# There’s No Place Like Home, but Can You Find It? How I Use Magnetoreceptive Feelings and Symptoms to Orient Myself.

By

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# Abstract

Starting in September 2007, I conducted a research project to determine if I have magnetoreceptive abilities, and, if so, to discover their nature. Beginning with the observation that I felt differently in different places, I did a systematic study of how and where I felt differently, and how various factors affected how I felt. The following summarizes my discoveries, broken down by topics:

Orientational Abilities

My orientational abilities can be described as a "limited functionality GPS," or LFGPS. This LFGPS allows me to determine if I am north or south of "magnetic home." Magnetic home has been observed in Utah and North Carolina and extends northwest to southeast in the continental United States, at a ratio of 5.69 degrees longitude east / degree latitude south (on Jan 1, 2008). North of home I feel negative symptoms (i.e. depressed mood), south of home I feel positive symptoms (i.e. tics and involuntary body movements), and at home I have reduced or no symptoms. While I can sense if I'm north or south of home, I can't reliably determine *how far* north or south I am.

I term the region north of home the "Negative Zone," south of home the "Positive Zone," and home the "Happy Zone." I can reliably distinguish the transition between the Negative Zone and Happy Zone (the N-H transition) based on an intense psychological and motor reaction, which I term "the peak." The peak is only about a meter north-south distance. I have a similar

intense reaction at the transition between the Happy Zone and the Positive Zone (the H-P transition).

The LFGPS works best (i.e. I have a clear indication of which zone I'm in) when I look directly at the early afternoon sky (not the sun, but anywhere in the sky). I can experience the peak at night, but I can't distinguish between the different zones. My LFGPS becomes completely suppressed when I'm blindfolded—I can't feel the peak nor distinguish between the different zones.

The LFGPS doesn't allow me to distinguish if I'm east or west of home. I have, however, observed peak reactions at about 6.6 degrees longitude west of the city I grew up in as a child (New Providence, NJ), at about 13.0 degrees west of this city (= 2 * 6.5 degrees), and at about 38.6 degrees longitude west of this city (~ 6 * 6.4 degrees). This data has led me to hypothesize that my body divides Earth's 360 degrees of longitude into 56 Natural Time Zones (NTZ's) of 6.43 degrees longitude, or 25.7 minutes of solar time, with the Prime Meridian passing through New Providence. The east-west peak measurements come out slightly west of predicted, although there is a wide spread (mean error = 0.11 degrees longitude west, std dev = 0.11, n = 11).

While the east-west (NTZ) transitions seem to be relatively fixed in space, with a clear geographical relationship to the city I grew up in, the north-south (N-H and H-P) transitions are constantly in flux, and show no clear dependence to my childhood home, nor to any geomagnetic model parameters. I have, however, found that the north-south transitions vary in a predictable manner based on three factors: bed angle, circadian rhythm, and seasonal effects.

Bed Angle Effects

The N-H transition (peak) moves north or south each day a varying amount of distance that is dependent on the compass angle in which my bed is oriented, which I term “bed angle.” This phenomenon, known as bed angle drift (BAD), shows a more predictable relationship to bed angle in Utah than in North Carolina. In Utah, the relationship seems to be a quasi-tangent function, with a period of 22.5 degrees of bed angle, and with a peak-to-peak amplitude of about 1 degree latitude. In North Carolina, unlike Utah, BAD is always north when bed angle is close to 45 degrees, and can be up to 0.85 degrees latitude per day.

The Happy Zone Width (HZW), or the north-south distance between the N-H transition and the H-P transition, is a quasi-Gaussian function of bed angle, with a peak near a 45 degree angle. In Utah, HZW varies from 0.02 degrees latitude near the cardinal bed angles (N-S and E-W) to 0.85 degrees latitude near a 45 degree bed angle. In North Carolina, HZW varies from 0.02 degrees latitude to 1.64 degrees latitude.

The effects of BAD can be reset by switching from a bed angle near a cardinal bed angle to a bed angle near 45 degrees, or vice-versa. This bed angle reset (BAR) takes two days. After the first night at the new bed angle, my LFGPS abilities become suppressed, and I can’t tell if I’m north or south of home. After the second night at the new bed angle, my LFGPS abilities return. The location of the peak after the BAR shows a high correlation to future BAD. Regression analysis indicates that about 1/3 of future BAD is associated with peak BAR latitude.

Regression analysis of BAR peak latitude indicates that secular change is about 1.8 km / south per week in Utah. Secular change in North Carolina is too small to be determined via regression analysis.

Circadian Rhythm Effects

The peak shifts north if I'm phase advanced (relative to solar day) compared to reference, and shifts south if I'm phase delayed compared to reference. This shift is not continuous but is based on a fixed interval of circadian rhythm change, which is between 20 and 30 minutes. Evidence for this comes from peak observations after the change to and from daylights savings time, and after a change in bedtime. The change in peak latitude per shift is about 0.29 degrees latitude when bed angle is near a cardinal bed angle, and about 0.35 degrees latitude when bed angle is near a 45 degree angle.

Reference, or ideal circadian rhythm is determined by feelings. I feel much better at ideal circadian rhythm than when I'm phase delayed or phase advanced. I'm calmer, with fewer tics and less shaking.

Seasonal Effects

I observed seasonal effects in Wilmington, North Carolina (which is ~ 6.5 degrees latitude south of New Providence), but not in Salt Lake City, Utah (which is about the same latitude as New Providence). Seasonal effects show the following behavior:

1) For both the winter solstice and the summer solstice changes, the peak always shifts north before the solstice, then returns south after the solstice.
2) The first seasonal shift occurs when day length is approximately 25 minutes different from New Providence.
3) Each subsequent shift north occurs at approximately 5 minutes difference in day length.

I compensated for seasonal effects by adjusting my bedtime later, causing a circadian phase delay and peak shift south. There's evidence that the seasonal peak shift size is larger than the circadian rhythm shift size, although it's not clear from the data exactly how much larger it is.

## Need for Double-Blind Research

All my data is based, ultimately, on my subjective feelings and symptoms. Although I had few preconceived ideas about human magnetoreception when I began this project, and arrived at the above conclusions based on data, the lack of experimental blindness makes it impossible to rule out the placebo effect. For example, I almost always found the peak while driving alone to the location. Although at the beginning of the project I didn't know where to find it, by the end I usually could predict its location.

Although my LFGPS ceases to function when I'm blindfolded, thus eliminating one kind of test, there are other double-blind tests that can be done. For example, I can be driven around in a bus with a retractable sunroof and with all windows darkened or covered. If I'm allowed to look directly at the early afternoon sky through the sunroof, my LFGPS will function but I'll be blind to landscape details. Other tests, including lab tests, are possible. Any testing must be cognizant of the fact that my sleeping behavior needs to be experimentally controlled.

*So many animals are now known to possess a magnetic sense that I confidently believe the final search will be to find an animal that is magnetically 'blind'. Against such a background, it would be surprising if Man just happened to be that animal.*

*--Robin Baker*

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# Scientific Introduction

## Geomagnetism

### The Magnetic Vector

In everyday life, we're aware of the geomagnetic field by its effect on the magnetic compass. The typical compass has a needle that is free to rotate in the horizontal plane. The needle aligns itself with the horizontal component of the geomagnetic vector. The compass is polar, in the sense that it has separate north and south poles. If we walk in the north direction indicated by the compass, we walk toward the magnetic north pole. This magnetic north pole is not the same as true north. There's an error, known as *declination*, which varies at different locations and over long periods of time.

What most people aren't aware of is that the geomagnetic vector is three dimensional. It enters and leaves the earth at an angle to the horizontal. This angle is known as *inclination* (Fig. 1). Inclination varies from zero at the magnetic equator to 90 degrees at the poles. The variation as one moves north or south is reasonably regular across most of the Earth (Fig. 2), enough so that inclination can be thought of as the magnetic equivalent of latitude. Like declination, inclination changes slowly over time.

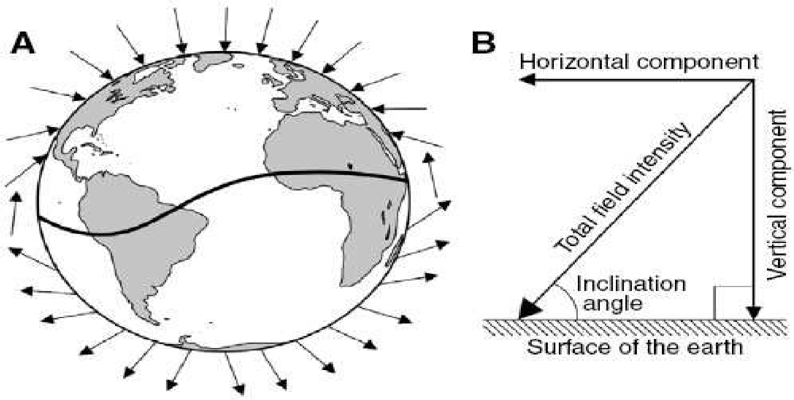


Fig. 1 (A). Representation of how the direction of the geomagnetic vector changes across different parts of the Earth. The vector goes into the Earth in the northern hemisphere, and out of the Earth in the southern hemisphere. The vector is parallel to the ground along the magnetic equator (represented by the curved line near the center of the Earth), and perpendicular at the magnetic poles. Note the gradual change from parallel to perpendicular as one increases in latitude.
(B) Diagram showing how the magnetic vector can be broken down into horizontal and vertical components. The inclination angle (Inc) is the angle between the magnetic vector and the ground. The Total Field Intensity (F) can be broken down into a Horizontal Component (H) and Vertical Component (Z). $H = F * \cos(Inc)$, $Z = F * \sin(Inc)$. Figure from Lohmann, Lohmann, & Putnam, 2007.

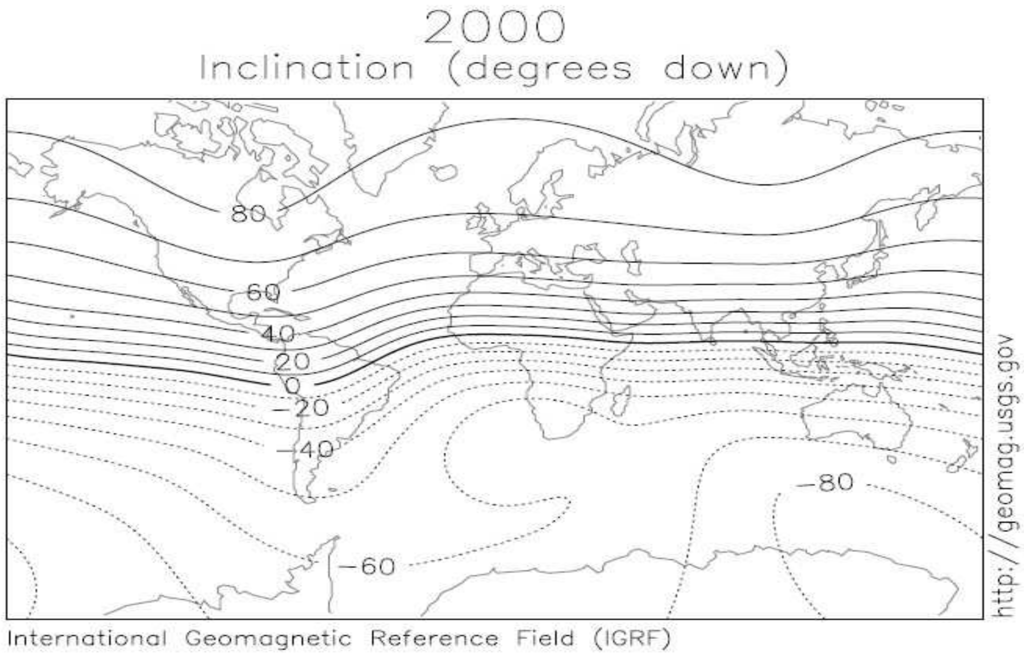


Fig 2. Map of lines of constant inclination across the world in 2000. Note the irregularities at 80 degrees north and 50-80 degrees south. Figure from IGRF Inclination Mercator Chart, 2000.

Diurnal and Secular Variation

The geomagnetic field changes over the course of the day. This change is known as *diurnal variation*. Both the intensity and angle of the vector fluctuate throughout the day, a phenomenon largely due to the Earth's rotation. Fig. 3 shows the change in Inclination (Inc) over the course of the day on 12/31/06 as recorded at the Boulder, Colorado Observatory. (All numerical dates in this paper use the American format mm/dd/yy.) Note the drop in mid-afternoon, and the subsequent rise in the early evening. The range of variation of Inc is approximately 0.03 degrees.

Say that one wanted to walk the equivalent of 0.03 degrees of inclination. Since Inc as a function of north-south distance in the western U.S. is about 0.0075 degrees / kilometer, the rise in inclination between 15:00 and 18:00 corresponds to walking north over 4 kilometers.

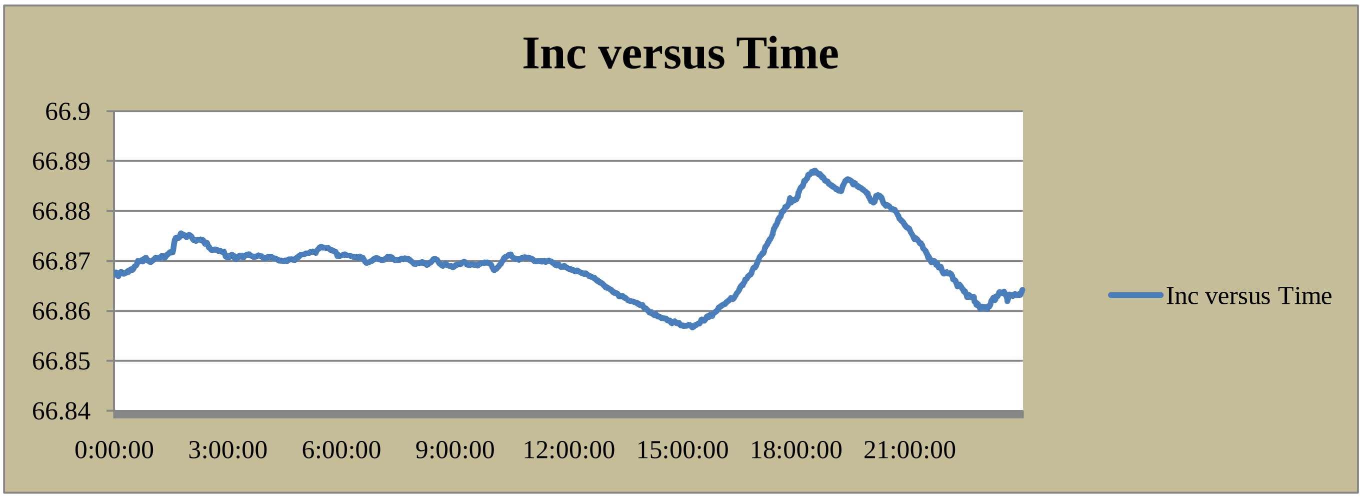


Fig. 3. Inclination versus Time at the Boulder Observatory on 12/31/06 (a quiet day—i.e. a day with very little solar/geomagnetic activity). Data from Intermagnet Definitive Data.

<u>Secular Variation</u>

From Fig. 3, one can see that at the end of the day inclination returns to a value close, but not exactly the same, as the beginning value. The small changes each day in inclination and other magnetic field parameters sum to produce a long-term effect, known as *secular variation*. Fig. 4 shows the model secular variation of inclination in Queens, New York City (the city where I was born) during my lifetime. Note the nearly linear decrease of about four degrees in inclination over the course of four decades. If one drove four degrees inclination south of New York City, one would end up in North Carolina.

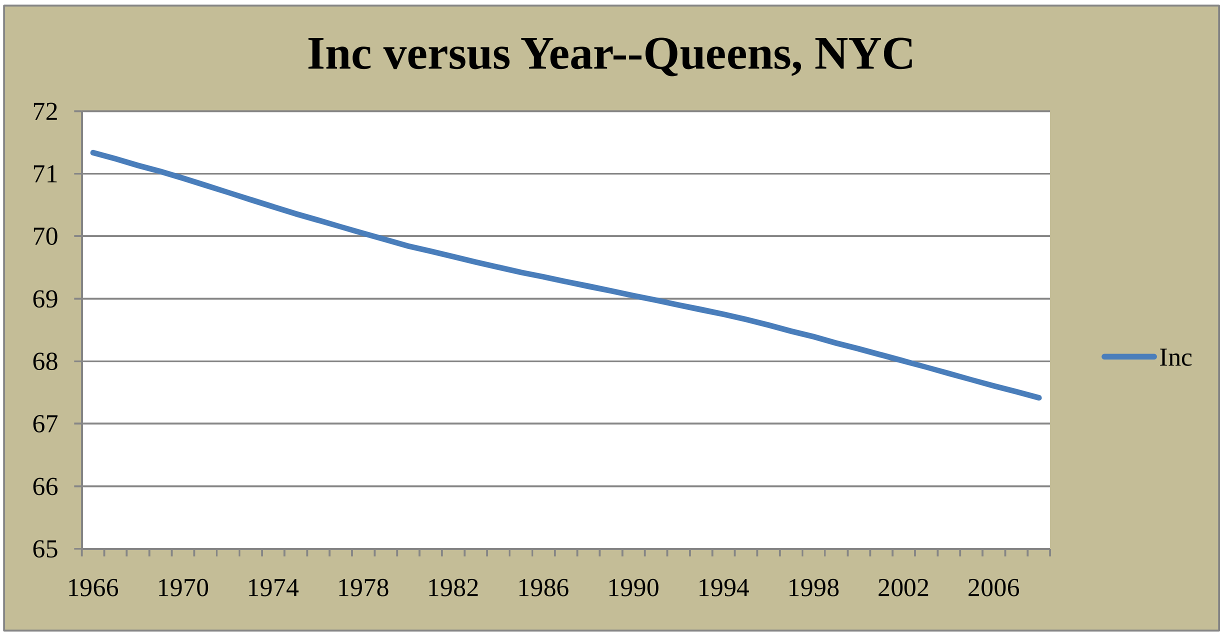


Fig. 4. Inclination in degrees versus year in Queens, NYC, as estimated by the IGRF-10 model calculator. Data from National Geophysical Data Center.

<u>Observatories and Models</u>

In the previous section, the diurnal variation data came from an observatory, and the secular variation data came from a model. Geomagnetic observatories are places in which sensitive equipment measure the direction and intensity of the Earth's magnetic field (Fig. 5). As one can see from the map, there are only seven observatories in the continental United States, and only one on the East Coast.

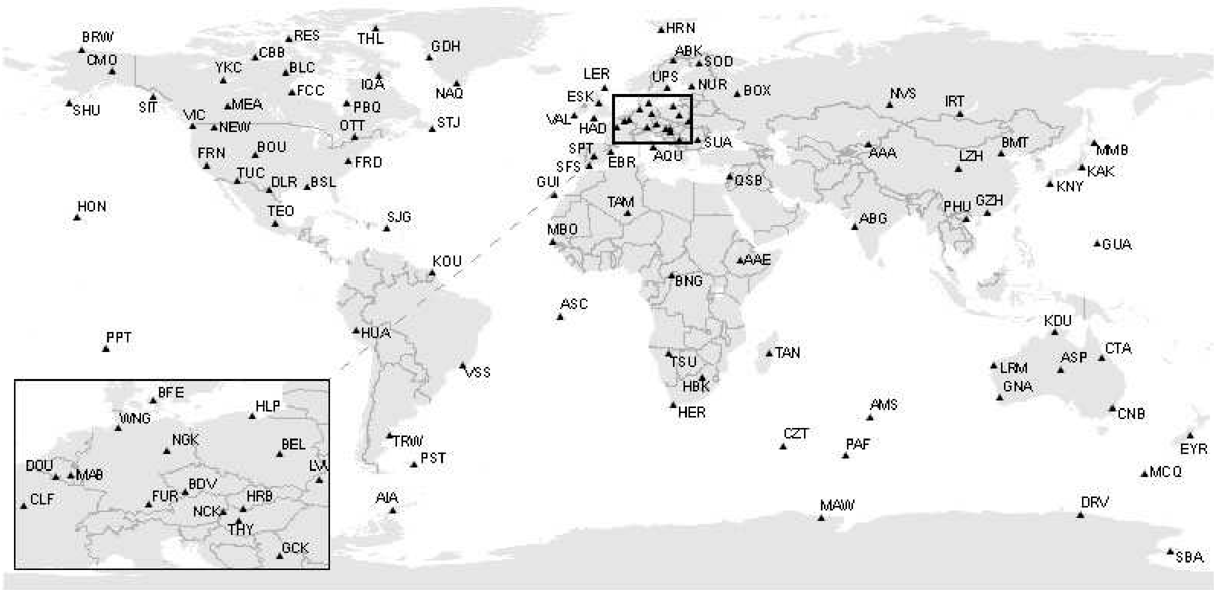


Fig. 5. Map of Intermagnet Observatories in 2008 (i.e. observatories that meet minimum requirements regarding magnetometer specifications, and that participate in a real time data recovery system). Figure from Intermagnet participating observatories.

If one wants to know magnetic field intensity, inclination, or declination at any location on Earth, one can use a magnetic model. Models rely on data acquired by observatories, aircraft, spacecraft, and satellites to provide a mathematical representation of the geomagnetic field. A model calculator takes latitude, longitude, altitude, and date as input, and provides magnetic field parameters as output. Models have several limitations (Lowes, 2005):

1) They are only updated every five years. The last update was in 2005, so calculations done for data gathered in 2007 - 2009 rely on a model that is already several years old.
2) They don't take into account local anomalies, which are geographic variations in the magnetic field resulting from materials in the Earth's crust.
3) They don't take into account diurnal variation.
4) They don't take into account solar/geomagnetic activity, which during solar active periods (see below) can result in fluctuations in the magnetic field.
5) They don't take into account DC and AC fields resulting from various man-made things (e.g. buildings, cars, power lines, and cell phones)

Notwithstanding these limitations, magnetic models provide a reasonably accurate estimate (< 1% error) of the geomagnetic field at a given location. Unless one is prepared to invest in expensive magnetic measuring equipment, find a location free of all magnetic noise, and learn how to use the equipment properly (or hire someone who does), there aren't any other options.

Solar/Geomagnetic Activity

The geomagnetic field is influenced by solar activity. Solar activity is commonly measured by the sunspot number. Sunspots are visible through the telescope as small and dark regions, usually occurring in groups. Sunspot number/solar activity is not constant, but follows an eleven year cycle. We are currently just at the beginning of a new cycle (Fig. 6), which is predicted to peak in 2013. Geomagnetic activity, or the disturbance in the Earth's magnetic field resulting from solar activity, usually trails the solar cycle by one to three years (Campbell, 2003, p. 179), so we should expect to see a lot of activity through the middle of the next decade. Peak activity is punctuated by magnetic storms, which depending on their intensity can disrupt communication and power systems. These storms also produce wild fluctuations in magnetic parameters (Fig. 7). Geomagnetic activity is measured by the k index, a 3-hour average of activity, and the Ap index, a daily average.

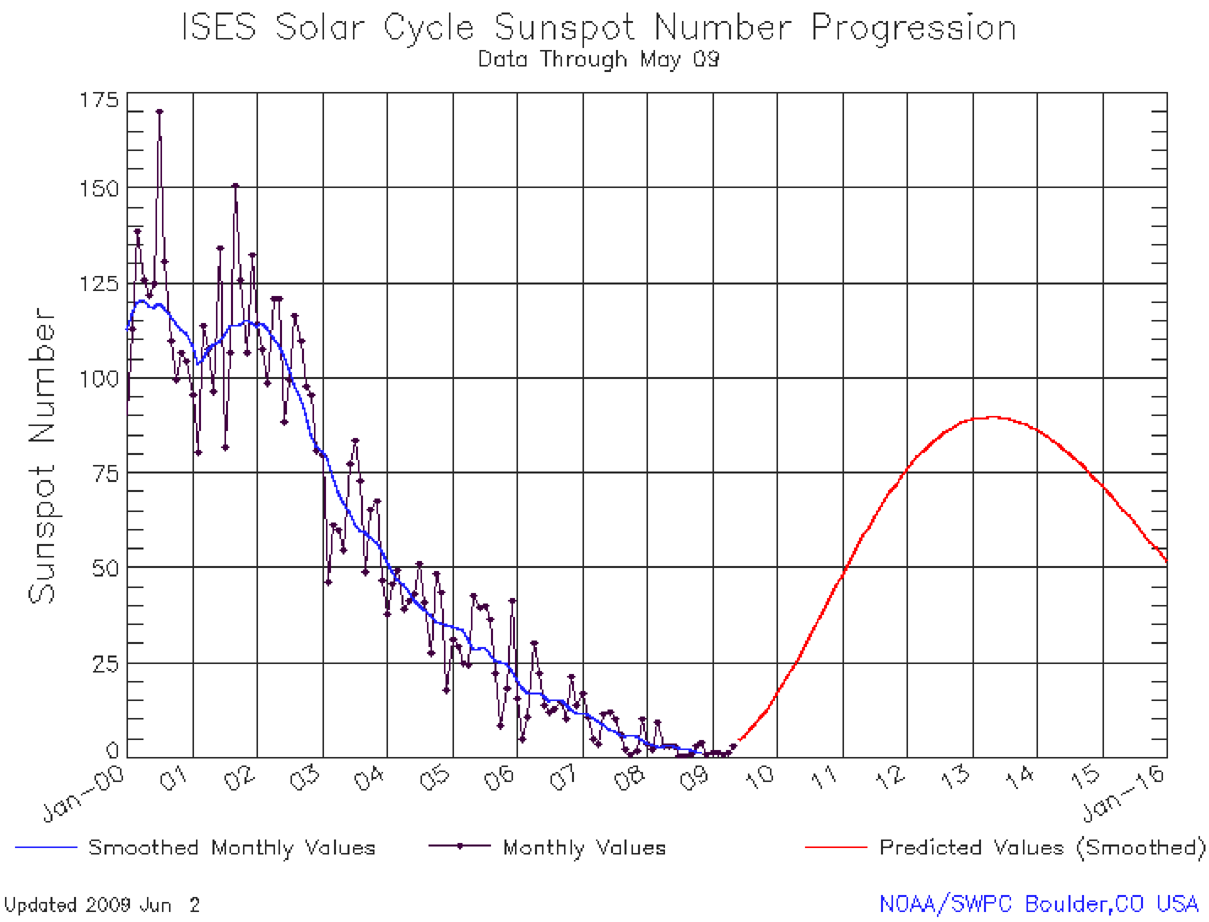


Fig. 6. Solar cycle progression from 2000 through 2016. Figure from Solar cycle progression, 2009.

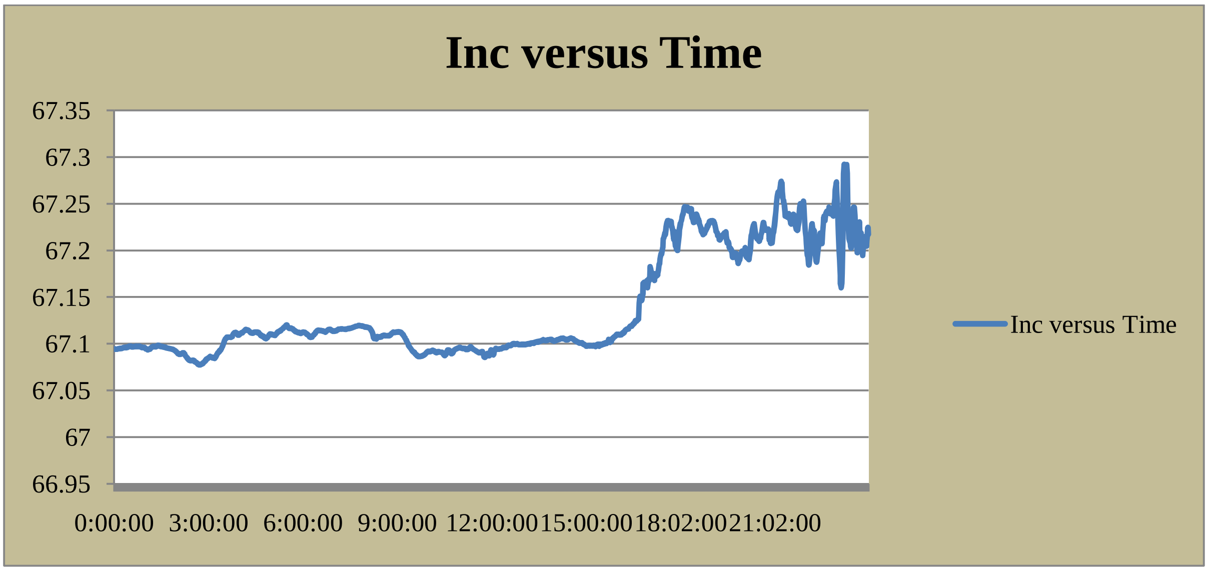


Fig. 7. Diurnal variation of inclination as recorded at the Boulder observatory during the magnetic storm of 4/6/2000. Compare with Fig. 3. Note the difference in amplitude (0.20 degrees low-to-high here, 0.03 degrees in Fig. 3). The storm began at 9:40 local time. Data from Intermagnet Definitive Data.

# Animal Magnetoreception

## Definition of Magnetoreception

Platt (2007, p. 1) defines *magnetoreception* as “an ability to detect magnetic fields and behave based on that information.” The second part of the definition is critical in distinguishing magnetoreception from more general effects of magnetic fields. For an animal to have magnetoreception, it must act differently based on the information in the magnetic field. This different behavior consists of orientation and navigation. Based on magnetic information, animals acquire a sense of their position relative to a goal. Based on their knowledge of their position, they then set a course toward that goal, using an internal compass and/or GPS.

## GPS versus Compass

Since we know that some animals have the ability to navigate long distances when migrating, and other animals (e.g. pigeons) can find their way home when displaced, we infer that these animals have some internal GPS to ascertain their position (Lohmann, Lohmann, & Putnam, 2007), and they have some internal compass to direct themselves toward their goal (Wiltschko & Wiltschko, 2006). Various experiments have indicated the magnetic nature of this GPS and compass. A typical experiment to study either the GPS or compass is to capture an animal, put it in a cage, alter the magnetic field surrounding the animal, and then see if it behaves differently than control animals (i.e. animals in the same type of cage without any changes in the ambient magnetic field). “Behave differently” means to move in a different direction. Experiments have shown that changes in magnetic field intensity, inclination, and polarity can cause different behavioral changes in different species. (For the most recent book-length treatment of animal magnetoreception, see Wiltschko & Wiltschko, 1995).

Magnetoreceptive Processes

Unlike with the classic senses, some of the most basic questions concerning magnetoreception are unknown—including the location of the magnetoreceptors, and the neural and biophysical mechanisms by which they perceive the magnetic field (Johnsen & Lohmann, 2005). Nevertheless, two theories have been advanced to explain how magnetoreception works. Each is backed by evidence, and there's some indication that both theories may be correct—i.e. that animals have two different ways to perceive the magnetic field. The theories are the magnetite theory and the radical pair theory.

Magnetite is an iron-containing compound whose properties depend on its size and shape. Magnetite particles can be thought of as tiny magnets inside an animal's body, which move in response to changes in the magnetic field. The theory is that the movements of magnetite particles can be used by an animal to detect the direction and intensity of the magnetic field (Kirschvink, Walker, & Diebel, 2001). While magnetite has been identified in different animals, it's still unclear where the magnetite-based magnetoreceptors are located (although see Fleissner et al., 2003, regarding magnetite receptors in homing pigeons).

