



HamSCI

HAM RADIO SCIENCE CITIZEN INVESTIGATION

HOW HAM RADIO OPERATORS (CITIZEN SCIENTISTS) ARE
SUPPORTING RADIO SCIENTIFIC ENDEAVORS

LOREN ANDERSON

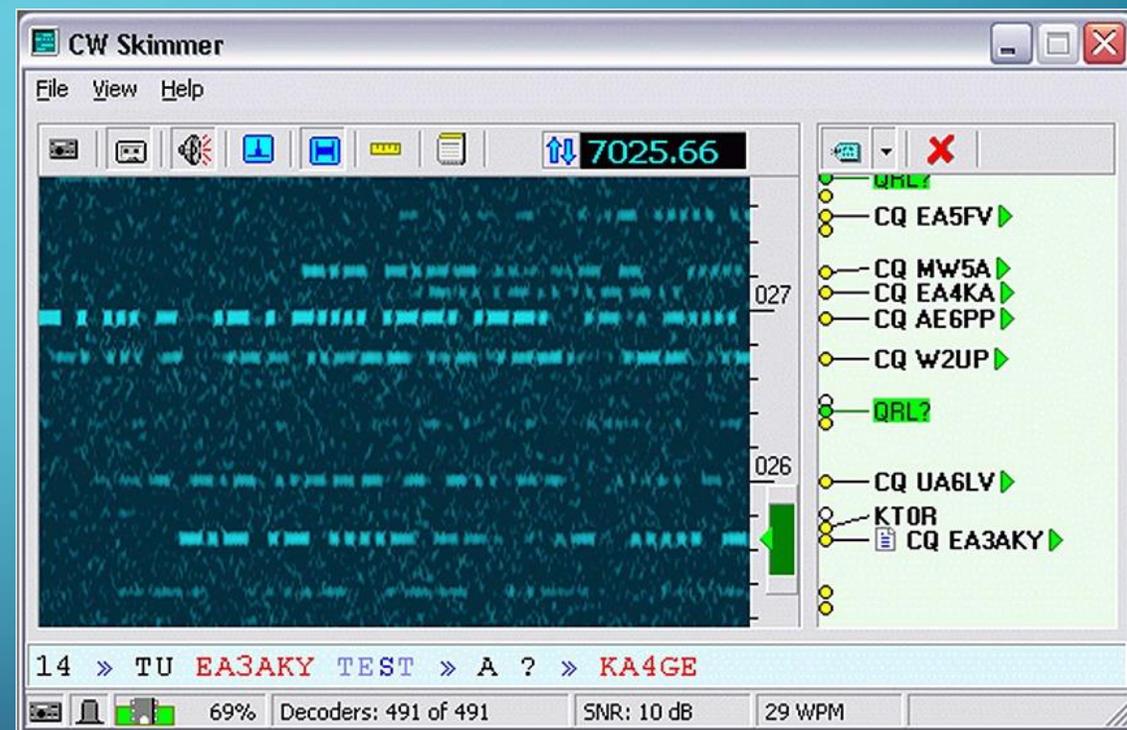
KEØHz



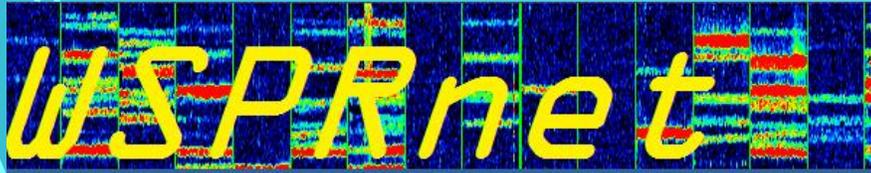
How many here are participating in
HamSCI?

HOW MANY OF YOU ARE USING

- WSPR & WSPRnet?
- PSK Reporter?
- Reverse Beacon Network (RBN)?
- DX Cluster?



YOU ARE ALREADY CONTRIBUTING TO HamSCI



WSPRnet

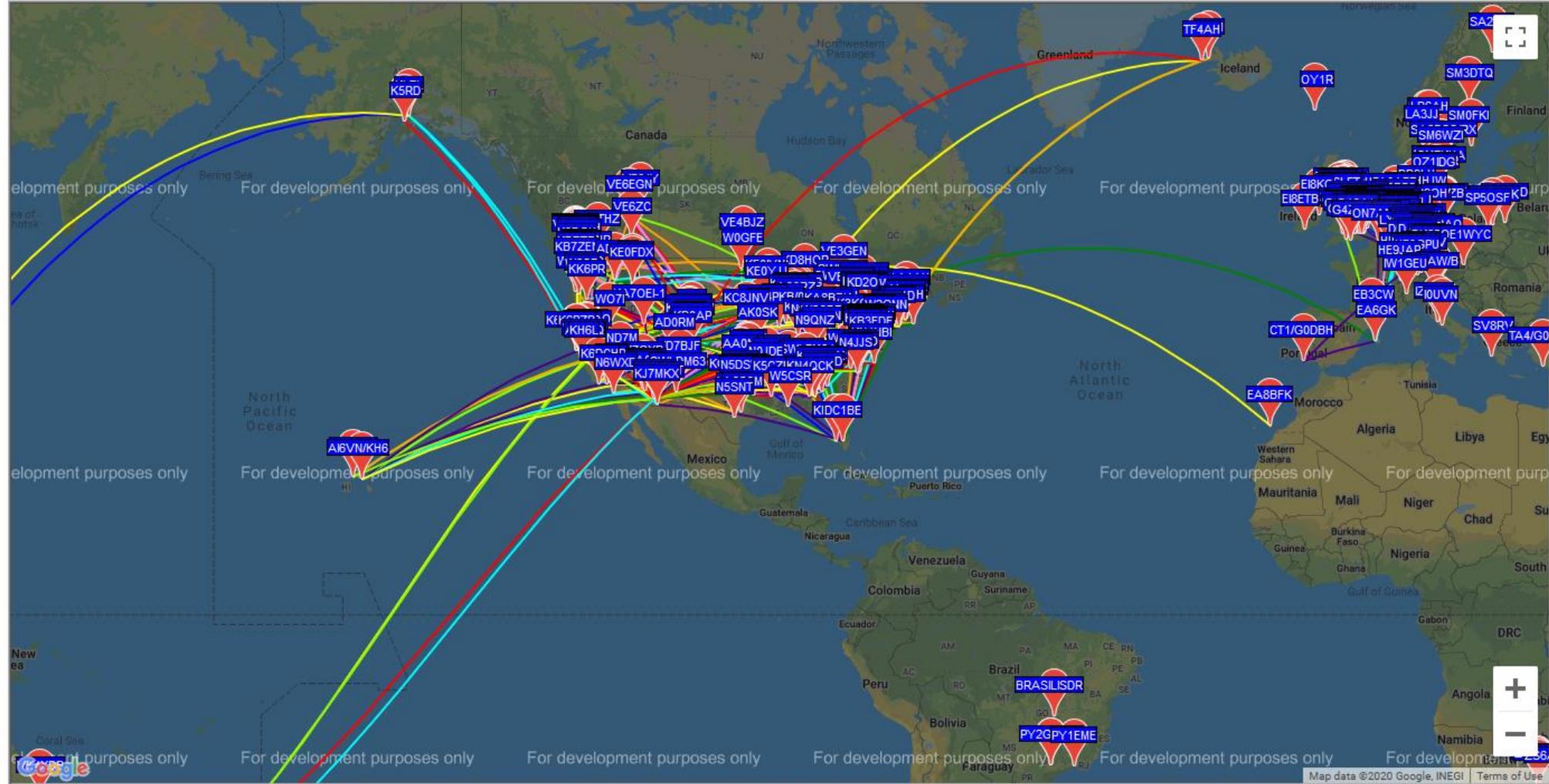
Welcome to the Weak Signal Propagation Reporter Network

Chat | Activity | Map | Database | Forum | Downloads

My account | Log out



Map



5/11 0201 UTC – 20M (last 10 minutes) SFI 67

All bands
 6 10 12 15 17 **20** 30 40 60 80 160 VHF UHF
 WEB CLUSTER
 Telnet connection (dxfun.com port:8000)

WP4IRV	14074.5		WZ6P		02:07
UA9YHA	14075.0		RU0SYL	tnx QSO FT8	02:06
W5ZZ	14267.0		VA3AAA	59	01:54
K5AAT	14261.0		VP2MNI	Scott and Frankie making the DX, thx guys	01:45
UA9CDC	14011.1		RU0LL		01:40
K2CD	14278.1		ZL1WN		01:10
VE6MRV	14016.5		RV0CG	Serge S8 in AB	01:10
N4WMB	14261.0		VP2MNI		01:09
K4WMS	14009.5		EX8TR	Nice signal in VA	01:08
VE6MRV	14006.0		UA0AAT	Toly S9 in AB	01:04
K5DTX	14074.9		LB3TBY		00:56
W7GTF	14009.5		EX8TR	559 in wa	00:53
KN2CZZ	14006.0		UA0AAT	mni tnx Toly	00:52
K5DTX	14075.5		LB3TBY		00:48
KA2R	14261.0		KD0TDH	FN31CQ	00:48
W5FKN	14246.0		KJ7GDN	pota k3214	00:43
EA4GTJ	14074.0		K0KKU		00:42
W2ADW	14261.0		VP2MNI	54 into Western WA.	00:41
N8OCN	14074.0		HS5XWY	FT8	00:35
YB5QZ	14261.0		VP2MNI	tnx Frankie	00:29
HK6JG	14074.0		VK2WJ	FT8 TKS	00:26
K1RI	14074.0		HS5XWY	FT8	00:26
JA1BOQ	14074.0		VY1FC	FT8 TNX	00:25
TG4AEM	14246.0		NP4SS		00:16
N2KHH	14261.0		VP2MNI		00:16

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Data provided by DXfun Web Cluster. The table will reload after 10 seconds.



