All Things Digital

Amateur Radio for the 21st Century

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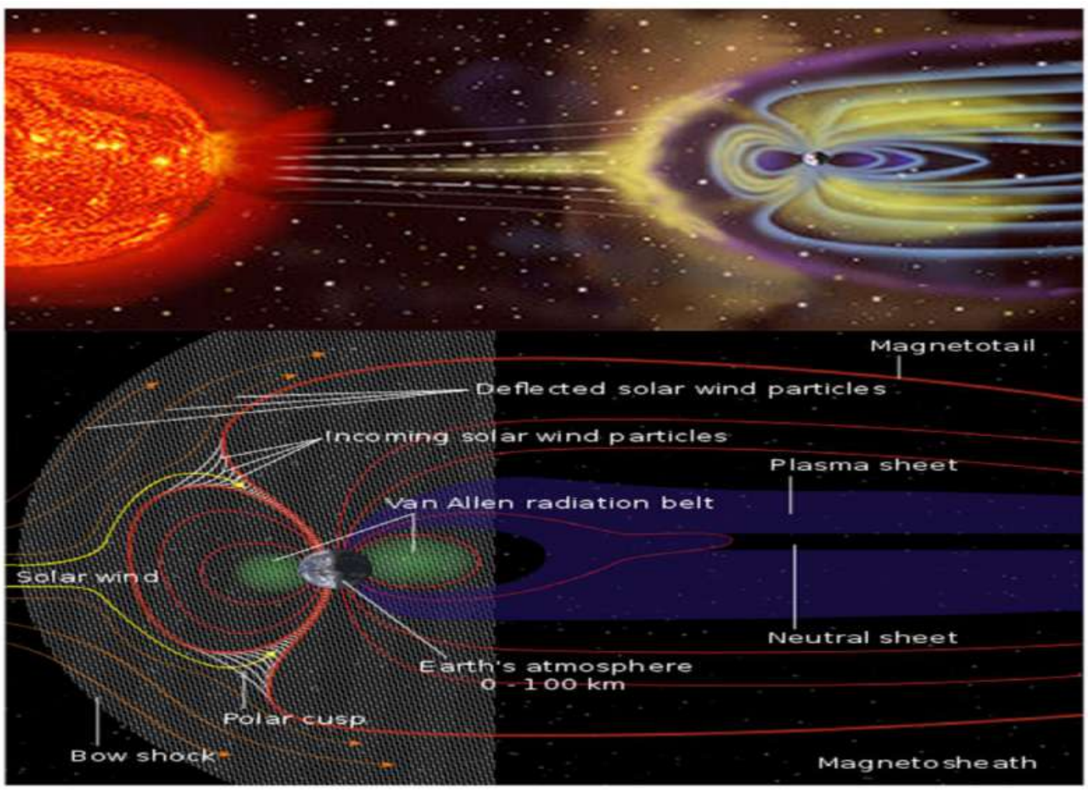
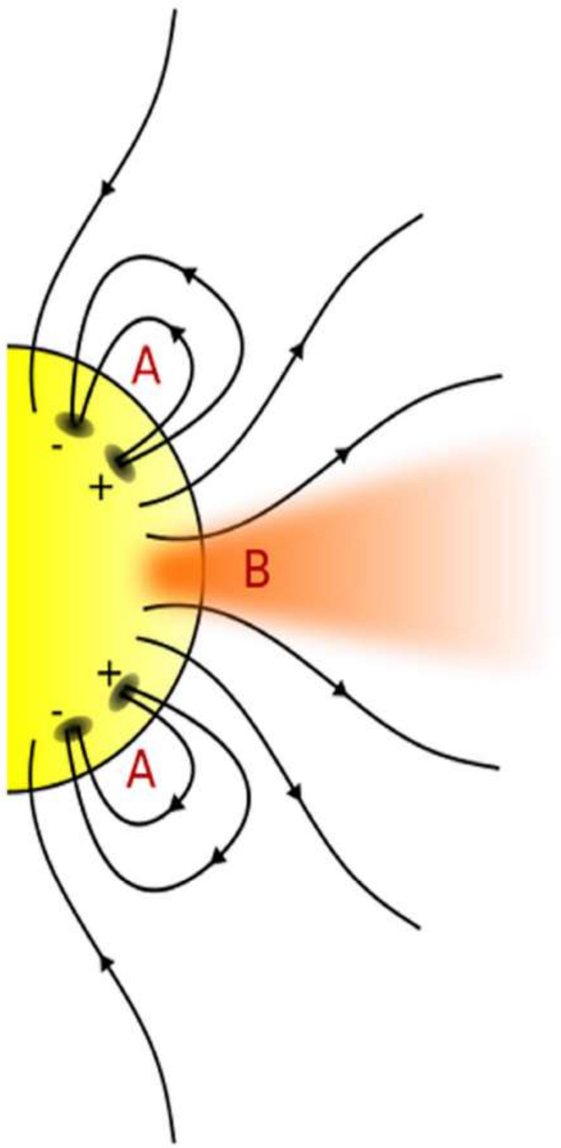