The radical pair theory states that photoreceptors in the retina detect the magnetic field by comparing yields in a chemical reaction (Ritz, Adem, & Schulten, 2000). The term "radical pair" refers to a stage in the chemical process in which two molecules or parts of molecules have an unpaired electron each. The way that this process can be used to perceive the magnetic field is that the chemical yield is different based on the animal's orientation relative to the magnetic vector. In other words, the animal perceives the direction of the geomagnetic vector by sophisticated analysis of chemical reaction yields in its retina.

A key difference between the two theories is that while the magnetite theory is not light-dependent, the radical pair theory is. For an animal to use the radical pair process to perceive the Earth's magnetic field, it must have the ability to perceive light. That magnetoreception is light-dependent in some animals was experimentally demonstrated by displacing young homing pigeons in total darkness (Wiltschko & Wiltschko, 1981). The birds were disoriented upon release, unlike control pigeons that had access either to outdoor or indoor light.

There are behavioral experimental methods to distinguish between the two magnetoreception processes (Wiltschko & Wiltschko, 2006). Magnetite-based magnetoreception is disrupted by a brief, strong magnetic pulse. This effect is transient—lasting three days or less in birds. Radical pair-based magnetoreception is disrupted by weak high frequency fields (MHz range). These disruptive effects are specific to either magnetite or radical pair—a pulse, for example, will only affect magnetite receptors, not radical pair receptors.

## Light-Dependent Magnetoreception

Recent years have seen a number of experiments not only demonstrating that some animals' magnetoreceptive abilities are dependent on light, but dependent on specific combinations of light frequency and intensity. The results from these experiments call into question the radical pair theory, which postulates that light is necessary to start a chemical reaction, but doesn’t specify frequency and intensity of light. The results point to a direct effect of spectral characteristics of light on magnetoreception.

For example, it’s been determined that migratory birds and homing pigeons require low wavelength light for normal orientation. They are oriented when exposed to blue, turquoise, or green light, but not when exposed to yellow or red light (Wiltschko & Wiltschko, 2006). The radical pair theory can still accommodate this, if one assumes that only photoreceptors responsive to low-wavelength light are involved in magnetoreception.

The problem for the radical pair theory comes from an experiment in which the intensity of low-wavelength light was modified (Wiltschko, Stapput, Bischof, & Wiltschko, 2007). The results on magnetoreception are difficult to interpret (Fig. 9).

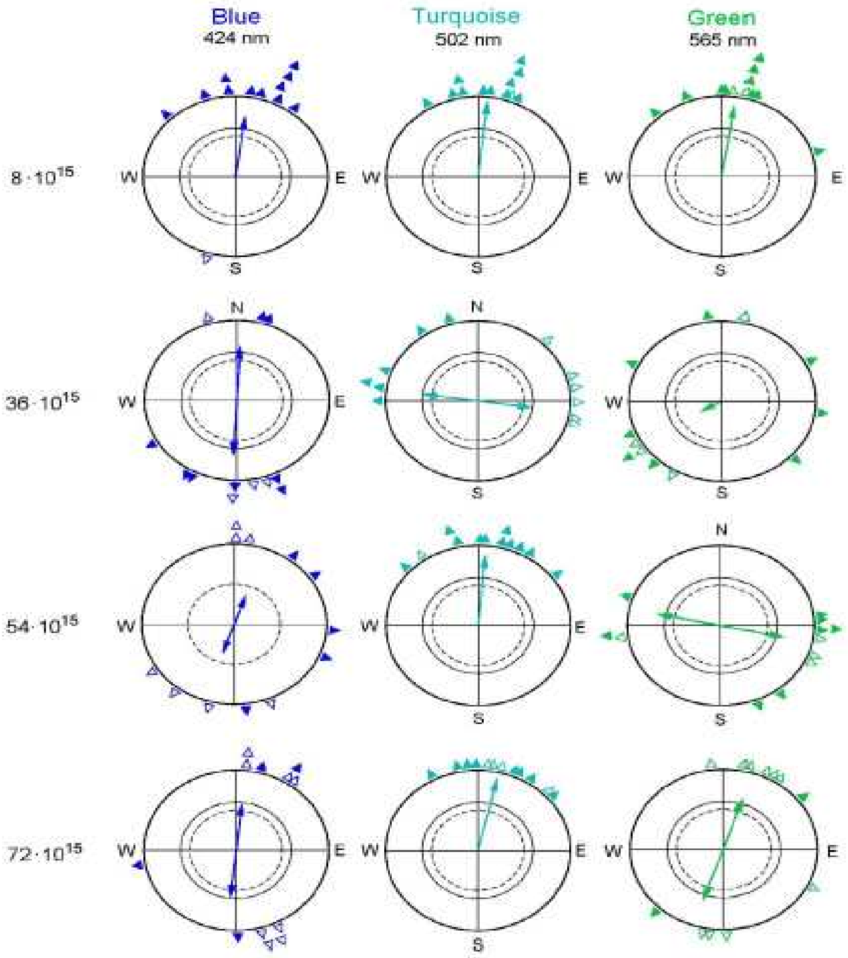


Fig. 9. Orientation of European Robins under Blue, Turquoise, or Green light of different intensities. The left side indicates the light intensity, with increasing intensity as you go down. The triangles at the edges of each circle indicate headings of individual birds. The arrows indicate average directional tendency of the group of birds. Arrows that extend beyond the dotted inner circle are significant at 5%. Arrows that extend beyond the solid inner circle are significant at 1%. Figure from Wiltschko, Stapput, Bischof, & Wiltschko, 2007.

The birds are normally oriented at the lowest intensity (top row). The arrows all point slightly east of north, which is the normal migratory direction for these birds in the spring. They are significant at the 1% level.

At higher intensities, however, the birds show unusual behavior: sometimes they are normally oriented, sometimes they are axially north-south directed (i.e. some birds go north, others go south), sometimes they are axially east-west directed, and sometimes they aren't significantly directed at all.

These high light intensities correspond to intensities found in nature well after sunset, i.e. at a time when the birds migrate. The authors thus rejected effects on circadian rhythm or saturation of receptors as explanations. Interestingly, another study found evidence that these unusual responses are mediated in part by a magnetite-based receptor system (Wiltschko, Stapput, Ritz, Thalau, & Wiltschko, 2007). High frequency fields didn't disrupt the unusual responses, indicating that the radical pair mechanism wasn't involved. Local anesthesia of the upper beak, where magnetite in birds has been located, *did* disrupt them, indicating that magnetite is involved.

Magnetite receptors aren't responsive to light, so there must be an interaction between magnetite receptors and visual receptors. Perhaps there's a second type of light-dependent magnetoreception which interacts with a magnetite system.

# Human Magnetoreception

It's an unresolved scientific question whether or not humans have magnetoreceptive abilities similar to many animals. It's clear that we don't have anything approaching the natural orientational abilities of migratory birds or homing pigeons. We don't migrate long distances when the seasons change (unless we're retired and wealthy). Our homing ability depends mainly on conventional senses, memory, and, more recently, technological devices. If unable to rely on vision and hearing to orient ourselves, if we forget our route, or if we don't recognize landmarks, we get lost.

Still, the fact that our natural orientational abilities are weak doesn't imply that we have no magnetoreceptive abilities. We could perceive the magnetic field, but not be able to utilize this information to orient ourselves. Or we could subconsciously use the magnetic field for orientation, a process that occurs outside our awareness.

In the 1970's and 1980's, Robin Baker of the University of Manchester conducted a pioneering series of studies designed to answer the question if humans have orientational abilities that depend on magnetoreception (Baker, 1989). He and his colleagues did three types of studies:

1) Bus Experiments—Groups of subjects were either blindfolded (experimental) or not blindfolded (control), and driven together to a location between 0.2 km and 52 km from their university. The journey was complicated enough that subjects couldn't navigate by counting turns. Upon reaching the destination, subjects were asked to draw on a clipboard an arrow representing the direction of the university. They were also asked to write down the compass direction to which the arrow was pointing, and an estimate of the distance to the university. Experimental (blindfolded) subjects had to do this while still blindfolded.
2) Walkabout experiments—Groups of subjects were taken on walks in unfamiliar wooded areas (usually 100 km or more from their "normal" home). They were guided by people familiar with the route. Routes were 2-4 km in length, ending at a test site about 1 km from the home base where the journey began. Distant landmarks weren't visible, but

celestial clues (sun, moon, stars) frequently were. On completion of the walk, subjects were asked to indicate the same things that the bus subjects were asked.

3) Chair experiments—Subjects were placed in a chair made of wood with brass and aluminum fittings. 50% of the tests were in a magnetically “quiet” environment—a wood hut at the edge of a woodland; the other 50% were rooms at the university and elsewhere with some magnetic anomalies. The subject sat in the chair while still sighted, and the chair was turned in 8 different directions, completing a circle. The subject was then double blindfolded and fitted with earmuffs. The experimenter rotated the chair clockwise and then anticlockwise by randomly selected angles of no more than 540 degrees. When the chair stopped, the subject was asked to say aloud the compass direction. This was repeated 8-20 times.

In the bus and walkabout experiments, Baker and colleagues did experimental manipulations such as putting bar magnets on the side of some subjects’ heads, and comparing results to putting non-magnetic brass bars on the side of their heads.

In the chair experiments, Baker and colleagues sometimes used large electromagnetic coils around the body to manipulate the magnetic field, and other times had subjects wear bar magnets or brass bars on the side of their heads.

In all three types of experiments, Baker and colleagues compared results from those sleeping in a north-south orientation, to those sleeping in an east-west orientation.

It’s beyond the scope of this paper to give a detailed account of Baker’s results, and the results of attempted replications. The reader is directed to Baker’s book (1989), and to a section in Kirschvink, Jones, & MacFadden (1985, pp. 535-622) in which Baker makes his case, those who attempted to replicate his experiments make their cases, and several authors argue over statistical and methodological issues. See also a recent attempted replication (Platt, 2007).

I want to make a few points about Baker’s correlational study of the effects of bed orientation (east-west versus north-south) on navigation. Baker got his information about subjects’ bed orientation based on their responses in a questionnaire. Granted that most people don’t pay attention to what compass position their bed is oriented, it’s likely that many of these responses were inaccurate. Also, the bipolar division between east-west and north-south obscures any possible effect from intermediate angles. One may have wished that Baker had asked his subjects to actually measure the compass angle of their bed. If he had asked that, he would have found that this can be difficult (Table 1).

| x | y | z | comp | x | y | z | comp | x | y | z | comp | x | y | z | comp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 42 | 0 | 318 | 40 | 42 | 0 | 296 | 60 | 42 | 0 | 296 | 80 | 42 | 0 | 281 |
| | | 5 | 312 | | | 5 | 299 | | | 5 | 292 | | | 5 | 278 |
| | | 10 | 307 | | | 10 | 297 | | | 10 | 285 | | | 10 | 275 |
| | | 15 | 300 | | | 15 | 293 | | | 15 | 283 | | | 15 | 272 |
| | | 20 | 290 | | | 20 | 288 | | | 20 | 281 | | | 20 | 272 |
| | | 25 | 290 | | | 25 | 285 | | | 25 | 277 | | | 25 | 270 |
| | 58 | 0 | 317 | | 58 | 0 | 299 | | 58 | 0 | 286 | | 58 | 0 | 270 |
| | | 5 | 305 | | | 5 | 295 | | | 5 | 286 | | | 5 | 270 |
| | | 10 | 303 | | | 10 | 292 | | | 10 | 286 | | | 10 | 267 |
| | | 15 | 297 | | | 15 | 290 | | | 15 | 283 | | | 15 | 267 |
| | | 20 | 294 | | | 20 | 288 | | | 20 | 277 | | | 20 | 267 |
| | | 25 | 289 | | | 25 | 286 | | | 25 | 271 | | | 25 | 266 |
| | 74 | 0 | 315 | | 74 | 0 | 286 | | 74 | 0 | 283 | | 74 | 0 | 269 |
| | | 5 | 305 | | | 5 | 288 | | | 5 | 279 | | | 5 | 269 |
| | | 10 | 300 | | | 10 | 286 | | | 10 | 279 | | | 10 | 268 |
| | | 15 | 293 | | | 15 | 285 | | | 15 | 277 | | | 15 | 265 |
| | | 20 | 293 | | | 20 | 284 | | | 20 | 275 | | | 20 | 265 |
| | | 25 | 289 | | | 25 | 282 | | | 25 | 275 | | | 25 | 263 |
| | 90 | 0 | 310 | | 90 | 0 | 282 | | 90 | 0 | 275 | | 90 | 0 | 269 |
| | | 5 | 300 | | | 5 | 285 | | | 5 | 275 | | | 5 | 269 |
| | | 10 | 295 | | | 10 | 285 | | | 10 | 275 | | | 10 | 269 |
| | | 15 | 291 | | | 15 | 284 | | | 15 | 275 | | | 15 | 269 |
| | | 20 | 289 | | | 20 | 282 | | | 20 | 273 | | | 20 | 267 |
| | | 25 | 285 | | | 25 | 282 | | | 25 | 273 | | | 25 | 267 |
| | 106 | 0 | 300 | | 106 | 0 | 280 | | 106 | 0 | 271 | | 106 | 0 | 259 |
| | | 5 | 292 | | | 5 | 280 | | | 5 | 270 | | | 5 | 259 |
| | | 10 | 286 | | | 10 | 279 | | | 10 | 265 | | | 10 | 259 |
| | | 15 | 284 | | | 15 | 277 | | | 15 | 266 | | | 15 | 259 |
| | | 20 | 283 | | | 20 | 277 | | | 20 | 266 | | | 20 | 259 |
| | | 25 | 281 | | | 25 | 277 | | | 25 | 266 | | | 25 | 259 |

Table 1. Magnetic map of my innerspring bed. The long axis of the bed is oriented at 261 degrees relative to the geomagnetic field (measured from head to foot).
x: distance in cm along the long axis of the bed, increasing from head to foot (total bed length = 204 cm) .
y: distance in cm along the short axis of the bed, increasing from right to left (looking from head of bed to foot) (total bed width = 153 cm)
z: vertical distance in cm above the mattress
comp: compass reading in degrees when pointed along the long axis of the bed, from head to foot, at coordinates (x, y, z).

The table shows the compass angle of my Serta queen-sized innerspring mattress as a function of horizontal and vertical location relative to the mattress. In each measurement, the compass is directed along the long axis of the bed, from head to foot. But it comes up with different readings depending on where it's located. I haven't sampled many beds, so I can't say that this bed is typical. It's not an unusual, exotic, or rare bed, however. The bed isn't the only source of uneven magnetic fields in a typical bedroom. They can also come from the steel bed frame or headboard, from electric/electronic appliances, and from sources outside the room (e.g. power lines, utility machines, steel building structure, etc.)

# Personal Introduction

Since the data in this research project is based ultimately on my subjective experience, which includes psychiatric symptoms, it’s important for the reader to know something about my background. I’ll focus on autobiographical facts directly relevant to the topics presented in this paper.

Where and When I Spent my Childhood

I was born in February 1967 in Queens, New York City (geographic latitude 40.70, geographic longitude -73.92; all further coordinates are in “geographic latitude, geographic longitude” format unless otherwise noted). In August 1968, I moved to Plainfield, New Jersey (40.63, -74.39). In December, 1972, I moved to New Providence, New Jersey (40.70, -74.39). I lived from ages 5 to 18 in New Providence. At age 18, I went away to college at the University of Virginia (UVA) in Charlottesville (38.13, -78.45), where I stayed until I graduated in May, 1989. During my college years, on summers and holidays I went back to New Providence to visit my parents.

According to my mother and my own personal recollection, my entire childhood was spent in the New York City metropolitan area, from conception until age 18. We traveled very rarely and for short vacations outside of the area.

## Educational / Professional Background

I received a bachelor's degree in physics from the University of Virginia in 1989. I received a second bachelor's degree in psychology from the University of Utah in 1999. I worked as a computer programmer from 1990 until 2004. I lived in Northern New Jersey (1990-1992), Los Angeles, California (1992-1994), the Salt Lake City, Utah area (1994-2008), and Wilmington, North Carolina (2008-present). Having saved enough money to support myself, I semi-retired in 2004, pursuing various research and creative-writing projects. I wrote a number of short stories and started a novel. I researched a variety of topics including the psychology and sociology of creativity, subjects relevant to the novel I began.

## Psychiatric Problems

While in college at UVA, I developed a combination of OCD and a tic disorder. The tics were unusual both in their late onset and in their being mainly triggered by touching sensitive areas of my body, especially my abdominal area. I eventually received professional help, and the OCD gradually improved with pharmacological treatment (clomipramine and sertraline) and cognitive/behavioral changes. The tics, however, didn't respond well to treatment, although they were managed for a long time with clomipramine, and later with alprazolam.

I also developed a variant of dysthymia which manifested itself as low motivation and emotional blunting. The dysthymia was never intense enough to require hospitalization, but interfered with my functioning mainly in my social life. For many years I had few friends, but this gradually improved over time in Salt Lake City.

Events Leading to my Geomagnetism Research Project

In June 2007, I had inguinal hernia surgery. The hernia surgery had the beneficial effect (in addition to correcting the hernia) of lowering my abdominal sensitivity to the point that I no longer needed to take alprazolam on a regular basis (i.e. the surgery prevented one of the major triggers of my tics from happening). For some unknown reason, however, I lost my creative writing motivation soon after the surgery, and did not regain it. In August, I spent a month on the East Coast. My original intention was to move to New York City in order to research my novel, set in the Big Apple. But I didn't feel like moving, and didn't feel like writing anything. During this month, I stayed at my parents' house in Northern New Jersey. I also traveled to Boston, MA; Mystic, CT, Baltimore, MD; and Washington, DC. I was unmotivated, somewhat depressed, and apathetic. My mood didn't change much in any of the places I visited. When I flew back to Salt Lake City, I noticed an immediate change. I had more abdominal sensitivity and tics, and less depression.

From about the time of the surgery, I had been dating a woman. In September, 2007, we took a driving trip to Moab, 387 km southeast of Salt Lake City. I noticed stronger abdominal sensitivity in Moab. As we drove back, I could feel these symptoms diminish.

The differences in how I felt between the Northeastern U.S., Salt Lake City, and Moab, got me thinking about geomagnetism again. I had done some reading about geomagnetism in the past. One was in relation to multiple sclerosis (MS), a disorder that a woman I dated from 1996 to 2002 suffered from. The strong correlation between multiple sclerosis (MS) prevalence and latitude seemed to me to point to some geophysical factor. I read an article (Resch, 1995) that reported that the correlation between MS prevalence and geomagnetic latitude (i.e. inclination) was stronger than the correlation between MS prevalence and geographic latitude. As an enthusiastic response to this article, I purchased various magnetic “treatments” for my girlfriend, none of which had any effect. After I broke up with my girlfriend in 2002, I filed away my geomagnetism papers and went onto other things.

I retrieved my geomagnetism file in 2006 while researching my novel. The novel’s protagonist was a musical genius, and I read some psychology of creativity literature, including Hans Eysenck’s book (1995). While discussing environmental factors that affect creativity, Eysenck (pp. 162-169) mentioned Ertel’s research. Ertel (1997) found that there was a significant correlation between creative achievement and low sunspot number. There’s more creative achievement in the nadir of the 11-year solar cycle as compared to the peak. There are also worldwide bursts of creativity that occur when there is little solar activity for an extended period of time (e.g. the Maunder Minimum in the $17^{th}$ and early $18^{th}$ centuries). Since sunspots (i.e. solar activity) directly affect geomagnetic activity, this research suggests that the geomagnetic field has an influence on human creative behavior.

These geomagnetism correlations, and others, such as the correlation between psychotic behavior of hospitalized patients and geomagnetic activity (Campbell, 2003, pp. 266-268) were on my mind as I thought about why I felt differently in different places. Having a lot of time (being out of work) and nothing to do (being unmotivated to write), I decided in September 2007 to begin a systematic investigation of whether the geomagnetic field had any effect on my feelings and symptoms. I drove to different places, observed how I felt, and recorded these observations in a journal. By chance, the first place I drove to (Rock Springs, Wyoming) happened to be in the prepeak zone (see Results section for what this means). I felt much more motivated and happy than in other places. These feelings went away when I returned to Utah.

After my Rock Springs experience, I formulated three hypotheses:

1) That my symptoms were some type of navigational tool, directing me away from places I felt bad, and toward places I felt good.
2) That I responded to some combination of geomagnetic inclination and total intensity. I rejected declination because it would require an innate knowledge of true north, something unlikely in any animal. Perceiving inclination required only the knowledge of horizontal and vertical, which we perceive via how gravity interacts with our vestibular system. Perceiving total intensity also seemed possible, given some biological version of a magnetometer (e.g. magnetite).
3) That how I responded to the magnetic field was set during a critical developmental period (CDP) in childhood. It didn't seem likely that the body was infinitely adaptable to any magnetic environment, just as it wasn't infinitely adaptable to changes in temperature, humidity, air pressure, etc. Since it seemed that magnetic factors were directing me toward a place I felt good, then this place was likely set during childhood, and represented "home."

My knowledge of geomagnetism was minimal when I began. As I drove to places, and observed my feelings, I also learned how to use the magnetic model calculator, learned the basic physical properties of geomagnetism, and started reading the animal and human geomagnetism literature. Virtually everything in the Results section came from experience—they were not preconceived or expected things. For example, I didn't even think to measure bed angle when I started. I had to discard much of my early data because I didn't account for bed angle. I only thought of measuring this after reading Baker's book (1989). All the data presented in the Results section below were based on experience, not preconceived notions.

There were many incorrect hypotheses which I formulated and then had to discard. For example, for many months I thought that NTZ transitions shifted the peak south as one moved east. I had to discard this when I flew to central Florida, expecting to find the East Coast peak there, but ended up having to drive 1000 km north to North Carolina.

It’s beyond the scope of this paper to give a detailed historical account of my research project. This paper is intended to present the method, data and results in a concise and logical manner. This presentation can fool the reader into thinking that all my findings occurred together, in one burst of insight. This couldn’t be further from the truth.

# Methods

## Materials

The items used in this research project include a 2002 Toyota Camry car (in Utah), a 2006 Toyota Corolla car (in North Carolina), a handheld Garmin Etrex Vista HCX GPS device (http://www.garmin.com), a laptop computer with an Internet connection, several pocket magnetic compasses accurate to one degree, a queen-size Serta pillowtop innerspring mattress bed, and a twin-size Coleman Comfortsmart Quickbed Airbed with external pump.

## Software

Garmin Mapsource (version 6.11.6) was used to track GPS Waypoints and Routes. Microsoft Excel 2007 was used for data and statistical analysis. The NOAA IGRF-10 magnetic model calculator (National Geophysical Data Center) was used to compute magnetic parameters (total intensity, horizontal intensity, vertical intensity, and inclination) from GPS coordinates and altitude. It was also used to get historical information about magnetic parameters from places I lived in as a child.

## Procedure

I drove to places where I felt differently. I got out of my car, walked to the location, and saved the GPS coordinates as waypoints on my handheld device (more detail about how I found these locations will be provided in the Results section). The GPS unit recorded date, time, elevation, longitude and latitude. I wrote up the coordinates and other observations in a notebook. When I got home, I uploaded the GPS waypoints to my computer, where I used the coordinates and the model calculator to get the magnetic properties. I saved the magnetic properties into Excel Spreadsheets. I also used Excel to compare properties of different locations, and other statistical analysis. I typed up my handwritten notes into an MS Word document.

For the bed angle experiments, there were three different methodologies. From November 2007 until March 2008, I slept on an innerspring mattress, along with matching foundation, metal frame, and wooden headboard. Since the uneven magnetic field (Table 1) made it impossible to determine actual bed angle, I measured it at the center-top of the headboard (58 cm above the mattress). As I rotated the mattress, I continued measuring from this position. In other words, even though my magnetoreceptor(s) was not 58 cm above the mattress, I remained consistent. Using Baker's (1989, p. 77-78) convention of measuring bed orientation, I pointed my compass from the head of the bed to the foot of the bed, along the long axis. Since the magnetic field varied from one side of the bed to the other (along the short axis), and one end of the bed to the other (along the long axis), I tried to remain consistent by sleeping in the same position each night. There were still movements during sleep that I was unable to control, that could have affected the magnetic field angle that my body perceived.

From March 2008 until present, I used the airbed. While in Utah from March through August 2008, I found an area of my living room (or second bedroom) with an even (DC) magnetic field, and slept in this area. My operational definition of an "even magnetic field" is an area in which the compass maintains a consistent reading when pointed along the long axis of the bed, from the top of the bed to the foot of the bed, from side to side, and from ground level to approximately 50 cm above the bed. I also limited my exposure to AC magnetic fields (which were invisible to the compass) by turning off various appliances or, if this wasn't possible, positioning myself as far as I could from them. The airbed did not have a frame to immobilize it, so the first month or so I found that the bed frequently shifted in position between bedtime and wake-up time (probably when I woke up at night to go to the bathroom). As I gained more experience using the bed, I was usually able to prevent this from happening. To be sure of this, I always measured the bed angle before going to bed, and after waking up. If the two were significantly different (i.e. > 2 degrees), I assumed that bed angle was unknown and noted that when entering the data.

When I measured bed angle in Utah, I pointed the compass along the long axis of the bed, and took just one measurement. Usually I'd have a predetermined bed angle I wanted to set the bed at, so I moved the bed until the compass reading showed that angle.

For both the innerspring and the air mattress experiments, I tried to maintain a consistent sleeping schedule. I avoided napping, and slept as much as possible in my own bed. Beginning April 26, 2008, I made daily notes of my sleep and wake-up times in my journal. Before this date, I recall that my usual bed time was around 10:30 p.m., and my usual wake-up time was around 6:30 a.m., but don't have precise records. During the time I did these experiments, I wasn't working, and did not have to be up at a specific time. As a consequence, I usually didn't set my alarm, and woke up naturally.

In August 2008, I moved to Wilmington, North Carolina, a move that was based in part on geomagnetic factors. I knew from two previous visits that the East Coast magnetic peak was in North Carolina, and I wanted to move to a place that was south of the peak, which would make it in the Happy Zone. I moved into a 3-bedroom single family house that, to my surprise, had DC magnetic anomalies underneath the floor throughout the house. I ended up sleeping in a corner of the kitchen/dining area that had the fewest anomalies. I positioned my bed such that my head and upper body were in an anomaly-free area. This room had linoleum floors, which frequently led to the airbed sliding on the floor overnight. To counteract this effect, I bought a rug grip and used it underneath the airbed for friction.

In Wilmington, also to my surprise, when sleeping I was much more sensitive to artificial AC and DC magnetic fields than in Utah. In Utah, I had some appliances and other devices running (e.g. computer, refrigerator, cordless phone, smoke alarm, CO alarm, cell phone), and lived in a duplex, in which I was likely exposed to electromagnetic noise from my neighbors. The only time I remember perceiving any sleep disturbance from these devices was from my neighbor's evaporative cooler (I never ran mine while sleeping). To counteract this, I moved my bed to a second bedroom that was further from my neighbor's cooler. In Wilmington, to sleep undisturbed I had to shut off the main circuit breaker, turn off anything that operated on battery power (e.g. cordless phone, cell phone, computer, smoke detector), and disconnect and remove batteries from all components of the home security system. See the Results section for a more detailed description of how artificial magnetic fields disturbed my sleep.

In Wilmington, I felt a need to come up with a more precise method of measuring bed angle. I found that if I repeated a compass measurement I would frequently be off by a degree or two from the previous reading. I would also be off by a degree or two when comparing Head-Foot readings to Foot-Head readings (taking into account the theoretical 180 degree difference between the two). I thus decided to take 10 independent compass readings from Head-Foot, and another 10 readings from Foot-Head. I combined the 20 measurements, and compared the combined average reading to the combined reading the next day (after any possible bed shifts or movements occurred). I also combined all measurements at the same bed angle for the duration of a peak test, and came up with an overall average and standard deviation bed angle. I entered all this data in a spreadsheet.

In Utah, I used a simple Silva pocket needle compass, with rotating bezel. In Wilmington, I purchased a Suunto MCA sighting needle compass with rotating bezel and mirror. I found that using the mirror for sighting when trying to measure bed angle didn’t work very well (this method is designed for sighting at a distance). I thus kept the mirror side horizontal, and used the line bisecting the mirror to help sight the bed.

# Results

## North-South Map (aka "The Psychological Magnetic Map")

Space is subjectively divided into three zones (in the Northern Hemisphere). The Happy Zone (HZ), aka Magnetic Home, is surrounded to the north by the Negative Zone (NZ), and to the south by the Positive Zone (PZ) (Fig. 10). The Happy Zone width (i.e. its north-south distance) depends on bed angle (see section on Bed Angle effects).

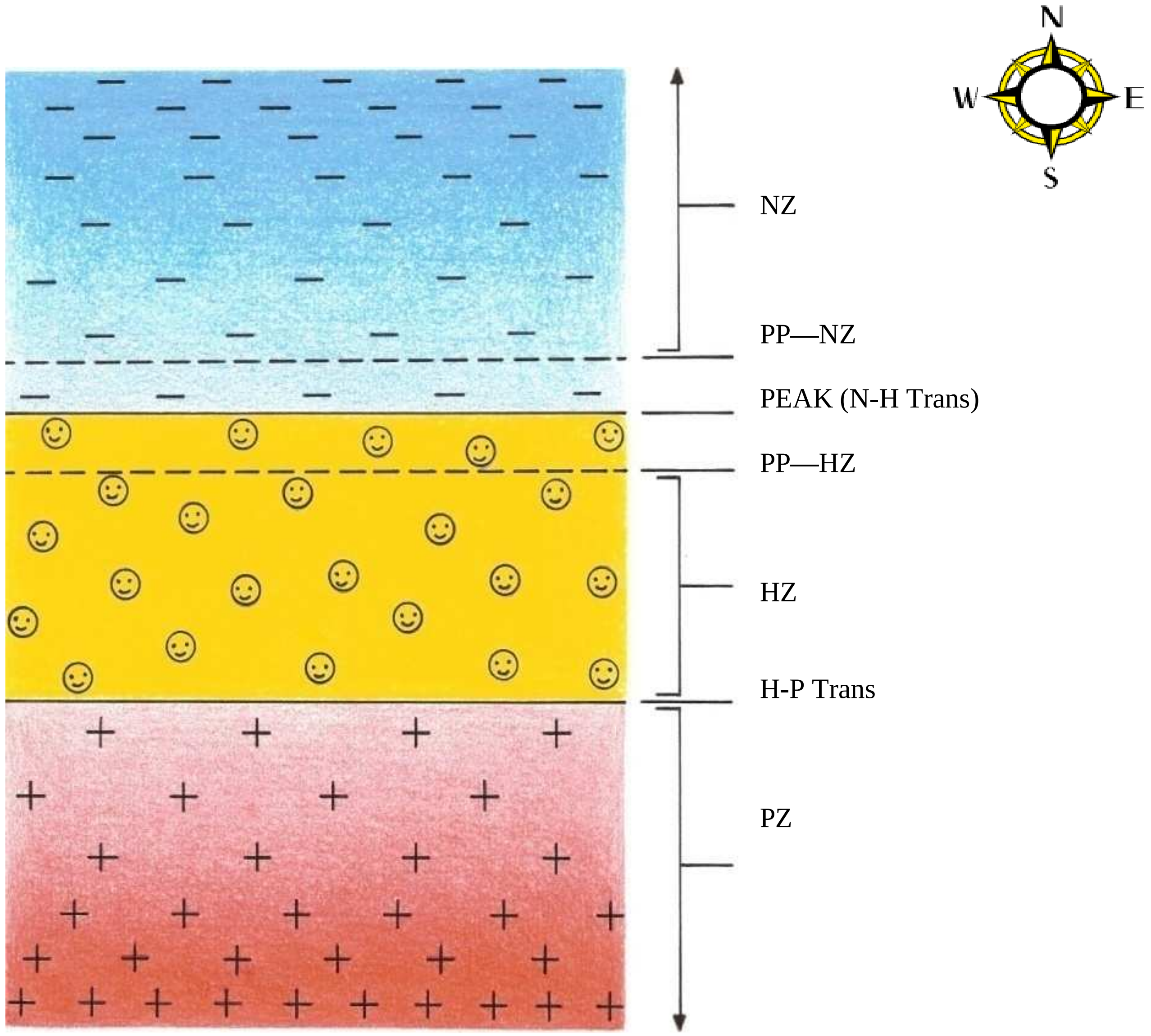


Fig. 10. The Psychological Magnetic Map. NZ = Negative Zone, HZ = Happy Zone, PZ = Positive Zone, PP—NZ = Prepeak Negative Zone, PP—HZ = Prepeak Happy Zone, N-H Trans = Negative to Happy Transition, H-P Trans = Happy to Positive Transition. Illustration by Mariana Brevis.

