

# HamSCI Link Budget: Observations and Modeling the Signal Strength of HF Radio Links from WWV to W2NAF

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## Abstract

This work explores the ionospheric High Frequency (HF) absorptions, specifically at 5 and 10 MHz. We investigate the HF absorption levels for the radio links from the two National Institute of Standards and Technology (NIST) dedicated Radio transmitting Stations, WWV Colorado and WWV Hawaii, to the Personal Space Weather Station (PSWS) receiver W2NAF. W2NAF, located near Scranton, Pennsylvania, is equipped with the GPS-disciplined Great Radio Amateur Propagation Experiment (GRAPE) receiver. Our work utilizes the International Reference Ionosphere (IRI-2020) model and PHaRLAP ray tracer to calculate the absorptions of the HF rays from the two WWV transmitters to W2NAF connected by 1, 2, or 3 hop links. For the modeled rays, we also calculate the percentage of successful rays connecting WWV and W2NAF. Our results show that the modeled absorptions are consistent with the signal strength observations for some of the quiet days, albeit with divergences at others. We present these results on the data-model comparison of the Ham Radio Science Citizen Investigation (HamSCI) link budget.

## Dataset & Modeling

### Observations from HamSCI GRAPE Digital RF Project

- We use observations from PSWS Software Defined Radio (SDR) instrument, WSPR Daemon-Grape, which uses RX-888 HF SDR, KA9Q-Radio & WSPRDaemon Software, and a GPS-disciplined oscillator to make precision frequency measurement [2]. The system can receive multiple bands simultaneously from 0.5-60 MHz. HamSCI PSWS is NSF-funded Distributed Array of Small Instruments (DASI) project.
- HF signal strength data are taken from PSWS station W2NAF near Scranton, PA.

### Modeling HF absorption levels

- We use PHaRLAP raytracing with IRI-2020 model based ionosphere [3, 4]
- Model HF absorptions for radio propagations from WWV and WWVH to W2NAF.
- Modeling for 5 and 10 MHz; and for 1, 2 and 3 hop propagation modes.

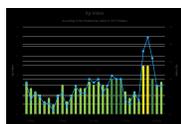
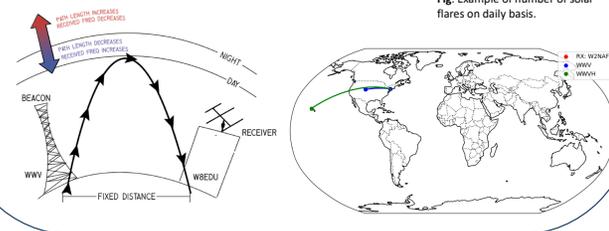


Fig: Example of final Kp index from GFZ Potsdam.



Fig: Example of number of solar flares on daily basis.



## Methodology

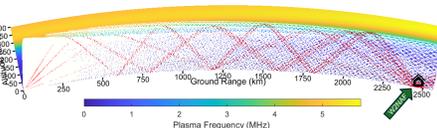
### Filtering Days of Interest

- Geomagnetically Quiet Day: WDC Kyoto quiet days list using Kp index [7]
- No X-Class flare: using SpaceWeatherLive archive [8, 9]

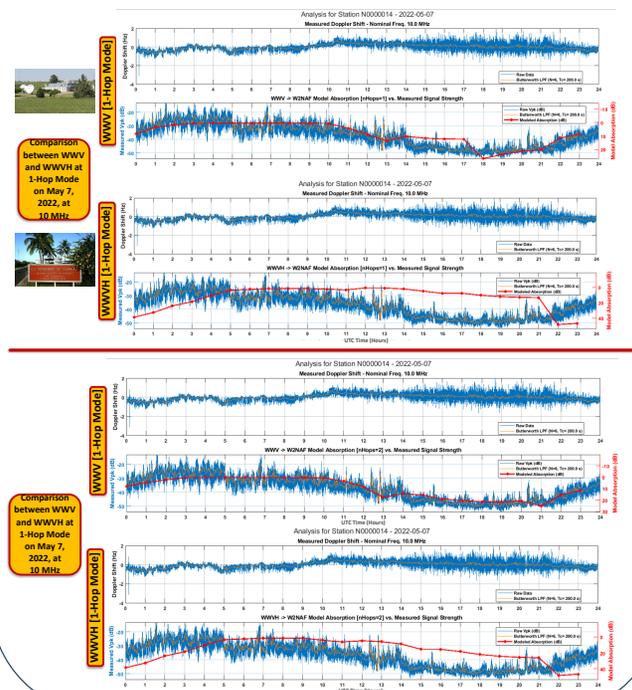
### PHaRLAP raytracing and successful radio link

- Launched ray tracing for elevations from 0° to 80°
- Observe the ray path data for the 1, 2 and 3 hop modes
- Filter based on the Ray Label with non-negative values (ground to ground rays)
- Tolerance radius of 50 kms, rays received within this are considered successful
- Per simulating hour, out of all elevations, pick the elevation of successful ray. Obtain absorption levels of this successful ray.

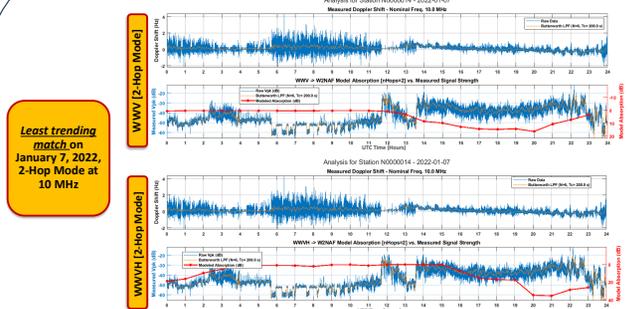
Fig: Example raytracing from WWV to W2NAF at 5 MHz. Highlighted in red are successful rays.



## Results



## Results..



Least trending match on January 7, 2022, 2-Hop Mode at 10 MHz

- May 7, 2022: Best trend-matching HF absorptions with PSWS observations at 10 MHz, both 1 and 2 hop modes.
- January 7<sup>th</sup>, 2022: Least trend-matching HF absorptions with PSWS observations at 10 MHz, 1-Hop Mode.

## Conclusions

- For **many** seasonal days, we can model HF absorptions as model-signal match
- For **some** days, model and data do not perfectly match, even in quiet days
- Both models and observations show higher absorption at lower frequencies, and changes with seasonal variations.
- Our modeled absorptions show coincidence with the observation trends for the WWV Colorado transmitters more than the case of WWVH.
- The results can help examine whether the received HF is from WWV or WWVH.
- Future work includes investigating the cause for the non trending matching days, which we believe in relation to other wave activities that are not filtered based on Kp and solar flare indices.

## References

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