Figure 1: Solar wind versus Earth. Credit: Wikipedia.

Which Way the Solar Wind Blows

Our middle-aged sun "Sol" is the primary source of radiation (both good and bad) that bombards planet Earth daily with over 170 petawatts (10^{15} watts!) of free energy, but less than 1% is converted to electrical power—the rest is wasted.

Sol radiates equally in all directions, which is mostly composed of light speed velocity, dual wave-particles called “photons”, which are bundles or packets of electromagnetic (EM) energy that take less than 8-1/2 light minutes to reach Earth at different wavelengths: radio frequency (RF) waves, visible light waves, microwaves, extreme ultraviolet (EUV) and X-rays. The latter three are types of “ionizing” radiation, and sunspots increase ionizing radiation resulting in better high band radio propagation because of its effects on the “ionosphere”.



Then we the solar “wind” (see Figure 1, previous page), composed of heavier, sub-light speed particles of free protons and electrons stripped from hydrogen atoms; they can take anywhere from a half-hour to several days to reach us. Usually, the solar wind usually isn’t a problem because our planet has a strong magnetic field generated by its rotating, molten iron-nickel core generating the “magnetosphere”. It’s a protective EM shield that deflects and/or absorbs incoming energy, creating permanent aurora around both poles. Normally, the solar wind speed is less than 500 kilometres per second (km/s), but coronal holes, coronal mass ejections (CME), solar flares and solar electro-magnetic pulses (EMP) can shoot out very focussed energy streams increasing its velocity and force (see Figures 2 and 3, next page).

Figure 2: Solar “breaking bad”. When the Sun can’t hold a magnetic field loop closed, all the energy contained is directionally and explosively released into space. The energy can exceed that of millions of hydrogen bombs going off all at once on the solar surface! Credit: Wikipedia.