The distinction between Positive and Negative Zone is between two different symptom clusters. The terms “positive symptoms” and “negative symptoms” are used in psychiatry to describe opposing symptom clusters in schizophrenia (American Psychiatric Association, 2000).

Positive symptoms include delusions, hallucinations, and disorganized speech. Negative symptoms include affective flattening (restricted emotional expression), alogia (limited speech), and avolition (lack of motivation). According to the DSM-IV-TR, "positive symptoms appear to reflect an excess or distortion of normal functions, whereas the negative symptoms appear to reflect a diminution or loss of normal functions" (American Psychiatric Association, 2000, p. 299).

The positive/negative distinction is not limited to schizophrenia. Bipolar disorder is one characterized by two opposing symptom clusters—positive symptoms (i.e. mania), and negative symptoms (i.e. depression). This link between schizophrenia and bipolar disorder has been recognized by some psychiatrists. A "Positive and Negative Syndrome Scale" (PANSS), originally developed for typological and dimensional assessment of schizophrenia (Kay, Fiszbein, & Opler, 1987), has been extended to assess symptoms of bipolar disorder (Daneluzzo et al., 2002).

Since I have neither schizophrenia nor bipolar disorder, the reader may wonder about the relevance of the last two paragraphs. I have OCD/tics, which is a more subtle example of a positive/negative syndrome. Tics can be thought of as positive symptoms, while obsessions and compulsions are negative symptoms. The fact that tics are usually treated by neuroleptics (Walkup, 1999), which were originally developed to treat the positive symptoms of schizophrenia, indicates a connection between tics and schizophrenia. The fact that obsessions and compulsions are usually treated by serotonin reuptake inhibitors, which were originally developed to treat depression, i.e. the negative symptom of bipolar disorder, indicates a connection between OCD and mood disorder.

There's evidence of a discontinuous spectrum involving "pure" OCD, OCD + tics, and OCD + Tourette Syndrome (Swerdlow et al. 1999). Symptoms and effective treatments are different for the different disorders in this spectrum. My disorder was never helped by neuroleptic treatment, although it was helped by an older serotonin reuptake inhibitor (clomipramine). In recent years, my obsessions and compulsions haven't been strong enough to require pharmacological treatment.

It's important not to make too much of the HZ concept. The HZ is *not* a combination of nirvana, heaven, and paradise. It's a location in which I have *relatively* fewer symptoms (relative to the NZ and PZ). Being in the HZ is not even the only magnetic factor affecting mood (see bed angle, circadian rhythm, and seasonal effects below).

In the NZ, I have *predominantly* negative symptoms. My negative symptoms consist of depressed mood, apathy, and lack of motivation. I also have abdominal sensitivity and some tics. In the PZ, I have *predominantly* positive symptoms. I have abdominal and other shaking, and motor and vocal tics. Occasionally I'll have a hypomanic episode. I may also have depressed mood.

Note that there is some crossover in symptoms between the NZ and the PZ. I can have tics in either zone, although I have more of them in the PZ. I can also feel depressed in either zone, although I usually feel more depressed in the NZ. This crossover can make it difficult to distinguish between the two zones. Other factors that make it difficult to distinguish between the zones include type of bed, bed angle, magnetic anomalies in the bedroom, amount and quality of sleep, circadian rhythm, seasonal effects, and other factors affecting mental or physical health (see below for a description of some of these other factors).

Experience is helpful in being able to distinguish between the NZ, HZ, and PZ. Another important factor is that my ability to distinguish between the various zones is greatly enhanced by looking directly at the early afternoon sky (not the sun, but anywhere in the sky). Under ideal, or near-ideal conditions (see below for a description of ideal conditions), I am near-perfect in being able to distinguish between the zones. There are certain things I key on that help me make this determination. In the NZ, I feel a deep and pervasive sense of melancholy. In the PZ, I have frequent involuntary contractions of my lower torso. In the HZ, I have reduced or no symptoms. When crossing from the NZ to the HZ, the melancholic mood disappears at once. When crossing from the PZ to the HZ, the involuntary contractions disappear. The symptoms appear as soon as I reverse myself and cross back.

Note from Fig. 10 that negative symptoms increase as I move north from home, and positive symptoms increase as I move south from home. Even after years of experience, I find it very difficult to get an accurate idea of how far north or south I am based on intensity of symptoms. For example, in the Introduction I mentioned that I flew to Florida, expecting to find the peak, and ended up driving 1000 km north to North Carolina. When in Florida, I felt strong positive symptoms. This indicated that my magnetic home was far north. But I really had no idea *how far* north. It could have been 200 km, 300 km, 600 km, 2000 km, etc. Perhaps with experience my ability to distinguish distance may improve. But it will never be as accurate as my ability to distinguish between positive and negative.

The fact that I feel these different symptom clusters based on north-south location is interesting, but doesn't lead to a quantitative analysis of the causal factors. At the same time that I discovered these symptom clusters, I also discovered another phenomenon—the "peak" experience.

<u>"Peak" Phenomenon (N-H Transition)</u>

The existence of three different N-S zones implies the existence of two transitions—the NZ-HZ (N-H) transition, and the HZ-PZ (H-P) transition (Fig. 10).

During initial stages of my research, I observed that I had an intense reaction at the N-H transition (aka "the peak"). This reaction consists of shaking, facial contortions, and an intense "high". It occurs if I enter it from either side. The reaction occurs for however long I'm in the location, and immediately stops when I leave it.

The peak is long but narrow. In the continental United States, I have found it in Utah and surrounding states, and North Carolina and Virginia. It extends northwest to southeast, at a ratio of 5.69 degrees longitude east / degree latitude south (on Jan 1, 2008) when comparing Utah and North Carolina "ideal" 2-Day reset peak locations. (See the NTZ and Two-Day Reset sections below for data supporting this). Its width is relatively tiny, only about a meter north-south distance, which allows for a precise GPS reading of its location.

For an example, see the video (Harry Magnet, 2009). Note that I do have spontaneous shaking, sometimes intense, but never as intense or as spatially located as the peak. This video was taken in central Utah (39.42, -110.44), on March 12, 2008, in the midafternoon. (See Appendix A for a transcript of the video).

“Prepeak” Phenomenon

Just north and south of the peak, there’s a wider area in which I feel a semi-intense sensation, which I term “prepeak”. “Prepeak” is just a milder version of the “peak”. I don’t have shaking, but feel somewhat intense. Think of it as a juxtaposition of both Negative and Happy Zones, with one zone being dominant over the other. This dominance allows me to distinguish between Prepeak Negative, or the prepeak area in the NZ, and Prepeak Happy, or the prepeak area in the HZ. To find the peak, when I’m in Prepeak Happy, I move north, and when I’m in Prepeak Negative, I move south. I’ve always been able to find the peak by using this method.

H-P transition

At the H-P transition, I have a burst of tics (verbal and motor) and shaking. Unlike the “peak” experience, it is only a few seconds in duration, and only happens when I enter the Positive Zone from the Happy Zone. Like the “peak” experience, it is bounded by a “prepeak” zone (juxtaposition of Happy Zone and Positive Zone), although this prepeak zone is less intense than that for the N-H transition. It is very narrow in width (a meter or less), allowing for a precise GPS reading.

Natural Light Dependence of Magnetoreceptive Feelings

(Note—I use the term “magnetoreceptive feelings” to mean the feeling of being in the NZ, HZ, or PZ. I acknowledge that these feelings may not have anything to do with my perception of the Earth’s magnetic field.)

I have done most of my magnetic mapping, including finding the N-H and H-P transitions, by driving to one or both of these transitions during the day. I use my symptoms (positive versus negative) to guide me. I'm obviously not blind to the outside world.

On March 15, 2008, with my girlfriend's help, I tested if I could sense the peak when using a blindfold. I put on a cloth bandana as a blindfold at a stopping point approximately 40-50 km south of the expected peak location. My girlfriend then drove me north. Immediately, I felt very tired and drowsy. More importantly, I lost the sense of where I was relative to the peak. I took the blindfold off as we drove toward the peak, but the magnetic sense didn't come right back. It put it on and took it off a few times. When we came close to the expected location of the peak, I had my girlfriend stop, although I didn't feel anything initially. After a few minutes without the blindfold, I felt that I was in the Negative Zone. We drove south, and I was able to locate the peak with the blindfold off. I then put the blindfold on, and walked to the location of the peak, but didn't feel the peak. I took the blindfold off and found the peak after a few tries.

I conclude from this that it's not possible to find the peak with a blindfold on. The blindfold not only prevents me from sensing the peak, but also prevents me from feeling positive or negative symptoms.

Is daylight necessary for me to find the peak? No. On November 25, 2007, I found the peak in Southern Utah at around 9:30 p.m., off an unlit road at night. I don't recall how much starlight or moonlight was available. My car had its headlights on as I drove to the peak. I used a flashlight as I walked from the car to the peak.

Daylight isn't necessary for me to find the peak, but it is necessary for me to have magnetoreceptive feelings. On June 25, 2008, I spent an entire day and evening near the peak (in Northern Utah) to observe and record diurnal variation. Sunset was at 9:04 p.m. local time. I took peak readings from about 10:30 a.m. until about 10:30 p.m. Up until the 6:35 p.m. reading, I felt magnetoreceptive feelings, and found the peak. At 8:30 p.m. and 10:30 p.m., I found the peak without feeling magnetoreceptive feelings. I found the peak by driving to the previous location of the peak, then going north or south until I felt prepeak and then peak in the car (see Bed Angle section below for more detail on how I find the peak). I then walked the peak, and it felt as strong as it did in regular daylight. In other words, I was "blind" to whether I was north or south of the peak, but still could find the peak. From other tests I've found that I lose magnetoreceptive feelings 2 to 4 hours before sunset, and don't regain them until 4 to 6 hours after sunrise the next morning.

In North Carolina I obtained some precise measurements of when magnetoreceptive feelings started. I describe below (in the Bed Angle effects section) that when bed angle is close to 45 degrees (the 45-peak) I can feel magnetoreceptive feelings while driving in the car. On Feb 13, 2009, when driving to the peak, I frequently looked out the open driver's side window, trying to find the exact time when magnetoreceptive feelings started. I clocked this at 12:13 p.m. Sunrise that day was at 6:58 a.m., so magnetoreceptive feelings started at 5 hours, 15 minutes after sunrise. When driving home, I did the same thing, seeking to find when magnetoreceptive feelings stopped. I clocked it at 3:51 p.m., which was 2 hours, 1 minute prior to sunset.

The reader may wonder if this window of magnetoreceptive feelings changes with the seasons. On May 16, 2009, at my North Carolina home, sunrise was at 6:09 a.m. Although I wasn't continuously checking for magnetoreceptive feelings, I made two checks outside my house, one at 10:50 a.m., in which I felt no magnetoreceptive feelings, and one at 11:04 a.m., in which I did. So at 4 hours, 41 minutes after sunrise I had no magnetoreceptive feelings, and at 4 hours, 55 minutes after sunrise I felt in the Positive Zone.

On August 7, 2009, while driving to the 45-peak near the North Carolina-Virginia border, I clocked magnetoreceptive feelings starting at 12:17 p.m., and ending at 4:57 p.m. Sunrise that day was 6:21 a.m., and sunset at 8:10 p.m. Therefore magnetoreceptive feelings started 5 hours, 56 minutes after sunrise, and ended 3 hours, 13 minutes before sunset.

On October 8, 2009, I stood outside my motel in Fuquay-Varina, NC, waiting for magnetoreceptive feelings to start. I started feeling in the Negative Zone at 1:04 p.m. Sunrise was at 7:15 a.m., so magnetoreceptive feelings started 5 hours, 49 minutes after sunrise.

Can I feel magnetoreceptive feelings with only artificial indoor light as the source of illumination? No, at least with standard incandescent and fluorescent white lights. I can't feel magnetoreceptive feelings during the day if I am indoors with the window shut (regardless of whether or not the blinds are open). I can feel them if I open the window and look at the sky. In a car, I can only feel magnetoreceptive feelings if I open a window or sunroof and look outside at the sky.

On June 4, 2009, I tested how far a car window needed to be opened for me to have magnetoreceptive feelings. I opened the window to the point at which I started feeling magnetoreceptive feelings. My car was parked in the driveway of my Wilmington, NC, home. There were trees obstructing the view at the lower end of the horizon for all four windows. The day was partly cloudy. I tested at 12:30 p.m., and was in the Positive Zone. The measurements (in vertical open distance) from the four windows were 13.5 cm, 14.2 cm, 13.5 cm, and 13.5 cm. This comes out to an average of 13.7 cm and a standard deviation of 0.4 cm.

Note that looking at any part of the sky allows me to feel magnetoreceptive feelings (this includes a cloudy daytime sky). Looking at reflected sunlight from objects in my field of view *doesn't* give me magnetoreceptive feelings. Wearing prescription sunglasses when gazing at the sky has no effect on the existence or intensity of these feelings.

Am I completely dead to the world if I'm not looking at the sky? No. I feel a weak sense of positive, negative, or happy. I have more tics in the positive zone, and feel more depressed in the negative zone. But considering crossover effects (see above), my orientational abilities become weaker and less reliable.

Lack of Dependence of Magnetoreceptive Feelings on Magnetic Noise

My magnetoreceptive feelings, including sensing the peak, don't seem affected by virtually any source of electromagnetic noise. I can feel them in a car, with radio blaring. I can feel them near power lines, near steel structures, and near most appliances and electronic devices. The only device that seems to cause any psychological reaction is my AT&T cell phone. If I talk on the phone for an extended period of time (over 20 minutes), I feel slightly agitated. This agitation persists for a short time, usually less than an hour. Talking on a cordless landline phone doesn't cause me problems.

No Compass Ability

The reader may wonder if I have any (internal) compass ability. I'm not aware of any. I don't feel different as I rotate around and face different directions. I don't feel different if I walk or run or drive in one direction versus another. Although I "know" magnetic home is north or south of my current location, I have no special ability to direct myself north or south. On my

Florida trip, I did what anyone else with a car who wants to drive north does—I got on I-95 North.

# Bed Angle Effects

The psychological magnetic map is affected by various factors associated with sleeping. The most important factor is the compass angle in which one's bed is oriented, which I shorten to "bed angle." There are two periodic functions associated with bed angle.

i) Bed Angle Drift (BAD)—The peak (N-H transition) moves north or south every night a distance that's dependent on bed angle (Tables 2 and 3, Figs. 11 and 12). (For detailed supporting data, see Appendices B and C).

| Bed Angle | BAD | HZW |
|---|---|---|
| 258 | -0.01869 | 0.01785 |
| 263 | 0.10939 | 0.02579 |
| 280 | -0.03258 | 0.17941 |
| 289 | 0.20723 | 0.26137 |
| 293 | 0.59962 | 0.36267 |
| 298 | -0.35347 | 0.62881 |
| 309 | 0.02012 | 0.85038 |
| 318 | 0.57100 | 0.71094 |
| 357 | 0.02785 | 0.01710 |

Table 2. BAD and HZW versus Bed Angle, Utah. BAD = Bed Angle Drift (in degrees latitude) per day. Positive BAD = north, negative BAD = south. HZW = Happy Zone Width in degrees latitude (i.e. north-south distance between the N-H transition and the H-P transition).

| Bed Angle | BAD | HZW |
|---|---|---|
| 263 | -0.03696 | 0.04753 |
| 265 | 0.01252 | 0.02816 |
| 268 | 0.62540 | 0.12941 |
| 303 | 0.79910 | 0.93510 |
| 307 | 0.52530 | 1.53877 |
| 310 | 0.84721 | 1.42728 |
| 315 | 0.79287 | 1.63533 |
| 346 | -0.15011 | 0.28260 |
| 348 | -0.56570 | 0.28397 |
| 358 | -0.20055 | 0.02093 |
| 360 | -0.04769 | 0.02226 |
| 363 | 0.61852 | 0.02937 |

Table 3. BAD and HZW versus Bed Angle, North Carolina. BAD = Bed Angle Drift (in degrees latitude) per day. Positive BAD = north, negative BAD = south. HZW = Happy Zone Width in degrees latitude (i.e. north-distance distance between the N-H transition and the H-P transition).

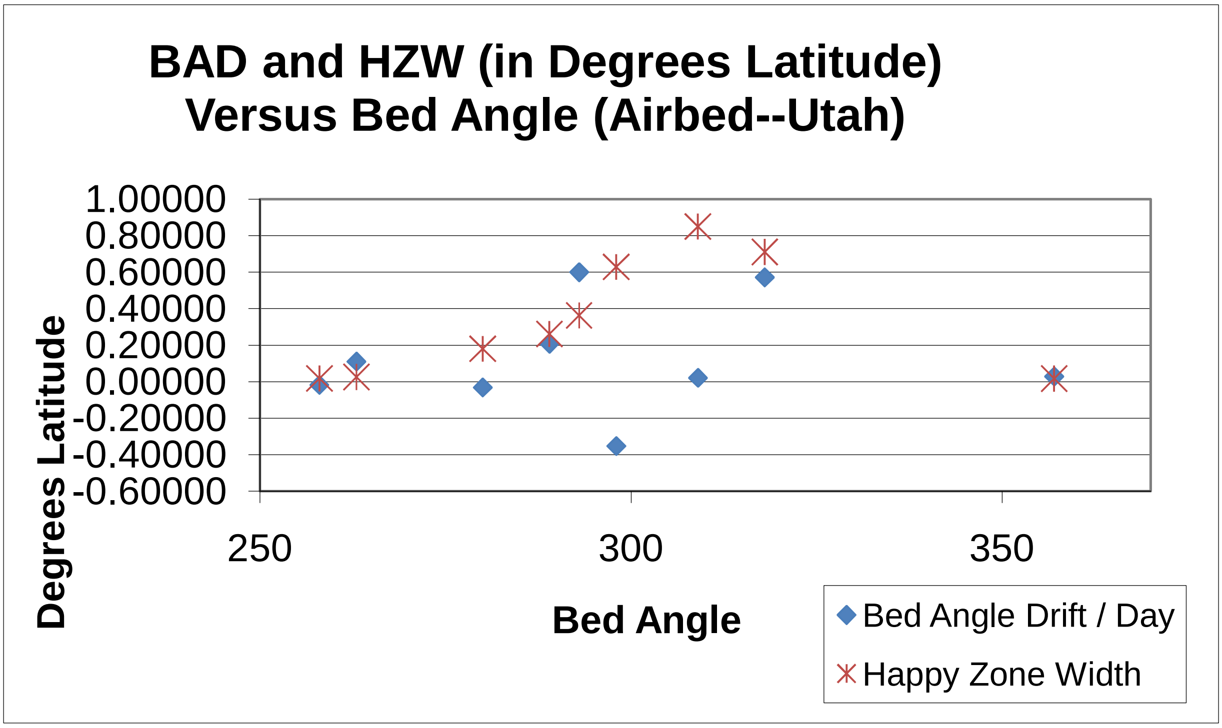


Fig. 11. Plot of Bed Angle Drift (BAD) and HZW (Happy Zone Width) versus bed angle for Utah, when sleeping on an airbed. For BAD, positive means northward drift, negative means southward drift. HZW refers to the north-south distance in degrees latitude between the peak (N-H transition) and the H-P transition.

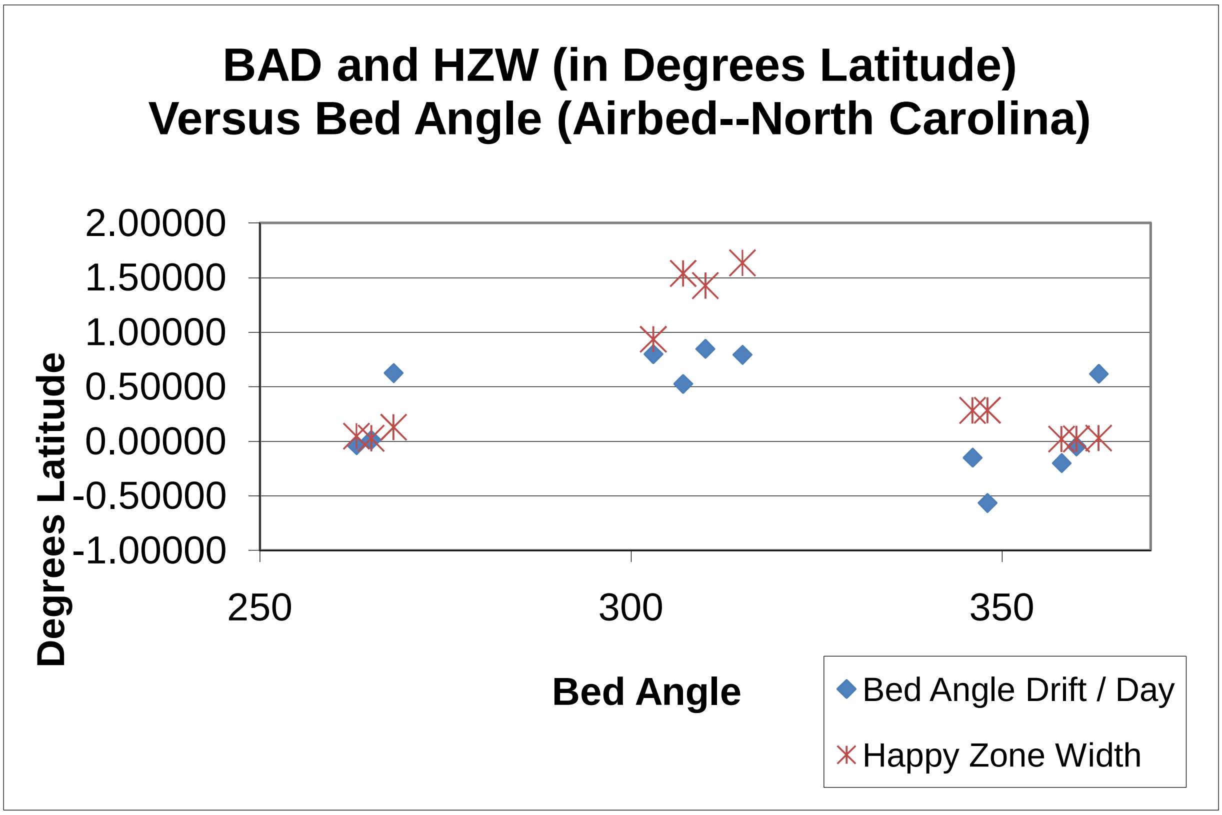


Fig. 12. Plot of Bed Angle Drift (BAD) and HZW (Happy Zone Width) versus bed angle for North Carolina, when sleeping on an airbed. For BAD, positive means northward drift, negative means southward drift. HZW refers to the north-south distance in degrees latitude between the peak (N-H transition) and the H-P transition.

The small amount of data makes it difficult to draw conclusions about these plots. Practical considerations limited my ability to gather data. Each data point required me to spend two days driving to the peak (for before and after measurements), and during at least one of these days also driving to the H-P transition. Depending on various factors, these locations could be up to several hundred kilometers from my home. See Appendices B and C for a listing of all the locations I drove to in order to collect the data. Due to these practical considerations, I focused most of my efforts on the bed angles from 270 degrees to 360 degrees.

These data points are only a fraction of the total number of peak measurements. I limited these samples to cases in which I slept on an airbed in a reasonably even magnetic field, the bed angle and bed location remained constant for the duration of the test, I found the 2-day reset (see below for a definition of this) as a starting point, BAD was measured within 3 days of the 2-day reset (since the rate of BAD changes over time), I managed to limit the longitude deviation between before and after (since the peak runs slightly southeast to northwest), the timing of the peak measurements were within a few hours of each other (since there is diurnal variation), and there were no circadian rhythm or seasonal shifts (see below) contaminating the data.

The Utah BAD curve seems to be more regular than the North Carolina BAD curve, especially at or near a 45 degree bed angle (315 degrees in this context). A quasi-tangent function with a 22.5 degree period is a possibility for the Utah BAD curve. Notice how the Utah BAD curve behaves similarly across the entire quadrant, while the North Carolina data shows unusual behavior near the 45 degree bed angle, with BAD being always north (in Utah it went from south to north), and with all data points being between 0.5 and 1.0 degrees latitude north *per day*.

ii) Happy Zone Width (HZW). The HZW (i.e. the north-south distance from the N-H transition to the H-P transition) appears to be a 90-degree period quasi-Gaussian function of bed angle for both Utah and North Carolina (Figs. 11 and 12). HZW reaches a maximum near a 45 degree bed angle, and minima near the E-W and N-S bed angles. Notice how maximum HZW is 0.85 degrees latitude for Utah, but is 1.64 degrees latitude for North Carolina.

BAD is Cumulative

BAD appears to be cumulative, at least over a period of a week, although the rate of BAD isn't constant. From June 20, 2008 to June 27, 2008 (in Utah) I kept bed angle constant (at 309 degrees) and took peak measurements on June 20 (2-day reset), June 23, June 25, and June 27 (Table 4).

| City | Date | Time (Local) | Lat | Long | Elev (meters) | # Day BAD | Change Lat |
|---|---|---|---|---|---|---|---|
| Farmington | 6/20/2008 | 11:14 | 40.97239 | 111.89112 | 1286 | | |
| Kaysville | 6/23/2008 | 14:20 | 41.03275 | 111.93794 | 1304 | 3 | 0.06036 |
| Clearfield | 6/25/2008 | 10:28 | 41.10196 | 112.01402 | 1342 | 5 | 0.12957 |
| Ogden | 6/27/2008 | 12:30 | 41.27165 | 112.02808 | 1243 | 7 | 0.29926 |

Table 4. Peak measurements between June 20 and June 27, 2008, in Northern Utah. Bed angle was (reasonably) constant during this test. The 2-day reset occurred on 6/20/08. Change Lat is relative to the 2-day reset (Farmington 6/20/2008).

BAD was 0.06036 degrees latitude on the third day, or about 0.02 degrees latitude per day. Notice that by the seventh day BAD was 0.2993, or about 0.04 degrees latitude per day, twice the rate at day 3. This difference could be due to a genuine increase in BAD over time, or it could be due to bed angle shifting up by a degree or two by the end of the week (see the Methods section for a description of how I measured bed angle in Utah).

HZW usually increases over time

Table 5 shows the change in HZW in Northern Utah from the same time period and with the same peak data as in Table 4.

| City | Date | Time (Local) | Lat | Long | Elev (meters) | N-H / H-P | HZW |
|---|---|---|---|---|---|---|---|
| Farmington | 6/20/2008 | 11:14 | 40.97239 | -111.89112 | 1286 | N-H | |
| Spanish Fork | 6/20/2008 | 13:09 | 40.12201 | -111.59793 | 1423 | H-P | 0.85038 |
| Ogden | 6/27/2008 | 12:30 | 41.27165 | -112.02808 | 1243 | N-H | |
| Orem | 6/27/2008 | 14:20 | 40.31000 | -111.73420 | 1406 | H-P | 0.96165 |

Table 5. N-H (peak) and H-P transition data for Northern Utah on 6/20/08 and 6/27/08. N-H = Negative-Happy Transition. H-P = Happy-Positive Transition. HZW = Happy Zone width.

In a one-week period, HZW increased from 0.85 to 0.96 degrees latitude, or 13%.

