Modeling the Spread of the Gospel

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In Matthew 13, Jesus is recorded sharing a series of parables about His coming Kingdom of Heaven, one of which reads as follows:

"The kingdom of heaven is like leaven, which a woman took and hid in three measures of meal till it was all leavened." [NKJV]

Unlike two of the other parables in Matthew 13, there is no recorded interpretation from Jesus explaining this parable, but one common interpretation is that the leaven is the message of the gospel, working its way throughout all of humanity (with the three measures possibly representing the descendants of the three sons of Noah). This interpretation seems consistent with another saying of Jesus recorded later in Matthew (24:14), where He is quoted as saying:

"And this gospel of the kingdom will be preached in all the world as a witness to all the nations, and then the end will come." [NKJV]

We are taught elsewhere by Paul (Romans 10:14) <u>how</u> the gospel is spread throughout the world, which is quite obviously by a growing number of people hearing it:

How then shall they call on Him in whom they have not believed? And how shall they believe in Him of whom they have not heard? And how shall they hear without a preacher? [NKJV]

Now the actual means by which a person might hear the gospel no longer actually requires that the hearer be in the physical presence of a preacher. "Hearing" can now take place via a vast number of media not available in Paul's day, including at least the following: books, radio, TV, and an array of new mechanisms now available via the Internet. Not every person on the planet has the same access to the message of the gospel (such as by limitations of translations into a local language or technology), but it is fair to say that we are fast approaching the day prophesied by Jesus in Matthew 24: the gospel is indeed very soon going to have been preached throughout all the world.

Of course, merely hearing (or reading or viewing) the gospel preached does not automatically result in conversion to Christianity. Earlier in Matthew 13, Jesus explained this in the Parable of the Sower, which (as interpreted by Jesus Himself) makes it clear that there are at least four different kinds of human hearts across humanity, each having varying degrees of receptivity to the gospel. Only those having the highest degree of receptivity become fruitful, some yielding "a hundredfold, some sixty, some thirty."

But how quickly has the gospel actually spread throughout humanity and in what numbers? As a small summer project, I have set out to take a new quantitative approach to this question. As my primary model, I'm employing the <u>same CDE-k equation</u> that I began applying to the spread of COVID-19 back in the spring of 2020. That equation is one that I borrowed from a paper I wrote back in my twenties,¹ when I could still solve partial differential equations! Although the topic of that paper was using novel solutions to the Convective Dispersion Equation (CDE) to better describe the movement of chemicals through soil, it turns out that completely analogous physical processes are involved in the "diffusion" of COVID-19

¹ DI Gustafson (1988). Modeling root zone dispersion, Chem. Eng. Comm., 73:77-94.

through human communities. As shown in **Figure 1** (from the <u>May 2020 blog</u>, as are **2** and **3**) such an equation gave a compelling fit to observed mortality data for Italy, which was struck by COVID-19 just a bit earlier than the US. Here is the relevant equation (simplified from Equation 11 in the 1988 paper):

$$D_i = \frac{\delta \exp[-\{(t_m/t_i) - 1\}^2/2k]}{(t_i/t_m)}$$

where D_i is the number of deaths on day t_i (the number of days since first death); k is a fitted constant (~0.25-0.5) proportional to the rate at which dispersion increases; t_m is a fitted constant (37 days) proportional to the time from first death to peak deaths: $t_m = 2k t_{peak}/(\text{sqrt}[1+4k]-1)$; and δ is a fitted constant proportional to mortality.

The parameter k was initially fit to the observed Italian data using a transformation method given in the 1988 paper (see **Figure 2**). The fact that the data are linear when transformed in this manner (lower right of **Figure 2**) is strong evidence that this equation is giving a good fit to the data. I found that the data far before and far after the peak had to be removed to preserve linearity, and so when reconstructing the overall curve shown in **Figure 1**, the model was built by assuming Italy was infected by four waves offset by 5 days each. Based on the still slowing decline in Italy revealed in the weekly averages, the model was reparameterized on April 25, resulting in a value for k of 0.25. Later analyses of the US dataset (see **Figure 3**) resulted in a value of 0.5 for k.