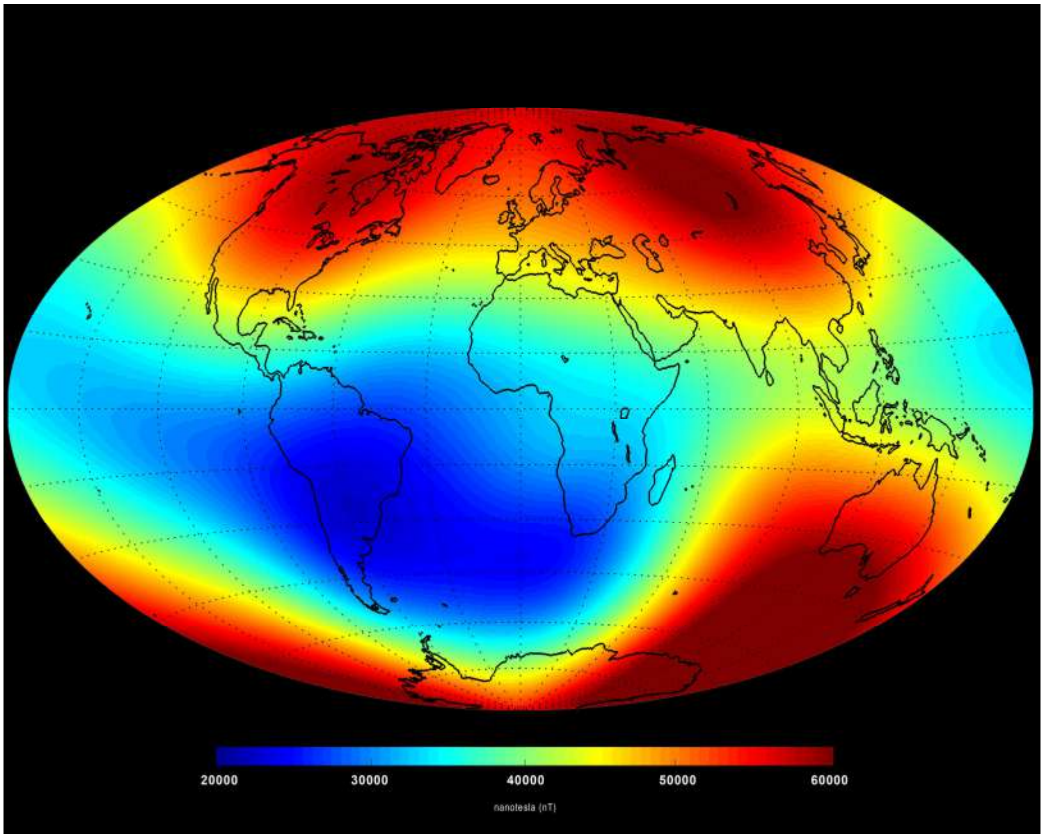


Figure 3: Earth's magnetic (geomagnetic) field strength (flux) varies around the world. The colour scale is in nanotesla (nT). Field strength is weakening slowly over time, and it's about 0.3 nT a day for North America, which isn't a good thing. The tesla (T) is the derived Système International d'Unités (SI) or metric unit for magnetic induction (magnetic flux density) named in honour of Nikola Tesla (one tesla equals 10,000 gauss). Average strength of Earth's magnetic field on the prime meridian is about 31870 nT, but the magnetic field strength of a typical solar sunspot is about 300 millitesla (mT)! Credit: Earth Changes and Wikipedia.

Low energy solar wind particle streams exceeding 500 km/s and hitting Earth's magnetosphere induce a geomagnetic "storm" (rated from "G1" to "G5") that can overwhelm it and then the ionosphere, greatly intensifying the constant but weak "ring" current always flowing in the ionosphere. Low "G" levels result in auroras moving out from the poles, covering a larger area and becoming more intense, which also degrades high band shortwave radio propagation. But higher "G" levels can affect satellite telecommunications and terrestrial power grids. But all these affects are usually on a small scale and they don't last very long. We also get a few days warning to prepare ahead because the solar wind particles are moving slower.

High energy solar wind radiation storms can unbelievable speeds exceeding 10,000 km/s (rated from “S1” to “S5”)! Fortunately, they occur less frequently, and statistically it’s about one “S5” per century, but their effects are more intensive, more disruptive, more destructive, and can wreak worldwide chaos and havoc. Protons and electrons are energized and accelerated to 1/3 light speed (or even faster), and taking less than 30 minutes to reach Earth so there’s not much time for us to do much of anything about it except that there are some signs solar scientists can look for prior to a solar “tsunami” occurring. But if planet Earth happens to be in the wrong spot at the wrong time…

