Fitting Ionospheric Models Using Real-Time HF Amateur Radio Observations

J.D. Katz[1], N.A. Frissell[1], J.S. Vega[1], A.J. Gerrard[1], R. Gerzoff[1], P.J. Erickson[2], E.S. Miller[3], M. Moses[4], F. Ceglia[5], D. Pascoe[5], N. Sinanis[5], P. Smith[5], R. Williams[5], A. Shovkoplyas[6]
[1]New Jersey Institute of Technology [2]MIT Haystack Observatory [3]Johns Hopkins University Applied Physics Laboratory [4]Virginia Tech [5]Reverse Beacon Network [6]Afreet Software, Inc.

Introduction

Using novel, spatially distributed data sources, we have begun an investigation into ionospheric morphology over wide observational areas, with a goal of improving ionospheric and radio propagation models. These data sources also have information density that is ideal for advancing knowledge on high time cadence radio propagation trends at shortwave frequencies in ways that are difficult to obtain by other means. The initial investigation reported here focuses on transmissions in the 7 MHz (40 M) radio band.

Research Questions

- Using RBN propagation data, can we identify significant space weather events that affect ionospheric structure?
- How well do RBN observations agree with IRI HF Raytracing predictions?

Data and Methodology

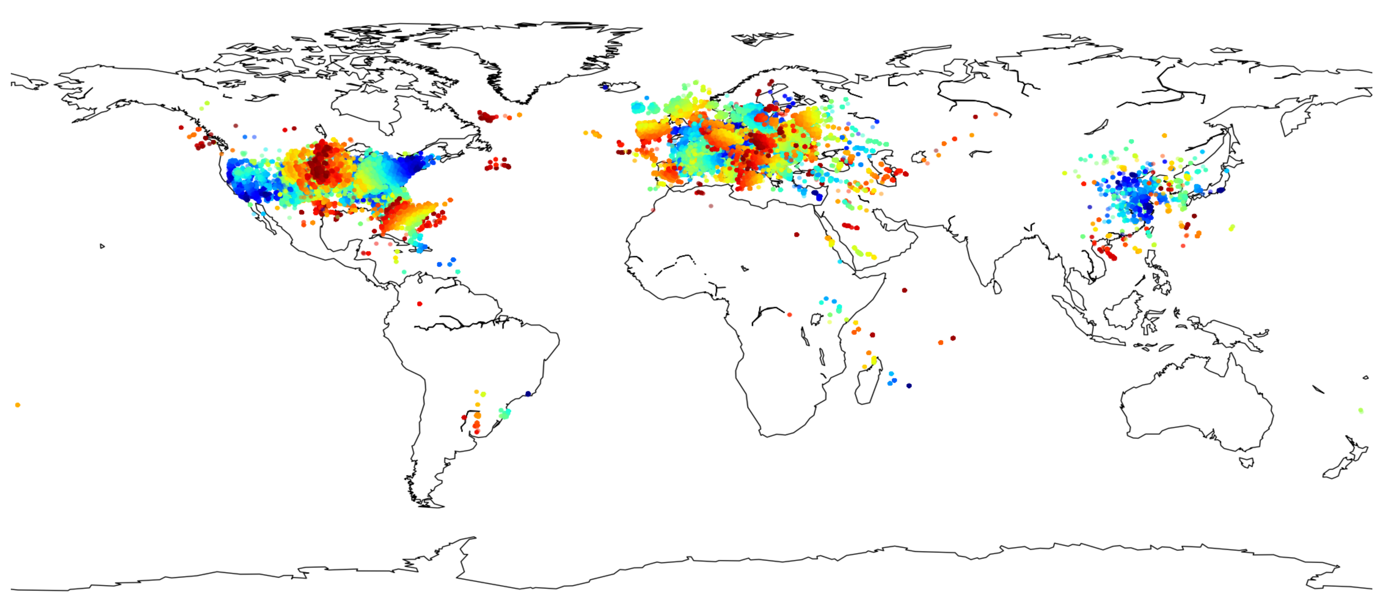
The data used during this analysis comes from the **Reverse Beacon Network (RBN).** The **Reverse Beacon Network** is an automated radio (1.8 – 144 MHz) receiving network created and maintained voluntarily by ham radio operators that has been shown to be sensitive to ionospheric effects [*Frissell et al.*, 2014].

