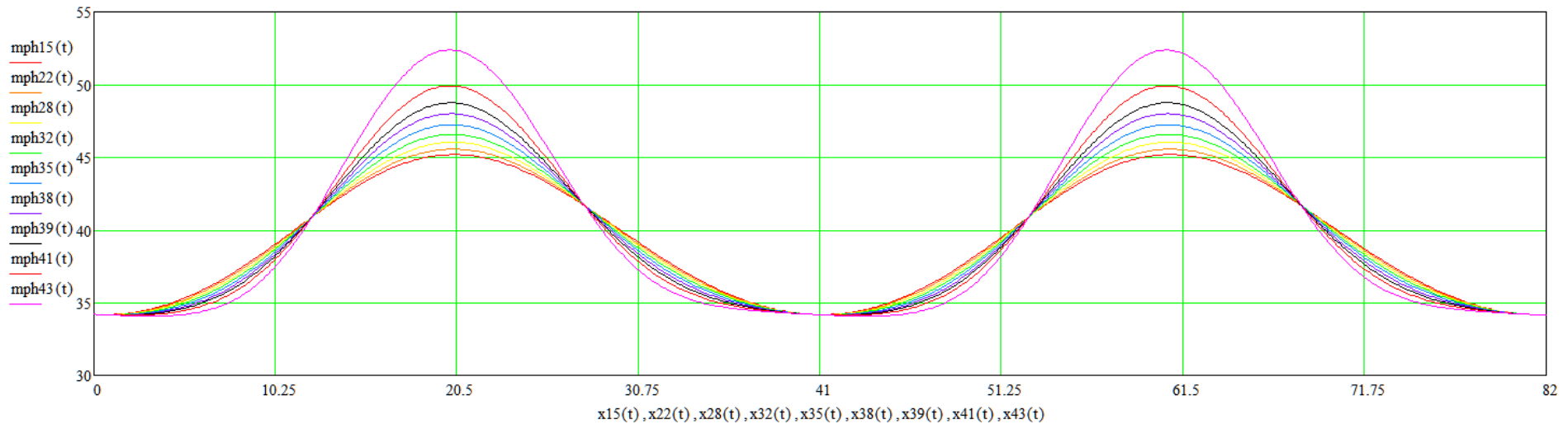
- This plots the G force associated with slowing down and speeding up
 - it does not include the G force of turning rapidly, called centrifugal force, trying to throw skier outward, which can be another 2.5G's with this style
 - managing all these forces becomes impossible sooner or later, and a fall or less aggressive path results
- at 15 & 22off where this strategy got embedded in our brain, the speed and G force extremes were quite manageable. So we rarely question our intuition when we run into problems at shortline – we just keep trying harder to ski the impossible line.
- beyond about 32 off these lines are impossible for most skiers to ski. We compromise from lack of strength and quickness, and take a path closer to the efficient style described next. But ask any 39off skier who has 'wide-early' still implanted in his brain how he ski's 39off, and he'll likely tell you 'wide and early'. Then when you take video of that skier and he see's he's crossing much further down course at 39 than he did at 28, he doesn't know what to say. (I see this a lot!)