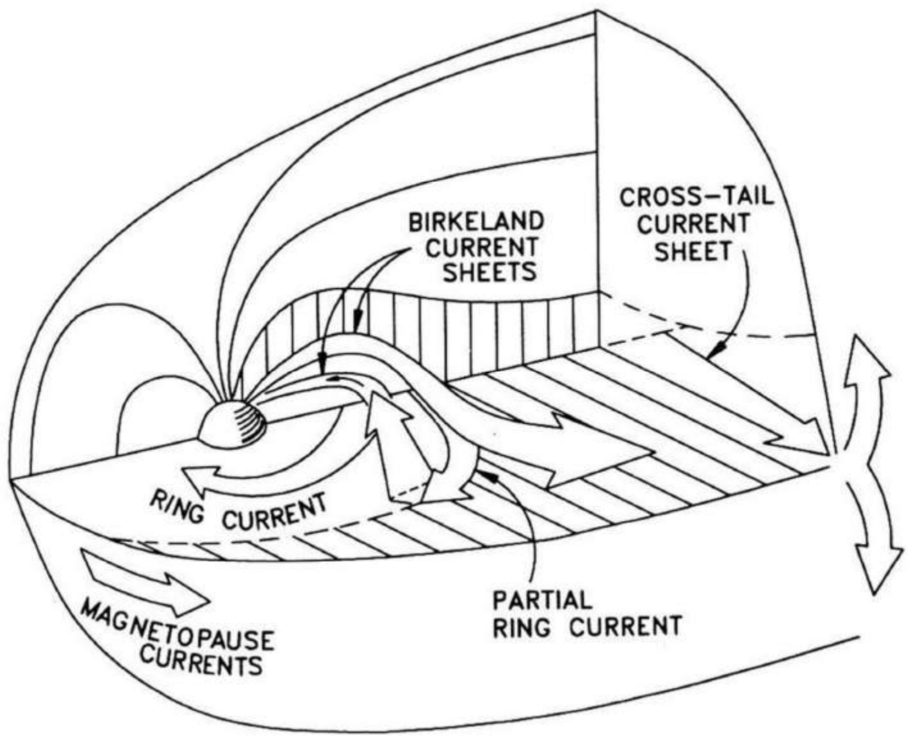


Figure 4: Earth’s electromagnetic currents. Image credit: David P. Stern, 1994: “The art of mapping the magnetosphere” (Journal of Geophysical Research).

The perpetual ring current flowing in the ionosphere is caused by Earth’s magnetic (geomagnetic) field (see Figure 4). Free atmospheric oxygen and/or nitrogen ions plus any incoming protons (the primordial hydrogen ion) are the primary ring current carriers, circulating it clockwise in a horizontal plane around the world, producing a very weak magnetic field opposite to that of the Earth’s.

During high “G” level solar wind particle storms and especially “S” level solar wind radiation storms, more and more incoming free protons (+1 charge) and free electrons (-1 charge) stream in and “overwhelm” the magnetosphere. Then they “flood” the ionosphere, increasing the potential difference (force) driving its ring current making its magnetic field stronger and stronger. As a result, Earth’s magnetic field gets weaker and weaker (more negative) trying to resist the increasing opposing magnetic field, which further weakens the magnetosphere, which allows in more and more particles. And on and on it goes until something breaks bad.

Solar Really Breaking Bad

The solar wind radiation “superstorm” (“S5”) of September 1859 (the famous Carrington Event) created world-wide auroras so bright (for three days) that people could read newspapers outdoors in the middle of the night by their light, and auroras were visible to 10 degrees latitude! Landline telegraph equipment and inter-connected lines and cables across Europe and North America burnt/blew up knocking out landline telecommunications for a several days. In the lower stratosphere, the protective ozone layer was severely depleted for several years (it blocks more than 99% of the incoming and deadly solar EUV). Of course, back then, there were no electrical power grids, satellite telecommunications, email, radio, electronic banking, radios, internet, computers, etc., so it was more of a spectacular sky show for a few nights rather than a world-wide disaster. But if a Carrington type event hit the Earth head-on today, its effects would blast us all back to the 19th century—literally—wreaking havoc and chaos around the globe. And given today’s geopolitics, hostile governments could take advantage of the situation depending on how badly damaged their opponent’s internal infrastructure was. We just barely missed being hit by a combined CME, solar flare and EMP in July 2012 (only revealed two years later), so we are literally running on or rather orbiting on pure dumb luck! Reference: “Space Weather Super-Storm Not If but When and Extreme Solar Minimum” (M. Guhathakurta, Presentation to the United Nations Committee on the Peaceful Uses of Outer Space [UNCOPUOS] Meeting, Vienna, Austria, 2011).

An Innovative Amateur Radio Citizen Science Concept

"The Personal Space Weather Station" (PSWStn) by Ward Silver, N0AX, (*QST*, April 2018) outlines his idea for a monitoring system similar to a terrestrial personal weather station (PWS). His concept creates an international and standardized system to monitor and collect specific space weather telemetry (24/7/365), and upload telemetry received by "citizen scientists" from around the world to a central server to provide a database that everyone can freely use (see Figure 5).