At this point, I pause to interject that I am absolutely **NOT** saying the gospel is a "virus that has infected humanity." Rather, I am saying there is reason to believe that the pattern of its transmission through the world would be similar, albeit at a **MUCH** slower rate. As for the analogies with the model that I found describing the dispersion of chemicals in surface soils and through rivers at a wide varieties of spatial scales (millimeters to thousands of kilometers), I would simply note that people have tended to settle near rivers and continue to be distributed across the world in a non-uniform pattern largely determined by natural geographic (fractal-like) features – the same natural features that circumscribe the dispersion of pollutants.

With that digression now concluded, let us proceed. I assumed a value of 0.5 for k in this new "Gospel Model," when attempting to fit data on the reported size of the early church (through the year 350). At that time the entire world population is estimated to have been a little less than 200,000,000 (see **Figure 4**), and only a relatively small fraction of the known world (mostly those in the Eastern Mediterranean) would have had any chance of "exposure." As noted earlier, the time-scales are **FAR** slower than with COVID-19, but the pattern is assumed to be described by the same equation, simply with different parameters. In order to fit the entire period of record (fast approaching 2000 years), I assumed a series of waves of exposure to increasing (eventually exponentially) target populations as we enter the modern era (see **Table 1**), resulting in the predictions for the full period of Church history shown in **Figure 5**.

Year (CE)	Target Population
30	2,000,000
200	40,000,000
500	40,000,000
800	40,000,000
1100	40,000,000
1400	80,000,000
1500	80,000,000
1600	160,000,000
1700	320,000,000
1800	640,000,000
1900	1,280,000,000

Table 1. Assumed Target Populations for Successive Introductions of the Gospel

Of course, there are important differences between modeling COVID-19 and modeling the spread of the gospel. Instead of estimating the number of deaths, the **CDE-k** equation now gives the number of conversions. In order to calculate the number of living Christians in any given year, we must assume how long a Christian lives after being converted. For this initial version of the model I simply assumed 40 years (likely a low figure). It would be better to assume some type of a distribution or get a better number from the literature, but the net result is that the current model probably over-states the number of conversions. It gives about 6.4B total conversions, or 6% of all people who have ever lived, accepting the Wikipedia estimate of 117B humans having ever lived. But the biggest difference with this modeling exercise is that the size of the total population potentially exposed is increasing at different rates in different countries, especially during the modern era. The assumptions stated in **Table 1** attempt to account for this, but this is an important complication in applying the **CDE-k** model that I've not yet attempted to address.

A few other comments. I've accepted the values given by Stark for the number of early Christians through the year 350, as well as the more recent reports from the <u>Pew Research Center</u> for the years 1910 and 2010. I personally believe the Pew Center numbers are **VERY** exaggerated (possibly by as much as 5-10X), but I am simply plotting from both sources just as reported, and thereby showing that this relatively simply model is able to replicate those reported values. Based on first-hand experience (from living in various parts of the US and from having visited Europe many times), I believe the actual proportion of "Bible-believing Christians" is **FAR** less than reported by Pew, especially in Europe. If we had data on "authentic believers" we could adjust and re-fit the model accordingly, though I doubt any good data will ever become available.

I haven't yet decided whether to revisit this topic, but it was a nice summer diversion and I thought some folks might find it interesting. If so, I'd be happy to enter into a dialogue about it. Just send me a <u>note</u>!

Disclaimer: This is only a model. As the saying goes: "All models are wrong - some are useful." So we know this model is wrong, but we don't yet know if it is useful. Perhaps!



Figure 1. Application of the **CDE-k** model to observed COVID-19 mortality data reported in Italy through the end of May 2020.



Figure 2. Source document (Gustafson 1988) for the **CDE-k** model. I later reported (in <u>Gustafson et al., 2004</u>) that the exact same equation accurately describes dispersion of pollutants in large-scale watersheds, likely as a consequence of fractal behavior.



Figure 3. Application of the **CDE-k** model (dark blue) and the March 23 Wuhan model (light blue) to the US, overlaid by Worldometer data (gray bars, black boxes), as well as May 12 data (solid red line) and projections (red dashed line and shading) from IHME.





Figure 5. Application of the **CDE-k** model to the entire history of the Church.