What Happened to the Map?

Google changed its system and broke the website. They have also announced a big price jump on their map service, which would be prohibitive for us, so we're working on a new approach using open-source maps. It'll take a while, and in the meantime if you keep the map hidden, the other features will continue to work.

[show/hide my last filters](#)

no filter selected, showing all spots

rows to show:

[search spot by callsign](#)

de	dx	freq	cq/dx	snr	speed	time
K1FC	KO4LZ	7058.0	CW CQ	17 dB	12 wpm	0209z 11 May
W1NT	KO4LZ	7058.0	CW CQ	10 dB	12 wpm	0209z 11 May
W1NT	UY0ZA	3502.2	CW CQ	27 dB	23 wpm	0209z 11 May
N6TV	N6KIX	3556.0	CW CQ	17 dB	21 wpm	0209z 11 May
HB9BXE	ES3AX	3522.0	CW CQ	29 dB	23 wpm	0209z 11 May
G4HSO	ES3AX	3522.0	CW CQ	35 dB	22 wpm	0209z 11 May
G0LUJ	ES3AX	3522.0	CW CQ	19 dB	22 wpm	0209z 11 May
W1NT	ES3AX	3522.0	CW CQ	22 dB	22 wpm	0209z 11 May
ON6ZQ	ES3AX	3522.0	CW CQ	26 dB	22 wpm	0209z 11 May
KQ8M	K0QLM	7041.5	CW CQ	21 dB	25 wpm	0209z 11 May
W1NT-6	ES3AX	3522.0	CW CQ	20 dB	22 wpm	0209z 11 May
LZ4UX	RT5T	7023.0	CW CQ	12 dB	29 wpm	0209z 11 May
VE7CC	W6WX	18110.0	CW NCDXF	6 dB	23 wpm	0209z 11 May
WA7LNW	W3IUU	21026.7	CW CQ	17 dB	19 wpm	0209z 11 May
NC7J	W6WX	18110.0	CW NCDXF	5 dB	22 wpm	0209z 11 May
DE1LON	ES3AX	3522.0	CW CQ	20 dB	22 wpm	0209z 11 May
SM6FMB	ES3AX	3522.0	CW CQ	35 dB	22 wpm	0209z 11 May
SM6FMB	RT5T	7023.0	CW CQ	11 dB	30 wpm	0209z 11 May
RU9CZD	RT5T	7023.0	CW CQ	31 dB	30 wpm	0209z 11 May
HA1VHF	ES3AX	3522.0	CW CQ	26 dB	22 wpm	0209z 11 May
HA1VHF	RT5T	7023.0	CW CQ	22 dB	30 wpm	0209z 11 May
F6IIT	ES3AX	3522.0	CW CQ	30 dB	22 wpm	0209z 11 May
DL1OD	ES3AX	3522.0	CW CQ	33 dB	22 wpm	0209z 11 May
DL1OD	RT5T	7023.0	CW CQ	9 dB	30 wpm	0209z 11 May
SV1CDN	GB0GIG	3516.9	CW CQ	5 dB	27 wpm	0209z 11 May

options:

[show/hide](#)

news

[RBN blog: stay tuned!](#)

we have 150 skimmers online

skimmers online:

3B8CW - no spot last 15min
 3V/KF5EYY - 40m
 4X6HP - 40m
 6K2XF/2 - 20m
 7N4XCV - no spot last 15min
 9A1CIG - 80m, 40m
 9V1RM - no spot last 15min
 AA4VV - 160m, 80m
 AC0C - 160m, 80m, 40m, 20m
 AE4PM - no spot last 15min
 BA7KW - 20m
 BG4GOV3 - no spot last 15min
 BG7JAW - no spot last 15min
 BG8FT - no spot last 15min
 BG8PA - no spot last 15min
 BH4BWX - 20m
 BU2EQ - no spot last 15min
 CX6VM - 160m, 30m
 DD5XX - no spot last 15min
 DE1LON - 160m, 80m, 40m
 DF4XX - 160m, 80m, 40m
 DJ2BC - 160m, 80m, 40m
 DJ9E - 160m, 80m, 40m
 DJ9E-1 - no spot last 15min
 DK0TE - 80m, 40m
 DK3UA - 160m, 80m
 DK8NE - 6m
 DK9IP - 160m, 80m, 40m
 DL0LBS - no spot last 15min
 DL1AXX - no spot last 15min
 DL1OD - 160m, 80m, 40m
 DL1RNN - 80m, 40m
 DL3DTH - 160m, 80m, 40m
 DL9GTB - 160m, 80m, 40m
 DQ8Z - no spot last 15min
 DR4W - 160m, 80m, 40m
 E28AC - 20m
 EA5WU - no spot last 15min
 EA8BFK - 40m, 30m, 20m, 15m, 12m
 EC1CT - no spot last 15min
 ES5PC - 160m, 80m, 40m



[Donate](#)
[support us](#)

02:11:55 UTC

options:

[show/hide](#)

Hello! Please [log in](#) or [register](#) if you are a new visitor.

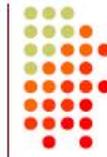
[show/hide my last filters](#)

band: 20m

rows to show: ▾
[cancel filter selection](#) / [send a spot](#) / [search spot by callsign](#)

de	dx	freq	obs	time
WP4IRV	 KA4YZR	14074.5	[LoTW]	0210z 11 May
WP4IRV	 WZ6P	14074.5	[LoTW]	0207z 11 May
UA9YHA	 RU0SYL	14075	tnx QSO FT8	0206z 11 May
W5ZZ	 VA3AAA	14267	59	0154z 11 May
K5AAT	 VP2MNI	14261	[NA-103] Scott and Frankie making the DX, thx guys	0145z 11 May
UA9CDC	 RU0LL	14011.1	[LoTW]	0140z 11 May
K2CD	 ZL1WN	14278.1	[LoTW]	0110z 11 May
VE6MRV	 RV0CG	14016.5	Serge S8 in AB	0110z 11 May
N4WMB	 VP2MNI	14261	[NA-103]	0109z 11 May
K4WMS	 EX8TR	14009.5	Nice signa I in VA	0108z 11 May
VE6MRV	 UA0AAT	14006	Toly S9 in AB	0104z 11 May
K5DTX	 LB3TBY	14074.9		0056z 11 May
W7GTF	 EX8TR	14009.5	559 in wa	0053z 11 May
KN2CZZ	 UA0AAT	14006	mni tnx Toly	0052z 11 May
K5DTX	 LB3TBY	14075.5		0048z 11 May

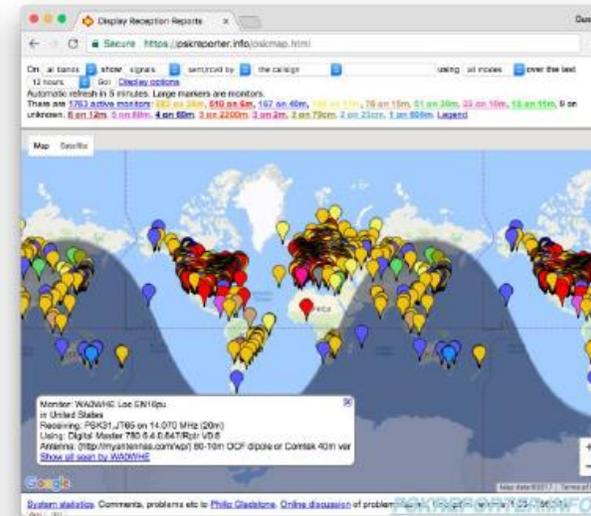
Ham Radio Observation Networks



Reverse Beacon Network (RBN)
reversebeacon.net



WSPRnet
wsprnet.org



PSKReporter
pskreporter.info

- Quasi-Global
- Organic/Community Run
- Unique & Quasi-random geospatial sampling
- Data back to 2008 (A whole Solar Cycle!)
- Available in real-time!