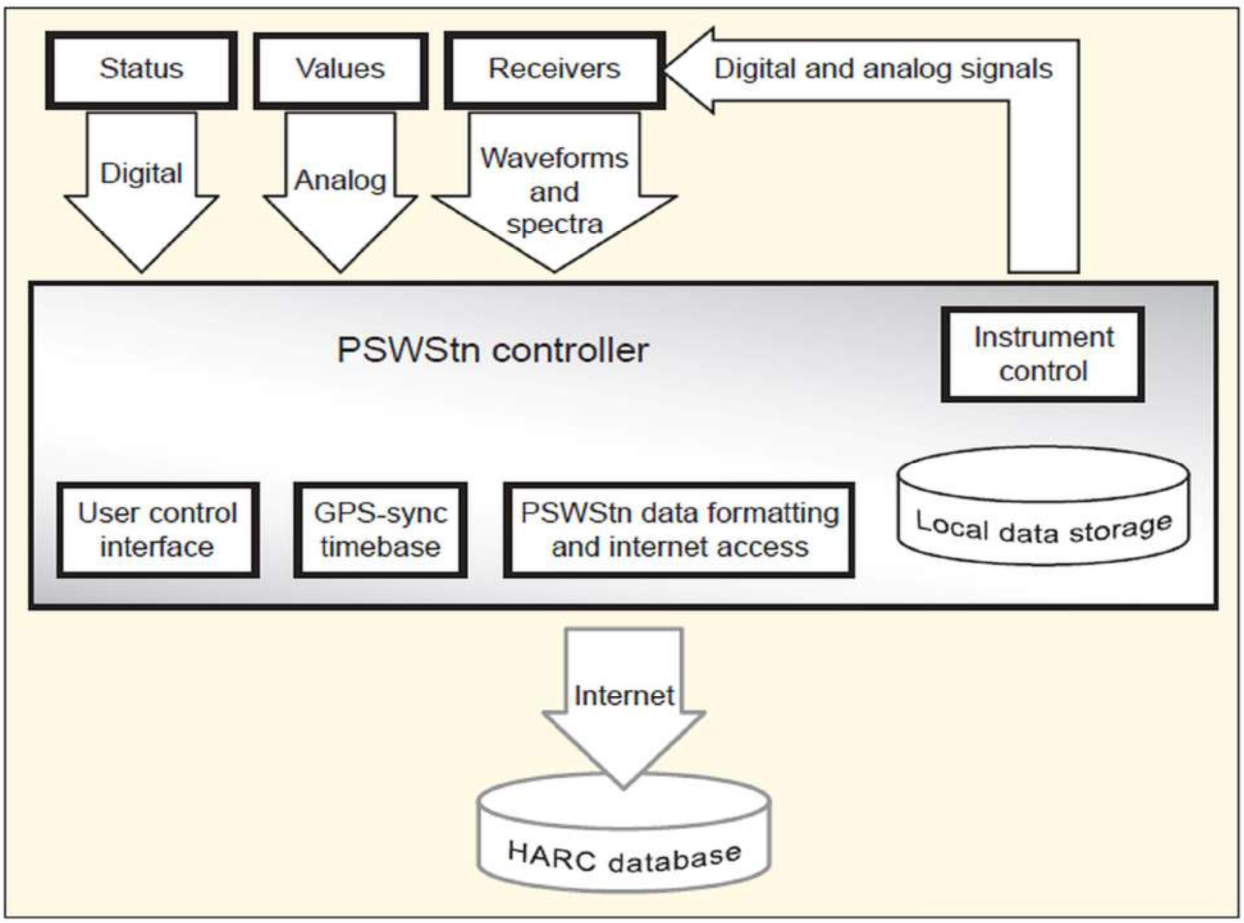


Figure 5: Personal space weather station concept. Credit and copyright: Ward Silver and ARRL (2018). Used with permission.

It didn't take too long for the Ham Radio Science Investigation (HamSCI) group, lead by Nathaniel Frissnell, W2NAF to take notice and form a working group to investigate and possibly develop Ward's idea.

From their webpage: “The Personal Space Weather Station project ultimately aims to create a small, multi-instrument system that can make ground-based measurements of the space environment. Observations from this project will not only be useful to the owner of the system, but also aggregated into a central database for space science and space weather research purposes. Initial work focuses on the development of a scientific-grade high frequency (HF) radio receiver, as well as the necessary software and network infrastructure. This project is led by the New Jersey Institute of Technology Center for Solar Terrestrial Research (NJIT-CSTR) in collaboration with the Massachusetts Institute of Technology (MIT) Haystack Observatory, and the Tucson Amateur Packet Radio (TAPR), Inc.” *Update (August 2019): TAPR announces that the project will now be called the “TangerineSDR” (https://tangerinesdr.com).*