We ignored all communication paths observed by the **RBN** over 4000 km. This was done to remove multi-hop ionospheric propagation from the data to more easily highlight variations in reported signal to noise ratio (SNR) data.

The Ap and 10.7 cm indices were obtained from CDAWeb's hourly OMNI data set and were smoothed over a 3 month period.

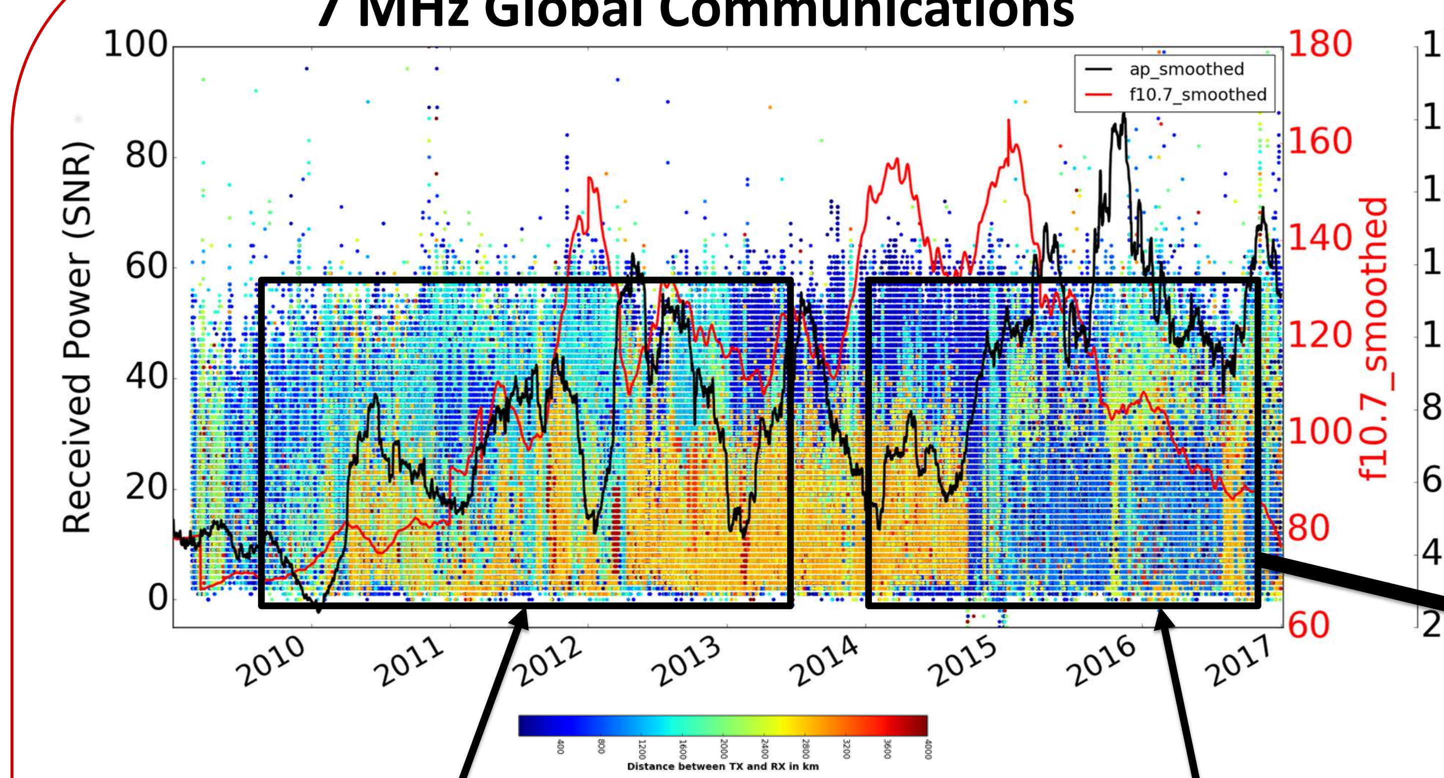
We simulated the communication paths seen by the **Reverse Beacon Network** using PHaRLAP [*Cervera and Harris*, 2014]. This provided us with a baseline for comparison of ionospheric model predictions with observations derived from the **RBN**.