efficient style: path



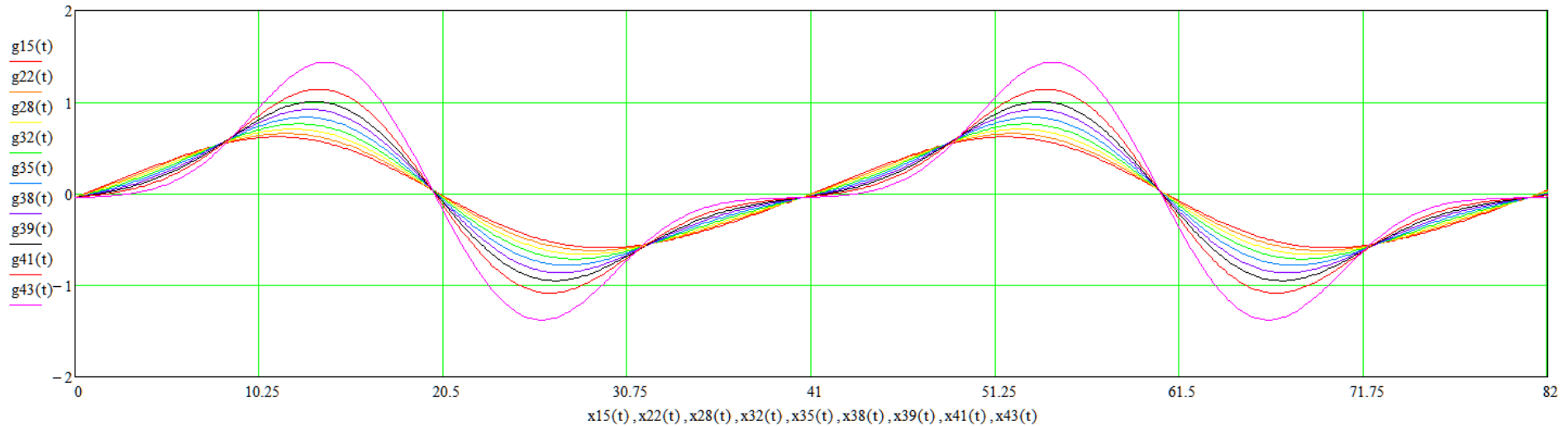
- brown line is path of sine wave, red line is 15off, orange 22off, etc., pink is 43off. The horizontal axis is the course position in meters. Skier crosses centerline midway between buoys.
- strategy:
 - skier starts loading line 5 meters past buoy at 35% of max at 15off (5 meters is 0.26 seconds from buoy, about equal to skier reaction time)
 - as line shortens and rope angle increases, skier gets big assist from the centerline directed force vector powered by the boat through the rope
 - skier backs off and supplies less of the force (down to 20% at 38off), letting boat do more work
 - skier concentrates on path and form

efficient style: speed



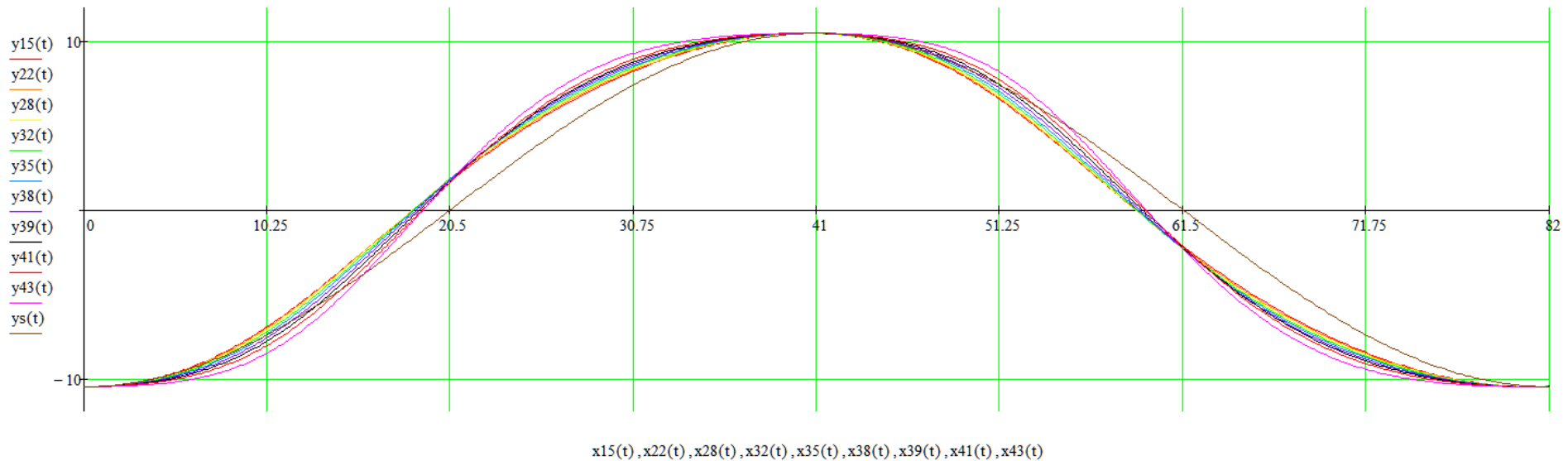
- this plot shows the speed plotted versus course position for each line length
- keeping rope tight is not a problem, as speed never drops below boat speed
- max speeds are 4-5mph slower than in wide-early case
- speed increase and decrease versus course position is very symmetrical at every line length, making it easier to adapt to this constant rhythm