WHAT'S THE DIFFERENCE BETWEEN A SCIENTIST AND AN ENGINEER?

- Knowledge – Invention
- Explores laws of nature – Attempts to use laws of nature
- Create theories – Implement theories
- Create tools – Use tools
- Solve theoretical problems – Solve practical problems



HamSCI MISSION

- Advance scientific research and understanding through amateur radio activities
- Encourage the development of new technologies to support this research
- Provide educational opportunities for the amateur community and the general public



WHAT IS HamSCI'S SCIENTIFIC FOCUS?

HamSCI was started by ham-scientists who study upper atmospheric and space physics. These scientists recognized that projects such as the Reverse Beacon Network, WSPRNet, PSKReporter, DX Cluster, ClubLog, and more are generating BIG DATA sets that could provide useful observations of the Earth's ionosphere and related systems. Because of this, HamSCI's initial focus is on these fields of research. In the future, other researchers may join HamSCI and broaden its scope.¹¹



A FEW OF THE KEY PARTICIPANTS

- Dr. Nathaniel A. Frissell, W2NAF, [Department of Physics and Electrical Engineering, The University of Scranton](#)
 - Lead HamSCI Organizer
 - [QSO Today Episode 262](#)
- Dr. Philip J. Erickson, W1PJE, MIT Haystack Observatory
 - <http://www.haystack.mit.edu/>
 - [QSO Today Episode 259](#)
- [Johns Hopkins University Applied Physics Laboratory](#)



PROJECTS

- Personal Space Weather Station (PSWS)
- Ionospheric Studies
 - Total Solar Eclipse
 - Swarm-E (formerly know as e-POP)/Golden Ears
 - Response to Solar Flares
 - Large Scale Traveling Ionospheric Disturbances
 - Total Electron Count (TEC) Enhancements during Substorms
- Aurorasaurus: Citizen Science Observations of the Aurora



Personal Space Weather Station

SPACE WEATHER - SO WHAT?

- HF Communications Impacts
 - Maximum Usable Frequency (MUF)
 - Modify Propagation Paths
 - Improve/Degrade/Block Communications
 - Noise
- VHF
 - Sporadic E Propagation
 - Aurorae Propagation (HF may be blocked)
- GNSS (GPS, Galileo, GLONASS, Beidou)
 - Degradation due to Scintillations

Solar
Data/Propagation

Click to add to your website
Solar-Terrestrial Data
18 May 2020 1454 GMT

SFI 70 SN 0
A 3 K 1
X-Ray n/a
304A 91.8 @ SEM
Pf No Rpt Ef No Rpt
Aurora /n=
Bz 2.8 SW 312.7

HF Conditions

Band	Day	Night
80n-40n	Fair	Good
30n-20n	Fair	Fair
17n-15n	Poor	Poor
12n-10n	Poor	Poor

VHF Conditions

Aur Lat No Report
Aurora Band Closed
6n EsEU 50MHz ES
4n EsEU Band Closed
2n EsEU 144MHz ES
2n EsNA Band Closed
EME Deg Fair
Solar Flare Prb 1%

MUF

MS 0 6 12 18 Utc
MIN MAX

Geomag Field VR QUIET
Sig Noise Lvl S0-S1
MUF US Boulder NoRpt

Current Solar Image

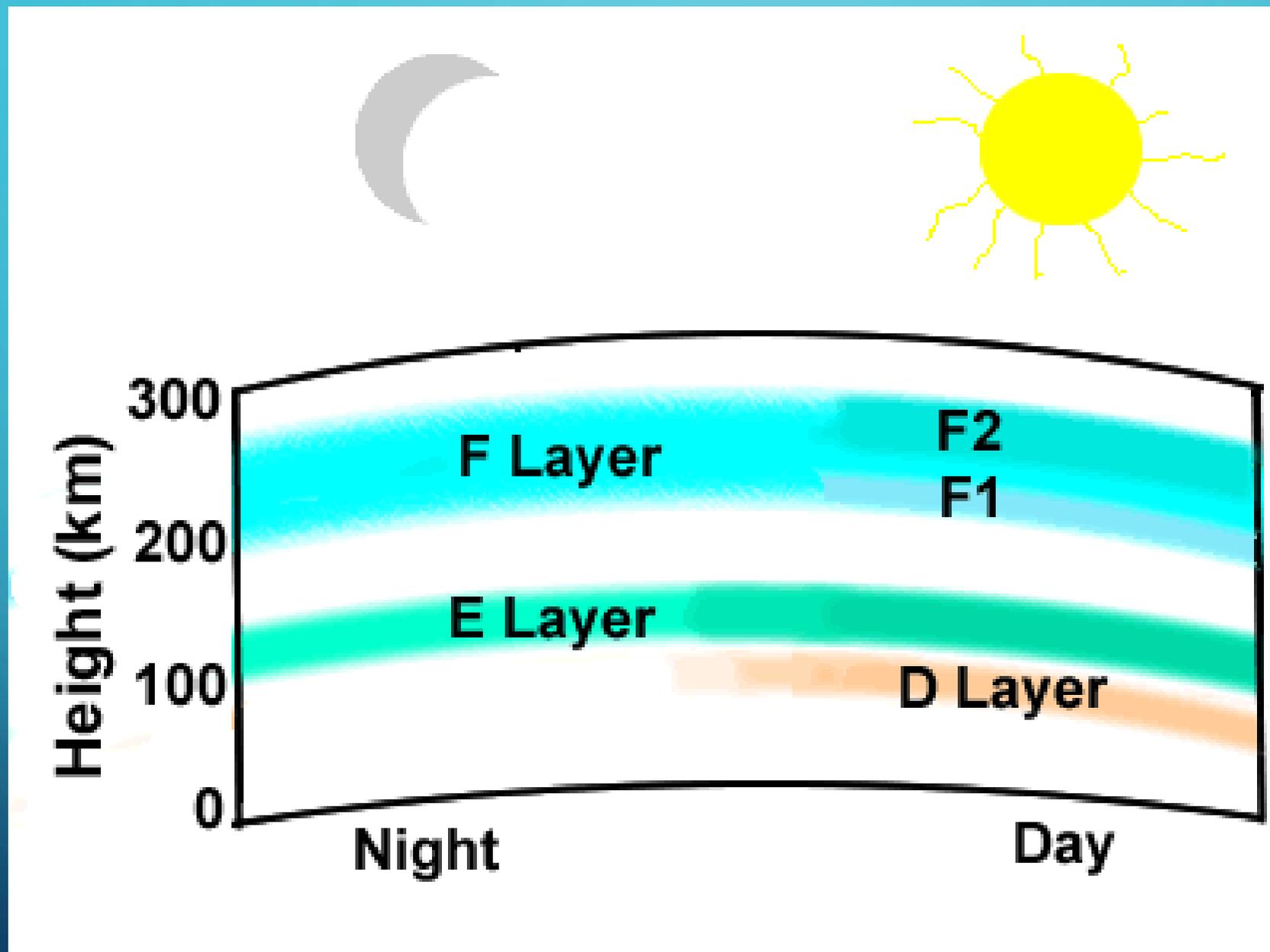
<http://www.n0nbh.com>
Copyright Paul L Herrman 2013

Solar-Terrestrial Environment



Steele Hill/NASA/NOAA

16





[The Ionosphere and GNSS: Explained](https://youtu.be/w-5HI2b_wKE)
https://youtu.be/w-5HI2b_wKE

EU Response to Solar Flares



06 Sep 2017
 Ham Radio Networks
 N Spots = 185579
 RBN: 14%
 WSPRNet: 86%

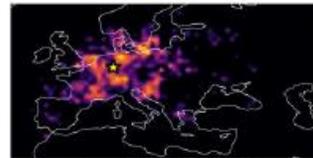
Quiet Kp/Sym-H

GOES Flares
 X2.2: 0857 UT
 X9.3: 1153 UT

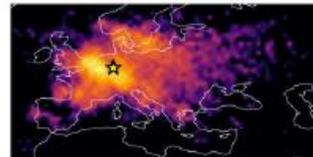
- Europe in daylight.
- Both flares cause deep blackouts.