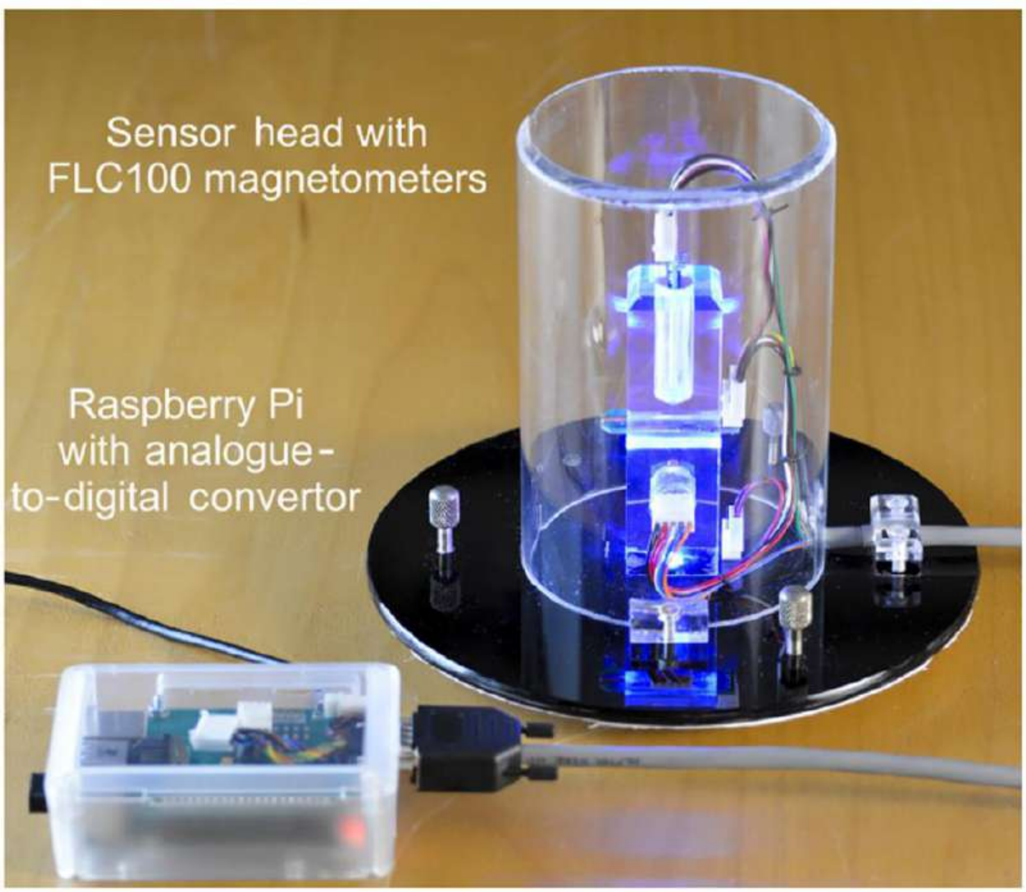


Figure 6A: Raspberry Pi magnetometer. Credit and copyright from “Building a Raspberry Pi school magnetometer network in the UK”, Beggan and Marple (2018).

A Raspberry Pi Magnetometer

The concept of a Raspberry Pi based magnetometer device, built from inexpensive off-the-shelf equipment, is the brain child of Ciarán D. Beggan and Steve R. Marple. They came up with an affordable, easy to build, programmable magnetometer to measure Earth's magnetic (geomagnetic) field in real-time and upload the collected data to a central server (see Figure 6A, previous page). A magnetometer is one of the devices being considered for the TangerineSDR project. Professional geomagnetic monitoring stations around the world aren't that numerous, and are very expensive to build, staff and maintain, so a network of hundreds of hobbyist magnetometers streaming to a central server is a very good thing for scientists because as far as they are concerned, there's no such thing as having "too" much information.