efficient style: G force



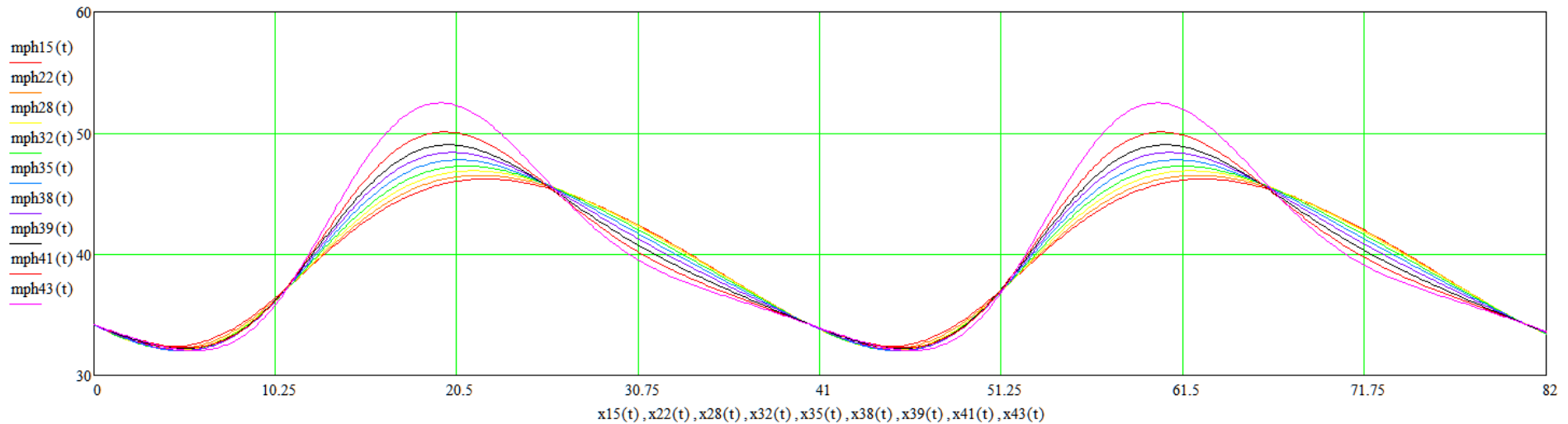
- This plots the G force associated with slowing down and speeding up
 - it does not include the G force of turning rapidly, called centrifugal force, trying to throw skier outward, which can be another 2G's with this style
 - these deceleration-acceleration levels are much lower than for wide-early style
 - max G force occurs just before 1st wake, min G force occurs just after 2nd wake
 - no deceleration-acceleration to worry about around buoy when the centrifugal force is max
 - the consequence is a smoother pass – if you do get in trouble when you're loading at only 25% of max, you have plenty of reserve strength to use in that event. In the wide-early style your reserve is being earlier, but you have only 10% reserve strength if something goes wrong.
- the efficient path is a possible path – it just takes a lot of practice to overcome bad habits, faulty intuition, and develop new muscle memory. Still, the forces on this path are considerable, and not every skier has the necessary athleticism to make it to the pro level, but every skier should be able to make considerable improvement using it.