Table 6 shows the changes in HZW in North Carolina. Eight out of nine of the measurements show an increase in HZW.

| City | Date | Time | Lat | Long | Elev (m) | Bed Ang | Type | HZW | % Δ |
|---|---|---|---|---|---|---|---|---|---|
| Goldsboro | 12/4/2008 | 13:19 | 35.42420 | -77.98179 | 39 | 312 | N-H | | |
| Wilmington | 12/4/2008 | 15:48 | 34.15124 | -77.89243 | 8 | 312 | H-P | 1.27296 | |
| Wilson | 12/7/2008 | 13:11 | 35.72069 | -77.89300 | 26 | 312 | N-H | | |
| Wilmington | 12/7/2008 | 16:21 | 34.21101 | -77.88689 | 4 | 312 | H-P | 1.50968 | 18.6% |
| | | | | | | | | | |
| Wilson | 2/12/2009 | 12:28 | 35.70459 | -77.92278 | 50 | 315 | N-H | | |
| Wilmington | 2/12/2009 | 17:15 | 34.06926 | -77.89703 | 1 | 315 | H-P | 1.63533 | |
| Gaston | 2/13/2009 | 12:56 | 36.49746 | -77.64463 | 35 | 315 | N-H | | |
| Wilmington | 2/13/2009 | 16:34 | 34.21350 | -77.88754 | -3 | 315 | H-P | 2.28396 | 39.7% |
| | | | | | | | | | |
| Wilson | 3/3/2009 | 12:43 | 35.70811 | -77.90596 | 32 | 303 | N-H | | |
| Greenevers | 3/3/2009 | 14:52 | 34.77301 | -77.96045 | 76 | 303 | H-P | 0.93510 | |
| Gaston | 3/4/2009 | 12:41 | 36.50721 | -77.63073 | 24 | 303 | N-H | | |
| Tin City | 3/4/2009 | 15:48 | 34.74075 | -77.97753 | 15 | 303 | H-P | 1.76646 | 88.9% |
| | | | | | | | | | |
| Rt 117 | 3/18/2009 | 14:20 | 35.59231 | -77.97269 | 15 | 363 | N-H | | |
| Rt 117 | 3/18/2009 | 14:20 | 35.56294 | -77.97541 | 34 | 363 | H-P | 0.02937 | |
| Ringwood | 3/19/2009 | 15:15 | 36.21083 | -77.84676 | 67 | 363 | N-H | | |
| Rt 4/48 | 3/19/2009 | 15:42 | 36.17963 | -77.81596 | 45 | 363 | H-P | 0.03120 | 6.2% |
| | | | | | | | | | |
| Goldsboro | 4/15/2009 | 13:30 | 35.34374 | -78.02856 | 25 | 358 | N-H | | |
| Rt 117 | 4/15/2009 | 13:55 | 35.32281 | -78.03724 | 35 | 358 | H-P | 0.02093 | |
| Rt 117 | 4/16/2009 | 13:10 | 35.14319 | -78.12923 | 36 | 358 | N-H | | |
| Rt 117 | 4/16/2009 | 13:34 | 35.12524 | -78.16845 | 39 | 358 | H-P | 0.01795 | -14.2% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Goldsboro | 4/22/2009 | 13:15 | 35.35421 | -78.01256 | 15 | 360 | N-H | | |
| Rt 117 | 4/22/2009 | 13:39 | 35.33195 | -78.03584 | 19 | 360 | H-P | 0.02226 | |
| Rt 117 | 4/23/2009 | 13:04 | 35.30652 | -78.04509 | -20 | 360 | N-H | | |
| Rt 117 | 4/23/2009 | 13:26 | 35.25997 | -78.05426 | 20 | 360 | H-P | 0.04655 | 109.1% |
| | | | | | | | | | |
| Rt 301 | 5/15/2009 | 14:55 | 35.84487 | -77.83215 | 41 | 346 | N-H | | |
| Rt 117 | 5/15/2009 | 16:41 | 35.56227 | -77.97542 | 49 | 346 | H-P | 0.28260 | |
| Wilson | 5/16/2009 | 15:04 | 35.69476 | -77.94026 | 33 | 346 | N-H | | |
| Goldsboro | 5/16/2009 | 16:01 | 35.37956 | -78.01049 | 20 | 346 | H-P | 0.31520 | 11.5% |
| | | | | | | | | | |
| Goldsboro | 8/21/2009 | 13:52 | 35.35473 | -78.01210 | 21 | 265 | N-H | | |
| Rt 117 | 8/21/2009 | 14:20 | 35.32657 | -78.03619 | 24 | 265 | H-P | 0.02816 | |
| Goldsboro | 8/22/2009 | 13:35 | 35.36725 | -78.00775 | 11 | 265 | N-H | | |
| Rt 117 | 8/22/2009 | 13:59 | 35.33248 | -78.03562 | 10 | 265 | H-P | 0.03477 | 23.5% |
| | | | | | | | | | |
| Fuquay-Varina | 10/8/2009 | 13:16 | 35.58693 | -78.77286 | 102 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 13:29 | 35.57855 | -78.77124 | 101 | 265 | H-P | 0.00838 | |
| Fuquay-Varina | 10/9/2009 | 13:16 | 35.60072 | -78.77427 | 130 | 265 | N-H | | |
| Fuquay-Varina | 10/9/2009 | 13:37 | 35.58788 | -78.77298 | 135 | 265 | H-P | 0.01284 | 53.2% |

Table 6. N-H (peak) and H-P transition data for North Carolina. Time = Local Time. N-H = Negative-Happy Transition. H-P = Happy-Positive Transition. Bed Ang = Bed Angle. HZW = Happy Zone width. % Δ = % Change in HZW.

<u>Bed Angle Reset (aka 2-Day Reset)</u>

The effects of BAD can be reset by switching from a bed angle near 45 degrees to a bed angle near a cardinal angle (N-S or E-W), and vice versa. It seems that within +/- 22.5 degrees of the "central zero crossing" of the BAD curve near a cardinal angle, i.e. where the curve intersects with 0 degrees latitude, is the "C-peak range." This range includes bed angles which when switched from one to the other do *not* cause a reset. Analogously, within +/- 22.5 degrees of the central zero crossing of the BAD curve near a 45 degree angle is the "45-peak range."

In Utah, the central zero crossing near the N-S bed angle appears to be about 356 degrees, and in North Carolina this appears to be about 360 degrees. In Utah, the central zero crossing near the E-W bed angle appears to be at around 258 degrees, and in North Carolina about 265 degrees. Note how the N-S central zero crossing is about 4 degrees lower for Utah than North Carolina, and the E-W central zero crossing is about 7 degrees lower.

In Utah, the central zero crossing near the 45 degree angle appears to be around 307 degrees. In North Carolina, there is no central zero crossing near the 45 degree angle, since all BAD near the 45 degree bed angle is northward .

Assuming that for Utah the BAD curve is a tangent function with a 22.5 degree period, then if the tangent function crosses zero at 356 degrees, then the point at which it next crosses zero (hypothetically 333.5 degrees) is likely the transition point between the C-peak (N-S) and 45-peak bed angle ranges. Similarly, if the tangent function crosses zero at 258 degrees, then the point at which it next crosses zero (hypothetically 280.5 degrees) is the transition point between the C-peak (E-W) and 45-peak bed angle ranges. While I did not find a data point near this transition between the C-peak (N-S) and 45-peak, I did find it near the C-peak (E-W) and 45-peak. This point, at a 280 degree bed angle, had a BAD of only -0.03 degrees latitude, indicating that it is just shy of the crossing. This 280 degree angle was definitely in the C-peak range, as I couldn’t feel the peak while driving in the car (see below for an explanation of this).

By sleeping at a bed angle within 22.5 degrees of the central zero crossing of the BAD curve near a 45 degree angle, then sleeping at a bed angle within 22.5 degrees of the central zero crossing of the BAD curve near a cardinal bed angle, or vice-versa, a bed angle reset (BAR) will be initiated. The BAR requires two nights (2-day reset). After the first night, and before the second night, my magnetoreceptive abilities become suppressed. I don’t have a clear sense of which zone I’m in, and thus cannot search for the peak. After the second night, my magnetoreceptive abilities return. The peak can be found close to the location in which it was at the last 2-day reset, erasing all effects of northward or southward BAD.

BAR allows for comparison of peak locations across different bed angles, and over time. One finding that I'll explain quantitatively further below is that the BAR includes some (new) BAD. The 2-day reset peak values are north of average if (future) BAD is northward, and south of average if (future) BAD is southward, and the degree to which they are northward or southward correlates highly with the degree of BAD.

Another finding is that Utah has a southward secular change of 1.8 km / week (small compared to typical BAD amounts), while North Carolina doesn't exhibit this secular change.

A BAR *doesn't* occur when I switch from N-S to E-W bed angles. On March 4, 2009, in North Carolina, I switched from a 45 degree bed angle (~ 303 degrees) to an N-S angle (~ 2 degrees). The reset occurred two days later, on March 6 (I felt in the Positive Zone). I continued with an N-S bed angle until March 10. On that day I switched to E-W (~ 262 degrees). The next day, on March 11, I felt in the Positive Zone, indicating that a reset was *not* taking place (if a reset were taking place, I would not have any magnetoreceptive feelings the day after making a bed angle change).

Split 45 peak

In Utah, but not in North Carolina, the 45-peak was frequently far south (~ 2 degrees latitude) of the C-peak. This split 45-peak effect was independent of BAD (it would occur if future BAD was northward or southward). It was dependent, however, on a combination of circadian rhythm effects (see below) and/or artificial magnetic fields when sleeping. If I slept at ideal circadian rhythm, with a relatively even magnetic field, then the 45-peak split went away. I'll discuss this further in other sections below.

Psychological Reaction due to Bed Angle

I get differing psychological reactions from sleeping at different bed angles. These reactions are independent of my location relative to the peak, and also the peak's location relative to its ideal location (see sections below for more about peak location). In general, I feel best (most stable, most symptom-free) when the bed angle is such that BAD is close to zero. I feel worse (least stable, more symptoms), when the bed angle is such that BAD is maximized (or minimized). In other words, I feel best at bed angles in which there is little to no BAD, and I feel worse at bed angles in which there is a lot of BAD (either northward or southward).

As an example of this, note from Fig. 12 that bed angles near 45 degrees in North Carolina are highly unstable. Note also that the HZW is very big, extending in some cases over 1.5 degrees of latitude. The net result of these two factors is that in Wilmington I would be in the Happy Zone most of the time when I set bed angle to near 45 degrees, but I would feel agitated and unstable. So I ended up usually avoiding 45 degree angles and setting bed angle to the more stable N-S angle, even though that would result in my being in the Positive Zone.

The cumulative effects of BAD exact a psychological toll. The more the peak moves away from its "ideal" (i.e. 2-day reset) location, the worse I feel. In Wilmington, if I reset to an unstable 45 degree bed angle, I never let BAD accumulate for more than a few days.

If I change bed angles after a 2-day reset, but the change is not sufficient to initiate a new reset, then I feel agitated, regardless of the angles from which or to which I change the bed. In other words, even if I switch from a “bad” angle (high BAD), to a “good” angle (low BAD), I still feel unstable and symptomatic.

If I continuously alternate 45-peak and C-peak bed angles, so that I’m in the middle of a BAR that never completes, I feel agitated.

Sensitivity to Magnetic Noise When Asleep

Unlike when I’m awake, when asleep my body is highly sensitive to electromagnetic noise. One source of noise is the uneven magnetic field of the innerspring mattress (Table 1). Frequently when sleeping on an innerspring mattress, I’ll wake up in the middle of the night, begin shaking, and continue shaking for one to two hours. The next day, I’ll shake and tic more than usual. A similar effect occurs (although less intense) when I sleep on an airbed in an uneven DC magnetic field, or if I sleep on an airbed with sources of AC magnetic noise nearby. This doesn’t happen if I sleep on an airbed in an even magnetic field (assuming no circadian rhythm or seasonal effects; see below).

As I stated in the Methods section, I had much greater sensitivity to magnetic noise in Wilmington than in Salt Lake City. While the psychological effects were the same (shaking, increased tics), the threshold of sensitivity was much lower in Wilmington. There virtually any source of magnetic noise (AC, DC, battery powered) within the house could cause these symptoms. One example was a smoke detector located about 8.5 meters from my bed. I installed it, putting a battery in it the night of Nov 17 – Nov 18, 2008. The next early morning I woke up with shaking symptoms. I removed the battery from the detector and slept well the next night.

While conducting this research I have paid attention and taken notes on my sleeping behavior when I traveled to different places. I seemed to have lower sensitivity to magnetic noise when sleeping in northern cities like Boston, Chicago, and New Providence than I did in Wilmington. For example, the week of March 30 – April 6, 2009, I stayed at my sister's house in Boston. I slept on an innerspring mattress, the first time I did so in a year. I didn't have any noticeable shaking reactions.

I visited a friend who lived in a high-rise in Chicago May 22–26, 2009. I slept on an airbed in a strongly uneven magnetic field, near various sources of electromagnetic noise (e.g. computer, wireless router, refrigerator). The only source of magnetic noise that bothered me when sleeping was the air pump that was attached to the airbed I slept on. The first night I slept with the pump near my head when sleeping (the pump was of course off at the time). I woke up 2.5 hours after going to sleep, shaking. I rotated the bed 180 degrees so that the pump was near my feet, and kept it in this position for the next three nights. While I had some shaking, it was never as intense as the first night.

The above paragraph makes an important point about the location of the putative sleeping magnetoreceptor (SMR)—it seems to be either in the head or closer to the head than the feet. There are other examples to support this. When I visited my parents in New Providence in November, 2008, I slept on an airbed in an even magnetic field. The room has an innerspring bed with a steel frame. The small floor surface area in which I can put the airbed made it necessary for me, if I wanted the bed angle to be N-S, to position one end of the airbed near the innerspring bed and steel frame. On November, 29, 2008, I positioned my head near the innerspring bed/steel frame, and went to bed at 9:39 p.m. I woke up at 2:30 a.m., with shaking symptoms and abdominal contractions. I switched to an E-W orientation to position my head away from the innerspring bed/steel frame, and the following night I didn't have any shaking symptoms.

On April 1, 2009, I slept in my parents' house in New Providence with the bed in a N-S orientation, but with my feet near the innerspring bed/steel frame. I didn't have any shaking symptoms that night.

A similar example occurred in my Wilmington, NC, home. In the corner of the kitchen/dining room area in which I usually positioned my airbed, there were cabinets with steel door handles. When I positioned my head 110 cm from the closest cabinet door handle, I had shaking symptoms. When I slid the bed so that my head was 136 cm away the door handle, I didn't get these symptoms.

## Procedure to Find the Peak

I can now give a more detailed description of how I drive to find the peak. My procedure depends on bed angle. If bed angle is within the 45-peak range, I have magnetoreceptive feelings and can sense the peak when driving in the car at speeds up to 110 km/h. Before I leave, I make note of my feelings. If I'm in the Positive Zone, I'll drive north. If I'm in the Negative Zone, I'll drive south. If I'm in the Happy Zone, then I'll either drive north or south depending on whether I want to find the N-H transition (north), or H-P transition (south).

Since magnetoreceptive feelings don't begin until 4 to 6 hours after sunrise, when days are short I don't have time to wait for magnetoreceptive feelings. I drive north from home based on prior expectations of where the peak should be. Once magnetoreceptive feelings kick in, I make adjustments if I overshoot the peak.

Finding the 45-peak (N-H) transition while driving is easy. As I approach the peak, I feel prepeak feelings. I know that the peak is close. As long as I keep the speed below 110 km/h, I can feel the peak in the car as a burst of tics. After I feel the peak, I note my odometer reading, and drive until I find a safe spot to turn around. Usually I *can't* feel the peak when I drive from the opposite direction, so I need to drive past the peak, then turn around and approach it from the original direction. If I'm on an interstate highway, I'll have to find a parallel road in which it is legal to pull over. I stop the car when convenient, get out, turn on my GPS, and note how I feel. If I feel prepeak/negative feelings, then I know I need to walk south. If I feel prepeak/happy symptoms, then I know I need to walk north. I then walk until I find the peak. I record the GPS coordinates of the north end and the south end of the peak, and then average the two to come up with the coordinates that I plug into the magnetic model calculator (the north-south peak distance of about one meter is less than the GPS unit's rated accuracy {3 meters in North America}, so it's useless to try to compare north and south readings).

Finding the C-peak is more difficult. I can't feel the peak while driving in the car. I can't reliably detect changing from one zone to another while driving in the car. To accommodate these limitations, I developed a procedure based on experience. I drive north or south depending on which zone I feel I'm in, as I do with the 45-peak. In most cases, I have a general idea of where the peak will be based on a combination of how I feel, and past experiences. I stop off at selected locations, usually a place where I can go to the bathroom. I need to be stopped for *ten to fifteen minutes* in order to get an accurate feeling of my location relative to the peak. During this time, I can walk around, or I can sit in the car, but I can't drive the car. After the wait is up, I make a determination of what zone I'm in, and whether I'm in the prepeak area or not. If I'm in the prepeak zone, then I'll get out and walk to the peak. Usually I never have to walk more than

500 meters. If I'm not in the prepeak zone, I'll drive again in the appropriate direction. Frequently, I'll overshoot the peak, and find that I'm in the opposing zone. I'll backtrack or walk to the peak depending on how far I drove, and how wide I predicted the Happy Zone to be based on bed angle. For example, for some bed angles near the cardinal bed angles the Happy Zone Width is under two kilometers, so I'll drive directly from the Negative Zone to the Positive Zone, or vice versa. Based on my predicted knowledge of the size of the Happy Zone, and my knowledge of how far I traveled in the last car trip, I can get a sense of how far I am from the peak. I've never failed to find the peak using this method.

The H-P transition doesn't have as strong or as wide a prepeak zone as does the peak. This makes it easy to miss. The sudden burst of tics when going from Happy to Positive Zone is the characteristic sign (the Happy Zone is characterized by no tics, while the Positive Zone is characterized by tics). As in the case of the N-H transition, I can feel the burst of tics in the car when crossing from Happy to Positive Zone only when the bed angle is within the 45-peak area. When I feel this, using the procedure described above I pull over and walk to the transition. If I'm walking north from the Positive Zone, I'll notice at some point that involuntary abdominal movements cease. I'll find myself in the Happy Zone. I'll then walk south until I feel a burst of tics. This is the H-P transition. I set a GPS Waypoint and write down the coordinates in my notebook.

When bed angle is within the C-peak area, I can't feel the H-P transition in the car. As I described above, I have to stop the car and wait ten to fifteen minutes to get an accurate sense of my location. Since the H-P transition doesn't have as strong a prepeak zone, it's more difficult to determine when I'm close to the transition, so I frequently overshoot it. Based on my knowledge of Happy Zone Width as a function of bed angle, I can predict how big the Happy Zone is. This knowledge limits the amount of distance that I overshoot. After I feel I’m close enough to walk it, I’ll park the car and walk to the transition. I find it the same way I find it when bed angle is within the 45-peak area.

The fact that for the C-peak I temporarily lose magnetoreceptive feelings when driving seems to imply that magnetoreceptive feelings are disrupted by motion that is artificially increased beyond natural human ranges. One may wonder how the body responds to traveling in an airplane, at speeds up to 10 times what one experiences in a car. On Dec 22, 2008, I flew from Raleigh, NC to Newark, NJ, a flight distance of about 670 kilometers. In New Jersey I stayed at my parents’ house, sleeping on an airbed in an even magnetic field. The first night I switched from N-S (~359 degrees) to 45 degree (~305 degrees) bed angle. While the bed angle fluctuated somewhat during my 8-night stay at my parents’ house (going up to 309 degrees), it remained in the 45 degree range the whole time. I noted feeling in the Negative Zone as late as December 28. On December 30, I flew back to Raleigh (in a Bombardier Dash 8-Q400 Turboprop, cruising speed 670 km/h). I didn’t feel magnetoreceptive feelings at 12:25 p.m. in Cary, NC, and didn’t feel magnetoreceptive feelings at 1:46 p.m., in Warsaw, NC. Sunrise in Warsaw that day was 7:20 a.m., and sunset 5:10 p.m. At 1:46 p.m. in Warsaw, therefore, which was about 6.5 hours after sunrise and 3.5 hours before sunset, I should have felt magnetoreceptive feelings under normal conditions. The fact that I didn’t feel magnetoreceptive feelings after returning to North Carolina indicates that magnetoreception is disrupted by flying. I changed bed angle to N-S that night, but didn’t feel magnetoreceptive feelings on the second day (Jan 1) as I expected to. I felt in the Positive Zone on Jan 2.

# East-West Map (NTZ's)


Fig 13. Map of North America broken out by Natural Time Zones (NTZ's). 1W is the first NTZ west, 2W is the second NTZ west, etc. 1E is the first NTZ east. Note that NTZ 0 is twice the size of the other zones, as it extends 6.43 degrees east and west from the prime meridian (-74.39 degrees longitude). Map from Oxford Essential World Atlas, 2006.

My body divides the 360 degrees of Earth's longitude into 56 Natural Time Zones (NTZ's) of approximately 6.4286 degrees each (Fig. 13). This corresponds to a difference in solar time of about 25.7 minutes. The prime meridian passes through the location in which I spent a critical developmental period (CDP) during childhood. This is either Plainfield, NJ, or

New Providence, NJ (both at -74.39 degrees longitude). It isn't Queens, New York (-73.92 degrees longitude), which is too far east. It isn't Charlottesville, VA (-78.45 degrees longitude), which is too far west. Thus the CDP (affecting NTZ's) happened between ages 18 months and 18 years. The first seven predicted NTZ's crossings west of reference are: -80.82, -87.25, -93.68, -100.10, -106.53, -112.96, -119.39.

## Evidence for the existence of NTZ's

I experience peak reactions when I walk east or west across an NTZ. I have crossed NTZ 0—NTZ 1W, NTZ 1W— NTZ 2W, and NTZ 5W—NTZ 6W, experienced peak reactions, and noted the GPS coordinates (Table 7).

| Location | Date | Time | Lat | Long | Expected Long | Diff |
|---|---|---|---|---|---|---|
| **NTZ 0—NTZ 1W** | | | | | | |
| Central Florida | 5/8/2008 | 12:21 | 28.54392 | -80.93590 | -80.82 | -0.12 |
| Port Orange, FL | 5/8/2008 | 14:13 | 29.10819 | -81.02621 | -80.82 | -0.21 |
| Ridgeland, SC | 5/8/2008 | 19:44 | 32.47980 | -80.97370 | -80.82 | -0.15 |
| near Hilton Head, SC | 5/12/2008 | 16:52 | 32.24092 | -80.82069 | -80.82 | 0.00 |
| Arcadia Lakes, SC | 8/6/2009 | 15:24 | 34.06761 | -80.95540 | -80.82 | -0.14 |
| Statesville, NC | 9/20/2009 | 16:29 | 35.77100 | -80.93514 | -80.82 | -0.12 |
| Average | | | 32.04 | -80.94 | | -0.12 |
| **NTZ 1W—NTZ 2W** | | | | | | |
| Gary, Indiana | 9/1/2009 | 14:03 | 41.54812 | -87.38355 | -87.25 | -0.13 |
| **NTZ 5W—NTZ 6W** | | | | | | |
| Western Utah | 11/5/2007 | 18:09 | 40.73534 | -113.11621 | -112.96 | -0.16 |
| Western Utah | 11/26/2007 | 9:58 | 38.43993 | -113.16313 | -112.96 | -0.20 |
| Delle, Utah | 5/5/2008 | 12:28 | 40.76886 | -112.79358 | -112.96 | 0.17 |
| Western Utah | 6/13/2008 | 12:42 | 40.74620 | -113.06527 | -112.96 | -0.11 |
| Average | | | 40.17 | -113.03 | | -0.07 |
| Overall Average | | | | | | -0.11 |
| Overall Std Dev | | | | | | 0.11 |

Table 7. Location of NTZ peak reactions. Time = local time. Expected Long is calculated based on the following formula: -74.39 - (360/56)* {Trans}, where Trans = 1 for the first NTZ west crossing, 2 for the second NTZ west crossing, etc. Negative Diff corresponds to west of predicted location, positive Diff east of predicted location.

The overall average is 0.11 degrees west of predicted, with a standard deviation of 0.11 (n = 11). In order to attempt to explain the variance of this data, I'll present some possible explanatory variables in Table 8.

| Location | Date | Time | Lat | Diff | Circadian | Bed Angle | Ap | K |
|---|---|---|---|---|---|---|---|---|
| **NTZ 0—NTZ 1W** | | | | | | | | |
| Central Florida | 5/8/2008 | 12:21 | 28.54392 | -0.12 | -1 | 2 | 3 | 0 |
| Port Orange, FL | 5/8/2008 | 14:13 | 29.10819 | -0.21 | -1 | 2 | 3 | 1 |
| Ridgeland, SC | 5/8/2008 | 19:44 | 32.47980 | -0.15 | -1 | 2 | 3 | 0 |
| near Hilton Head, SC | 5/12/2008 | 16:52 | 32.24092 | 0.00 | 0 | 1 | 3 | 1 |
| Arcadia Lakes, SC | 8/6/2009 | 15:24 | 34.06761 | -0.14 | 0 | 2 | 8 | 2 |
| Statesville, NC | 9/20/2009 | 16:29 | 35.77100 | -0.12 | 1 | 2 | 3 | 2 |
| **NTZ 1W—NTZ 2W** | | | | | | | | |
| Gary, Indiana | 9/1/2009 | 14:03 | 41.54812 | -0.13 | 0 | 1 | 2 | 0 |
| **NTZ 5W—NTZ 6W** | | | | | | | | |
| Western Utah | 11/5/2007 | 18:09 | 40.73534 | -0.16 | | | | |
| Western Utah | 11/26/2007 | 9:58 | 38.43993 | -0.20 | | | | |
| Delle, Utah | 5/5/2008 | 12:28 | 40.76886 | 0.17 | 1 | 1 | 12 | 3 |
| Western Utah | 6/13/2008 | 12:42 | 40.74620 | -0.11 | 0 | 2 | 3 | 1 |

Table 8. Possible explanations of variance in E-W peak difference from predicted location. Time = local time. Negative Diff corresponds to west of predicted location, positive Diff east of predicted location. Circadian = -1 (phase delayed), 0 (in phase), 1 (phase advanced). Bed Angle = 1 (cardinal bed angle—N/S or E/W), 2 (45 degree bed angle). Ap = Geomagnetic daily activity index, K = Geomagnetic 3 hour activity index. Ap and K are measured at the closest observatory in which data is available online (Fredericksburg for all data points except the 2008 Utah values; Boulder for the 2008 Utah values). Both Ap and K values are from National Weather Service.

I list correlations of possible explanatory variables versus Diff here (I have incomplete records for the 11/5/2007 and 11/26/2007 data points, so I can't accurately estimate Circadian or Bed Angle):

| | | | |
|---|---|---|---|
| r(Lat, Diff) | 0.25 | df = 9 | ns |
| r(Time, Diff) | -0.09 | df = 9 | ns |
| r(Circadian, Diff) | 0.64 | df = 7 | ns |
| **r(Bed Angle, Diff)** | **-0.68** | **df = 7** | **p < 0.05** |
| **r(Ap, Diff)** | **0.62** | **df = 9** | **p < 0.05** |
| **r(K, abs(Diff)** | **0.61** | **df = 9** | **p < 0.05** |

There are three significant correlations. Diff decreases (i.e. the peak becomes more west of predicted) as Bed Angle changes from cardinal to 45 degrees. Diff increases (i.e. the peak becomes less west of predicted) as both Ap and K increase (i.e. as there is more solar activity). Note that the only data point in which the peak is east of predicted (Delle, Utah—5/5/2008) is one in which both Ap and K have their highest values. Circadian is close to significance. In this case, as circadian rhythm (discussed below) becomes more advanced, Diff increases (i.e. the peak becomes less west of predicted).

I tried a 3-factor regression analysis with Diff as the dependent variable, and Circadian, Bed Angle, and Ap as independent variables (Table 9). I used the 9 data points with complete information:

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.890924 |
| R Square | 0.793746 |
| Adjusted R^2 | 0.669994 |
| Standard Err | 0.063181 |
| Observations | 9 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Sig F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.076812 | 0.025604 | 6.413987 | 0.036332 |
| Residual | 5 | 0.019959 | 0.003992 | | |
| Total | 8 | 0.096771 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* |
|---|---|---|---|---|---|
| Intercept | 0.00931 | 0.093965 | 0.099081 | 0.924924 | -0.23223 |
| Circadian | 0.026714 | 0.035239 | 0.758084 | 0.482581 | -0.06387 |
| Bed Angle | -0.1012 | 0.049545 | -2.04261 | 0.096547 | -0.22856 |
| Ap | 0.016538 | 0.007807 | 2.118393 | 0.087684 | -0.00353 |

RESIDUAL OUTPUT

| *Observation* | *Predicted Y* | *Residuals* | *Standard Residuals* |
|---|---|---|---|
| 1 | -0.17019 | 0.054294 | 1.08698 |
| 2 | -0.17019 | -0.03602 | -0.72105 |
| 3 | -0.17019 | 0.016494 | 0.330213 |
| 4 | -0.04228 | 0.041588 | 0.832614 |
| 5 | -0.06079 | -0.07461 | -1.49368 |
| 6 | -0.11677 | 0.001626 | 0.032562 |
| 7 | -0.05882 | -0.07473 | -1.49619 |
| 8 | 0.133275 | 0.033145 | 0.66358 |
| 9 | -0.14348 | 0.03821 | 0.764979 |

Table 9. Regression analysis of East-West peak variance.

As can be seen from the analysis, none of the variables are statistically significant. Bed angle has the largest coefficient at -0.10. Perhaps further research can elucidate whether these factors influence east-west peak location.

## Mathematical Formula to compute NTZ

The mathematical formula to compute NTZ for any location on Earth is as follows (this is of course theoretical; I've only observed NTZ's in the United States):

Let reference longitude (i.e. the longitude at which the CDP occurred) be -74.39. Let long be the longitude of the location one is interested in (positive for degrees east, negative for degrees west). Let longDiff be: long - (-74.39). Then

```
IF ((ABS(longDiff )  <=  180)
        NTZ = TRUNC (longDiff / 6.4286)
ELSE  //  ((ABS(LongDiff) > 180))
        NTZ = TRUNC((longDiff – 360) / 6.4286)
ENDIF
```

Where ABS(x) is the absolute value of x.

TRUNC(x) is the truncated value of x, resulting from the removal of the decimal portion.
Positive NTZ is east of reference, and negative NTZ is west of reference.

Let's take a few examples:

Miami, Florida (long = -80.27)
longDiff = -80.27 – (-74.39) = -5.88
ABS (longDiff) = 5.88
NTZ = TRUNC(longDiff/6.4286) = 0

Salt Lake City, Utah (long = -111.83)
longDiff = -111.83 – (-74.39) = -37.44
ABS(longDiff) = 37.44
NTZ = TRUNC(longDiff/6.4286) = -5

Madrid, Spain (long = -3.69)
longDiff = -3.69 – (-74.39) = 70.70
ABS(longDiff) = 70.70
NTZ = TRUNC(longDiff/6.4286) = 10

Manila, Philippines (long = 120.96)
longDiff = 120.96 – (-74.39) = 195.35
ABS(longDiff) = 195.35
NTZ = TRUNC((longDiff – 360) / 6.4286) = -25

<u>Procedure to Find the NTZ Transition Peak</u>

The peak reaction when crossing an NTZ is very similar to the peak reaction when crossing the N-H transition. The only difference is that while the former happens when I move east to west (or vice-versa), the latter happens when I move north to south (or vice-versa).

Finding the NTZ crossing is much more difficult than finding the N-H transition, however. While with the N-H transition I feel different on either side of the peak, with the NTZ crossing I feel the same. The NTZ crossing peak is surrounded by prepeak, similar to the prepeak surrounding the N-H transition peak. I originally discovered NTZ crossings by accidentally stopping at rest areas in prepeak areas, areas that were not near the N-H transition. I stopped at prepeak near the NTZ 5W—NTZ 6W crossing (Idaho, approximately -112.9 degrees longitude), and NTZ 4W—NTZ 5W crossing (Wyoming, approximately -106.4 degrees longitude). I noted the prepeak feelings, but also noted that the N-H peak shouldn't be close to these areas. Since these two prepeak areas were separated by 6.5 degrees longitude, I did some calculations based on a prime meridian intersecting New Providence and came up with the 6.4286 degree NTZ hypothesis. I then drove to western Utah to verify it, and found the NTZ crossing peak 0.16 degrees west of the predicted location.

To find the peak, I drive to the predicted location. When bed angle is in the 45 degree range, I can feel the NTZ crossing peak in the car. After I feel the peak, I note my odometer reading, and drive until I find a safe spot to turn around. As in the case of the N-H transition, I can’t feel the peak when I drive from the opposite direction, so I need to drive past the peak, then turn around and approach it from the original direction. If I’m on an interstate highway, I’ll have to find a parallel road in which it is legal to pull over. Once I feel the peak, I stop the car and walk back to the peak. I then note the GPS coordinates.

When bed angle is in the cardinal angle range, I can’t feel the NTZ crossing in the car. Since I can’t tell which side of the NTZ crossing I’m on, it’s difficult to find the peak. I drive to the predicted location. I may or may not feel prepeak at the predicted location. In either case, I need to pick a direction (east or west) to drive, and make frequent stops. If I don’t feel prepeak after driving in one direction and stopping, then I’ll turn around and drive in the other direction. I’ll keep stopping until I feel prepeak. Once I feel prepeak, then I know I’m approaching the peak. I’ll drive a little and see if I still feel prepeak, and also note whether or not the prepeak is greater in intensity than in the previous stop. If I no longer feel prepeak, or if the prepeak is weaker in intensity, then I know I’ve driven too far. Eventually I’ll stop close to the peak. I know that I’m close based on the strong prepeak sensation. I’ll get out of the car and find the peak. Although it’s not easy, I’ve never failed to find the peak using this method.