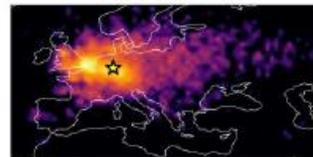
Radio Spots (N = 2351)



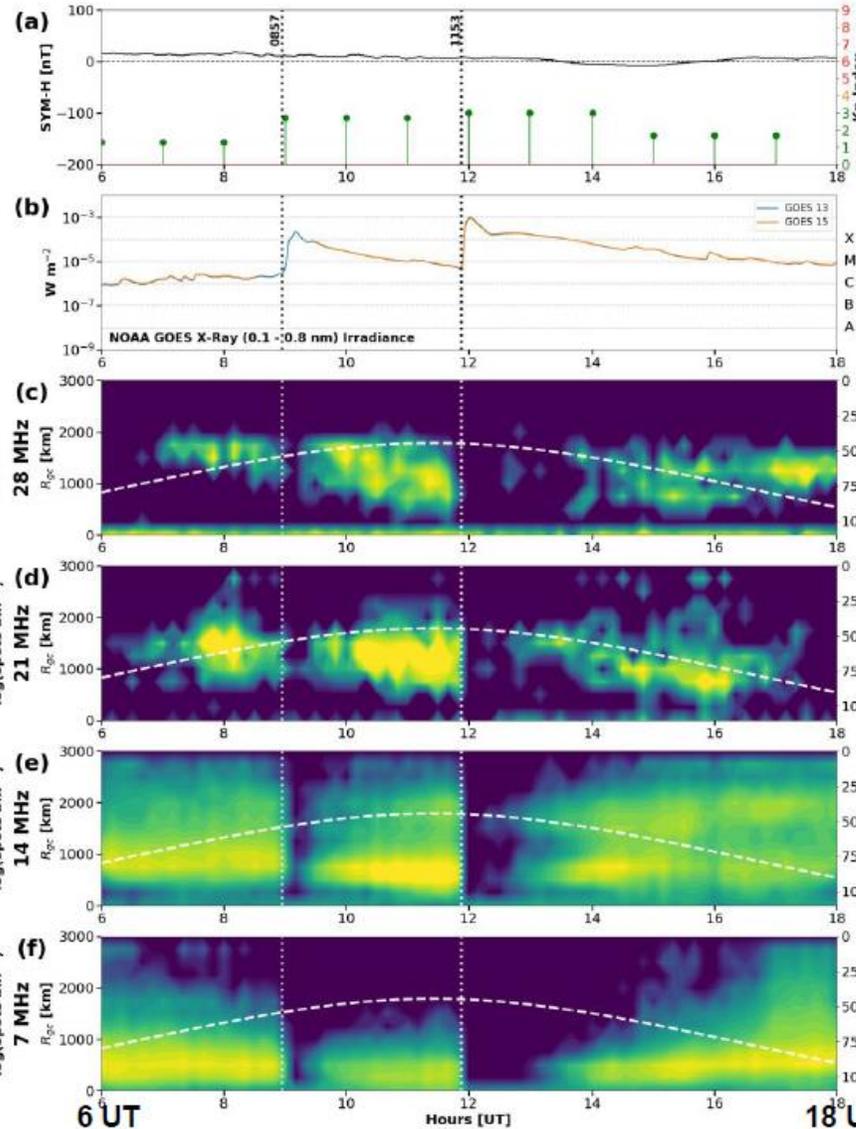
Radio Spots (N = 2821)



Radio Spots (N = 88556)



Radio Spots (N = 91851)



28 MHz

21 MHz

14 MHz

7 MHz

250 km × 10 min bins

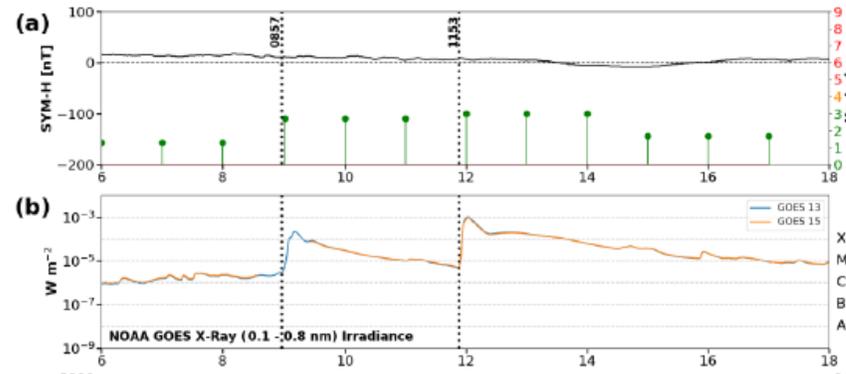
US Response to Solar Flares



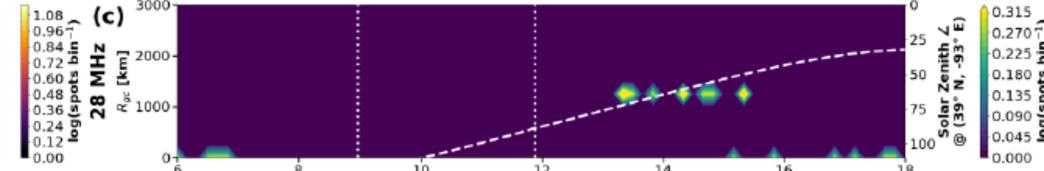
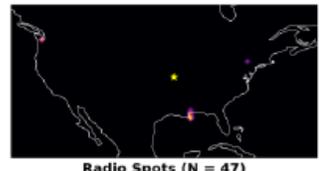
06 Sep 2017
 Ham Radio Networks
 N Spots = 50813
 RBN: 12%
 WSPRNet: 88%

Quiet Kp/Sym-H

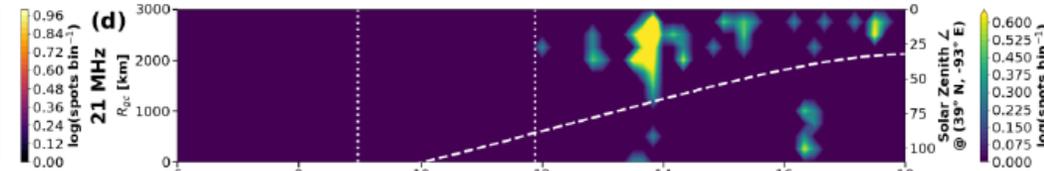
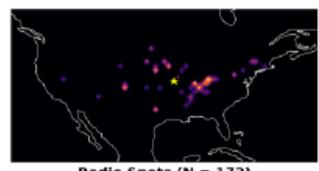
GOES Flares
 X2.2: 0857 UT
 X9.3: 1153 UT



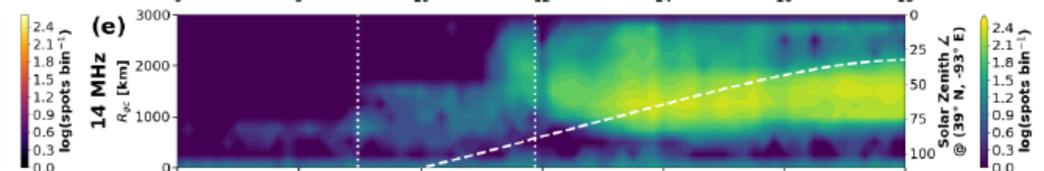
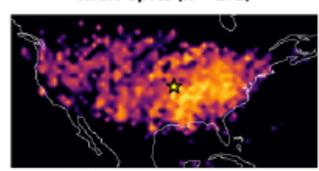
- US is at dawn.
- Diurnal variations evident
- 1st Flare has little effect
- 2nd flare has small effect



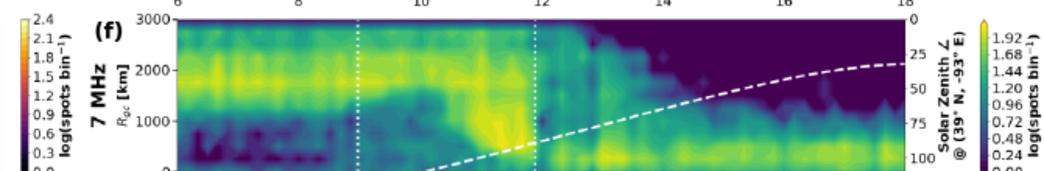
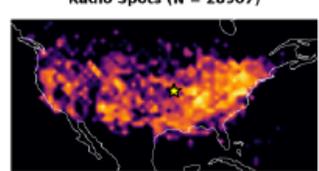
28 MHz



21 MHz



14 MHz



7 MHz

6 UT 8 10 12 14 16 18 UT 250 km × 10 min bins

PSWS GOALS



- **Scientists:**

- Better sample the environment
- Better understand near-Earth Space
- Advance scientific understanding

- **Hams:**

- Know the best frequencies for working DX
- Understand the RFI environment
- Communicate better during emergencies