Coverage



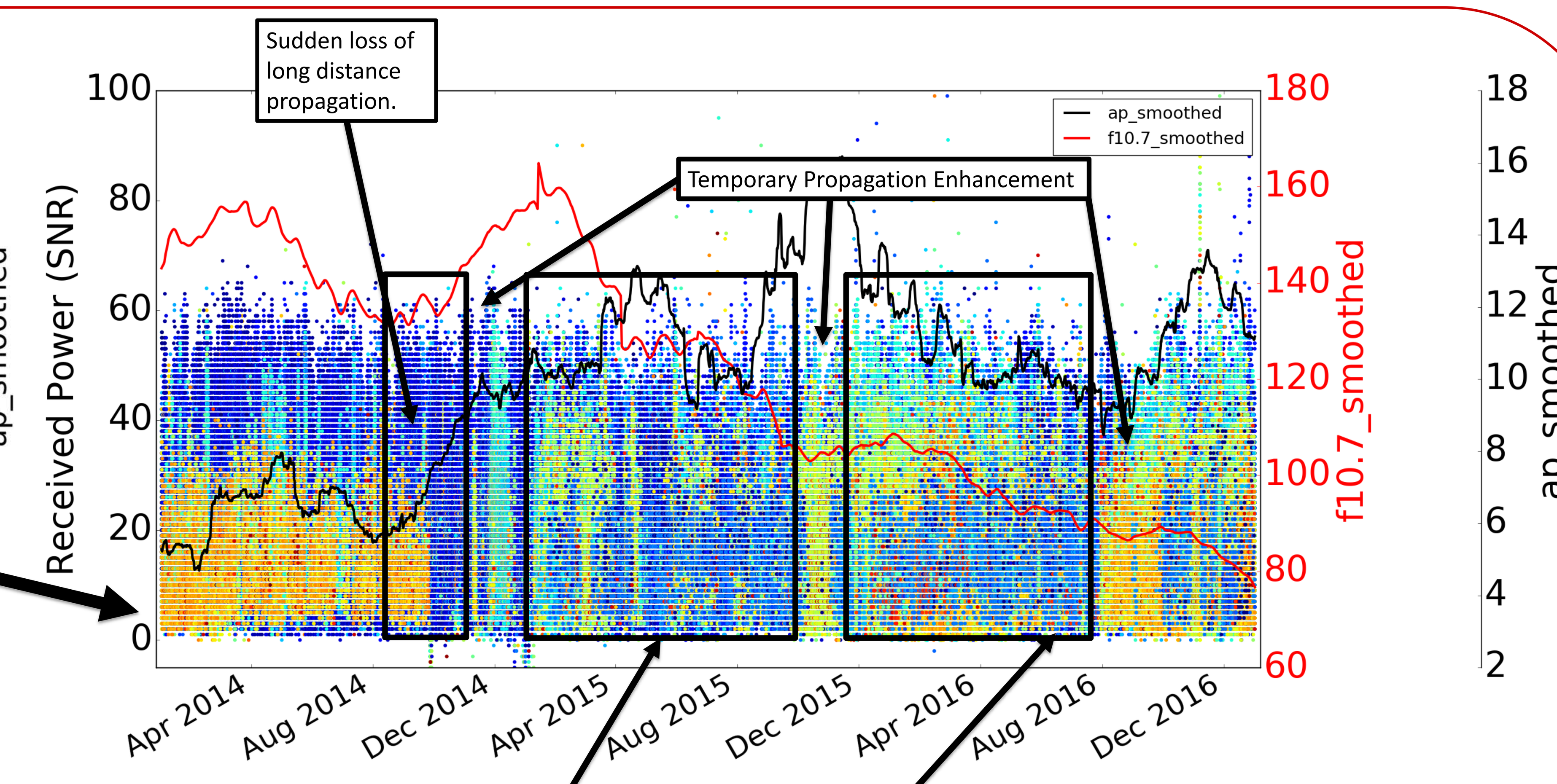
This plot shows midpoints for all communication paths observed by the **Reverse Beacon Network** where the transmitter and receiver are less then 4000 km apart. Most communications observed by the **Reverse Beacon Network** come from the United States and Europe with only minor participation from China and Japan. Our analysis focuses on communication from the United States and Europe for this reason.