Function of NTZ

It’s not clear what the function of the NTZ is. Since there is about a 6 degree separation of latitude between the peak in North Carolina (NTZ 0) and Utah (NTZ 5W), the function may be to push the peak north as one goes west. Within an NTZ, however, there is a southeast to northwest peak displacement (Table 10).

| City | Date | Time (Local) | Lat | Long | Elev (m) | Δ Lat | Δ Long | Long / Lat |
|---|---|---|---|---|---|---|---|---|
| **Utah** | | | | | | | | |
| Crossed NTZ 5W-6W barrier in between following measurements | | | | | | | | |
| Panguitch | 11/26/2007 | 8:08 | 37.96394 | -112.41311 | 1974 | | | |
| Beaver County | 11/26/2007 | 11:23 | 38.47176 | -113.68391 | 1619 | 0.50782 | -1.2708 | -2.50246 |
| Same NTZ measurements | | | | | | | | |
| Midvale | 2/24/2008 | 13:07 | 40.61092 | -111.93897 | 1344 | | | |
| Granite | 2/24/2008 | 13:50 | 40.56793 | -111.80270 | 1573 | -0.04299 | 0.13627 | -3.16981 |
| Riverton | 3/9/2008 | 13:57 | 40.52583 | -111.93890 | 1339 | | | |
| Draper | 3/9/2008 | 14:56 | 40.49085 | -111.85026 | 1569 | -0.03498 | 0.08864 | -2.53402 |
| | | | | | | | Avg | -2.73543 |
| **North Carolina** | | | | | | | | |
| Same NTZ measurements | | | | | | | | |
| Four Oaks | 5/9/2008 | 17:21 | 35.45356 | -78.39300 | 51 | | | |
| Goldsboro | 5/9/2008 | 18:20 | 35.37713 | -77.96386 | 25 | -0.07643 | 0.42914 | -5.61481 |
| Kinston | 5/9/2008 | 19:27 | 35.26677 | -77.57943 | 9 | -0.11036 | 0.38443 | -3.48342 |
| Kinston | 5/11/2008 | 9:10 | 35.31279 | -77.65146 | 43 | | | |
| Goldsboro | 5/11/2008 | 10:31 | 35.38108 | -78.00156 | 35 | 0.06829 | -0.3501 | -5.12667 |
| Smithfield | 5/11/2008 | 11:51 | 35.48546 | -78.36267 | 82 | 0.10438 | -0.36111 | -3.45957 |
| Wilson | 2/12/2009 | 12:28 | 35.70459 | -77.92278 | 50 | | | |
| Raleigh | 2/12/2009 | 14:15 | 35.91768 | -78.78909 | 110 | 0.21309 | -0.86631 | -4.06547 |
| Morrisville | 9/22/2009 | 15:02 | 35.83255 | -78.87997 | 103 | | | |
| Raleigh | 9/22/2009 | 17:45 | 35.76894 | -78.55817 | 70 | -0.06361 | 0.3218 | -5.05895 |
| Fuquay-Varina | 10/9/2009 | 13:16 | 35.60072 | -78.77427 | 130 | | | |
| Rt 15_501 | 10/9/2009 | 15:47 | 35.64581 | -79.17990 | 113 | 0.04509 | -0.40563 | -8.99601 |
| | | | | | | | Avg | -5.11498 |
| | | | | | | | Overall Avg | -4.40112 |

**Compare NC/UT 2-Day Reset**
Ideal Peak Location; 0 BAD

| | | | | | | |
|---|---|---|---|---|---|---|
| North Carolina | 1/1/2008 | 35.38497 | -77.98594 | | | |
| Utah | 1/1/2008 | 41.3469 | -111.89201 | 5.96193 | -33.90607 | -5.68710 |
| | | | | | Diff from Avg | -1.28598 |
| | | | | | / 5 | -0.25720 |

Table 10. Same-day peak measurements. The first two Utah measurements were taken in two different NTZ's; others were in the same NTZ. When 3 cities are compared in North Carolina, the change is relative to the previous one on the list. Since there is diurnal variation, and I couldn't be in two places at the same time, the latitude change data above contains an unknown amount of diurnal variation. The comparison at the bottom refers to the calculated ideal 2-day reset peak location in North Carolina and Utah (0 BAD, 1/1/2008) (see section "Two-Day Reset Data" for derivation).

In Utah, I have one measurement of same-day peaks across 2 different NTZ's (NTZ 5W and 6W), and two measurements of same-day peaks in the same NTZ (5W). The Long/Lat ratio of -2.50 for the different NTZ peaks is not that far off from the Long/Lat ratios for same NTZ peaks (-3.17, -2.53). If the peak shifts north or south across an NTZ, it's possible that the shift only occurs after sleeping a night or two in the new NTZ; so looking at same-day data would tell you nothing.

The average Long/Lat ratio in North Carolina (-5.11) is 86% higher than the average ratio in Utah (-2.74), indicating that the peak line is closer to east-west in North Carolina than in Utah.

Comparing the average Utah/North Carolina same-day peak Long/Lat ratio (-4.40) to the "ideal 2-day reset peak" ratio (-5.69, or 29% higher), one can see that the peak line is more east-west oriented when looking across the country than when looking at individual same-day peak measurements. It's possible that the NTZ's function is to shift the peak south as one moves west by a -0.26 Long/Lat ratio per NTZ, for a total of -1.29 over 5 NTZ's. It's possible, however, that these Long/Lat differences refer to geographical differences in the unknown magnetic property that the body uses to determine peak location. The contaminating effect of diurnal variation, along with the limited amount of data, makes any conclusion tentative.

Another NTZ function may be a natural method to phase advance or phase delay. Every NTZ one goes west may phase delay me 25.7 minutes, and every NTZ I go east may phase advance me 25.7 minutes. There's no direct evidence of this, however.

Could the NTZ be a smaller?

I've observed peak reactions at multiples of approximately 6.43 degrees longitude from my hometown. The fact that I've observed reactions at the first multiple of 6.43 degrees west excludes the possibility that an NTZ could be 2 * 6.43 degrees in length. It doesn't exclude the possibility, however, that the NTZ could be 1/2 * 6.43 degrees = 3.22 degrees in size, or $(1/2)^n$ * 6.43 degrees in size, with n being any integer.

To argue against this, consider that for any integer n, a $(1/2)^n$ * 6.43 degrees size NTZ *must* include all the 3.22 degree multiples west of New Providence, which would include -77.61 and -109.81 degrees longitude. I've crossed -77.61 degrees longitude many times in Eastern North Carolina and Virginia and have never experienced an E-W peak or prepeak reaction. Also, -109.81 degrees longitude is just west of Moab, Utah, a town that I stayed in a number of times and never experienced prepeak.

For other arguments supporting the 6.43 degrees / 25.7 minute hypothesis, see the sections below on circadian rhythm and seasonal changes.

# Circadian Rhythm Effects

The peak's N-S location is affected by my body's circadian rhythm relative to the solar day. My body compares my actual circadian rhythm relative to the solar day to a reference rhythm. I hypothesize that the reference circadian rhythm is the rhythm I had during the CDP. Evidence suggests that this CDP occurred in Northern New Jersey (see previous section).

For every 20 - 30 minutes that I am phase advanced compared to reference, my body shifts the peak north one transition. For every 20 - 30 minutes that I am phase delayed compared to reference, the body shifts the peak south one transition.

Evidence for the circadian rhythm effect: I first noticed this effect after the change from daylight savings time to standard time that occurred on November 4, 2007. It felt as if the peak, which was well north of Salt Lake City during daylight savings time, had shifted south (i.e. I felt less intense positive symptoms). For example, on October 3, 2007, I found the peak in Garden City, UT (41.97, -111.40). On November 9, 2007, after the change to standard time, I found the peak in Centerville, UT (40.92, -111.89), about one degree of latitude south. These measurements were taken before I controlled for bed angle, and contained an unknown amount of BAD, so cannot be used quantitatively. Subsequent (more controlled) measurements have confirmed the basic finding that (assuming constant bedtime) the peak shifts south two transitions during the change to standard time, and north two transitions after the change to daylights savings time. The peak transition size is about 0.29 degrees latitude for C-peak, and about 0.35 degrees latitude for 45-peak (see Two-Day Reset section below for supporting data).

Since the time change is one hour, and there are two transitions per time change, the circadian rhythm transition time must be between 20 and 30 minutes.

Let me consider what happens when we change from daylight savings time to standard time. Assume that under daylight savings time, sunrise is 8:00 a.m., and sunset 6:00 p.m. Assume that my normal bedtime is 10:30 p.m., and normal wakeup time is 6:30 a.m. Now let me analyze what happens with the change to standard time. Assuming that due to social and clock pressures (I'm very sensitive to clock time), my bedtime and wakeup *clock* time remain the same (i.e. I still go to bed at 10:30 p.m., and wake up at 6:30 a.m.) Thanks to the return to standard time, sunrise is now 7:00 a.m., and sunset at 5:00 p.m. So now I'm waking up a 0.5 hours before sunrise (instead of 1.5 hours before sunrise), and going to bed 5.5 hours after sunset (instead of 4.5 hours after sunset). From the constant *solar day* reference (leaving aside the time change), I've been phase delayed. So the change to standard time phase delayed me one hour.

I have found that a circadian rhythm effect occurs when I shift bedtime by about 45 minutes. If I go to bed 45 minutes later than normal, the peak shifts south one transition (phase delay). If I go to bed 45 minutes earlier than normal, the peak shifts north one transition (phase advance). Smaller changes in bedtime (e.g. 30 minutes or less) do not have any effect on the peak, indicating that there is not a continuous relationship between circadian rhythm and peak location.

<u>Psychological Effect of Circadian Rhythm Differences</u>

When circadian rhythm is different from ideal (either advanced or delayed), I feel symptoms similar to what I feel when I experience when I sleep in an artificial magnetic field:

shaking and increased tics. The symptoms are so similar, in fact, that I can't distinguish between the effects of artificial magnetic fields or non-ideal circadian rhythm.

I identify ideal circadian rhythm on the basis of not feeling these sleeping symptoms. Ideal circadian rhythm is primarily driven by my bedtime (wake-up time doesn't seem to have any effect). I can adjust bedtime to compensate for circadian rhythm effects. Ideal bedtime in Wilmington is approximately 9:15 p.m. (standard time) and 10:45 p.m. (daylight savings time). Ideal bedtime in New Providence is ~ 15 minutes earlier (which reflects the fact that my circadian rhythm in Wilmington is 14 minutes phase advanced relative to solar day compared to New Providence). If I get to bed (not get to sleep, but get into bed) within +- 15 minutes of the ideal time, then I usually don't have any symptoms. If I get to bed outside of this 30 minute window, then (depending on how long it takes me to get to sleep) I can feel symptoms. It is rare for me to have trouble getting to sleep initially. Sometimes during the night, I'll wake up and have trouble getting back to sleep.

The more my circadian rhythm is off, the stronger the symptoms. For example, I visited my parents in New Jersey late December 2007. Since I didn't know at the time about how bedtime could affect circadian rhythm, I went to bed at what was my normal bedtime, 10:30 or 11:00 p.m. This caused a two or three transition phase delay, however (since ideal bedtime was ~ 9:00 p.m.), resulting in severe symptoms which I identified but couldn't explain at the time.

If I change bedtime without resetting bed angle, I have symptoms, even if the change is from non-ideal to ideal bedtime. For example on the evening of September 12-13, I began a reset from a 45 degree angle to an E-W angle. I deliberately set my bedtime 45 minutes later than normal to produce a phase-delayed state (I wanted to find the peak). The reset occurred on Sept 15. I found the peak that day and the following day. My symptoms included shaking, tics, and obsessive-compulsiveness. On the evening of September 16-17, I went to bed at my normal ideal bedtime. Although some of my symptoms went away, I had other (new) symptoms, including allergic eye inflammation. These symptoms went away when I reset to a 45 degree bed angle the following evening.

## ATZ Effect on Circadian Rhythm

There's another circadian rhythm effect based on one's position in the artificial time zone (ATZ). For the first year of this research project, I lived in Salt Lake City, which is in the western part of the Mountain Time Zone (UTC - 7). My CDP occurred in New Jersey, which is in the eastern part of the Eastern Time Zone (UTC - 5). While there is a two hour artificial time difference between Salt Lake City and New Jersey, there is a 2.5 hour *solar* time difference. The approximately 30 minute difference between artificial time and solar time has a profound effect on magnetoreception. Since Salt Lake City is further west in its ATZ than New Jersey, sunrise and sunset are about 30 minutes delayed (according to artificial time) compared to New Jersey. The delayed sunrise and sunset imply that I'm about 30 minutes phase advanced year-round compared to New Jersey (assuming constant local bedtime).

Mathematically, one can determine how much phase advance or delay to expect from this ATZ effect, assuming that the circadian rhythm transition is the same as the NTZ transition, at 25.7 minutes. Let reference (New Providence) longitude be -74.39, and reference ATZ be -5 (Eastern Time is UTC -5). Let long be the longitude of any location, and let ATZ be its artificial time zone (in terms of UTC). Then:

phase difference = ({long – (-74.39 deg)} / 6.43 deg/transition) * 25.7 minutes/transition) – 60 minutes * (ATZ – (-5)).

For Salt Lake City, which is long = -111.83, ATZ = -7, this amounts to:

Phase difference = ({-111.83 deg – (-74.39 deg)} / 6.43 deg/transition) * 25.7 minutes/transition– 60 minutes * (-7 – (-5)) = -29.6 minutes, where the negative sign refers to a phase advance.

The 29.6 minute phase advance due to the ATZ position difference shifts the peak north one transition from what its expected location would be considering bedtime. Say for example that during daylight savings time in Salt Lake City I went to bed at 10:30 p.m. MST. Ideal bedtime assuming no ATZ effect is about 10:30 p.m. Then due to the 29.6 minute ATZ Effect I would be one transition phase advanced relative to solar day compared to reference. To compensate I'd need to go to bed 45 minutes later.

I never precisely measured my ideal bedtime in Utah, although going to bed around 11:30 p.m. (during daylight savings time) consistently resulted in ideal circadian rhythm.

<u>45-Peak Split is Dependent on Circadian Rhythm</u>

If circadian rhythm relative to solar day was within the ideal range, *and* I slept in an even magnetic field, then the ~ 2 degree latitude 45-peak split I observed in Utah went away. In other words, the peaks were no longer split, and the 45-peak could be found at about the same latitude as the C-peak.

In North Carolina, I didn't observe any 45-peak split. If circadian rhythm was off, and bed angle was within the 45-peak range, then the 45-peak shifted north or south from the ideal location ~ 0.35 degrees in latitude.

Due to a combination of using the innerspring mattress and not compensating for the ATZ effect in Utah, for the first six months of my research the only 45-peak I observed was a split 45-peak. I first observed an unsplit 45-peak in Utah after spending a night in Moab, Utah, which is 2.26 degrees longitude east of Salt Lake City, and thus far enough east to cancel the ATZ effect mentioned above. I slept in a relatively even magnetic field in Moab on April 10 - 11, 2008, on an airbed, at a bed angle of 308 degrees. On my way to Moab on April 10, after sleeping 3 nights at my Salt Lake City home at 308 degrees, I measured the split 45-peak at (39.36, -110.39). On my way home from Moab on April 11, I measured the unsplit 45-peak at (41.01, -111.92), or 1.65 degrees latitude north. Considering that the 308 degree bed angle is reasonably stable in Utah (Fig. 11), this shift north was likely not due to BAD.

Subsequent peak measurements in Utah confirmed that 45-peak split disappeared when I was at ideal circadian rhythm and in a relatively even magnetic field.

## Circadian Rhythm Changes Can Delay a BAR

For a Bed Angle Reset (BAR) to occur in 2 days, bedtime must be constant enough to prevent a circadian rhythm shift from occurring. If I go to bed earlier or later enough to cause a circadian rhythm shift on the second night of the reset, the reset will not occur. For example, on April 17, 2009, I changed bed angle from 357 to 312 degrees, starting a reset. I went to bed 11:11 p.m the first night. I kept bed angle constant and went to bed at 11:14 p.m. the second night. I had some difficulty getting to sleep that second night, however, and had shaking symptoms the next morning. I attributed these symptoms to a circadian rhythm shift (since everything else was constant, and it was too early for seasonal effects). I checked for magnetoreceptive feelings the next day at 1:47 p.m., and didn't have any, indicating the reset did not occur. The following night I kept bed angle constant and went to bed at 10:57 p.m. That night I didn't have shaking symptoms, and the next day I felt in the Happy Zone, indicating that I was in-phase, and a reset had occurred.

The data in the above paragraph demonstrates three things:

1) A circadian rhythm shift can delay a 2-day reset.
2) The transition bedtime between in-phase and phase-delay for Wilmington is ~ 11:15 p.m.
3) Circadian rhythm doesn't need to be constant on consecutive days for a reset to occur. In the above example, the sequence was in-phase, phase-delayed, in-phase.

# Seasonal Effects

The peak shift north after the change to daylight savings time and south after the change to standard time, although associated with seasonal changes, is not a true geomagnetic seasonal effect. It's an effect of an artificially-induced circadian rhythm change relative to solar day. A true seasonal effect is something that happens due to changes in day length between the solstices. I did not notice any such change in Salt Lake, which at 40.72 degrees latitude is at virtually the same latitude as New Providence (40.70). This similarity in latitude implies that seasonal changes in day length are identical between the two cities. The lack of seasonal geomagnetic changes in Salt Lake could be due to an internal "seasonal clock" which compares observed day length to that which was experienced during the CDP. This seasonal clock didn't find any changes in day length, so it didn't trigger any geomagnetic changes. On the other hand, there may not be any human geomagnetic seasonal changes at all. There was no way for me to distinguish between these possibilities while I lived in Salt Lake.

Wilmington, NC, on the other hand, at 34.22 degrees latitude, is about 6.5 degrees south of New Providence. Day length compared to New Providence is 35 to 40 minutes shorter at the summer solstice and longer at the winter solstice. So if there are human geomagnetic seasonal changes, I might experience them in Wilmington.

I experienced seasonal changes in peak location in Wilmington around both the winter solstice and the summer solstice. Both seem to follow a general pattern (Table 11):

1) For both the winter solstice and the summer solstice changes, the peak always shifts north before the solstice, then returns south after the solstice.
2) The first seasonal shift occurs when day length is approximately 25 minutes different from New Providence.
3) Each subsequent shift north occurs at approximately 5 minute difference in day length.

4) The symptoms I experienced from these seasonal changes (shaking, increased tics) are identical to symptoms from circadian rhythm changes.
5) To compensate for the shifts before the winter solstice I adjusted my bedtime an hour later for each shift, causing the peak to shift back south and for the symptoms to disappear. I compensated for the first shift before the summer solstice, then partially compensated after that.

| Date | Sunrise | Ref Sunrise | Sunset | Ref Sunset | DL | Ref DL | DL Diff | Comparison | Peak Shift |
|---|---|---|---|---|---|---|---|---|---|
| Winter Solstice Seasonal Changes | | | | | | | | | |
| 11/9/2008 | 6:39 | 6:38 | 17:11 | 16:45 | 10:32 | 10:07 | 0:25 | Longer | North |
| 11/21/2008 | 6:51 | 6:52 | 17:04 | 16:35 | 10:13 | 9:43 | 0:30 | Longer | North |
| 12/5/2008 | 7:03 | 7:07 | 17:02 | 16:30 | 9:59 | 9:23 | 0:36 | Longer | North |
| 1/4/2009 | 7:18 | 7:22 | 17:15 | 16:44 | 9:57 | 9:22 | 0:35 | Longer | South |
| 1/19/2009 | 7:16 | 7:17 | 17:29 | 17:00 | 10:13 | 9:43 | 0:30 | Longer | South |
| 1/29/2009 | 7:11 | 7:10 | 17:39 | 17:12 | 10:28 | 10:02 | 0:26 | Longer | South |
| Summer Solstice Seasonal Changes | | | | | | | | | |
| 4/30/2009 | 6:23 | 5:57 | 19:55 | 19:53 | 13:32 | 13:56 | 0:24 | Shorter | North |
| 5/12/2009 | 6:12 | 5:43 | 20:04 | 20:05 | 13:52 | 14:22 | 0:30 | Shorter | North |
| (was out-of-town 5/22 - 5/26, when the next transition likely occurred) | | | | | | | | | |
| 6/6/2009 | 6:00 | 5:27 | 20:21 | 20:26 | 14:21 | 14:59 | 0:38 | Shorter | North |
| 6/29/2009 | 6:03 | 5:29 | 20:27 | 20:33 | 14:24 | 15:04 | 0:40 | Shorter | South |
| 7/9/2009 | 6:07 | 5:35 | 20:26 | 20:30 | 14:19 | 14:55 | 0:36 | Shorter | South |
| (was out-of-town 7/14 - 7/28, when the next transition likely occurred) | | | | | | | | | |
| 8/1/2009 | 6:23 | 5:54 | 20:12 | 20:13 | 13:49 | 14:19 | 0:30 | Shorter | South |

Table 11. Winter and summer solstice seasonal changes, as observed in Wilmington NC (34.22, -77.87). Ref = Reference, which is New Providence, NJ (40.70, -74.39). New Providence sunrise and sunset are calculated based on the same dates as in the table. Note that if the year of the critical developmental period (CDP) were known, then that year should be used as a reference. Date = First day I notice the shift (usually based on how I slept the previous night). DL = Day length (Sunset – Sunrise). Comparison = Longer if DL is longer than Ref DL, Shorter if DL is shorter than Ref DL. Data collected until August 1, 2009. Sunrise and sunset times from Earth Surface Research Lab.

Since there were 3 seasonal shifts north before the winter solstice, I gradually adjusted my bedtime later. After adjusting my bedtime, the shaking symptoms went away, until the next seasonal shift. After the winter solstice, as the seasonal changes reversed themselves, I gradually adjusted my bedtime back to 9:30 p.m.

For the seasonal changes before the summer solstice, I did a partial adjustment. The reason I did this partial adjustment was that I couldn't get enough sleep if I went to bed too late. I had to balance the deleterious psychological consequences of the peak being north of ideal versus the consequences of not getting enough sleep. I decided to compromise by doing a partial adjustment.

Evidence for Seasonal Effects

At the time that I first noticed seasonal effects, in November 2008, it had been a year since I first observed circadian rhythm changes, and six months since I had begun manipulating my bedtime to adjust my circadian rhythm. So I knew that going to bed an hour later would phase delay me and shift the peak south one transition, and going to bed an hour earlier would phase advance me and shift the peak north one transition. I thought that there might be seasonal effects in Wilmington, but didn't know exactly when and how frequently they would occur.

When I felt strong tics and abdominal sensitivity in the early morning of November 9, 2008, after going to bed at 9:30 p.m. the previous night, and after having slept well the night before, I suspected that a seasonal effect occurred. I didn't know the direction of the effect, but guessed that it pushed the peak north, which meant that I needed to phase delay to push it back south. I went to bed at 10:26 p.m. the next night and slept well. This pattern—disruption in sleeping, then adjusting my bedtime an hour later (or earlier after the solstice), then sleeping well the next night, were the main indicators that a seasonal effect occurred, and also which direction the peak shifted.

Note that at the time I believed that an hour change in bedtime produced a one transition circadian phase shift. I realize now that the bedtime change should have been 45 minutes. This meant that I overcompensated, producing more circadian phase shift than I realized.

By late April, 2009, I was hoping that there wouldn't be a summer solstice seasonal effect. During the late fall and early winter, I found seasonal transitions very destabilizing, especially considering I never knew the exact day that the next shift would occur. I thought that if a summer seasonal effect did occur, that the peak would shift in the opposite direction as it did in the winter, since the days were shorter compared to reference, not longer.

On April 30, 2009, I had some shaking and tics after going to bed the previous night at 10:59 p.m. I thought that it might be a seasonal effect, and went to bed that night at 9:59 p.m. The next morning I woke up with more severe symptoms than the night before. I realized that the seasonal shift pushed the peak north, and my going to bed an hour earlier had pushed it north a second transition. So the night of May 1 - May 2, I went to bed at 11:57 p.m. and slept well.

There is other evidence than feelings that seasonal effects occurred. On Nov 20, 2008, I found the peak after sleeping three nights at 323 degrees (the first night my sleep was disrupted by the magnetic field from a battery-powered smoke alarm). My bedtimes were 10:39 p.m., 10:44 p.m., and 10:39 p.m., about an hour later than usual for standard time since I had adjusted them due the Nov 9 seasonal shift. I had no magnetoreceptive feelings after the second night, indicating that sleep disruptions caused by artificial magnetic fields can delay the 2-day reset. After the third night I had magnetoreceptive feelings and found the peak at (35.52, -77.98). I went to bed at 10:49 p.m. that night (with bed angle still at 323 degrees), then woke up at 2:30 a.m. the next morning with shaking symptoms. I found the peak that day at (36.85, -77.43), or 1.33 degrees latitude north. While some of this shift was likely due to BAD, I have never observed BAD greater than 1 degree latitude (see Fig. 12), so some of this shift was likely due to the seasonal change. Note that this shift north is unlikely to be due to circadian rhythm phase advance, since I went to bed *later* than I did the previous three nights. I didn't immediately adjust bedtime after this incident, because I found it hard to believe that another seasonal shift had occurred so soon after the last one. It was only after a trip to visit my parents in New Providence Nov 24 – Dec 2 that I adjusted bedtime to ~ 11:30 p.m. and felt better. That is, until the next seasonal change on Dec 5, after which I had to shift bedtime to ~ 12:30 a.m.

Another, less ambiguous peak test was done near the winter solstice, on 12/18 and 12/19. I slept at 307 degrees two nights (bedtimes 12:38 a.m. and 12:35 a.m.), then found the 2-day reset 45-peak on 12/18 at (35.57, -77.97). I slept at the same bed angle the night of Dec 18 - Dec 19, going to bed at 12:39 a.m. I then found the Dec 19 peak at (36.10, -77.73). The 2-day reset peak is in a position consistent with the 0.53 degree latitude northward BAD, assuming canceling circadian rhythm and seasonal effects (see next section for supporting data). If there were no seasonal effects, the ~ 3.5 hour delayed bedtime (i.e. 4 or 5 transition south shift, based on a 45 minute bedtime transition) would have caused the peak to be about 1.5 degrees south of where I observed it.

I also did a peak test in the spring, after the second seasonal shift. I found the 2-day reset C-peak on May 15 at (35.84, -77.83) after sleeping two nights at 346 degrees (bedtimes 11:59 p.m. and 12:02 a.m.). Note that the bedtimes, being about 1.25 hours later than normal, could have produced one or two circadian shifts south (it's unclear when the cutoff time was). I went to bed at 12:05 a.m. the night of May 15 – May 16, then found the peak the next day at (35.69, -77.94). BAD was -0.15 degrees latitude southward, which means that the 2-day reset peak was 0.51 degrees north of its ideal location (see next section for supporting data). Since the C-peak circadian transition size is about 0.29 degrees, this test proves that the seasonal effect size is greater than the C-peak transition size.

The above examples suggest that seasonal effects and circadian rhythm effects operate independently of BAD, and independently of each other, to determine the actual peak location. In the next section I put all these factors together and arrive at a quantitative analysis of the 2-day reset peak location.

# Two-Day Reset Data

The data I present here is only a fraction of what I've collected. Like with the bed angle data, I rejected all data in which I slept in different beds during the test, or bed angle changed significantly (i.e. > 2 degrees), or I didn't find the peak after one to three days of BAD occurred. The last exclusion is necessary because I found a very high correlation between 2-day peak location and future BAD, and BAD isn't constant over time. Unlike with the bed angle data, I included a few Utah peak measurements when sleeping on an innerspring mattress. While bed angle is impossible to determine with the innerspring mattress, bed angle *drift* can be determined. Assuming that I slept at the same (unknown) bed angle during the test, I also assumed that bed angle was constant and that the bed angle which determined peak location also determined BAD.

## Utah Data

The above exclusions unfortunately required me to omit all 6 Utah C-peak phase delayed / phase advanced 2-day reset measurements I obtained. I will make a qualitative observation about the Utah C-peak phase delayed/phase advanced peaks that they were not split like the 45-peak ones. Phase advanced C-peaks were north of ideal, and phase-delayed C-peaks were south of ideal.

I was, however, able to use 3 split 45-peak phase delayed measurements, and one split 45-peak phase advanced measurement, along with 9 ideal peak location measurements (Table 12).

| Location | Date | Time | Lat | Long | Elev (m) | Days | Bed Angle | Bed Type | BAD (Lat) |
|---|---|---|---|---|---|---|---|---|---|
| **C/45-Peak Measurements (2-day bed angle reset)--Ideal Peak Location** | | | | | | | | | |
| Farmington | 6/20/2008 | 11:14 | 40.97239 | -111.89112 | 1286 | 171 | 309 | AB | 0.02012 |
| Farmington | 6/29/2008 | 12:41 | 40.97583 | -111.88321 | 1268 | 180 | 357 | AB | 0.02785 |
| Layton | 7/3/2008 | 11:51 | 41.04866 | -111.95583 | 1315 | 184 | 318 | AB | 0.571 |
| Centerville | 7/6/2008 | 11:27 | 40.93020 | -111.87905 | 1300 | 187 | 263 | AB | 0.10939 |
| Bountiful | 8/3/2008 | 12:08 | 40.88080 | -111.89207 | 1301 | 215 | 289 | AB | 0.20723 |
| Salt Lake | 8/6/2008 | 13:15 | 40.78560 | -111.89948 | 1285 | 218 | 258 | AB | -0.01869 |
| Kaysville | 8/12/2008 | 12:24 | 41.04308 | -111.94821 | 1284 | 224 | 293 | AB | 0.59962 |
| Salt Lake | 8/15/2008 | 11:29 | 40.79122 | -111.90218 | 1255 | 227 | 280 | AB | -0.06516 |
| Santaquin | 7/24/2009 | 14:12 | 39.97443 | -111.77697 | 1477 | 570 | 258 | AB | -0.10204 |
| **Split 45 Peak (2-day bed angle reset)--One Transition Phase Delayed Ideal** | | | | | | | | | |
| Yuba Lake | 12/7/2007 | 12:44 | 39.34201 | -112.05187 | 1589 | -25 | 315 | IS | 0.062565 |
| Rt 28 | 1/3/2008 | 12:49 | 39.23149 | -111.84807 | 1564 | 2 | 292 | IS | -0.16657 |
| Fayette | 1/8/2008 | 12:41 | 39.21020 | -111.84885 | 1547 | 7 | 305 | IS | -0.03017 |
| **Split 45 Peak (2-day bed angle reset)--One Transition Phase Advanced** | | | | | | | | | |
| Rt 28 | 4/22/2008 | 12:52 | 39.58188 | -111.86190 | 1583 | 112 | 298 | AB | -0.35347 |

Table 12. Utah 2-Day Reset peaks. Time = local time (MST). Days = # of days since reference date of Jan 1, 2008. Bed Type = AB (Airbed) or IS (Innerspring). See Methods section for how I computed bed angle for the innerspring mattress. BAD (Lat) = degrees latitude of future BAD. I never observed a split-45 peak "Ideal" Peak location. Ideal circadian rhythm 2-Day reset 45-peaks, which occurred on 6/20, 7/3, 8/3, and 8/12, were "unsplit."

As can be seen from the table, all measurements (with one exception) are within a ~ 0.2 degree longitude window, which is necessary because I used latitude as my primary measure, and there is a SE-NW displacement of the peak line.