PERSONAL SPACE WEATHER STATION

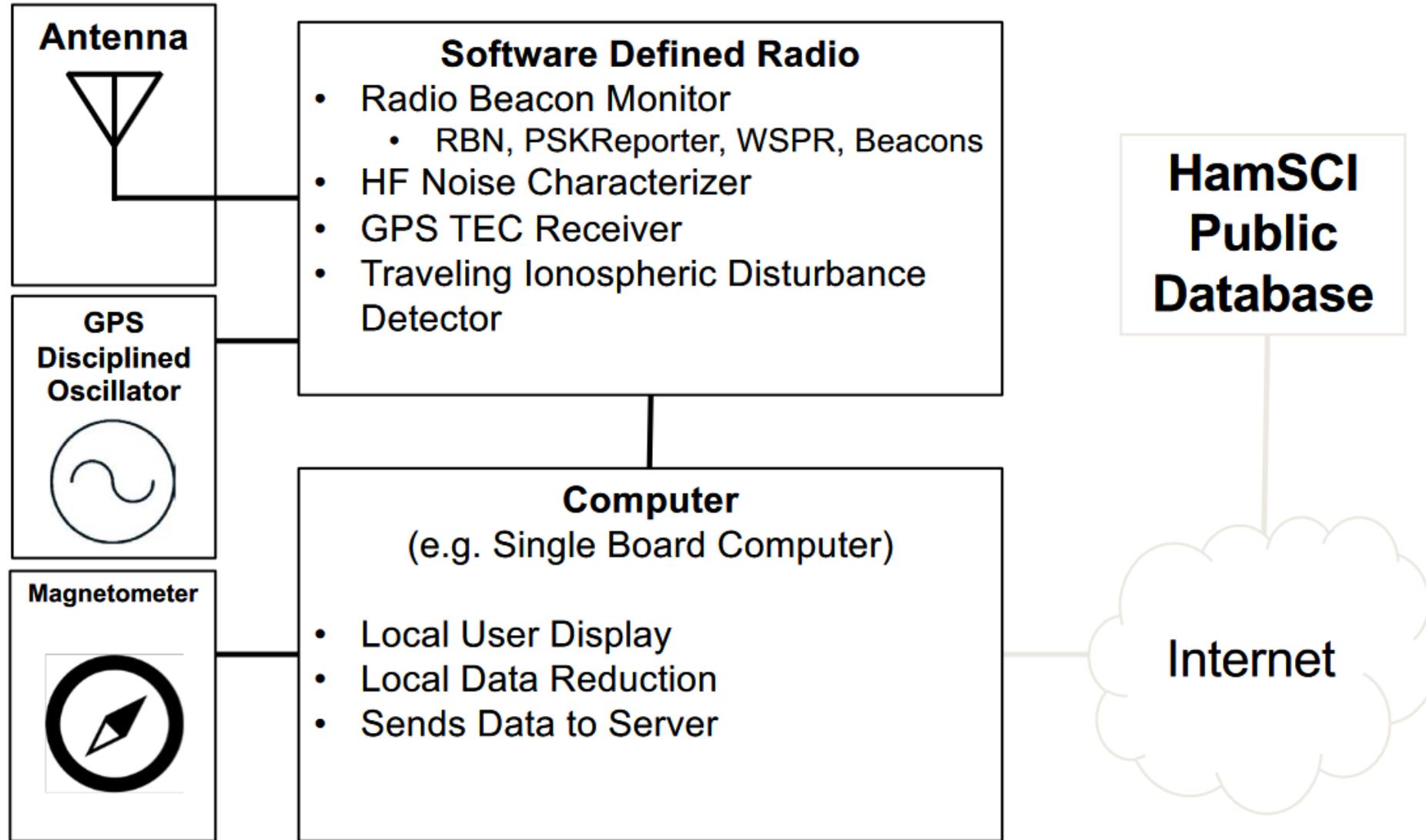
- The Personal Space Weather Station project ultimately aims to create a small, multi-instrument system that can make ground-based measurements of the space environment. The observations from this project will not only be useful to the owner of the system, but also aggregated into a central database 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 Haystack Observatory](#) and the [Tucson Amateur Packet Radio, Inc. \(TAPR\)](#).



PSWS OBJECTIVES

- Characterize the ionospheric and geomagnetic response to space weather events
 - Ground magnetic field fluctuations
 - Ionospheric density variations (receive transmissions from controlled sources)
- Characterize ionospheric variability and identify sources
 - Identify traveling ionospheric disturbances (TIDs) from measurements of at least two transmit-receive paths
- Determine impact on HF communications
 - Propagation paths open or closed, dominant propagation modes, signal scintillation, fading and polarization

PERSONAL SPACE WEATHER STATION



TangerineSDR



- The TangerineSDR is a Modular Software Defined Radio Project with the following objectives:
 - Development of SDR radios that allow experimentation in a variety of radio modes.
 - Provide support to unaffiliated other groups that need these radios to support their mission.
 - To provide hardware modularity so that the user can have a functioning radio with different subsets of the possible components.
 - To allow varying performance so that beginners can have a functioning radio with a minimum of parts yet allow an expert user more functionality as needed.
 - To allow users to experiment with differing configurations of data collection, networking, transport and visualization.



TangerineSDR: A Modular SDR for HamSCI

Ham Radio 2.0 • 2.3K views • 4 months ago

Scotty Cowling, WA2DFI, provides more detailed information about the Software Defined Radio SDR, being developed for a ...

<https://www.youtube.com/watch?v=KO3MO47UFVc>

<https://www.youtube.com/watch?v=KO3MO47UFVc>

Redpitaya “Swiss Army Knife for Engineers”



STEM^{lab} SDR transceiver module



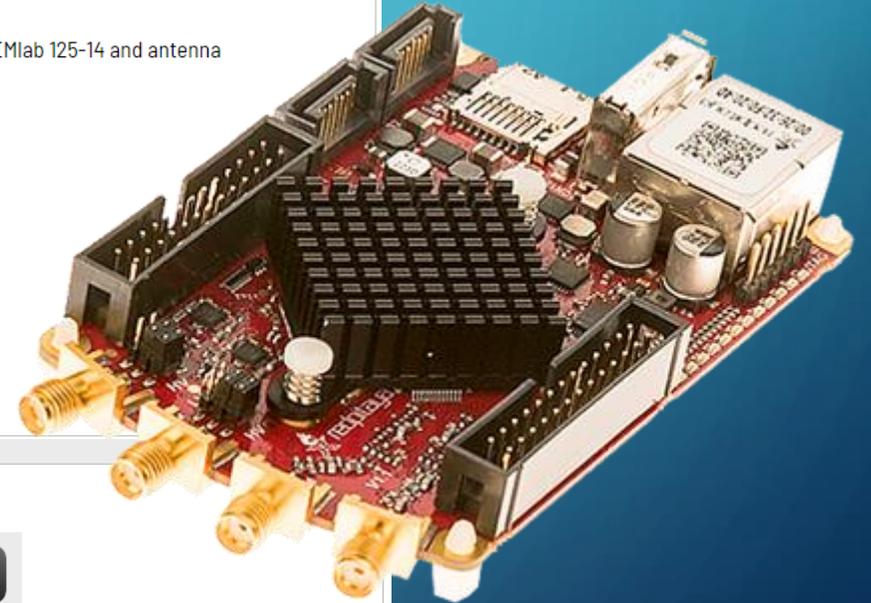
309,00€
+ shipping costs
+22% VAT (67,98€)

BUY



What is in the box:

- SDR transceiver 160-10 10W module
- DC power cord with Anderson Power Pole™ connector
- 4 x SMA cable for connecting SDR transceiver module with STEMlab 125-14 and antenna
- impedance adapter



STEM^{lab} 125-14 Calibrated kit



524,00€
+ shipping costs
+22% VAT (115,28€)