7 MHz Global Communications



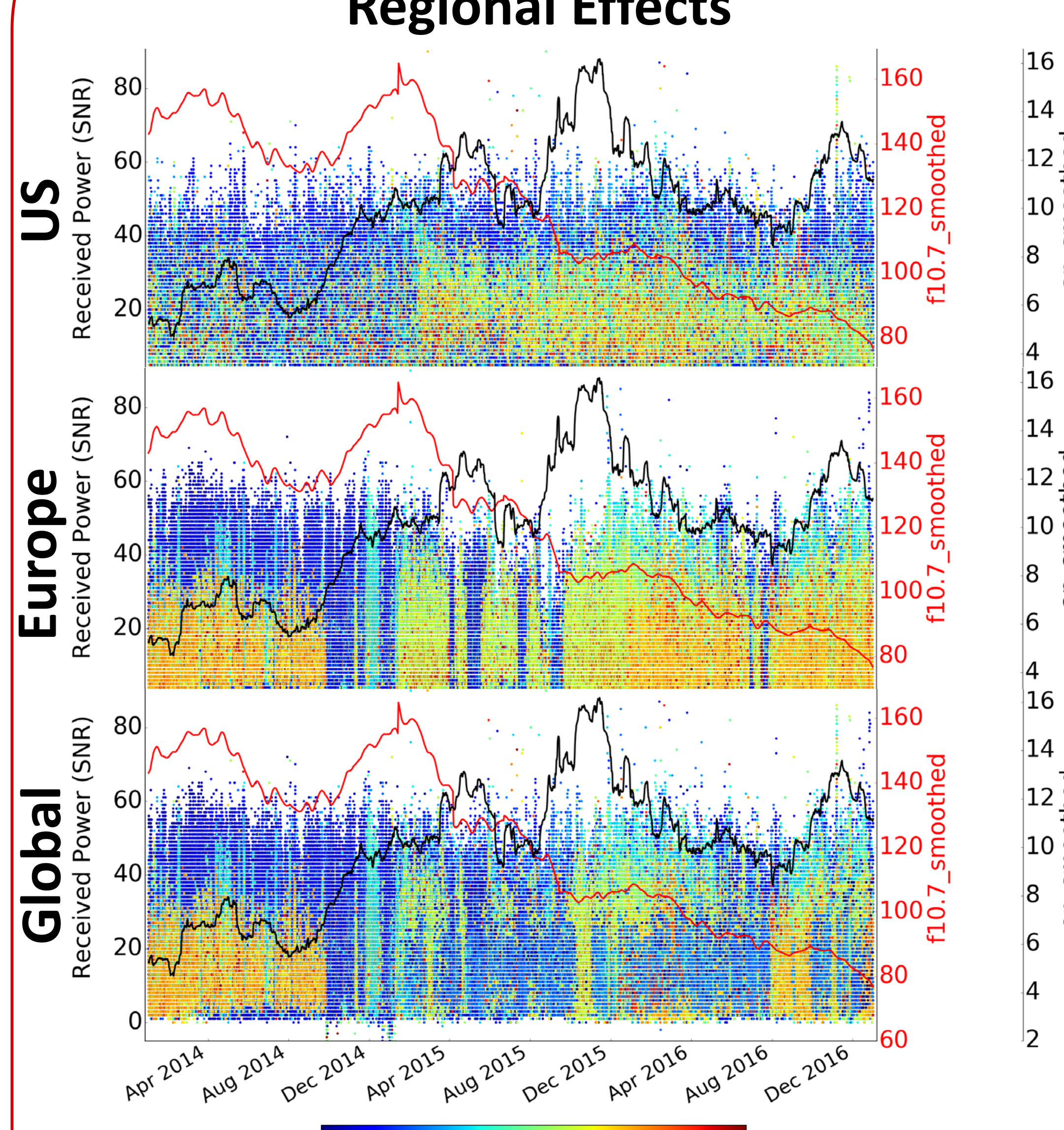
We define the time period from 2010 to 2013 as normal propagation. The ionosphere is supporting long-distance (above 2000 km) communications at moderate SNRs. Short distance (below 1000 km) communications are coming in at high SNRs. This is consistent with expectations. Closer signals are stronger, far signals are quieter.

During the transition from 2014 to 2015 the propagation supported by the ionosphere changes to support short-distance communication paths and we observe a loss in all communications over 1200 km path length.