Since there appeared to be a strong relationship between peak location and future BAD, I did a correlation on 2-day reset peak latitude (Ideal Peak Location) and future BAD latitude. This correlation was 0.55, df = 7, ns. Since there seemed to be a small but consistent secular change southward, I did a correlation on 2-day reset peak latitude (Ideal Peak Location) and # of days since 1/1/08. This correlation was -0.97, df = 7, $p < 0.01$ (2 tails).

I did a multiple regression on 2-day reset peak latitude versus future BAD latitude and # of days since 1/1/08 (Table 13).

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.995430845 |
| R^2 | 0.990882566 |
| Adjusted R^2 | 0.987843422 |
| Std Error | 0.036616695 |
| Observations | 9 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Sig F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.87429723 | 0.437148617 | 326.04 | 7.5791E-07 |
| Residual | 6 | 0.00804469 | 0.001340782 | | |
| Total | 8 | 0.88234193 | | | |

| | *Coefficients* | *Std Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 41.34690013 | 0.03267352 | 1265.456106 | 1.64E-17 | 41.26695091 | 41.42685 |
| BAD Lat | 0.304245531 | 0.05237224 | 5.80928965 | 0.001142 | 0.176095268 | 0.432396 |
| # Days | -0.00235773 | 0.00011042 | -21.3520319 | 6.88E-07 | -0.00262792 | -0.00209 |

RESIDUAL OUTPUT

| *Observation* | *Predicted Y* | *Residuals* | *Std Residuals* |
|---|---|---|---|
| 1 | 40.94985009 | 0.02253991 | 0.710791781 |
| 2 | 40.93098236 | 0.04484764 | 1.4142619 |
| 3 | 41.08680241 | -0.0381424 | -1.202813589 |
| 4 | 40.93928644 | -0.0090864 | -0.286539297 |
| 5 | 40.90303745 | -0.0222374 | -0.701253724 |
| 6 | 40.82722911 | -0.0416291 | -1.312766252 |
| 7 | 41.0012008 | 0.0418792 | 1.320652595 |
| 8 | 40.79187127 | -0.0006513 | -0.020537816 |
| 9 | 39.97195006 | 0.00247994 | 0.078204401 |

PROBABILITY OUTPUT

| *Percentile* | *Y* |
|---|---|
| 5.555555556 | 39.97443 |
| 16.66666667 | 40.7856 |
| 27.77777778 | 40.79122 |
| 38.88888889 | 40.8808 |
| 50 | 40.9302 |
| 61.11111111 | 40.97239 |
| 72.22222222 | 40.97583 |
| 83.33333333 | 41.04308 |
| 94.44444444 | 41.04866 |

Table 13. Regression Output for Utah 2-Day Reset Peak (Ideal Location) Latitude versus future BAD latitude and # of Days since 1/1/08.

BAD latitude is significant at $p < 0.002$ and # of days is significant at $p < 1$ E-06. The 0.30 coefficient for BAD implies that each 2-Day reset peak has about 1/3 future BAD associated with it. The -0.00236 coefficient for # of days can be used to compute secular change:

(0.00236 deg latitude south / day) * (7 days / week) * (111.05 km south / 1 deg latitude south) = 1.83 km south / week.

The 41.34690 intercept and -111.89201 average longitude (sd = 0.05108) imply that on Jan 1, 2008, the peak at its ideal location (i.e. no circadian rhythm effects) and with 0 BAD can be predicted to be at 41.35 degrees latitude and -111.89 degrees longitude.

Notice the last Ideal Peak Location measurement (Santaquin) was taken on 7/24/09, about a year after the other measurements, when I was vacationing in Utah. Its latitude (39.97) is about a degree south of the other peak measurements, indicating that the southward secular change continued while I was away from Utah.

To analyze the Split-45 peaks, I used the regression equation to predict where each peak should be (based on future BAD and # of days since 1/1/08) if there were no circadian rhythm effects (Table 14).

| Location | Date | Time | Lat | Long | Elev (m) | Days | BAD (Lat) | Pred Lat | Diff |
|---|---|---|---|---|---|---|---|---|---|
| **Split 45 Peak (2-day bed angle reset)--One Transition Phase Delayed** | | | | | | | | | |
| Yuba Lake | 12/7/2007 | 12:44 | 39.34201 | -112.05187 | 1589 | -25 | 0.062565 | 41.42494 | -2.08293 |
| Rt 28 | 1/3/2008 | 12:49 | 39.23149 | -111.84807 | 1564 | 2 | -0.16657 | 41.29150 | -2.06001 |
| Fayette | 1/8/2008 | 12:41 | 39.21020 | -111.84885 | 1547 | 7 | -0.03017 | 41.32120 | -2.11100 |
| | | | | | | | | | |
| Avg | | | | | | | | | -2.08465 |
| SD | | | | | | | | | 0.02554 |
| | | | | | | | | | |
| **Split 45 Peak (2-day bed angle reset)--One Transition Phase Advanced** | | | | | | | | | |
| Rt 28 | 4/22/2008 | 12:52 | 39.58188 | -111.86190 | 1583 | 112 | -0.35347 | 40.97504 | -1.39316 |

Table 14. Difference between ideal peak predicted location (based on future BAD and # of days since 1/1/08) and split-45 peak actual location. Pred Lat uses the following equation:
Pred Lat = 41.34690 + 0.30425 * BAD (Lat) - 0.00236 * Days
Days = # of Days since 1/1/08. Diff = Lat – Pred Lat.

One transition phase delayed has an average difference of -2.08465 (sd = 0.02554). One transition phase advanced has a difference of -1.39316. If we assume that the average of these two values is the length in degrees latitude of the peak split, then this length is 1.74 degrees latitude south. If we assume that the difference between one transition phase advanced and one transition phase delayed represents 2 circadian rhythm 45-peak transitions, then the length of one transition is 0.35 degrees latitude.

Let's assume for the sake of argument that considering that I didn't observe a split 45-peak in North Carolina (NTZ 0), that this split has something to do with the Utah peak values being in NTZ 5W. If we divide the peak split length of 1.74 by 5, we arrive at 0.35, which happens to be the length of one 45-peak transition.

North Carolina Data

Table 15 has North Carolina 2-day reset peak data.

| Location | Date | Time | Lat | Long | Elev (m) | Days | Bed Angle | Bed Type | BAD (Lat) |
|---|---|---|---|---|---|---|---|---|---|
| **C/45-Peak Measurements (2-day bed angle reset)--Ideal Peak Location** | | | | | | | | | |
| Rt 117 | 9/22/2008 | 14:00 | 35.48980 | -77.98201 | 3 | 265 | 357 | AB | 0.30548 |
| Rt 117 | 9/27/2008 | 12:44 | 35.26672 | -78.05306 | 46 | 270 | 351 | AB | -0.41085 |
| Pikeville | 10/13/2008 | 12:53 | 35.50142 | -77.98375 | 17 | 286 | 318 | AB | 0.54851 |
| Wilson | 2/12/2009 | 12:28 | 35.70459 | -77.92278 | 50 | 408 | 315 | AB | 0.79287 |
| Wilson | 3/3/2009 | 12:43 | 35.70811 | -77.90596 | 32 | 427 | 303 | AB | 0.7991 |
| Rt 117 | 3/18/2009 | 14:20 | 35.59231 | -77.97269 | 15 | 442 | 363 | AB | 0.61852 |
| Goldsboro | 4/15/2009 | 13:30 | 35.34374 | -78.02856 | 25 | 470 | 358 | AB | -0.20055 |
| Goldsboro | 4/22/2009 | 13:15 | 35.35421 | -78.01256 | 15 | 477 | 360 | AB | -0.04769 |
| Goldsboro | 8/21/2009 | 13:52 | 35.35473 | -78.01210 | 21 | 598 | 265 | AB | 0.01252 |
| **C Peak (2-day bed angle reset)--One Circadian Transition Phase Advanced** | | | | | | | | | |
| Pikeville | 10/1/2009 | 13:39 | 35.49425 | -77.98168 | 51 | 639 | 348 | AB | -0.5657 |
| **C-Peak (2-day bed angle reset)--One Circadian Transition Phase Delayed** | | | | | | | | | |
| Goldsboro | 9/15/2009 | 13:59 | 35.34165 | -78.03007 | 22 | 623 | 268 | AB | 0.6254 |
| **C Peak (2-day bed angle reset)--Two Seasonal Transitions North Minus One or Two Circadian Transitions Phase Delayed** | | | | | | | | | |
| Rt 301 | 5/15/2009 | 14:55 | 35.84487 | -77.83215 | 41 | 500 | 346 | AB | -0.15011 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **45-Peak (2-day bed angle reset)--One Circadian Transition Phase Delayed** | | | | | | | | | |
| Goldsboro | 2/23/2009 | 12:49 | 35.34008 | -78.02955 | 3 | 419 | 310 | AB | 0.84721 |
| **45 Peak (2-day bed angle reset)--Three Seasonal Transitions North Minus Four or Five Circadian Transitions Phase Delayed** | | | | | | | | | |
| Fremont | 12/18/2008 | 13:21 | 35.57030 | -77.97482 | 31 | 352 | 307 | AB | 0.5253 |

Table 15. North Carolina 2-Day Reset peaks. Time = local time (EST). Days = # of days since reference date of Jan 1, 2008. Bed Type = AB (Airbed). BAD (Lat) = degrees latitude of future BAD.

As with the Utah data, I kept longitude within an approximately 0.2 degree window. The correlation between 2-day reset peak latitude (Ideal Peak Location) and future BAD latitude was 0.97, df = 7, p < 0.01 (2 tails). The correlation between 2-day reset peak latitude (Ideal Peak Location) and # of days since 1/1/08 was -0.05, df = 7, ns, indicating little or no secular change.

Since the correlation between peak latitude and # of days was so small, I did a simple regression on 2-day reset peak latitude (ideal peak location) versus future BAD latitude (Table 16).

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.970362 |
| R^2 | 0.941602 |
| Adjusted R^2 | 0.93326 |
| Standard Error | 0.041977 |
| Observations | 9 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Sig F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.198878 | 0.198878 | 112.8673 | 1.43E-05 |
| Residual | 7 | 0.012334 | 0.001762 | | |
| Total | 8 | 0.211212 | | | |

| | *Coefficients* | *Std Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 35.38497 | 0.016583 | 2133.864 | 1.31E-21 | 35.34576 | 35.42418 |
| BAD Lat | 0.351921 | 0.033125 | 10.6239 | 1.43E-05 | 0.273592 | 0.43025 |

RESIDUAL OUTPUT

| *Observation* | *Predicted Y* | *Residuals* | *Standard Residuals* |
|---|---|---|---|
| 1 | 35.49247 | -0.00267 | -0.06808 |
| 2 | 35.24038 | 0.026338 | 0.670773 |
| 3 | 35.578 | -0.07658 | -1.95032 |
| 4 | 35.664 | 0.040594 | 1.033824 |
| 5 | 35.66619 | 0.041921 | 1.067633 |
| 6 | 35.60264 | -0.01033 | -0.26305 |
| 7 | 35.31439 | 0.029349 | 0.747455 |
| 8 | 35.36819 | -0.01398 | -0.35592 |
| 9 | 35.38937 | -0.03464 | -0.88231 |

PROBABILITY OUTPUT

| *Percentile* | *Y* |
|---|---|
| 5.555556 | 35.26672 |
| 16.66667 | 35.34374 |
| 27.77778 | 35.35421 |
| 38.88889 | 35.35473 |
| 50 | 35.4898 |
| 61.11111 | 35.50142 |
| 72.22222 | 35.59231 |
| 83.33333 | 35.70459 |
| 94.44444 | 35.70811 |

Table 16. Regression Output for North Carolina 2-Day Reset Peak (Ideal Location) Latitude versus future BAD latitude.

Compare the 0.35 coefficient here for BAD latitude to the 0.30 coefficient from the Utah data. The 35.38497 intercept and -77.98594 average longitude (sd = 0.04782) imply that the peak at its ideal location (i.e. no circadian rhythm effects) and with 0 BAD can be predicted to be at

35.38 degrees latitude and -77.99 degrees longitude. Until the magnetic basis (if any) for the peak is discovered, there's no way to know how long it's been stable at this location.

To analyze the peaks at non-ideal locations, I used the regression equation to predict where each peak should be (based on future BAD) if there were no circadian rhythm or seasonal effects (Table 17).

**Without Seasonal Effects**

| Location | Date | Time | Lat | Long | Elev (m) | Bed Angle | BAD (Lat) | Pred Lat | Diff |
|---|---|---|---|---|---|---|---|---|---|
| **C Peak (2-day bed angle reset)--One Circadian Transition Phase Advanced** | | | | | | | | | |
| Pikeville, NC, Peak | 10/1/2009 | 13:39 | 35.49425 | -77.98168 | 51 | 348 | -0.5657 | 35.18589 | 0.3083611 |
| **C-Peak (2-day bed angle reset)--One Circadian Transition Phase Delayed** | | | | | | | | | |
| Goldsboro | 9/15/2009 | 13:59 | 35.34165 | -78.03007 | 22 | 268 | 0.6254 | 35.60506 | -0.26341 |
| **45-Peak (2-day bed angle reset)--One Circadian Transition Phase Delayed** | | | | | | | | | |
| Goldsboro | 2/23/2009 | 12:49 | 35.34008 | -78.02955 | 3 | 310 | 0.84721 | 35.68312 | -0.34304 |

**With Seasonal Effects**

| Location | Date | Time | Lat | Long | Elev (m) | Bed Angle | BAD (Lat) | Pred Lat | Diff |
|---|---|---|---|---|---|---|---|---|---|
| **C Peak (2-day bed angle reset)--Two Seasonal Transitions North Minus One or Two Circadian Transitions Phase Delayed** | | | | | | | | | |
| Rt 301 | 5/15/2009 | 14:55 | 35.84487 | -77.83215 | 41 | 346 | -0.15011 | 35.33214 | 0.51273 |
| **45 Peak (2-day bed angle reset)--Three Seasonal Transitions North Minus Four or Five Circadian Transitions Phase Delayed** | | | | | | | | | |
| Fremont, NC, Peak | 12/18/2008 | 13:21 | 35.57030 | -77.97482 | 31 | 307 | 0.5253 | 35.56983 | 0.00047 |

Table 17. Difference between ideal peak predicted location (based on future BAD) and peak actual location. Pred Lat uses the following equation:
Pred Lat = 35.38497+0.35192*BAD (Lat)
Diff = Lat – Pred Lat.

The C-peak transition size is 0.31 degrees latitude for a N-S bed angle, and 0.26 degrees latitude for an E-W bed angle, for an average of 0.29 degrees latitude.

The 45-peak transition size is 0.34 degrees latitude, which is about 3% less than the 0.35 I reported for Utah from the split peak data. The average North Carolina C-peak transition size is 15% lower than the 45 peak transition size.

The difficulty in analyzing the peaks with seasonal effects is that there's some uncertainty in the number of circadian rhythm transitions that combine with the seasonal transitions. I'll examine each possibility individually and see if I can come up with a "consensus" seasonal effect size.

Let me start with the 5/15/2009 C-peak. The equations are:

(1) $0.51 = (2 * s) - c$ (1 circadian transition phase delayed)

Where s = seasonal transition size, and c = circadian transition size (both in degrees latitude) and:

(2) $0.51 = (2 * s) - (2 * c)$ (2 circadian transitions phase delayed)

Using the average value of c = 0.29, (1) gives s = 0.40, and (2) gives s = 0.55

Now let's do the 12/18/2008 45-peak. The equations are:

(3) $0 = (3 * s) - (4 * c)$ (4 circadian transitions phase delayed)

and:

(4) $0 = (3 * s) - (5 * c)$ (5 circadian transitions phase delayed)

Using the value of c = 0.34, (3) gives s = 0.45 and (4) gives s = 0.57.

Assuming that the C-peak and 45-peak seasonal shift sizes are the same, then it seems that the 0.55 and 0.57 values (average = 0.56) are the ones to go with. There's no way to be sure, however, if the seasonal shift sizes are the same. There's no question, however, that the seasonal shift sizes are larger than both the C-peak and 45-peak circadian rhythm shift sizes.

Effects of Driving on C-peak Location

The C-peak is almost always less than 500 meters from where I stop the car. It isn't always near the first place I stop, it may be as much as the third or fourth stop, but I don't recall ever having to walk more than 500 meters. Usually I only walk a few hundred meters or less. Since my stops can be as much as 5 to 10 kilometers apart, it's highly unlikely that the proximity of the C-peak to my car is due to chance. Since driving temporarily disrupts magnetoreceptive feelings, it may also have an effect on peak location. The key question is: how much effect?

Regression analysis in North Carolina shows an adjusted R^2 of 0.93, indicating that nearly all the variance in 2-day reset peak location is explained by future BAD. Adjusted R^2 in Utah is even higher, at 0.99 (Utah has a second significant factor, # of days since reference). There doesn't seem to be much unexplained variance that can be attributed to my choice of car stop location.

Another way to see what effect car stop location has on peak location is to compare 2-day reset peak location after sleeping at my Wilmington home and driving 180 km to the peak, versus sleeping at a motel within walking distance of the peak. On September 8, 2009, I found the 2-day reset peak at (35.62819, -78.82180), after driving from my Wilmington home. BAD was -0.03696 degrees, so using the BAD Lat coefficient from the regression equation the ideal 2-day reset peak at this longitude can be found at 35.62819 - 0.35192 * (-0.03696) = (35.64, -78.82).

On October 8, 2009, I found the 2-day reset peak at (35.58693, -78.77286) after sleeping 2 nights at a nearby motel, and walking to the peak. BAD was 0.01379, so using the BAD Lat coefficient from the regression equation the ideal 2-day reset peak at this longitude can be found at: 35.58693 - 0.35192 * (0.01379) = (35.58, -78.77). These peaks are separated by 0.06 degrees latitude, or 6.5 km north-south distance. Whether or not this error was caused by the difference between walking and driving to the peak isn’t clear.

# Putting it all together—What Geomagnetic attribute (if any) is the Body Perceiving to Determine Peak Location?

The reader may note that throughout the Results section I have used geographical coordinates but no geomagnetic model values. This was not my original intention. Recall from the Personal Introduction that I hoped to find some combination of total intensity and inclination that my body was looking at to determine magnetic home. I also hoped that this magnetic factor could be connected to model values from the New York City area, during the time that I grew up there.

When I discovered the peak phenomenon, I thought that this would be easy. All I had to do was find the model values for one peak measurement and compare them to another peak measurement. The model value or derived mathematical expression of model values with the lowest variability among all peak measurements would be the candidate.

As my research progressed, I discovered that not only was there diurnal variation, which confounded my attempt to connect same-day peak values, but there are also bed angle drift, circadian rhythm effects, and seasonal effects. When I discovered that BAD could be reset, I thought that all I had to do was compare 2-day reset values. But then I found that the 2-day reset peak contains some future BAD. Also, in Utah, there is secular change. Comparing Utah to North Carolina magnetic values is perilous because of the existence of 5 NTZ transitions between the two states.

Since I didn't find the peak exactly the same time of the day, diurnal variation could confound my results. Even if I did, seasonal changes, along with daylight savings time would mean that the Northern Utah magnetic field at 13:00 local time on February 1 isn't the same as the Northern Utah magnetic field at 13:00 on May 1.

I also need to consider that the magnetic models aren't completely accurate, that the current model is over 4 years old and is due to be replaced in 2010, and that no model takes into account local anomalies or solar-induced geomagnetic activity. Fortunately, during my research the sun has been relatively quiet and there has been little geomagnetic activity.

So trying to find the magnetic parameter involved in the peak experience isn't likely to come from comparing 2-day reset magnetic values for low variability. Although there is no perfect method, I think the following methods offer the most promise to elucidate the magnetic parameter: same-day peak measurements to determine the N-S inclination of the E-W peak line, same-day peak measurements to determine diurnal variation, secular change calculations from the 2-day reset values, and comparison of the ideal North Carolina peak location magnetic properties to magnetic properties in the NYC area during my childhood.

I will present the data for the four "primary geomagnetic parameters" that are output from the magnetic model, that vary in a fairly predictable manner in the N-S direction, and that are either directly measured by observatories, or easily derivable from simple expressions (see Fig 1B): H (horizontal component), Z (vertical component), F (total intensity), and I (inclination). I've tried some other simple mathematical expressions involving these factors, which don't seem to do any better than these four, so I'll omit these additional ones in my presentation.

<u>Same-day peak measurements to determine the N-S inclination of the E-W peak line</u>

The advantages of same-day measurements is that they control for all sleeping factors, including bed angle drift, circadian rhythm, and seasonal effects. Same-day measurements of the N-S inclination of the E-W peak line can elucidate the magnetic parameter because the model uses both latitude and longitude as input, and calculates the expected N-S inclination as one moves east or west. The problem with this method is that it doesn't control for diurnal variation. I presented my data using geographical coordinates in Table 10. I'll now present it using geomagnetic model values (Table 18).

| City | H | Z | F | I | % Diff H | % Diff Z | % Diff F | % Diff I |
|---|---|---|---|---|---|---|---|---|
| **Utah** | | | | | | | | |
| Crossed NTZ 5W-6W barrier in between following measurements | | | | | | | | |
| Panguitch | 22679.5 | 45799.7 | 51107.4 | 63.656 | | | | |
| Beaver County | 22589.9 | 45944.6 | 51197.8 | 63.818 | -0.40% | 0.32% | 0.18% | 0.25% |
| Same NTZ measurements | | | | | | | | |
| Midvale | 21444.8 | 48095.2 | 52659.5 | 65.969 | | | | |
| Granite | 21447.2 | 48084.7 | 52651 | 65.962 | 0.01% | -0.02% | -0.02% | -0.01% |
| Riverton | 21484 | 48023.5 | 52610 | 65.898 | | | | |
| Draper | 21488 | 48008.9 | 52598.4 | 65.888 | 0.02% | -0.03% | -0.02% | -0.02% |
| **North Carolina** | | | | | | | | |
| Same NTZ measurements | | | | | | | | |
| Four Oaks | 22177.4 | 45569.6 | 50679.6 | 64.049 | | | | |
| Goldsboro | 22232 | 45428.5 | 50576.7 | 63.924 | 0.25% | -0.31% | -0.20% | -0.20% |
| Kinston | 22298.3 | 45264.9 | 50459.2 | 63.774 | 0.30% | -0.36% | -0.23% | -0.23% |
| Kinston | 22275.4 | 45315.1 | 50494.1 | 63.823 | | | | |
| Goldsboro | 22228.3 | 45437.7 | 50583.4 | 63.932 | -0.21% | 0.27% | 0.18% | 0.17% |
| Smithfield | 22165.8 | 45588.7 | 50691.8 | 64.07 | -0.28% | 0.33% | 0.21% | 0.22% |
| Wilson | 22115.4 | 45571.4 | 50654.2 | 64.113 | | | | |
| Raleigh | 21979.3 | 45901.1 | 50892 | 64.413 | -0.62% | 0.72% | 0.47% | 0.47% |
| Morrisville | 22020.1 | 45755.1 | 50778.1 | 64.3 | | | | |
| Raleigh | 22063.8 | 45647 | 50699.8 | 64.203 | 0.20% | -0.24% | -0.15% | -0.15% |
| Fuquay-Varina | 22120.4 | 45539.8 | 50627.9 | 64.092 | | | | |
| Rt 15_501 | 22081.3 | 45647.5 | 50707.8 | 64.185 | -0.18% | 0.24% | 0.16% | 0.15% |

Table 18. Same-day peak measurements represented in geomagnetic model values. H, Z, and F are in nT. I is in degrees. For additional information on the above data points, see Table 10. % Diff H = % $(H_2 – H_1) / H_1$. Similar for the others. Model data from National Geophysical Data Center.

If the body uses one of these magnetic parameters to determine peak location, you'd expect to see very low values in the Change column (e.g. the model would calculate the same H at points 1 and 2). Since each magnetic parameter has a different base amount (whether expressed in nT or degrees), reporting absolute differences would mean nothing, so I report percentage differences. While there is no clear-cut winner, it seems that the competition is between F and I. % Diff for H and Z are usually higher.

Same-day peak measurements to determine diurnal variation

I noticed the existence of peak diurnal variation in the early stages of my research project. I did a systematic investigation of peak diurnal variation in Utah for a six hour period on one day, and a twelve hour period on another day. I also did a peak diurnal variation investigation in North Carolina during an eight hour period on one day, and a nine hour period on another day. The advantage of using diurnal variation as a basis for elucidating the magnetic parameter behind the peak is that there are no confounding factors as there are in all the other methods. Like the other same-day methods, it controls for all sleeping-related factors. It controls for N-S inclination of the E-W peak line by limiting observations to a small range of longitude. This limited longitude range implies that when one sees the peak move north over a time interval, one has to conclude that any magnetic parameter (e.g. Z, F, or I) that increases as one moves north must have actually *decreased*. The reason for this is that if the body were looking at, say constant F for determining peak location, and F decreased from 3 p.m. to 6 p.m., then for the body to perceive constant F it must relocate the peak north, to compensate for the decreased F (F increases as one moves north in North America). The opposite is the case for H, since H decreases as one moves north.

Magnetic models do not provide diurnal variation information. To find diurnal variation, you need to acquire definitive observatory data. The advantage of using observatory data is that, unlike model data, it is not an approximation of the magnetic field from mathematical models but actual data recorded on a specific date and time. To relate peak location changes to observatory data, however, you still need to use model data, since the model tells you e.g. how much F increased after one moved 3 km north.

My first two diurnal variation investigations were done in Utah, and the closest observatory to Utah is Boulder, CO. On November 25, 2007, I recorded the peak location near Panguitch, Utah (38.10, -112.34) at around 3:30 p.m., 6:30 p.m., and 9:30 p.m. local time. I had slept for 11 nights on an innerspring mattress, at an unknown bed angle, in the 45 degree range, and was one transition phase delayed. This was thus a phase-delayed split-45 peak after nine nights of BAD. The Boulder Observatory (40.14, -105.24) is about 7.1 degrees longitude east of where I measured the peak. This amounts to its being about 28 minutes advanced relative to the solar day (Boulder is in the same MST time zone as Utah). To compensate for this, I subtracted 28 minutes from the time I measured in Utah and found what magnetic values the observatory reported at that time. (Boulder is also about 2 degrees north of Panguitch, and in late November Boulder has shorter days, but I ignored this seasonal effect). I compared these values to model values from my peak measurements (Tables 19a, 19b).

| Location | Date | Time | Lat | Long | Elev (m) | H | Z | F | I |
|---|---|---|---|---|---|---|---|---|---|
| Panguitch | 11/25/2007 | 15:28 | 38.09867 | -112.33611 | 1877 | 22615.3 | 45934.5 | 51199.9 | 63.787 |
| Panguitch | 11/25/2007 | 18:40 | 38.09796 | -112.33627 | 1898 | 22615.3 | 45933.4 | 51199 | 63.787 |
| Panguitch | 11/25/2007 | 21:29 | 38.10219 | -112.33599 | 1903 | 22613.4 | 45936.9 | 51201.3 | 63.79 |
| Time Diff | 0:28:00 | | | | | | | | |
| Boulder | 11/25/2007 | 15:00 | 40.14 | -105.241 | 1682 | 20913.4 | 48898.4 | 53183.1 | 66.844 |
| Boulder | 11/25/2007 | 18:12 | 40.14 | -105.241 | 1682 | 20895.7 | 48892.1 | 53170.6 | 66.859 |
| Boulder | 11/25/2007 | 21:01 | 40.14 | -105.241 | 1682 | 20903.4 | 48896.1 | 53177.1 | 66.853 |

Table 19a. First part of data comparing 11/25/07 diurnal variation peak measurements to observatory data.

| Location | Date | Time | Change Lat | Change H | Change Z | Change F | Change I |
|---|---|---|---|---|---|---|---|
| Panguitch | 11/25/2007 | 15:28 | | | | | |
| Panguitch | 11/25/2007 | 18:40 | -0.00071 | 0 | -1.1 | -0.9 | 0.000 |
| Panguitch | 11/25/2007 | 21:29 | 0.00423 | -1.9 | 3.5 | 2.3 | 0.003 |
| Time Diff | 0:28:00 | | | | | | |
| Boulder | 11/25/2007 | 15:00 | | | | | |
| Boulder | 11/25/2007 | 18:12 | N/A | -17.7 | -6.3 | -12.5 | 0.015 |
| Boulder | 11/25/2007 | 21:01 | N/A | 7.6 | 4 | 6.5 | -0.006 |

Table 19b. Second part of data comparing 11/25/07 diurnal variation peak measurements to observatory data. H, Z, and F are in nT. I is in degrees. Change Lat = Change in latitude. Model data from National Geophysical Data Center. Boulder Observatory data from Intermagnet Definitive Data.

There doesn't seem to be any magnetic parameters that come close to being equal and opposite in change to that recorded by Boulder. “Z” and “F” changes are in the same direction. “H” and “I” changes are opposite in direction for the second change, but too small to measure at for first change. Note that Boulder recorded a bigger change between 15:00 and 18:12 than between 18:12 and 21:01, and the second change was opposite in direction to the first for all four parameters. Whether one considers any of the four magnetic parameters or simply latitude, my peak measurements showed a *smaller* change for the time corresponding to that in which Boulder showed a larger change.