BUY



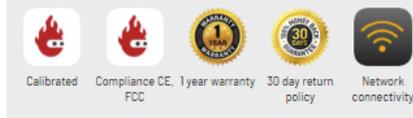
T&M Instruments



Development and learning tools/features



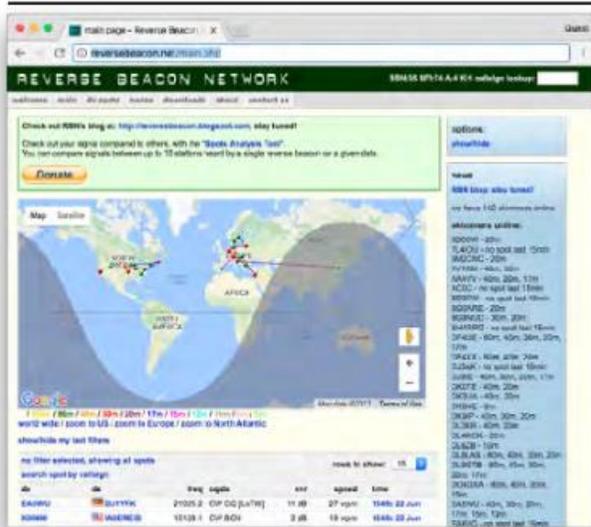
Other





IONOSPHERIC STUDIES

SEQP Observations



RBN
reversebeacon.net



WSPRNet
wsprnet.org



PSKReporter
pskreporter.info

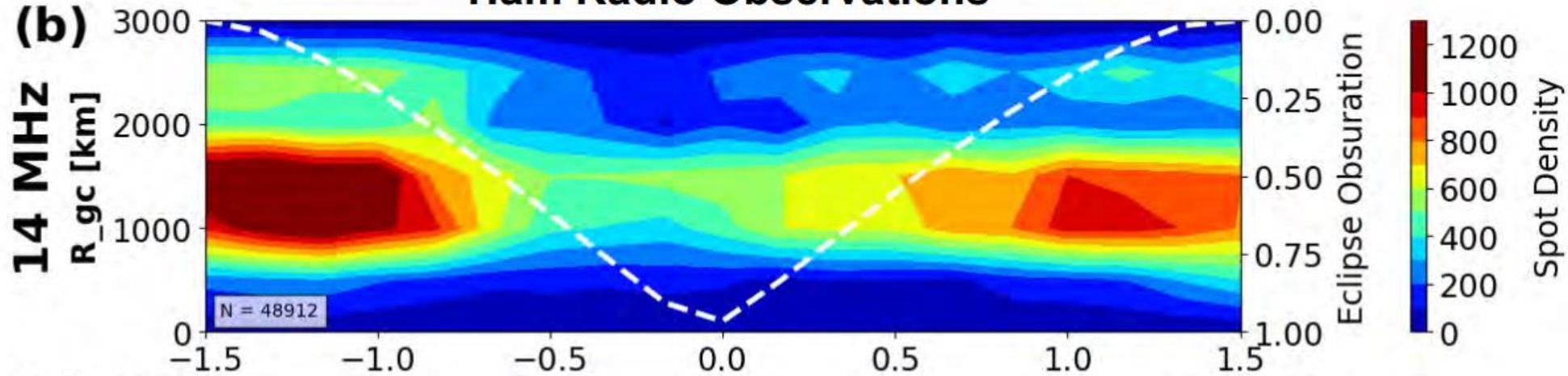
Observations from 21 August 2017 1400 – 2200 UT

Network	# Spots / QSOs
RBN	618,623
WSPRNet	630,132
PSKReporter	1,287,962
Participant Logs	29,809

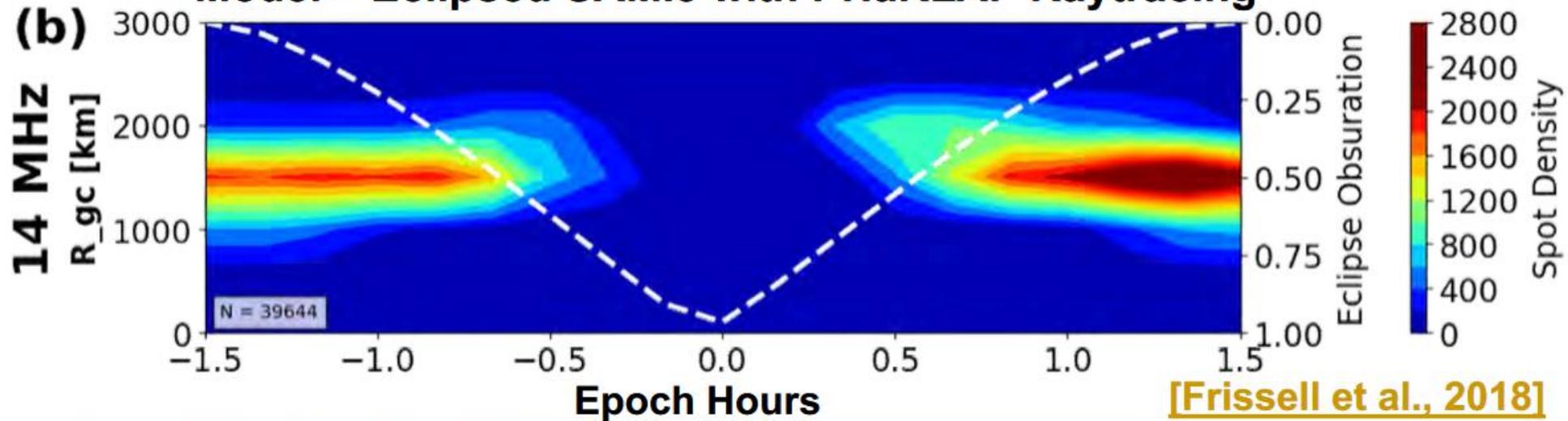
14 MHz SEQP RBN ($O_{300} \geq 0.9$)