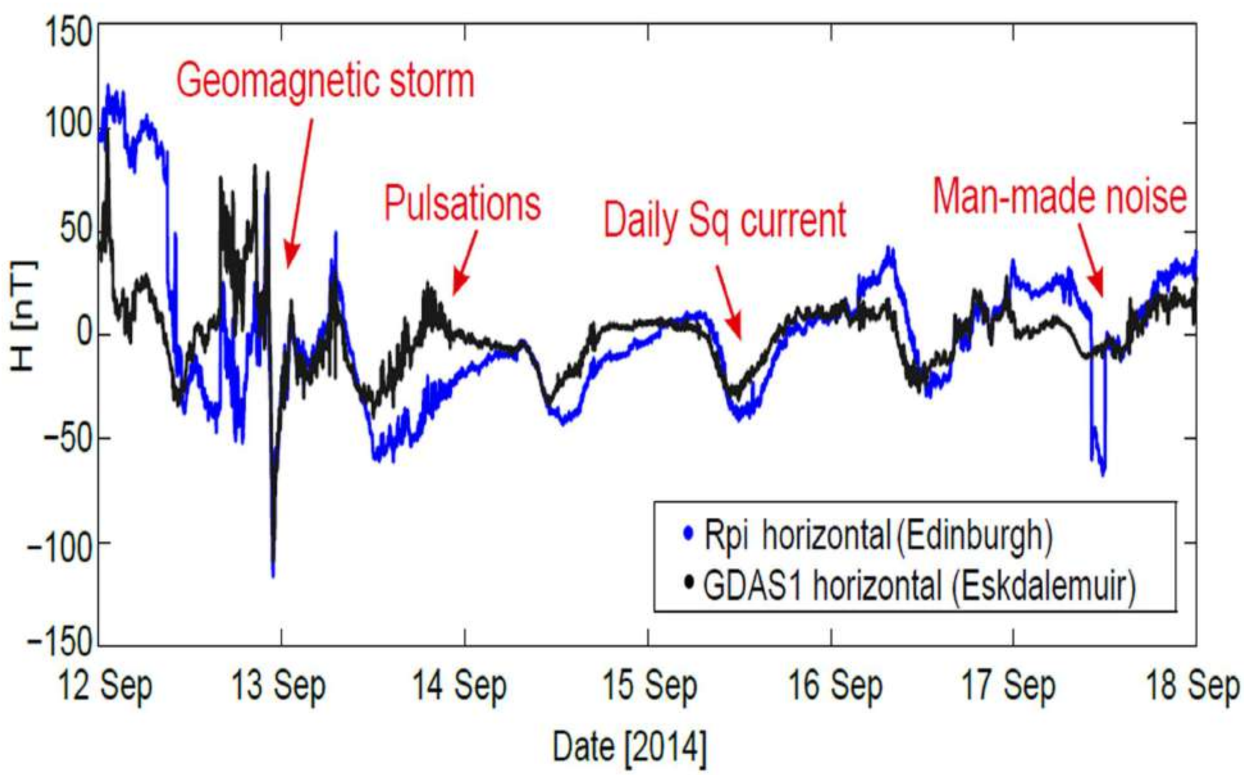


Figure 6B: Raspberry Pi magnetometer graph showing horizontal (H) geomagnetic field strength variation in nanotesla (nT) versus time. Blue trace is a Raspberry Pi magnetometer located in Edinburgh, UK; black trace is the GDAS1 system at the Eskdalemuir Geomagnetic Observatory (70 km south of Edinburgh). "Sq" means solar quiet time, which occurs daily at local solar noon. Credit and copyright: "Building a Raspberry Pi school magnetometer network in the UK", Beggan and Marple (2018).

In Figure 6B (previous page), the disturbance storm time index (D_{ST}) for the indicated minor geomagnetic storm is about minus 120 nT, while a major geomagnetic storm has a typical D_{ST} of around minus 300 nT. It's indicated by a sudden steep decrease (negative change) in magnetic field strength followed after by a slow rising recovery (positive change) after the event is over because it takes longer for the magnetosphere and ionosphere to "recover". The Earth's normal or "quiet" magnetic field daily variance is only plus/minus 20 nT. But to put that all into perspective, the D_{ST} recorded by magnetometers during the Carrington Event was minus 1760 nT (converted from gauss)! Credit: "The extreme magnetic storm of 1^{st} and 2nd September 1859", Tsurutani et al, Journal of Geophysical Research No. A7, 2003.

Note: D_{ST} is determined from the average hourly values measured at four different, near-equatorial, geomagnetic field observatories; it indicates how much the ionosphere's ring current weakens Earths magnetic field as a function of time.

Software Defined Radio (SDR) Networks

If you don't have your own radio equipment to use for radio science, there's the open access SDR.hu network, which is the creation of András Retzler, HA7ILM that you can freely access using a web browser. It's a collective comprised (mainly) of hundreds of GPS disciplined (frequency stabilized) KiwiSDRs, a software defined radio (SDR) with up to eight separate and simultaneous receivers designed by John Seamons, ZL/KF6VO. Because of its open source software design, several talented programmers have created various program add-ons (called "extensions") and/or websites to further enhance the KiwiSDR's awesome and growing list of features (see Figure 7, next page). Many receivers have specialized antennas designed for specific segments of the EM spectrum, and one or more Kiwis can be used to collect data from around the world, at any time of the day or night, all from the comfort of your home or classroom.