On June 25, 2008, I recorded peak location in Northern Utah at 7 different times within an approximately 12-hour window. I had slept 7 nights on an airbed at 309 degrees, and was at ideal circadian rhythm. This was thus an unsplit 45-peak with 5 nights of BAD. Sunrise that day in Northern Utah was 5:57 a.m., and sunset 9:05 p.m. Average longitude for these measurements was -112.02 degrees, which is about 6.8 degrees longitude west of the Boulder Observatory. Boulder is thus about 27 minutes advanced compared to these locations. (Boulder is also about one degree south of the average of these Utah locations, and near the summer solstice Boulder has shorter days, but I ignored this seasonal effect). As I did previously, I compared the Utah values to the Boulder values (Tables 20a, 20b).

| Location | Date | Time | Lat | Long | Elev (m) | H | Z | F | I |
|---|---|---|---|---|---|---|---|---|---|
| Clearfield | 6/25/2008 | 10:28 | 41.10196 | -112.01402 | 1342 | 21215.7 | 48441.6 | 52883.7 | 66.348 |
| Clearfield | 6/25/2008 | 12:28 | 41.10586 | -112.01762 | 1349 | 21214.2 | 48443.7 | 52885.1 | 66.351 |
| Clearfield | 6/25/2008 | 14:28 | 41.10838 | -112.02046 | 1366 | 21213.2 | 48444.6 | 52885.5 | 66.352 |
| Sunset | 6/25/2008 | 16:34 | 41.12924 | -112.02582 | 1394 | 21203.6 | 48459.4 | 52895.2 | 66.368 |
| Roy | 6/25/2008 | 18:35 | 41.16353 | -112.02588 | 1396 | 21187.2 | 48486.7 | 52913.7 | 66.396 |
| Roy | 6/25/2008 | 20:30 | 41.18324 | -112.02702 | 1383 | 21178.1 | 48502.5 | 52924.5 | 66.412 |
| Sunset | 6/25/2008 | 22:30 | 41.13583 | -112.02629 | 1398 | 21200.4 | 48464.5 | 52898.6 | 66.373 |
| Time Diff | 0:27:00 | | | | | | | | |
| Boulder | 6/25/2008 | 10:01 | 40.14 | -105.241 | 1682 | 20915.6 | 48837.7 | 53127.7 | 66.816 |
| Boulder | 6/25/2008 | 12:01 | 40.14 | -105.241 | 1682 | 20921 | 48841.5 | 53133.4 | 66.812 |
| Boulder | 6/25/2008 | 14:01 | 40.14 | -105.241 | 1682 | 20918.2 | 48842.3 | 53133 | 66.815 |
| Boulder | 6/25/2008 | 16:07 | 40.14 | -105.241 | 1682 | 20901.2 | 48824.2 | 53109.8 | 66.825 |
| Boulder | 6/25/2008 | 18:08 | 40.14 | -105.241 | 1682 | 20915.1 | 48823.3 | 53114.5 | 66.811 |
| Boulder | 6/25/2008 | 20:03 | 40.14 | -105.241 | 1682 | 20922.4 | 48828.8 | 53122.5 | 66.806 |
| Boulder | 6/25/2008 | 22:03 | 40.14 | -105.241 | 1682 | 20927.4 | 48830.8 | 53126.1 | 66.802 |

Table 20a. First part of data comparing 6/25/08 diurnal variation peak measurements to observatory data.

| Location | Date | Time | Change Lat | Change H | Change Z | Change F | Change I |
|---|---|---|---|---|---|---|---|
| Clearfield | 6/25/2008 | 10:28 | | | | | |
| Clearfield | 6/25/2008 | 12:28 | 0.0039 | -1.5 | 2.1 | 1.4 | 0.003 |
| Clearfield | 6/25/2008 | 14:28 | 0.00252 | -1 | 0.9 | 0.4 | 0.001 |
| Sunset | 6/25/2008 | 16:34 | 0.02086 | -9.6 | 14.8 | 9.7 | 0.016 |
| Roy | 6/25/2008 | 18:35 | 0.03429 | -16.4 | 27.3 | 18.5 | 0.028 |
| Roy | 6/25/2008 | 20:30 | 0.01971 | -9.1 | 15.8 | 10.8 | 0.016 |
| Sunset | 6/25/2008 | 22:30 | -0.04741 | 22.3 | -38 | -25.9 | -0.039 |
| | | | | | | | |
| Time Diff | 0:27:00 | | | | | | |
| | | | | | | | |
| Boulder | 6/25/2008 | 10:01 | | | | | |
| Boulder | 6/25/2008 | 12:01 | N/A | 5.4 | 3.8 | 5.7 | -0.004 |
| Boulder | 6/25/2008 | 14:01 | N/A | -2.8 | 0.8 | -0.4 | 0.003 |
| Boulder | 6/25/2008 | 16:07 | N/A | -17 | -18.1 | -23.2 | 0.01 |
| Boulder | 6/25/2008 | 18:08 | N/A | 13.9 | -0.9 | 4.7 | -0.014 |
| Boulder | 6/25/2008 | 20:03 | N/A | 7.3 | 5.5 | 8 | -0.005 |
| Boulder | 6/25/2008 | 22:03 | N/A | 5 | 2 | 3.6 | -0.004 |

Table 20b. Second part of data comparing 6/25/08 diurnal variation peak measurements to observatory data. H, Z, and F are in nT. I is in degrees. Change Lat = Change in latitude. Model data from National Geophysical Data Center.

Note that the peak moves northward throughout the late morning, afternoon and early evening. In the late morning and early afternoon, it moves slowly, then picks up pace in the late afternoon and early evening. The total amount of peak displacement from 10:28 to 20:30, about 10 hours, is about 0.08 degrees latitude. Between 20:30 and 22:30 it shifts southward for the first time, about 0.05 degrees latitude.

Similar to the 11/25/07 same-day peak measurement, there doesn't seem to be any magnetic parameters that come close to being equal and opposite to that recorded by Boulder. While in Utah, the magnetic parameters show the same direction of change until the 20:30 to 22:30 interval, in Boulder 3 out of the 4 parameters have the same direction of change between 10:01 to 12:01, and 16:07 to 22:03, but a different direction between 12:01 and 16:07. Boulder Z shows a slightly different behavior, having a different direction between 14:01 and 18:08. While

Utah shows the largest magnitude of change between 16:34 and 18:35 for all 4 parameters, Boulder shows the largest magnitude of change between 14:01 and 16:07 for 3 out of the 4 parameters. Boulder Inclination shows the largest magnitude of change between 16:07 and 18:08.

On August 7, 2009, I recorded peak locations 5 times during an approximately eight hour interval. These peak measurements occurred near the North Carolina-Virginia border. I had slept 3 nights on an airbed at 314 degrees. I was one transition phase delayed. This was thus a phase-delayed (unsplit) 45-peak with one night of BAD, with no seasonal effects. Sunrise in this area was at 6:21 a.m., and sunset 8:10 p.m. Average (latitude, longitude) for these measurements was (36.62, -77.53 degrees). The closest observatory is Fredericksburg, which at (38.20, -77.37) is about 1.6 degrees north and 0.16 degrees east. Fredericksburg is thus about a minute advanced compared to these locations. I'll present my peak measurements without matching observatory data (Table 21a, 21b). When the Fredericksburg data becomes available sometime in 2010, the same analysis can be performed as in the above two examples.

| Location | Date | Time | Lat | Long | Elev (m) | H | Z | F | I |
|---|---|---|---|---|---|---|---|---|---|
| Weldon, NC | 8/7/2009 | 12:53 | 36.42766 | -77.59312 | -40 | 21850.7 | 46022.1 | 50945.9 | 64.602 |
| Garysburg, NC | 8/7/2009 | 14:57 | 36.48410 | -77.54793 | -1 | 21829.9 | 46057.7 | 50969.2 | 64.64 |
| Rt 301, VA | 8/7/2009 | 17:06 | 36.62634 | -77.55613 | 26 | 21770.2 | 46172.4 | 51047.4 | 64.756 |
| Jarratt, VA | 8/7/2009 | 18:58 | 36.75871 | -77.47991 | 42 | 21720.1 | 46262.8 | 51107.8 | 64.85 |
| Jarratt, VA | 8/7/2009 | 20:56 | 36.79211 | -77.46659 | 41 | 21707 | 46286.9 | 51124.1 | 64.875 |

Table 21a. First part of data showing 8/7/09 diurnal variation peak measurements.

| Location | Date | Time | Change Lat | Change H | Change Z | Change F | Change I |
|---|---|---|---|---|---|---|---|
| Weldon, NC | 8/7/2009 | 12:53 | | | | | |
| Garysburg, NC | 8/7/2009 | 14:57 | 0.05644 | -20.8 | 35.6 | 23.3 | 0.038 |
| Rt 301, VA | 8/7/2009 | 17:06 | 0.14224 | -59.7 | 114.7 | 78.2 | 0.116 |
| Jarratt, VA | 8/7/2009 | 18:58 | 0.13237 | -50.1 | 90.4 | 60.4 | 0.094 |
| Jarratt, VA | 8/7/2009 | 20:56 | 0.03340 | -13.1 | 24.1 | 16.3 | 0.025 |

Table 21b. Second part of data showing 8/7/09 diurnal variation peak measurements.

Comparing the diurnal variation data here to the Utah data on 6/25/08, one can find the same general pattern (although the amount of peak movement is much greater here): the peak moving slowly north in the early afternoon, then picking up pace in the late afternoon and early evening, then slowing down and reversing direction after sunset. I didn’t stay late enough to observe the peak reverse direction and move south, but my 20:56 measurement definitely showed its northward movement slowing down (only .03 degrees north between 18:58 and 20:56, compared to 0.13 degrees north between 17:06 and 18:58). Total amount of peak displacement north is 0.36 degrees (compared to 0.08 degrees in Utah on 6/25/08)

On October 8, 2009, I recorded peak locations 7 times during an approximately nine hour interval. I also recorded 6 H-P transitions during this interval. These peak and H-P transition measurements occurred in Fuquay-Varina, North Carolina. I had slept 2 nights on an airbed in a nearby motel at 265 degrees. I was at ideal circadian rhythm. This was thus a 2-day reset C-peak at ideal circadian rhythm, with no seasonal effects. The differences between this day’s test and the first three tests are that this is the only C-peak test, and in this test I never used my car—I always walked to the peak and H-P transition. The fact that the H-P transition was so close to the peak at this (cardinal) E-W bed angle allowed me to see the diurnal variation of the H-P transition and HZW for the first time.

Sunrise in this area was at 7:15 a.m., and sunset at 6:50 p.m. Average (latitude, longitude) for the peak measurements was (36.60, -78.77 degrees). The closest observatory is Fredericksburg, which at (38.20, -77.37), is about 1.6 degrees north and 1.4 degrees east. Fredericksburg is thus about 6 minutes advanced compared to these locations. I'll present my peak measurements without matching observatory data (Table 22a, 22b). When the Fredericksburg data becomes available sometime in 2010, the same analysis can be performed as in the first two examples.

| Location | Date | Time | Lat | Long | Elev (m) | H | Z | F | I |
|---|---|---|---|---|---|---|---|---|---|
| Fuquay-Varina | 10/8/2009 | 13:16 | 35.58693 | -78.77286 | 102 | 22126.3 | 45529.3 | 50621.1 | 64.081 |
| Fuquay-Varina | 10/8/2009 | 13:46 | 35.58964 | -78.77317 | 117 | 22125 | 45531.3 | 50622.3 | 64.083 |
| Fuquay-Varina | 10/8/2009 | 14:42 | 35.59412 | -78.77407 | 119 | 22123.1 | 45535.1 | 50624.8 | 64.087 |
| Fuquay-Varina | 10/8/2009 | 16:05 | 35.59871 | -78.77443 | 117 | 22121.4 | 45538.8 | 50627.4 | 64.091 |
| Fuquay-Varina | 10/8/2009 | 18:11 | 35.60255 | -78.77426 | 115 | 22119.8 | 45542 | 50629.6 | 64.094 |
| Fuquay-Varina | 10/8/2009 | 20:00 | 35.59783 | -78.77439 | 112 | 22121.7 | 45538.2 | 50627.1 | 64.09 |
| Fuquay-Varina | 10/8/2009 | 22:00 | 35.59687 | -78.77434 | 118 | 22122 | 45537.4 | 50626.5 | 64.09 |

Table 22a. First part of data showing 10/8/09 diurnal variation peak (N-H transition) measurements.

| Location | Date | Time | Change Lat | Change H | Change Z | Change F | Change I |
|---|---|---|---|---|---|---|---|
| Fuquay-Varina | 10/8/2009 | 13:16 | | | | | |
| Fuquay-Varina | 10/8/2009 | 13:46 | 0.00271 | -1.3 | 2 | 1.2 | 0.002 |
| Fuquay-Varina | 10/8/2009 | 14:42 | 0.00448 | -1.9 | 3.8 | 2.5 | 0.004 |
| Fuquay-Varina | 10/8/2009 | 16:05 | 0.00459 | -1.7 | 3.7 | 2.6 | 0.004 |
| Fuquay-Varina | 10/8/2009 | 18:11 | 0.00384 | -1.6 | 3.2 | 2.2 | 0.003 |
| Fuquay-Varina | 10/8/2009 | 20:00 | -0.00472 | 1.9 | -3.8 | -2.5 | -0.004 |
| Fuquay-Varina | 10/8/2009 | 22:00 | -0.00096 | 0.3 | -0.8 | -0.6 | 0 |

Table 22b. Second part of data showing 10/8/09 diurnal variation peak (N-H transition) measurements.

The first thing to notice is that the same general pattern as the Utah 6/25/08 and NC/VA 8/7/09 tests holds: slow increase north in the early afternoon, followed by more rapid increase north in the late afternoon, followed by a slowdown and then reversal south after sunset. The second thing to notice is that total displacement north throughout the day is only 0.02 degrees latitude (compared to 0.36 degrees on 8/7/09, and .08 degrees on 6/25/08). Whether this smaller amount is due to this being a C-peak measurement, or due to it being a stable bed angle (BAD was only 0.01 degrees), or due to my walking to the peak instead of driving to it, is unclear.

Tables 23a and 23b show the diurnal variation of the H-P transition.

| Location | Date | Time | Lat | Long | Elev (m) | H | Z | F | I |
|---|---|---|---|---|---|---|---|---|---|
| Fuquay-Varina | 10/8/2009 | 13:29 | 35.57855 | -78.77124 | 101 | 22129.8 | 45522.2 | 50616.2 | 64.074 |
| Fuquay-Varina | 10/8/2009 | 14:55 | 35.58649 | -78.77275 | 120 | 22126.4 | 45528.4 | 50620.3 | 64.081 |
| Fuquay-Varina | 10/8/2009 | 16:22 | 35.58885 | -78.77304 | 127 | 22125.3 | 45530.4 | 50621.5 | 64.083 |
| Fuquay-Varina | 10/8/2009 | 18:34 | 35.58774 | -78.77298 | 126 | 22125.7 | 45529.5 | 50620.9 | 64.082 |
| Fuquay-Varina | 10/8/2009 | 20:16 | 35.58735 | -78.77295 | 119 | 22126 | 45529.2 | 50620.8 | 64.081 |
| Fuquay-Varina | 10/8/2009 | 22:16 | 35.58708 | -78.77288 | 124 | 22126.1 | 45528.8 | 50620.5 | 64.081 |

Table 23a. First part of data showing 10/8/09 diurnal variation H-P transition measurements.

| Location | Date | Time | Change Lat | Change H | Change Z | Change F | Change I |
|---|---|---|---|---|---|---|---|
| Fuquay-Varina | 10/8/2009 | 13:29 | | | | | |
| Fuquay-Varina | 10/8/2009 | 14:55 | 0.00794 | -3.4 | 6.2 | 4.1 | 0.007 |
| Fuquay-Varina | 10/8/2009 | 16:22 | 0.00236 | -1.1 | 2 | 1.2 | 0.002 |
| Fuquay-Varina | 10/8/2009 | 18:34 | -0.00111 | 0.4 | -0.9 | -0.6 | -0.001 |
| Fuquay-Varina | 10/8/2009 | 20:16 | -0.00039 | 0.3 | -0.3 | -0.1 | -0.001 |
| Fuquay-Varina | 10/8/2009 | 22:16 | -0.00027 | 0.1 | -0.4 | -0.3 | 0 |

Table 23b. Second part of data showing 10/8/09 diurnal variation H-P transition measurements.

Notice how the H-P transition does not move as far north as the peak (0.01 degrees north compared to 0.02 degrees north for the peak). Notice also that the H-P transition moves south before sunset (18:50 local time), while the peak moves south only after sunset. While there is no comparison observatory data yet, it's reasonable to conclude from the above data that the peak (N-H) and H-P transitions appear to be using different magnetic parameters.

Combining the N-H and H-P transition data, one can see the diurnal variation of HZW in degrees latitude (Table 24).

| City | Date | Time | Lat | Long | Elev (m) | Bed Ang | Type | HZW | % Δ |
|---|---|---|---|---|---|---|---|---|---|
| Fuquay-Varina | 10/8/2009 | 13:16 | 35.58693 | -78.77286 | 102 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 13:29 | 35.57855 | -78.77124 | 101 | 265 | H-P | 0.00838 | |
| Fuquay-Varina | 10/8/2009 | 14:42 | 35.59412 | -78.77407 | 119 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 14:55 | 35.58649 | -78.77275 | 120 | 265 | H-P | 0.00763 | -8.9% |
| Fuquay-Varina | 10/8/2009 | 16:05 | 35.59871 | -78.77443 | 117 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 16:22 | 35.58885 | -78.77304 | 127 | 265 | H-P | 0.00986 | 29.2% |
| Fuquay-Varina | 10/8/2009 | 18:11 | 35.60255 | -78.77426 | 115 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 18:34 | 35.58774 | -78.77298 | 126 | 265 | H-P | 0.01481 | 50.2% |
| Fuquay-Varina | 10/8/2009 | 20:00 | 35.59783 | -78.77439 | 112 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 20:16 | 35.58735 | -78.77295 | 119 | 265 | H-P | 0.01048 | -29.2% |
| Fuquay-Varina | 10/8/2009 | 22:00 | 35.59687 | -78.77434 | 118 | 265 | N-H | | |
| Fuquay-Varina | 10/8/2009 | 22:16 | 35.58708 | -78.77288 | 124 | 265 | H-P | 0.00979 | -6.6% |

Table 24. Diurnal variation of HZW on 10/8/09. HZW is in degrees latitude. % Δ = % Change in HZW.

Note how HZW decreases slightly in the early afternoon, increases greatly in the late afternoon, then decreases after sunset. An interesting result of this is that except for the first data point, my motel (i.e. my sleeping location) was in the Happy Zone for the remainder of the day.

Secular change calculations from 2-day reset data

Since magnetic models include secular change information, if my body were looking at one of the magnetic parameters for 2-day reset peak position, there should be no change in this parameter over time. In other words, the correlation between the magnetic parameter and # of days since reference should be very small. This assumes, of course, that the magnetic model is accurately representing secular change. The IGRF-10 model, which I am using, was last updated in 2005, and predicts secular change for the following five years based on past data. The IGRF-15 model, due out in 2010, should have a more accurate representation of magnetic field changes during the 2007-2009 time period, since it is based on actual changes that occurred during that period.

Table 25 includes Utah 2-day reset values (ideal peak location), containing the magnetic model parameters for the data originally presented in Table 12.

| Location | Date | Time | H | Z | F | I | Days |
|---|---|---|---|---|---|---|---|
| **C/45-Peak Measurements (2-day bed angle reset)--Ideal Peak Location** | | | | | | | |
| Farmington | 6/20/2008 | 11:14 | 21264 | 48367.4 | 52835.3 | 66.268 | 171 |
| Farmington | 6/29/2008 | 12:41 | 21261.3 | 48369.9 | 52836.4 | 66.272 | 180 |
| Layton | 7/3/2008 | 11:51 | 21234.3 | 48410.2 | 52862.5 | 66.316 | 184 |
| Centerville | 7/6/2008 | 11:27 | 21281.7 | 48331.8 | 52809.8 | 66.235 | 187 |
| Bountiful | 8/3/2008 | 12:08 | 21305.1 | 48282.4 | 52774 | 66.19 | 215 |
| Salt Lake | 8/6/2008 | 13:15 | 21350.8 | 48204.2 | 52720.9 | 66.11 | 218 |
| Kaysville | 8/12/2008 | 12:24 | 21234.5 | 48397.9 | 52851.3 | 66.311 | 224 |
| Salt Lake | 8/15/2008 | 11:29 | 21348.4 | 48206.5 | 52722.1 | 66.114 | 227 |
| Santaquin | 7/24/2009 | 14:12 | 21692 | 47481.9 | 52202.3 | 65.447 | 227 |

Table 25. Utah 2-day reset peak data including magnetic model values. H, Z, and F are in nT. I is in degrees. For additional information on these values, see Table 12. Days = # of days since 1/1/08. Model data from National Geophysical Data Center.

Here are the correlations between the magnetic parameters and # of days:

r (H, # days) =0.52, df = 7, ns.
r (Z, # days) = -0.52, df = 7, ns.
r (F, # days) = -0.52, df = 7, ns.
R (I, # days) = -0.52, df = 7, ns.

While due to the small sample size none of the correlations are significant, they are all above 0.50 in magnitude, indicating that none of the four magnetic parameters are accurately representing the secular change of the 2-day reset peak location in Utah.

Table 26 has North Carolina 2-day reset peak values (ideal peak location), containing the magnetic model parameters for data originally presented in Table 15.

| Location | Date | Time | H | Z | F | I | Days |
|---|---|---|---|---|---|---|---|
| **C/45-Peak Measurements (2-day bed angle reset)--Ideal Peak Location** | | | | | | | |
| Rt 117 | 9/22/2008 | 14:00 | 22192.3 | 45467.7 | 50595 | 63.983 | 265 |
| Rt 117 | 9/27/2008 | 12:44 | 22277.5 | 45294.6 | 50477 | 63.81 | 270 |
| Pikeville | 10/13/2008 | 12:53 | 22188.4 | 45468.5 | 50594 | 63.988 | 286 |
| Wilson | 2/12/2009 | 12:28 | 22115.4 | 45571.4 | 50654 | 64.113 | 408 |
| Wilson | 3/3/2009 | 12:43 | 22116.2 | 45563.4 | 50647 | 64.108 | 427 |
| Rt 117 | 3/18/2009 | 14:20 | 22159.9 | 45475.5 | 50587 | 64.02 | 442 |
| Goldsboro | 4/15/2009 | 13:30 | 22257.5 | 45270 | 50446 | 63.818 | 470 |
| Goldsboro | 4/22/2009 | 13:15 | 22254.7 | 45273 | 50447 | 63.823 | 477 |
| Goldsboro | 8/21/2009 | 13:52 | 22260 | 45222.5 | 50404 | 63.792 | 598 |

Table 26. North Carolina 2-day reset peak data including magnetic model values. H, Z, and F are in nT. I is in degrees. For additional information on these values, see Table 15. Days = # of days since 1/1/08. Model data from National Geophysical Data Center.

Here are the correlations between the magnetic factors and # of days:

r (H, # days) = 0.14, df = 7, ns.
r (Z, # days) = -0.40, df = 7, ns.
r (F, # days) = -0.47, df = 7, ns.
r (I, # days) = 0.27, df = 7, ns.

These correlations are smaller than those for the Utah data, indicating that these model values better predict secular change in North Carolina than in Utah. The winner among the factors is H (horizontal component), with a correlation only 52% of the magnitude of the next highest correlation (I).

Comparison of the ideal North Carolina peak location magnetic properties to magnetic properties during my childhood

The reader may wonder why the Happy Zone (i.e. magnetic home) in NTZ 0 is in North Carolina, at about 35 degrees latitude, considering that I grew up in the New York City area, about 5 degrees of latitude north. If one considers my college years (ages 18-22) as a part of my childhood, possibly influencing the location of magnetic home, then Charlottesville, VA at 38.13 degrees latitude is still about 3 degrees north of the current position of the peak.

Note also that the peak has a NW-SE inclination of about 5.11 degrees longitude / degree latitude in North Carolina, and that I reported the "ideal" 2-day reset peak (0 BAD, no circadian rhythm or seasonal effects) at (35.38, -77.99). The expected location of the peak at New Providence longitude (-74.39) is thus:

35.38 deg latitude – ((-77.99 deg longitude – {-74.39 deg longitude}) / (-5.11 deg longitude / 1 deg latitude))

= 34.68 deg latitude, which is about six degrees south of New Providence (40.70).

Perhaps the peak was near New Providence during my childhood, then shifted south due to magnetic secular change over the last 30-40 years. This can be seen from comparing the model magnetic field values at the "ideal" 2-day reset peak in North Carolina on Jan 1, 2008 to the range of values in northern New Jersey during my childhood (I'll assume 0 elevation for the sake of simplicity) (Table 27). Let’s assume northern New Jersey is New Providence (its proximity to Plainfield and New York City makes this assumption reasonable), and that my childhood went from 1/1/66 (about four months prior to conception), to 1/1/86 (just shy of my 19th birthday).

| Location | Date | H | Z | F | I | % Diff H | % Diff Z | % Diff F | % Diff I |
|---|---|---|---|---|---|---|---|---|---|
| North Carolina | 1/1/2008 | 22223.7 | 45489.9 | 50628.3 | 64.963 | | | | |
| New Providence | 1/1/1966 | 18096 | 53824 | 56784.6 | 71.417 | -18.57% | 18.32% | 12.16% | 9.93% |
| New Providence | 1/1/1986 | 19432.9 | 51810.8 | 55335.4 | 69.44 | -12.56% | 13.90% | 9.30% | 6.89% |

Table 27. Comparison of magnetic values between the North Carolina “ideal” 2-day reset peak (0 BAD, no circadian rhythm or seasonal effects) to New Providence. H, Z, and F are in nT. I is in degrees. % Diff H = %(H2 – H1) / H1. Similar for others. Model data from National Geophysical Data Center.

While the rate of geomagnetic secular change in New Providence during the 1966-1986 period varied, the direction of change didn’t, so the 1966 and 1986 values can be thought of as upper and lower ranges. As can be seen from the table, the errors are substantial (ranging from about 7% to about 19%), much more than can be expected from model errors (~50 nT or < 1%, Lowes, 2005).

What about comparing the North Carolina ideal 2-day reset peak to magnetic values in Charlottesville, VA, during my college years (approximately 1/1/1985 until 1/1/1990)? Table 28 has this comparison:

| Location | Date | H | Z | F | I | % Diff H | % Diff Z | % Diff F | % Diff I |
|---|---|---|---|---|---|---|---|---|---|
| North Carolina | 1/1/2008 | 22223.7 | 45489.9 | 50628.3 | 64.963 | | | | |
| Charlottesville | 1/1/1985 | 20544.3 | 50803.7 | 54800.4 | 67.982 | -7.56% | 11.68% | 8.24% | 4.65% |
| Charlottesville | 1/1/1990 | 20646.3 | 50256.9 | 54332.6 | 67.666 | -7.10% | 10.48% | 7.32% | 4.16% |

Table 28. Comparison of magnetic values between North Carolina “ideal” 2-day reset peak (0 BAD, no circadian rhythm or seasonal effects) to Charlottesville. H, Z, and F are in nT. I is in degrees. % Diff H = %(H2 – H1) / H1. Similar for others. Model data from National Geophysical Data Center.

As with the New Providence values, these Charlottesville values can be considered as upper and lower ranges. While the errors are (predictably) lower, they are still too high for any of the four parameters to be seriously considered as candidates.

Conclusion regarding magnetic parameters determining peak location

The only reasonable conclusion from the data above is that either the peak location isn’t determined by geomagnetic factors, or if it is, it isn’t determined by H, Z, F, or I.

# Discussion

North-South Map

The ability to perceive whether I'm north or south of magnetic home can be thought of as a "limited functionality GPS," or LFGPS. Although the potential is there for me to distinguish how far from home I'm located based on the severity of positive or negative symptoms, I find it hard to actualize this potential. The main problem is that so many other things can increase symptom severity, everything from sleeping factors (e.g. artificial magnetic fields, circadian rhythm and seasonal effects, bed angle), social factors, stress, etc., that it is hard to distinguish between these factors. So the LFGPS is only reliable as a way to distinguish *whether* one is north or south of home, not *how far*. The lack of any ability to distinguish between being east or west of home, along with the LFGPS's low sensitivity, makes it useless as a compass. Although I know I'm north or south of home, to get north or south I need to use some external navigational aid.

The data doesn't support that the north-south map is based on geomagnetic factors, although it doesn't contradict it, either. The fact that manipulating bed angles changes the north-south map indicates that there is some connection with a magnetoreceptive process. While I have shown that analyzed separately the magnetic parameters H, Z, F, and I do not appear to determine peak location, it's possible that the body perceives some mathematical combination of these factors. The fact that each of them varies in a reasonably regular manner in the north-south direction make them candidates for use in a north-south map.

<u>Bed Angle Data</u>

The fact that orienting one's bed at a particular compass angle can have such strong and consistent effects on peak location and HZW is difficult to explain other than by magnetoreception (ignoring for the moment the possibility of the placebo effect). What other physical factor than the geomagnetic field can cause physiological changes based on one's bed angle?

The BAD and HZW curves can, combined with a theoretical model, help reveal some of the characteristics of the sleeping magnetoreceptor (SMR). The SMR seems distinct from, but interacts with the waking magnetoreceptor (WMR). It's likely that the SMR is not light-dependent (since one's eyes are shut during sleep), which excludes radical pair-based processes. Since magnetite-based magnetoreception is not light dependent, the SMR is possibly magnetite based. The WMR, on the other hand, may be radical pair-based. The fact that I cannot feel the peak when blindfolded suggests that the WMR is light-dependent.

My ability to feel magnetoreceptive feelings by looking directly at the early afternoon sky indicates that there may be a third type of magnetoreceptive process occurring. The body may be perceiving geomagnetic information directly from sunlight, perhaps by analyzing its spectral composition (see Fig. 9 in the Scientific Introduction for indirect support for this from the animal literature). Another possibility, which obviates the need to come up with a separate magnetoreceptive process, is that the radical pair method may be enhanced by the sunlight. The fact that I can feel the peak after dark (although without the guidance of magnetoreceptive feelings) indicates that the WMR can still function in the absence of sunlight.

<u>Function of BAD?</u>

Since BAD shifts the position of magnetic home tens of kilometers per day, one may wonder what possible function it serves. If our primitive ancestors used the LFGPS for navigation, having magnetic home shift significant distances north or south would make it difficult for them to find their way home. One can’t imagine that these early navigators tried to align their beds in such a manner to minimize BAD, considering that they had no technical compass to guide them, and probably no conception of bed angle effects. It seems that evolutionary advantage would have been conferred on those navigators who did not experience BAD.

My hypothesis is that BAD is a result of living in an environment with significantly different magnetic properties than the environment during the CDP. From a theoretical perspective, inclination would seem to the magnetic parameter that is most responsible for BAD. While BAD represents peak movement per day as a function of two-dimensional bed angle, one must be cognizant of the fact that any magnetoreceptive process occurs in three dimensions. Inclination represents the magnetic vector’s deviation from horizontal. It’s reasonable to assume that during the CDP the SMR’s development was influenced by the inclination of the magnetic vector. It’s also reasonable to assume that evolution never provided a means for us to adapt to significantly different magnetic fields than those that we experienced during the CDP. It’s unlikely that our primitive ancestors either lived long enough or traveled far enough from their birthplace to experience inclination differences that I’ve experienced in my lifetime.

As further evidence supporting this hypothesis, compare Fig. 11 (Utah BAD curve) to Fig. 12 (North Carolina BAD curve). Notice that not only is Fig. 11 more regular, but it has lower amplitude (i.e. there is less BAD across most bed angles). The IGRF-10 model predicts inclination in my Salt Lake City, Utah bedroom at 66.1 degrees, and inclination in my Wilmington, NC bedroom at 62.9 degrees. Notice from the differences in the curves what a profound effect a ~ 3.2 degree difference in inclination has. In fact, the BAD curve is so irregular near the 45-peak range in North Carolina that it appears that magnetoreception is barely functioning. Consider also that inclination in New Providence during my childhood ranged from about 69.4 to 71.4 degrees, which is 3.3 to 5.3 degrees higher than the inclination I experienced in Utah. I predict that if I slept at ~70 degrees inclination and measured BAD, then the BAD curve would be flattened, i.e. there would be low BAD across most bed angles. Unfortunately for me, it's unlikely that I'll find the peak in the continental United States at any location that is close to 70 degrees inclination. It may be possible, however, to test this hypothesis in a sleep lab, in which I sleep surrounded by an artificial magnetic field with 70 degrees inclination.

Using similar reasoning, the fact that maximum HZW is 0.85 degrees latitude in Utah, and almost twice this much (1.64 degrees latitude) in North Carolina, indicates that as bed inclination approaches 70 degrees the HZW curve becomes flattened. A smaller HZW is functionally superior for navigation because it narrows the search area when one is trying to make one's way home.

NTZ's/Circadian Rhythm/Seasonal Effects

Natural Time Zones, circadian rhythm, and seasonal effects can be thought of as products of my body's perception of the time-varying characteristics of the geomagnetic field. NTZ's, which are the only kind of east-west mapping that my body does, are based on a 25.7 minute solar time interval. While the exact interval determining circadian rhythm and seasonal effects is unknown, there’s evidence that these effects are also based on a 25.7 minute interval.