combined style: path



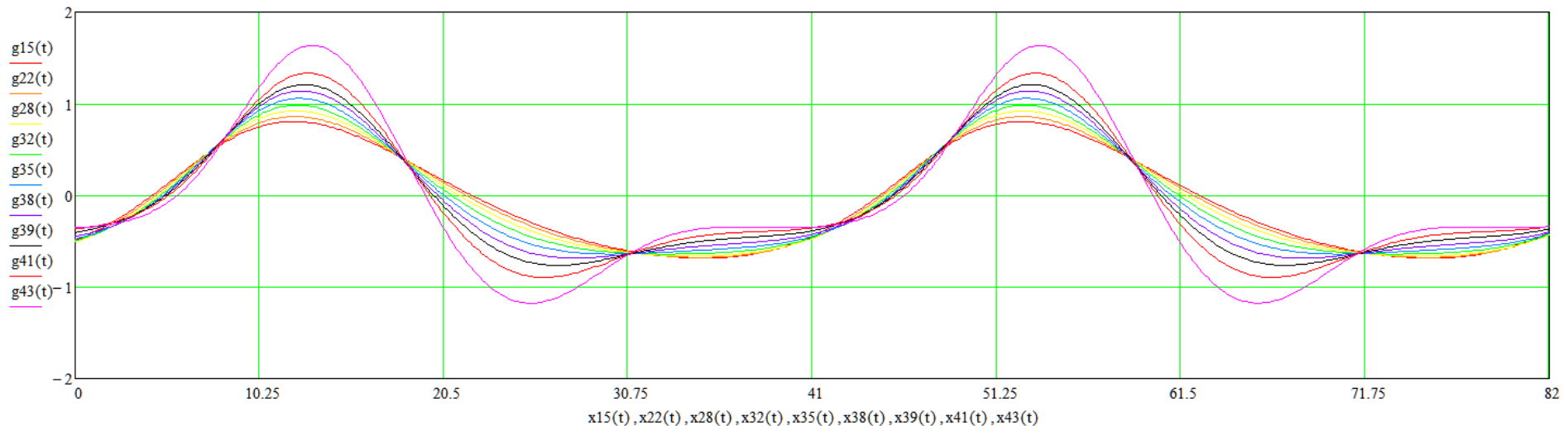
- brown line is path of sine wave, red line is 15off, orange 22off, etc., pink is 43off. The horizontal axis is the course position in meters. Skier crosses about 2 meters upcourse from center.
- strategy:
 - skier starts loading line 5 meters past buoy at **70% of max at 15 off** (5 meters is 0.26 seconds from buoy, about equal to skier reaction time) Cross centerline about 2m upcourse
 - **as line shortens** and rope angle increases, skier gets big assist from the centerline directed force vector powered by the boat through the rope
 - skier backs off and supplies less of the force (50% at 38off, 35% at 43off), letting boat do more work
 - skier concentrates on path and form

combined style: speed



- this plot shows the speed plotted versus course position for each line length
- keeping rope tight is not a problem, as speed never drops below boat speed
- max speeds are slower than in wide-early case
- speed increase and decrease versus course position is less symmetrical than the efficient path, but not as severe and hard to manage as the wide-early path

combined style: G force



- This plots the G force associated with slowing down and speeding up
 - it does not include the G force of turning rapidly, called centrifugal force, trying to throw skier outward, which can be another 2G's with this style
 - these deceleration-acceleration levels are much lower than for wide-early style
 - max G force occurs just before 1st wake, min G force occurs just after 2nd wake
 - no deceleration-acceleration to worry about around buoy when the centrifugal force is max
 - the consequence is a smoother pass – if you do get in trouble when you're loading at only 75% at 15off and 50% at 38off, you have plenty of reserve strength to use in that event. You are also a little upcourse, so that helps too.
- this combined path is relatively efficient and doesn't entirely go against our intuition. This path is probably closer to paths I've seen pro's ski than the efficient path, so this is a possible line. It should be easier to adapt to than 'efficient', and take us further than WE.