Ham Radio Observations



Model – Eclipsed SAMI3 with PHaRLAP Raytracing

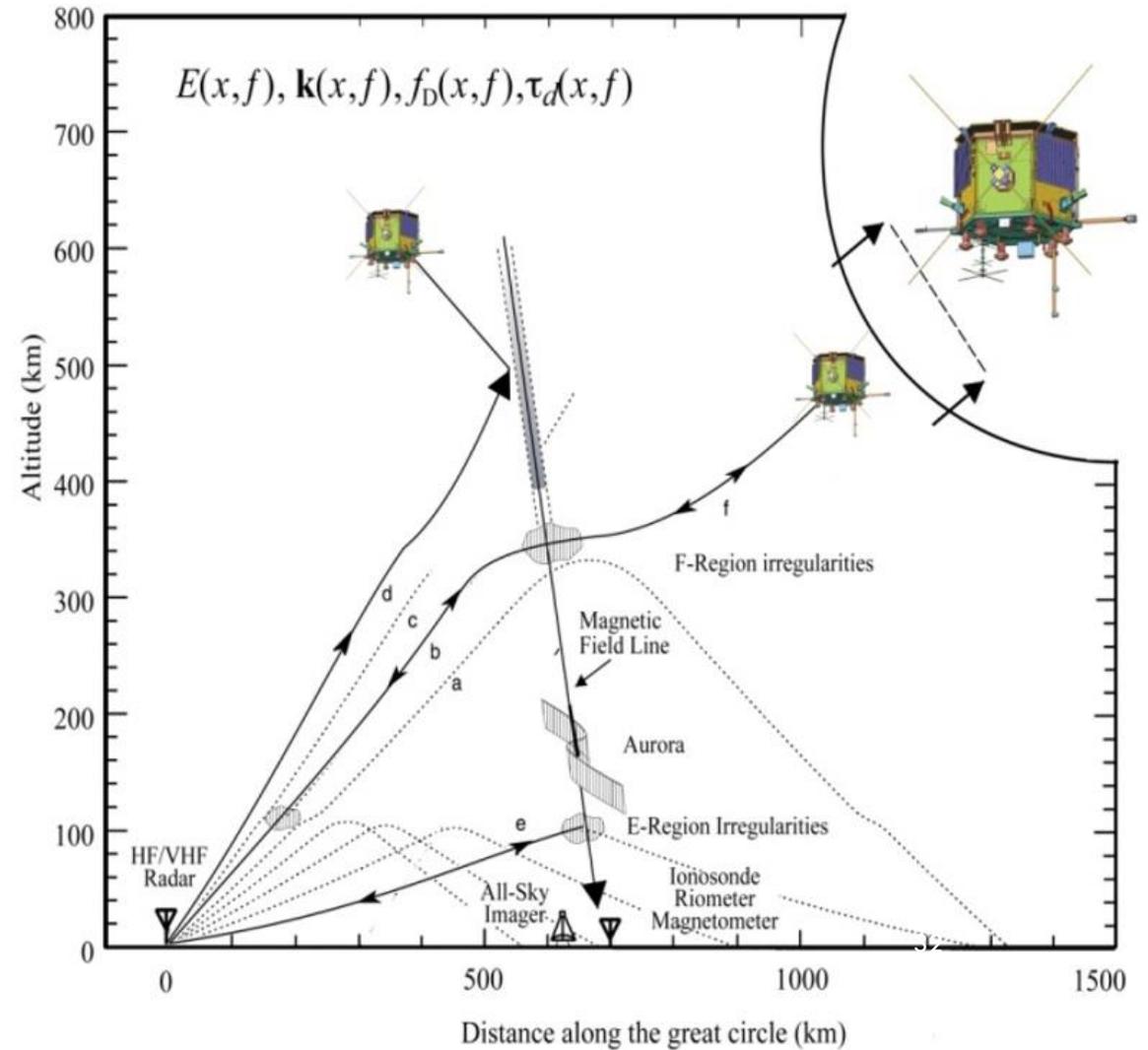
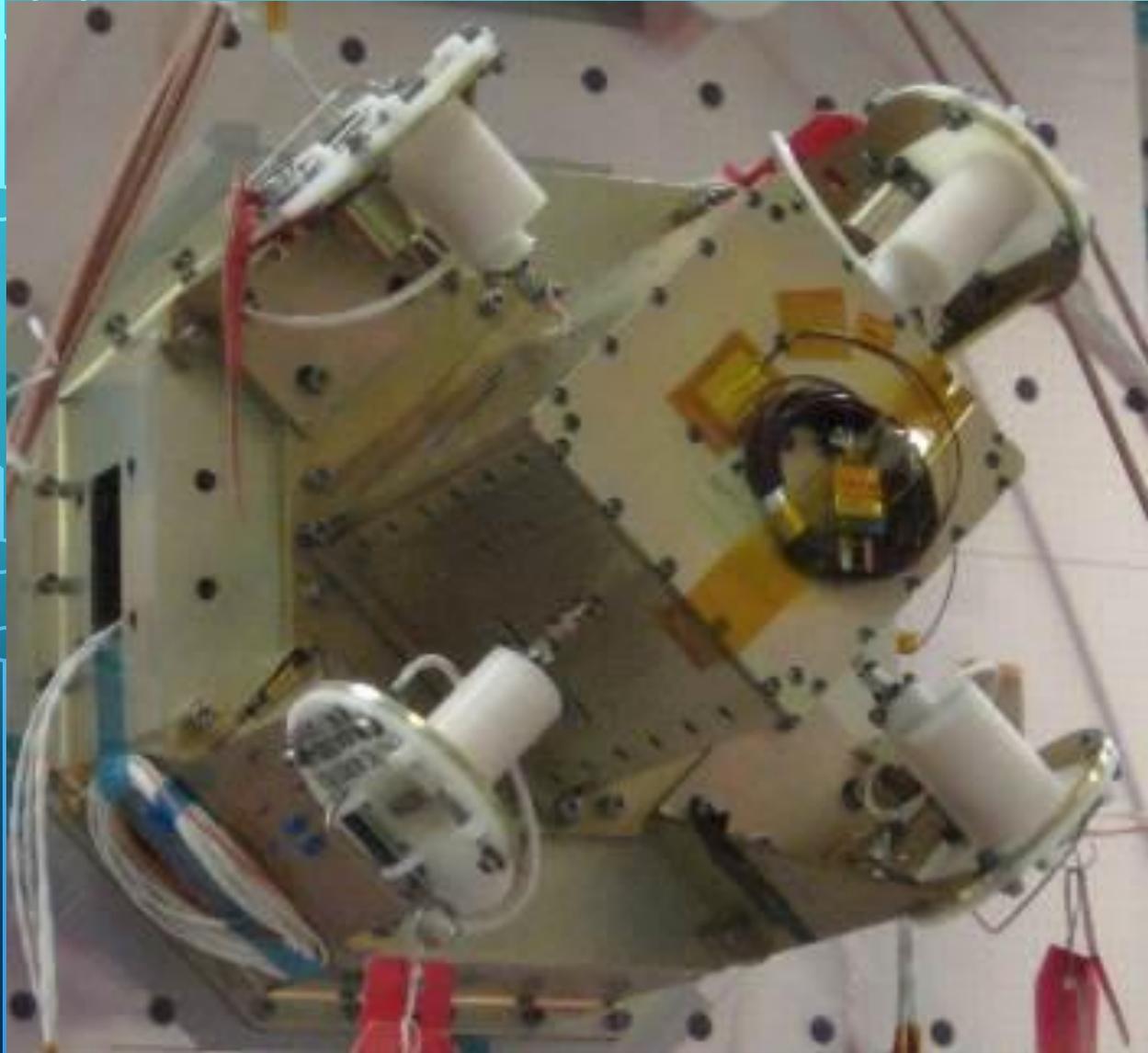


[Frissell et al., 2018]

Swarm-E

- The e-POP Radio Receiver Instrument (RRI) (1 of 8 scientific instruments on CASSIOPE) measures wave electric fields in the 10Hz – 18MHz range, at magnitudes from 1 $\mu\text{V}/\text{m}$ to 1 V/m .
- Study the morphology and dynamics of ionospheric density structures, auroral wave-particle interactions, plasma nonlinear processes created by intense high frequency waves, and the mechanism of coherent wave backscatter.

CASSIOPE



Swarm-E FIELD DAY – CASSIOPE 2015



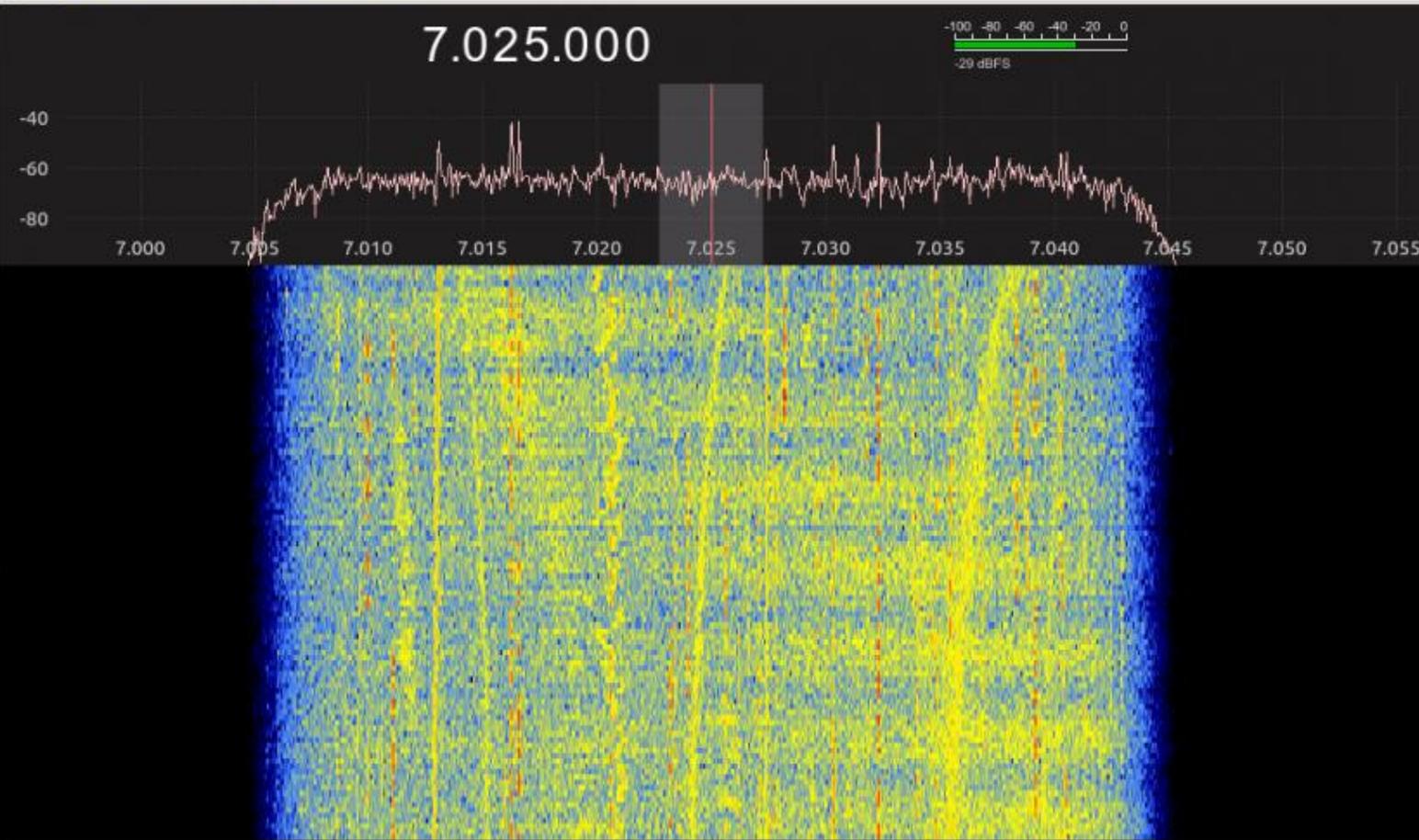
- Radio Receiver Instrument (RRI) eavesdropped on 2015 Field Day communications
- Identified 14 Hams by call sign and characterized unique signatures in their signals related to the nature of how the radio waves travel through the ionosphere.
- Deduced the structure of the ionosphere over the U.S.
https://hamsci.org/sites/default/files/publications/Perryetal_HamRadio_2017_rev2.1.pdf
- \$1.3M NSF Grant awarded November 2019
<https://news.scranton.edu/articles/2019/11/news-faculty-nsfgrant-frissell.shtml>



GOLDEN EARS

- Download I/Q samples and play in SDR running on your computer
- Requires gqrx SDR <https://gqrx.dk/> (Linux only but may be able to be run on Windows with Linux as an application)
- Each data file contains raw 32 bit complex I/Q samples for a given RRI dipole at a given frequency. The data files do not contain any metadata. Translate the CW signals for originating station call sign.