Does the 25.7 minute NTZ have any physical basis? Campbell (2003, p. 70) mentions (Fourier analysis) spectral peaks in the geomagnetic field at 6, 8, 12, and 24 hours, but not 25.7 minutes. But consider this indirect evidence: A 25.7 minute NTZ is 1/56 of a solar day. A 6 hour peak is 1/4 of a solar day (or 14 NTZ’s), an 8 hour peak is 1/3 of a solar day (not evenly divisible into 25.7 minute NTZ’s), a 12 hour peak is 1/2 of a solar day (or 28 NTZ’s), and a 24 hour peak is a full solar day (or 56 NTZ’s). Assume that the human body perceives the 6 hour, 12 hour, and 24 hour spectral peaks. Each of these is evenly divisible into NTZ’s. Perhaps the body combines the information from all three harmonics into a “temporal map” that it can use to locate one’s position in the day.

The fact that both NTZ west crossings (probably) and circadian phase delays (definitely) shift the peak south indicates a connection between NTZ’s and circadian rhythm shifts. Similarly for the NTZ east crossing and circadian phase advances shifting the peak north. The peak shift south when one moves west, and north when one moves east, may be my body’s attempt to compensate for the northwest-southeast inclination of the east-west peak line in North America. The fact that I have symptoms when circadian rhythm is out-of-sync with the solar day indicates that my body is trying to match some internal rhythm to the external diurnal variation of the geomagnetic field. When this rhythm is out-of-sync, my symptoms may be a type of “pain” signal. The fact that the NTZ transitions are located at ~ 6.43 degree longitude intervals from the town I grew up in indicates that the body is also matching the diurnal variation of the geomagnetic field to a reference rhythm set during the CDP. This connection is the only one I’ve been able to find that definitely links data gathered during this research project to a location I lived in as a child.

Which internal rhythm is the body using as a basis for circadian rhythm peak shifts? I've observed that any peak-shift related psychological effects from early or later bedtime happens within 5 hours of going to bed. Early or late wake-up time doesn't seem to have an effect on peak location, although early wake-up time can make me tired and cranky due to truncated sleep.

The fact that peak shifts are dependent on bedtime but not wake-up time seems to exclude the melatonin rhythm, which is strongly influenced by wake-up time (Burgess et al., 2003; Burgess & Eastman, 2006). Could it be simply the early part of the sleep rhythm? The problem with sleep rhythm as a basis for circadian rhythm effects is that it takes ~ 1.5 hours of later bedtime to compensate for the one hour phase advance due to daylight savings time. If the body were comparing the early part of the sleep rhythm to the diurnal geomagnetic rhythm, then there should only be one hour needed of later bedtime to compensate for the one-hour daylight savings time phase advance. Another problem with sleep rhythm is that I've noticed it takes several days for circadian rhythm to adjust to traveling to a city in a different NTZ. Until I fully adjust, I remain phase delayed (or advanced, depending on which direction I've traveled), regardless of bedtime in the new place.

So it seems that assuming a 25.7 minute circadian phase transition time, that the daylight savings time hourly change produces two transitions, but an hour of bedtime difference only produces one transition. Therefore there must be an independent rhythm that shifts a full hour when the daylights savings time change occurs, but only shifts about 30 minutes when bedtime is advanced or delayed an hour.

This rhythm could be one of the measurable rhythms (e.g. prolactin, rectal temperature, cortisol, etc.) that are known to vary independently of sleep rhythm and of each other (Wehr et al., 1993). It could also be a rhythm that contemporary techniques cannot measure. Lab studies can help ascertain what rhythm is being used.

Seasonal shifts are likely an evolutionary leftover from a seasonal-migrating common ancestor. It's possible that contemporary seasonal-migrating animals are motivated to carry out their migrations by geomagnetic peak shifts north or south. For a non-seasonal migrating animal like myself, the peak shifts are indicating the direction I should move (north before both solstices) to make the seasonal day length within 25 minutes of reference. Similar to NTZ and circadian rhythm effects, the body likely is comparing the diurnal variation of the geomagnetic field to a reference variation, but instead of measuring phase difference (NTZ and circadian rhythm) it is measuring length of day.

Split 45-peak and NTZ's

I suggested in the previous section that a probable function of the NTZ is to shift the peak south as one moves west. In the Results section I calculated, based on same-day peak measurements (Table 10), that this shift is 0.26 degrees latitude south per NTZ transition west. The change per transition for 45-peak circadian rhythm changes is 0.35 degrees latitude (averaging the Utah and NC values—Tables 14 and 17). The average C-peak change per transition is 0.29 degrees latitude (Table 17). So the NTZ shift amount is closer to the C-peak circadian shift amount than the 45-peak shift amount. Since under ideal conditions the 45-peak and C-peak in NTZ 5W are at about the same location, the NTZ shift amount must be the same for both 45 degree and cardinal bed angles.

If there are uneven magnetic fields when sleeping or circadian rhythm effects, however, then the Utah 45-peak becomes split. I calculated (Table 14) the size of this split to be 1.74 degrees latitude. Dividing by 5, the number of NTZ transitions in Utah, one arrives at 0.35 degrees, which is equal to the 45-peak circadian shift amount. So it seems that the split 45-peak is a result of the body's shifting the peak south an additional 5 circadian transitions.

## Future directions

(In this section I assume that experiments will be done on me, since I'm the one claiming to have magnetoreceptive abilities. Practical considerations, however, may prevent this from happening. Similar experiments can be done on others with selected clinical disorders, with the understanding that the location of the N-H, H-P, and NTZ transitions will be different for each individual, based on when and where they spent childhood.)

The most important thing needed is for double-blind experiments to be done to determine if the results presented in this paper are actually due to magnetoreception. Placebo effect has to be considered a possible explanation until such experiments are done.

I've argued against the placebo effect throughout this paper, trying to show how the observed results frequently contradicted *conscious* expectations (or I never had conscious expectations in the first place). But having studied psychology, I'll freely admit the power of the subconscious mind. It could be that the peak, bed angle and other effects, however mathematically consistent, are in fact the result of my deep-seated wish to have magnetoreceptive abilities.

There are two types of experiments that can elucidate what's going on: field experiments and lab experiments.

Field Experiments

Baker's (1989) paradigm of double-blind field experiments via literally blindfolding subjects will not work for studying this phenomenon. My WMR is light dependent, so using a blindfold will suppress my abilities. It's not clear, however, if being blindfolded en route to a destination, then having the blindfold removed at the destination, will lead to my being able to find the peak at its predicted location. My one experience with blindfolds indicates that I was able to find the peak after being temporarily blindfolded. I'm not sure, however, if the peak would have been in a different location if I didn't use the blindfolds.

Another argument against using blindfolds is that when I wear them, I get drowsy and feel like dozing off. Sleeping in an uncontrolled magnetic environment like a bus or a car is not advisable. Any studies of my magnetoreceptive abilities needs to be cognizant of the following fact: *my sleeping behavior needs to be experimentally controlled*. The reasons are clear from the Results section.

Let's be precise about the meaning of experimental blindness in this context: I don't need to be *literally* blind, but I need to be blind to outside cues that can help me ascertain my position. The need for early afternoon natural light to produce magnetoreceptive feelings (and thus a perception of being north or south of magnetic home) makes this tricky, but not impossible.

I'll propose an alternate experimental methodology. Take a standard passenger bus. Darken or cover the windows, and visually isolate the driver's section so that I get no outside visual clues. Install a sunroof, which will usually be kept closed and covered. During the drive, the only light I'll experience is indoor light. Have the bus drive to predetermined locations which are either north or south of the predicted magnetic home location (with allowances for errors in the prediction). At these locations, stop the bus and uncover and open up the sunroof so I can see the sky, but not any landscape features. Then after a fifteen minute wait I'll state whether I'm north or south of home. Then go to the next predetermined location, and repeat the procedure. If I have no special abilities, I'll do no better than chance—50/50. My claim is that I'll be near-perfect in my responses. (Note that if I sleep in the 45 degree bed angle range, I'll be able to indicate whether I'm north or south of home without any wait, and without the bus stopping. The 15 minute wait after stopping the bus is to accommodate limitations from my sleeping in the cardinal bed angle range).

If the experiment is designed correctly, and the bus has a bathroom and source of food and water, there will be no need for me to leave the bus at all during the experiment.

An alternate experimental design is to replicate my own field experiments in a double-blind way. Using the same experimental bus setup as before, drive to a predetermined location. I'll state whether I'm north or south of the peak. The driver will then drive a predetermined distance in the direction I guide him (i.e. toward the peak). Then he'll stop, and I'll make another judgment of my north-south position. If he overshoots, then I'll direct him the opposite direction. Gradually, as I do in my unblind experiments, I should be able to direct the bus to the peak. Once the bus is in prepeak (i.e. close to the peak), then whenever it stops it should be oriented north-south . This will allow me to walk the peak in the bus aisle—again obviating the need to ever leave the bus. The experimenter will record the GPS coordinates of my peak reaction, which will later be compared to prediction. While statistics in this case are harder to analyze, if I had no special abilities it's highly unlikely that I'd be able to direct the bus anywhere close to the predicted location. My claim is that I should be able to direct it within a reasonable error of the predicted location.

Another possibility is to let me out of the bus and fit me with an open-topped wooden box as described by Baker (1989, p. 90). With this box, I could see the sky but not the horizon.

The common thread among all these designs is that I need some way to directly look at the sky without being able to perceive objects. If there's any question as to whether I'm blind to landscape details, the bus test can be done with a control group. A good control group would consist of people who *are* familiar with the test areas. If people in the control group do no better than chance, then you can assume that the method is sufficient to block the conventional uses of vision.

Another experimental field paradigm is for me to sleep in the 45 degree bed angle range, so that I could feel the peak while moving in the bus. Then the bus could drive along various routes, one of which was randomly selected to be crossing an N-H or NTZ transition. I should be able to feel prepeak as we approach the peak, then the peak as we cross it. This can be done with a closed sunroof, as I can feel prepeak and peak without looking at the early afternoon sky (e.g. when I found the peak at night). Once I state that I feel the peak, the bus can then go back and retrace the route slowly (I won't be able to feel it when traveling in the reverse direction, so the bus will need to approach the peak from the same direction as it originally did). After several attempts, assuming the bus is correctly positioned over the peak, I should be able to walk the peak in the bus aisle.

The bus paradigm can be used for other experiments including finding the NTZ (E-W) peak, acquiring data for BAD and HZW curves, and studying the effects of circadian rhythm and seasonal changes.

The major practical limitation of a field experiment is that it must be done near *my* magnetic home. Since my magnetic home (theoretically) circles the earth, one can find home at any longitude. One is severely restricted with latitude, however. (This isn't the case with NTZ crossings which are unrestricted with latitude but restricted with longitude). It's true that bed angle, circadian rhythm, and seasonal effects can shift magnetic home, but the amount of shift is limited. More importantly, the initial experiments, those intended to verify whether or not I have magnetoreceptive ability, should be *control* experiments—i.e. experiments under ideal conditions. This means that the peak should be in its ideal location, with no BAD, circadian rhythm, or seasonal effects.

Another obvious problem is that since the magnetic basis of the peak is unknown, the exact location of the peak outside of Utah or North Carolina is also unknown. While one can make a reasonable guess where it is in the continental United States by drawing a line through the North Carolina and Utah ideal peak locations, this will likely have increasing error the further one gets from any known peak locations. If the research is to be done in other continents, the location of the peak in these places is unknown. By following my magnetoreceptive feelings, however, I should be able to eventually find it at any longitude. Consideration needs to be made, however, that if the magnetic parameters (e.g. inclination) are different enough from those I experienced in my childhood, or if inclination is reversed in sign (e.g. the Southern Hemisphere), my magnetoreceptive abilities may not function at all.

Lab experiments

The field experiments can suggest that I have an ability to spatially locate myself without using the traditional senses. They can't *prove*, however, that magnetoreception is involved in this ability. Similar to arguments given against Baker's (1989) experiments, other explanations are plausible: it's possible that I am actually seeing enough of the environment to determine my position, or that I have a special "inertial sense," which combined with a photographic map memory can allow me to determine which route the bus is taking. (As an aside, I am not aware of having a strong inertial sense, and definitely do not have a photographic memory.) Even if it can be shown that my ability to locate myself is not dependent on image-forming vision or inertial sense, there's no way to be sure that my body is using the earth's magnetic field to determine north-south position or east-west position. It could be altitude, humidity, temperature, spectral composition of sunlight, etc.

The control possible in lab experiments makes up for these deficiencies in field experiments. The most exciting aspect of the research I'm doing is that it leads to an experimental paradigm in which magnetoreception can be both verified and understood in a manner impossible before.

For example, my research suggests that my body may use some magnetic property to locate home on a north-south axis, and to feel whether I'm north or south of home. This can be tested in the lab. An experimental apparatus can be set up produce an artificial magnetic field around my body. To test this hypothesis, the magnetic field must be capable of being altered in a precise manner. The more precision, the better.

By randomly varying a particular magnetic property while holding everything else constant, then having me state which zone I'm in, it can be verified if in fact I'm using a magnetic property to locate myself. If I do significantly better than chance, this would be the most convincing evidence of human or animal magnetoreception to date.

Of course, I may not be perceiving the Earth's magnetic field. Or I may be perceiving it, but combining it with some other physical property (e.g. spectral composition of sunlight) to determine my position. Alternative hypotheses can also be tested in the lab. The spectral composition and intensity of the artificial light in the experimental chamber can be independently varied to see what effect they have on magnetoreception.

Any lab experiment needs to be cognizant of the fact that when awake I seem to be impervious to virtually any artificial magnetic field. Perhaps my body focuses on the time-varying characteristics of magnetic fields to filter out artificial ones from the natural geomagnetic field. In this case, the lab experiment will need to create artificial magnetic fields with time-varying characteristics that approximate the geomagnetic field's time-varying behavior.

I'm much more sensitive to artificial magnetic fields when sleeping, so there's a better chance of eliciting a response by manipulating magnetic fields in the sleep environment. While holding everything else constant, the experimenter can randomly create artificial magnetic fields. If I indicate that my sleep was disturbed when and only when it coincided with an artificial magnetic field test, this would support my hypothesis that artificial magnetic fields disrupt my sleep.

Combining field and lab experiments

By combining field and lab experiments, this research project can prove whether or not I have magnetoreceptive abilities. If I do have magnetoreceptive abilities, it can explain what magnetic and other properties I use to perceive the magnetic field, and it can explain how magnetoreception works in real life. Say, for example, that I do perceive some magnetic field property. If this property as revealed by field experiments is within a reasonable error of the property as revealed by lab experiments, then one can conclude that magnetoreception in the lab is essentially the same as magnetoreception in real life.

Experimental control of sleeping behavior

Due to the effects of bed angle and circadian rhythm on the location and size of magnetic home, my sleeping behavior for the duration of the experiment will need to be experimentally controlled. "Sleeping behavior" includes the bed, the environment around the bed, the bed angle, the time I go to bed and wake up, the timing and duration of any sleep interruptions, and the timing and location of naps. The ideal double-blind sleep environment would be a cylindrical room containing no ferrous materials and no electrical equipment, with a bed that can be rotated and then locked into place, and with no visual clues to indicate what direction the bed is oriented. I should enter the room blindfolded, so I have no frame of reference with which to judge the bed angle. All effort should be made to prevent me to nap.

An alternative double-blind sleeping chamber would be a room with an artificial magnet surrounding the bed. This magnet should be capable of generating a magnetic field the characteristics of which I and the experimenters with whom I interact will be blind to. The artificial magnet should allow for experimental manipulations such as varying the magnetic field inclination, declination, and total intensity across different parts of the body. This will allow for a determination of what elements of the magnetic field the body responds to, and the location of the sleeping magnetoreceptor.

If one wants to gather data for the BAD and HZW functions, then one will need to be prepared to spend a lot of time. Just one data point on the BAD curve requires three nights—two nights for the BAR and the first measurement of peak location, and a third night to allow for BAD, followed by the second measurement of peak location the following day. This assumes that all one is concerned with is the first night of BAD. If one wants to measure additional nights of BAD then more time is necessary. If one assumes that 20 data points in one quadrant are necessary to get a good idea of the BAD and HZW curves, then the minimal time needed is 60 days. If one wants to gather data across all 360 degrees, then the minimal time is 240 days.

Long range

It's premature to speculate on where this research may lead, considering that my magnetoreceptive abilities haven't been verified. But it's a relevant question especially when considering whether or not to spend time and money to do an in-depth case study.

It's highly unlikely that the majority of people have similar abilities to me. It's also highly unlikely that if I do have magnetoreceptive abilities, I'm the only one.

If verified in me, the most logical next step would be to study selected clinical populations. OCD/tics, bipolar disorder, and schizophrenia are clinical disorders that would make sense to study. All three disorders are characterized by opposing symptom clusters (positive/negative). Do people with bipolar disorder become depressed when they're north of magnetic home, and manic when south? Do people with OCD/tics have obsessions and compulsions when north of magnetic home, and tics when south? Do people with the unipolar correlates of these disorders (e.g. major depressive disorder, OCD) also have magnetoreceptive abilities, but only respond when they're at one side of magnetic home, but not the other? All these questions hint at a more fundamental question: are the symptoms of some serious psychiatric disorders the human equivalent of the animal instinctual response to being north or south of home?

This human research can guide future animal research. Many elementary questions, such as where the magnetoreceptors are located, by what mechanism do they perceive the magnetic field, and how animals use the information received from these receptors to navigate, are still largely unknown. If humans use a combination of natural light and a magnetic property to perceive the magnetic field, then likely many other animals do the same. If humans have an NTZ of 25.7 minutes, then likely some other animals have this. If humans have a fundamentally different type of sleeping magnetoreception that interacts with a waking magnetoreception, then some animals probably also have this. New discoveries involving animals can also shed light on human magnetoreception, as it does for the other senses. If human magnetoreception is linked with some psychiatric disorders, as I speculate above, then animal research can be used as it never has been able to before to help understand and treat psychiatric disorders.

# Conclusions

Since my research is ultimately based on subjective responses, it's impossible for me to scientifically *prove* that I have magnetoreceptive ability. What I have shown is that it's *possible* that the observations and data I've acquired are consistent with my having magnetoreceptive ability. It's also possible that they're partly or entirely due to the placebo effect. Double-blind studies are needed to verify if I indeed have magnetoreceptive abilities.

I had two goals when I began this study:

1) Understand if my feeling differently in different places may be due to my ability to perceive the geomagnetic field.
2) If it is due to my ability to perceive the geomagnetic field, then to use any knowledge gained both for my own benefit and for the benefit of mankind.

As far as I'm concerned, I do have magnetoreceptive abilities, and I know enough now to be able to use magnetoreception for my own benefit. I've already radically changed my sleeping behavior. At home, and as much as possible when traveling, I sleep on an air mattress, in an even magnetic field, at an angle that minimizes BAD. I do a BAR sometimes to clear out the cumulative effects of BAD. I set my bedtime so that circadian rhythm will be in sync with the solar day (which means being cognizant of where I'm sleeping and whether or not daylight savings time is in effect).

My move to Wilmington was based partially on geomagnetic factors. Any future moves will be based on magnetic factors. My experience in Wilmington has convinced me that if I want to be in the Happy Zone, I should live as close as possible to the peak at its ideal location. Wilmington, which was about 130 km south of the ideal location of the peak, was in the southern edge of the Happy Zone at 45 degree bed angles. But I didn't feel well there. The unstable BAD curve, the seasonal effects, and the high sensitivity to artificial magnetic fields when sleeping made Wilmington a less-than-ideal place. An alternative to living near the peak is to move a northern city, that although is deep in the Negative Zone has an inclination close to that which I experienced as a child. This ~ 70 degree inclination, which I experienced recently on a visit to Chicago, makes for less sensitivity to artificial magnetic fields when sleeping. This lower sensitivity gives me more flexibility in housing arrangements. The problem is that my symptoms increase the further I move from the peak.

To benefit mankind, my magnetoreceptive abilities, if they exist, need to be scientifically verified. If I continue to live near the peak, I plan to continue to research some areas, including effects of bed angle, but no matter how much more I research, and no matter how mathematically convincing my data, it's still limited by my subjective methodology. In other words, I think there are diminishing scientific returns from any further research. The information I've acquired to date should be enough to guide a scientist to perform the appropriate tests needed to verify my ability. And I hope a researcher will read this paper and decide that it's worth his or her valuable time to perform double-blind testing.

# Appendices

## Appendix A: Video Transcript

I am in the Negative Zone, I am walking towards the peak and [shaking] I'm entering the peak right now. As you can see, it's an intense experience, but very short lived [shaking stops]. Now, I'm stopped, I'm in the Happy Zone, and I feel markedly different. I'm going to reenter the peak from the south side. [Turns around and walks.] [shaking] I'm in the peak again [shaking stops]. Now, I'm out of the peak, I'm in the Negative Zone.

# Appendix B: Complete Utah BAD Data

| Location | Date | Time | Lat | Long | Elev (m) | Bed Angle | N-H / H-P | # Days BAD | BAD or HZW |
|---|---|---|---|---|---|---|---|---|---|
| Route 28 | 4/22/2008 | 12:52 | 39.58188 | -111.86190 | 1583 | 298 | N-H | | |
| Route 28 | 4/22/2008 | 14:20 | 38.95307 | -111.86021 | 1579 | 298 | H-P | | 0.62881 |
| Route 28 | 4/23/2008 | 12:14 | 39.22841 | -111.84800 | 1594 | 298 | N-H | 1 | -0.35347 |
| | | | | | | | | | |
| Farmington | 6/29/2008 | 12:41 | 40.97583 | -111.88321 | 1268 | 357 | N-H | | |
| Farmington | 6/29/2008 | 13:02 | 40.95873 | -111.88342 | 1277 | 357 | H-P | | 0.01710 |
| Farmington | 6/30/2008 | 12:52 | 41.00368 | -111.90337 | 1290 | 357 | N-H | 1 | 0.02785 |
| | | | | | | | | | |
| Farmington | 6/20/2008 | 11:14 | 40.97239 | -111.89112 | 1286 | 309 | N-H | | |
| Spanish Fork | 6/20/2008 | 13:09 | 40.12201 | -111.59793 | 1423 | 309 | H-P | | 0.85038 |
| Kaysville | 6/23/2008 | 14:20 | 41.03275 | -111.93794 | 1304 | 309 | N-H | 3 | 0.02012 |
| | | | | | | | | | |
| Layton | 7/3/2008 | 11:51 | 41.04866 | -111.95583 | 1315 | 318 | N-H | | |
| Bear River | 7/4/2008 | 13:30 | 41.61966 | -112.12836 | 1305 | 318 | N-H | 1 | 0.57100 |
| Bountiful | 7/4/2008 | 14:54 | 40.90872 | -111.88542 | 1302 | 318 | H-P | | 0.71094 |
| | | | | | | | | | |
| Centerville | 7/6/2008 | 11:27 | 40.93020 | -111.87905 | 1300 | 263 | N-H | | |
| Centerville | 7/6/2008 | 12:07 | 40.90441 | -111.87887 | 1312 | 263 | H-P | | 0.02579 |
| Kaysville | 7/7/2008 | 12:03 | 41.03959 | -111.93992 | 1301 | 263 | N-H | 1 | 0.10939 |
| | | | | | | | | | |
| Bountiful | 8/3/2008 | 12:08 | 40.88080 | -111.89207 | 1301 | 289 | N-H | | |
| Midvale | 8/3/2008 | 13:05 | 40.61943 | -111.89075 | 1322 | 289 | H-P | | 0.26137 |
| Layton | 8/4/2008 | 12:06 | 41.08803 | -111.97328 | 1378 | 289 | N-H | 1 | 0.20723 |
| | | | | | | | | | |
| Salt Lake City | 8/6/2008 | 13:15 | 40.78560 | -111.89948 | 1285 | 258 | N-H | | |
| Salt Lake City | 8/6/2008 | 12:40 | 40.76775 | -111.89990 | 1248 | 258 | H-P | | 0.01785 |
| Salt Lake City | 8/7/2008 | 11:19 | 40.76691 | -111.88563 | 1265 | 258 | N-H | 1 | -0.01869 |
| | | | | | | | | | |
| Kaysville | 8/12/2008 | 12:24 | 41.04308 | -111.94821 | 1284 | 293 | N-H | | |
| Murray | 8/12/2008 | 13:21 | 40.68041 | -111.88849 | 1283 | 293 | H-P | | 0.36267 |
| Rt 13 | 8/13/2008 | 13:00 | 41.64270 | -112.13069 | 1306 | 293 | N-H | 1 | 0.59962 |
| | | | | | | | | | |
| Salt Lake City | 8/15/2008 | 11:29 | 40.79122 | -111.90218 | 1255 | 280 | N-H | | |
| Midvale | 8/15/2008 | 13:01 | 40.61181 | -111.89085 | 1341 | 280 | H-P | | 0.17941 |
| Salt Lake City | 8/17/2008 | 12:12 | 40.72606 | -111.89944 | 1297 | 280 | N-H | 2 | -0.03258 |

Complete Utah BAD Data. Time is local time. N-H = Negative to Happy Transition. H-P = Happy to Positive Transition. BAD or HZW = Degrees latitude per day (BAD) or Degrees latitude (HZW). Bed location was in Salt Lake City (40.72, -111.81).

# Appendix C: Complete North Carolina BAD Data

| Location | Date | Time | Lat | Long | Elev (m) | Avg Bed Angle | SD Bed Angle | N-H / H-P | BAD or HZW |
|---|---|---|---|---|---|---|---|---|---|
| Fremont | 12/18/2008 | 13:21 | 35.57030 | -77.97482 | 31 | 306.6 | 0.8 | N-H | |
| Carolina Beach | 12/18/2008 | 16:45 | 34.03153 | -77.89508 | -5 | 306.6 | 0.8 | H-P | 1.53877 |
| Rt 301 | 12/19/2008 | 14:20 | 36.09560 | -77.72622 | 111 | 306.6 | 0.8 | N-H | 0.52530 |
| Wilson | 2/12/2009 | 12:28 | 35.70459 | -77.92278 | 50 | 314.8 | 0.9 | N-H | |
| Wilmington | 2/12/2009 | 17:15 | 34.06926 | -77.89703 | 1 | 314.8 | 0.9 | H-P | 1.63533 |
| Gaston | 2/13/2009 | 12:56 | 36.49746 | -77.64463 | 35 | 314.8 | 0.9 | N-H | 0.79287 |
| Goldsboro | 2/23/2009 | 12:49 | 35.34008 | -78.02955 | 3 | 309.5 | 0.8 | N-H | |
| Sunset Beach | 2/23/2009 | 16:06 | 33.91280 | -78.58217 | 1 | 309.5 | 0.8 | H-P | 1.42728 |
| Hollister | 2/24/2009 | 13:38 | 36.18729 | -77.82335 | 54 | 309.5 | 0.8 | N-H | 0.84721 |
| Wilson | 3/3/2009 | 12:43 | 35.70811 | -77.90596 | 32 | 302.6 | 1.0 | N-H | |
| Greenevers | 3/3/2009 | 14:52 | 34.77301 | -77.96045 | 76 | 302.6 | 1.0 | H-P | 0.93510 |
| Gaston | 3/4/2009 | 12:41 | 36.50721 | -77.63073 | 24 | 302.6 | 1.0 | N-H | 0.79910 |
| Rt 117 | 3/18/2009 | 14:20 | 35.59231 | -77.97269 | 15 | 363.2 | 0.9 | N-H | |
| Rt 117 | 3/18/2009 | 14:20 | 35.56294 | -77.97541 | 34 | 363.2 | 0.9 | H-P | 0.02937 |
| Ringwood | 3/19/2009 | 15:15 | 36.21083 | -77.84676 | 67 | 363.2 | 0.9 | N-H | 0.61852 |
| Goldsboro | 4/15/2009 | 13:30 | 35.34374 | -78.02856 | 25 | 357.7 | 0.8 | N-H | |
| Rt 117 | 4/15/2009 | 13:55 | 35.32281 | -78.03724 | 35 | 357.7 | 0.8 | H-P | 0.02093 |
| Rt 117 | 4/16/2009 | 13:10 | 35.14319 | -78.12923 | 36 | 357.7 | 0.8 | N-H | -0.20055 |
| Goldsboro | 4/22/2009 | 13:15 | 35.35421 | -78.01256 | 15 | 359.9 | 0.7 | N-H | |
| Rt 117 | 4/22/2009 | 13:39 | 35.33195 | -78.03584 | 19 | 359.9 | 0.7 | H-P | 0.02226 |
| Rt 117 | 4/23/2009 | 13:04 | 35.30652 | -78.04509 | -20 | 359.9 | 0.7 | N-H | -0.04769 |
| Rt 301 | 5/15/2009 | 14:55 | 35.84487 | -77.83215 | 41 | 346.0 | 1.2 | N-H | |
| Rt 117 | 5/15/2009 | 16:41 | 35.56227 | -77.97542 | 49 | 346.0 | 1.2 | H-P | 0.28260 |
| Wilson | 5/16/2009 | 15:04 | 35.69476 | -77.94026 | 33 | 346.0 | 1.2 | N-H | -0.15011 |
| Goldsboro | 8/21/2009 | 13:52 | 35.35473 | -78.01210 | 21 | 264.5 | 1.6 | N-H | |
| Rt 117 | 8/21/2009 | 14:20 | 35.32657 | -78.03619 | 24 | 264.5 | 1.6 | H-P | 0.02816 |
| Goldsboro | 8/22/2009 | 13:35 | 35.36725 | -78.00775 | 11 | 264.5 | 1.6 | N-H | 0.01252 |
| Rt 55 | 9/8/2009 | 13:52 | 35.62819 | -78.82180 | 117 | 263.0 | 1.6 | N-H | |
| Fuquay-Varina | 9/8/2009 | 14:23 | 35.58066 | -78.79971 | 103 | 263.0 | 1.6 | H-P | 0.04753 |
| Fuquay-Varina | 9/9/2009 | 14:02 | 35.59123 | -78.79433 | 126 | 263.0 | 1.6 | N-H | -0.03696 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Goldsboro | 9/15/2009 | 13:59 | 35.34165 | -78.03007 | 22 | 268.4 | 1.4 | N-H | |
| Mt. Olive | 9/15/2009 | 13:03 | 35.21224 | -78.07122 | 50 | 268.4 | 1.4 | H-P | 0.12941 |
| Rocky Mount | 9/16/2009 | 13:52 | 35.96705 | -77.80733 | 34 | 268.4 | 1.4 | N-H | 0.62540 |
| | | | | | | | | | |
| Pikeville | 10/1/2009 | 13:39 | 35.49425 | -77.98168 | 51 | 348.3 | 1.0 | N-H | |
| Mt. Olive | 10/1/2009 | 14:52 | 35.21028 | -78.07071 | 47 | 348.3 | 1.0 | H-P | 0.28397 |
| Rt 117 | 10/2/2009 | 14:45 | 34.92855 | -78.06792 | 37 | 348.3 | 1.0 | N-H | -0.56570 |

Complete North Carolina BAD Data. Time is local time. N-H = Negative to Happy Transition. H-P = Happy to Positive Transition. BAD or HZW = Degrees latitude per day (BAD) or Degrees latitude (HZW). Bed location was in Wilmington (34.22, -77.87). Note that due to a more precise bed angle data collection method in North Carolina (versus Utah), I present average and standard deviation bed angle in this table.

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