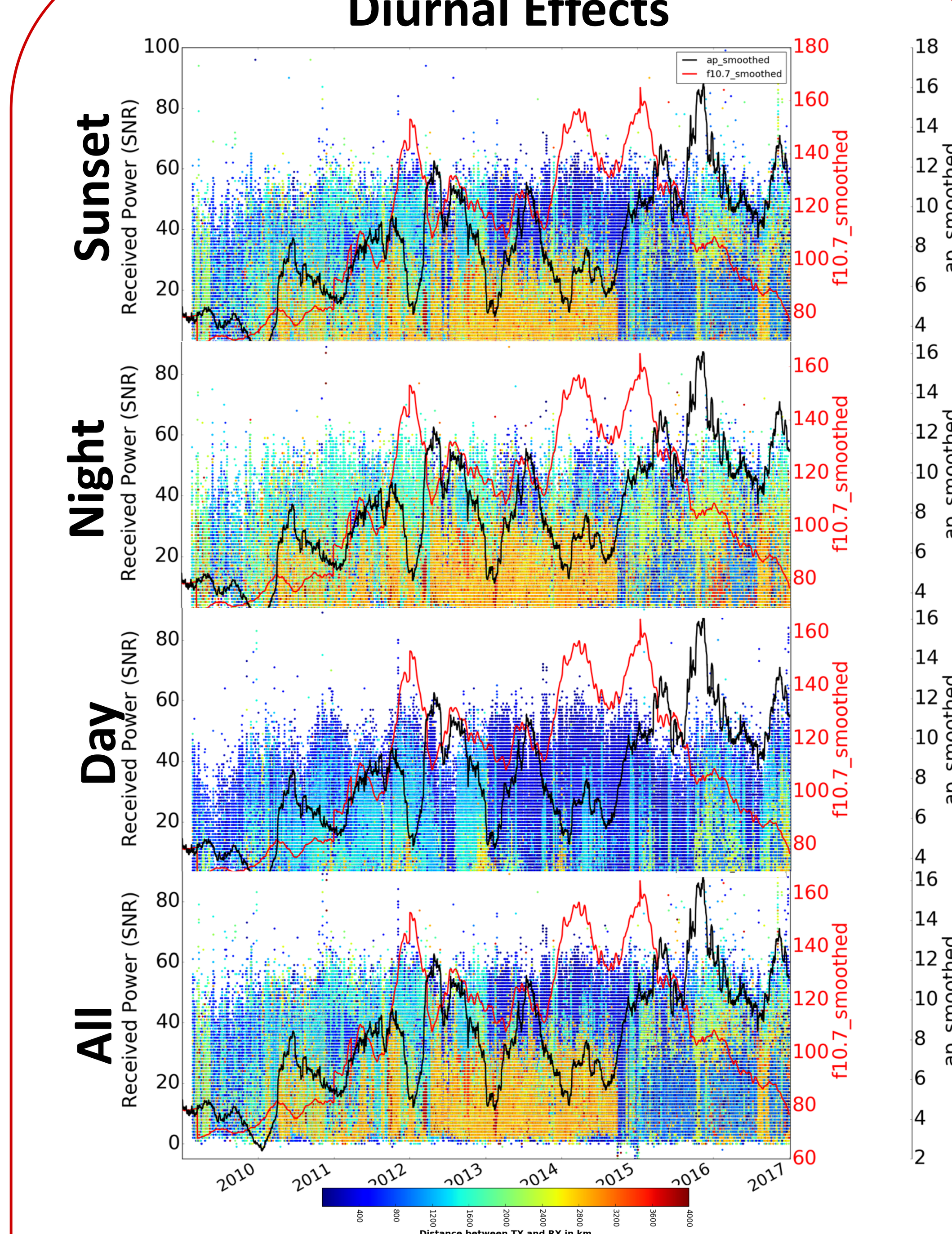
Inversion Regions
Long-distance propagation makes up the majority of high SNRs and short-distance propagation makes up most of the low SNRs.