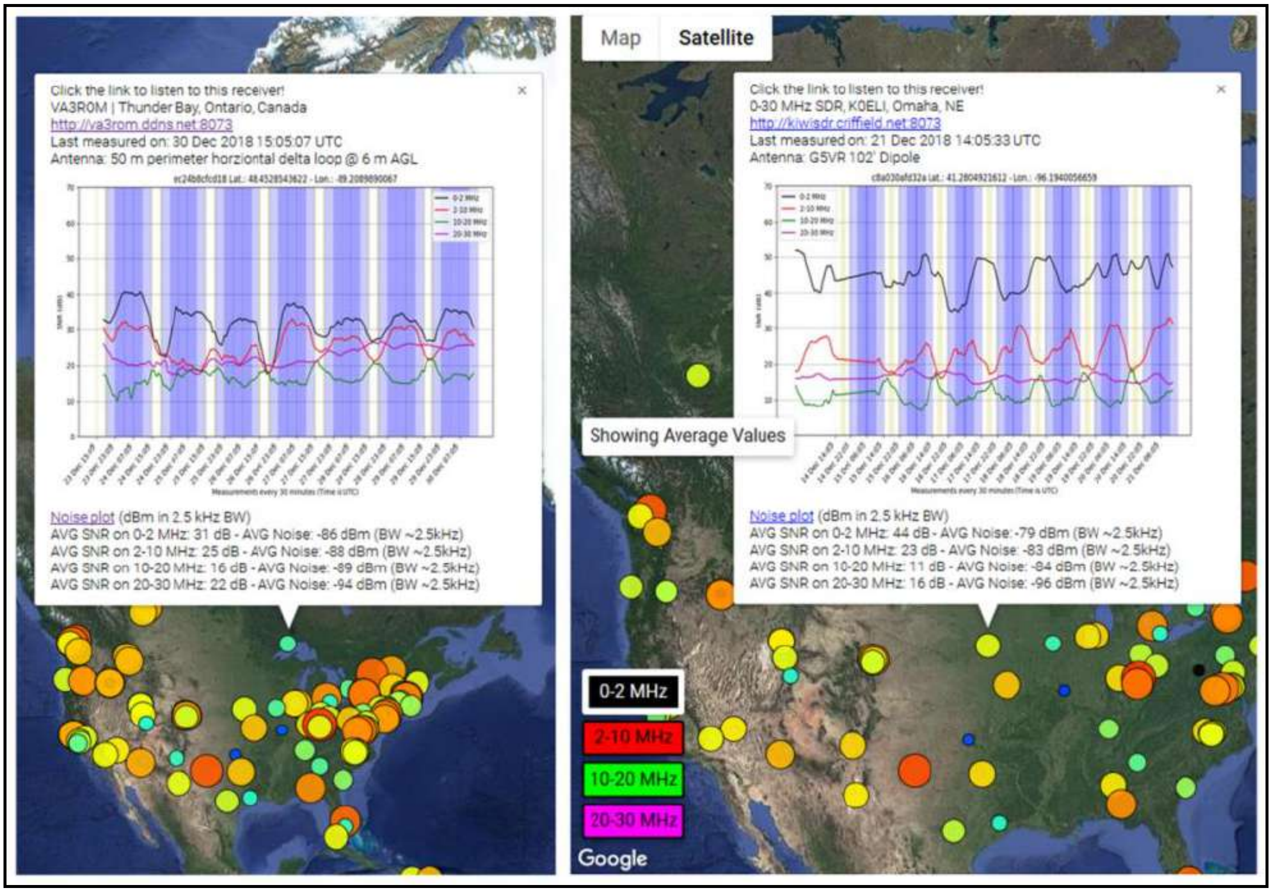


Figure 6: KiwiSDR antenna comparisons of receive signal-to-noise ratios (SNR) with my SDR.hu connected KiwiSDR using a horizontal delta loop against another KiwiSDR connected to a G5RV dipole. You can download high resolution graphs to see more details, and also download and overlay other stations' graphs over yours for more detailed analysis (using Photoshop or Gimp).

My Final

Because much of what we can do with today's technology and the internet is mostly automated (you "set it and forget it"), there's really no reason why you can't leave your equipment running continuously working on various radio science projects of personal interest when it's not being used for regular radio communications (except during thunderstorms, of course!). In only 20 short years, the internet has truly changed the way we work, exchange ideas and can conduct research from almost anywhere on the planet!—73