Regional Effects



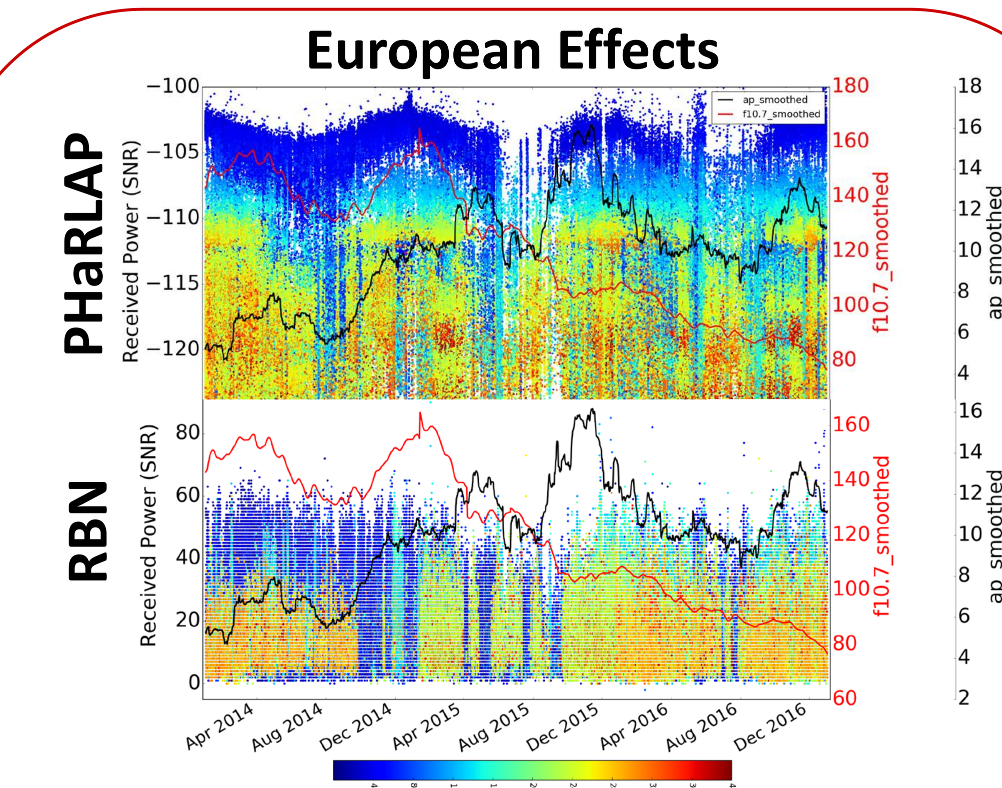
The sharp cutoffs for long-distance propagation we observe in the global dataset is largely contributed from Europe. In contrast the US presents a more uniform spread of communications until a sharp change is observed some time around December 2014 when suddenly more long-range communications become dominant.

Diurnal Effects



Day is defined as between 0900 and 1500 LST, Night is defined as between 2100 and 0300 LST, and Sunset are defined as not being Day or Night. Within these time bins we can see that the 7 MHz propagation at night favors long distance communications while day favors shorter range communications.

European Effects



In these plots we are comparing observed and simulated spots from Europe. We have simulated all observed communications seen by the **Reverse Beacon Network** over the entire lifetime of the network. PHaRLAP does not predict the large variations in SRNs that we see in the observed data. Most of PHaRLAP's predictions seem to be grounded in month-to-month variations.

Summary

- We can see space weather effects on radio propagation as seen by the RBN.
- RBN observations reveal large-scale propagation signatures inconsistent with HF raytracing through the IRI.

Acknowledgements and References

Cervera, M. A., and T. J. Harris (2014), Modeling ionospheric disturbance features in quasi-vertically incident ionograms using 3-d magnetoionic ray tracing and atmospheric gravity waves, Journal of Geophysical Research: Space Physics, 119 (1), 431{440, oi: 10.1002/2013JA019247.

Frissell, N. A., E. S. Miller, S. R. Kaeppler, F. Ceglia, D. Pascoe, N. Sinanis, P. Smith, R. Williams, and A. Shovkoplyas (2014), Ionospheric sounding using real-time amateur radio reporting networks, Space Weather, doi:10.1002/2014SW001132.

All simulated data in this poster was obtained using the HF propagation toolbox, PHaRLAP, created by Dr. Manuel Cervera, Defence Science and Technology Group, Australia (manuel.cervea@dsto.defence.gove.au) . This toolbox is available by request from it's author.

The solar indices we have plotted which include 10.7 cm and Ap come from the OMNI data set.

The Reverse Beacon Network has provided all experimental radio communications data used in this experiment.

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jk369@njit.edu

NJIT HamSCI NSF

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