File Tools View Help



Receiver Options

0 . 0 0 0 kHz

Hardware freq: 0.000000 MHz

Frequency kHz

Filter width

Filter shape

Mode

AGC

Squelch

Noise blanker

I/Q recording and replay tool

Location:

00:05:00 / 00:09:56

Bookmarks

Frequency	Name	Modulation	Bandwidth	Tag
				<input checked="" type="checkbox"/> Untagged

Start/stop DSP processing

Gain: 12.6 dB

DSP

Audio



15:49
15:49
13:43
13:47

RBN-WSPR DAILY HISTOGRAMS



REVERSE BEACON NETWORK

welcome main dx spots nodes FT8 downloads about contact us

What Happened to the Map?

Google changed its system and broke the website. They have also announced a big price jump on their map service, which would be prohibitive for us, so we're working on a new approach using open-source maps. It'll take a while, and in the meantime if you keep the map hidden, the other features will continue to work.

show/hide my last filters

no filter selected, showing all spots

rows to show: 25

search spot by callign

de	dx	freq	cq/dx	snr	speed	time
K7EG	USA N0AC	3527.0	CW CQ	4 dB	26 wpm	0219z 28 Mar
OK1IAK	USA AA3B	7022.7	CW CQ	11 dB	29 wpm	0219z 28 Mar
NN3RP	USA W0CP	3523.1	CW CQ	7 dB	30 wpm	0219z 28 Mar
N6WIN-7	USA KZ5D	3524.3	CW CQ	34 dB	28 wpm	0219z 28 Mar
KC4YVA	USA W1AO	3528.9	CW CQ	12 dB	29 wpm	0219z 28 Mar
N2QT	USA W7GKF	7035.0	CW CQ	13 dB	30 wpm	0219z 28 Mar
WE9V	USA W7GKF	7035.0	CW CQ	42 dB	30 wpm	0219z 28 Mar
K9IMM	USA W1AO	3528.8	CW CQ	20 dB	28 wpm	0219z 28 Mar
6K2IXF/2	JPN JA0IOF/0	7011.0	CW CQ	10 dB	25 wpm	0219z 28 Mar
EA8BFK	USA K5VWW	7028.5	CW CQ	24 dB	26 wpm	0219z 28 Mar
W8WWW	ITA I1MMR	7004.3	CW CQ	3 dB	18 wpm	0219z 28 Mar
W8WWW	USA K5VWW	7028.5	CW CQ	35 dB	27 wpm	0219z 28 Mar
WB6BEE	USA K5VWW	7028.5	CW CQ	43 dB	27 wpm	0219z 28 Mar
W2AXR	USA K5VWW	7028.5	CW CQ	28 dB	26 wpm	0219z 28 Mar
LZ7AA	USA W8FJ	3524.7	CW CQ	4 dB	30 wpm	0219z 28 Mar
OE9GHV	USA K5VWW	7028.5	CW CQ	12 dB	27 wpm	0219z 28 Mar
DL1OD	USA W1AO	3528.8	CW CQ	21 dB	28 wpm	0219z 28 Mar
W3LPL	USA K5VWW	7028.5	CW CQ	13 dB	26 wpm	0219z 28 Mar
VE6AO	USA K5VWW	7028.6	CW CQ	29 dB	26 wpm	0219z 28 Mar
KQ8M	USA W1AO	3528.8	CW CQ	10 dB	28 wpm	0219z 28 Mar
KQ8M	USA K5VWW	7028.5	CW CQ	23 dB	26 wpm	0219z 28 Mar
N8AI	USA K5VWW	7028.5	CW CQ	14 dB	26 wpm	0219z 28 Mar
EA5WU	USA W1AO	3528.8	CW CQ	7 dB	28 wpm	0219z 28 Mar

options:

show/hide

news

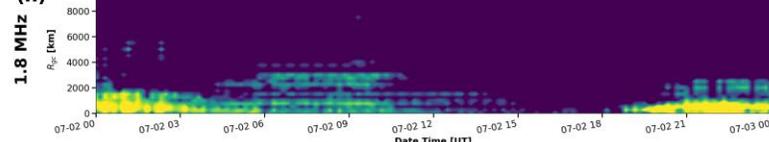
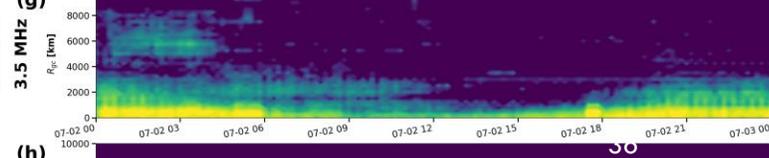
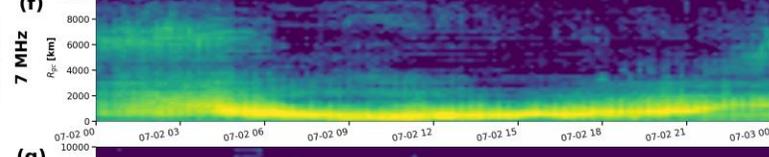
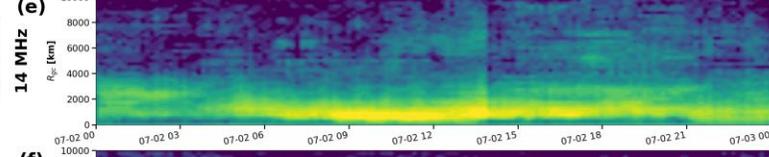
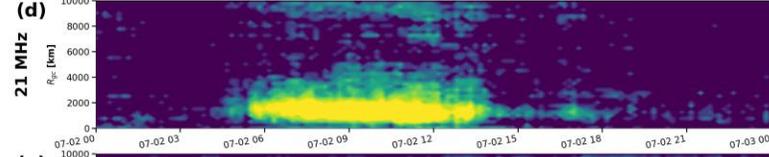
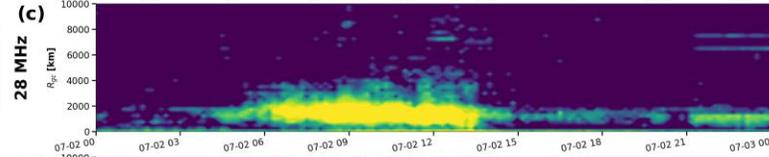
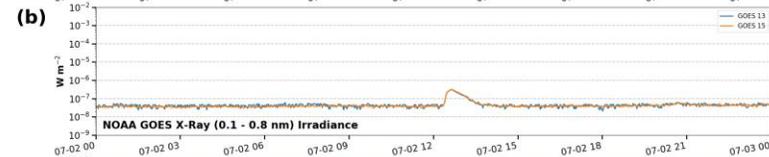
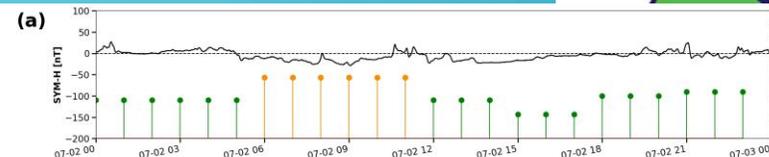
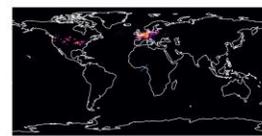
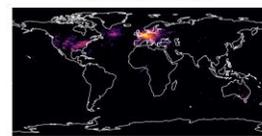
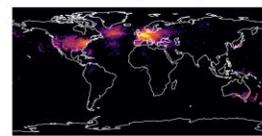
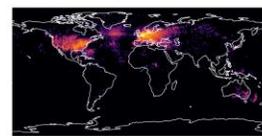
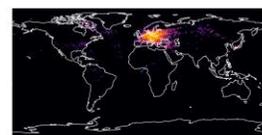
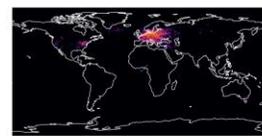
RBN blog: stay tuned!

we have 162 skimmers online

skimmers online:

3B8CW - no spot last 15min
 6K2IXF/2 - 40m
 7N4XCV - 40m
 9A1CIG - 160m, 80m, 40m
 9V1RM - no spot last 15min
 AA4VV - no spot last 15min
 AC0C - 160m, 80m, 40m
 AE4PM - no spot last 15min
 BA7QT - no spot last 15min
 BD7JNA1 - no spot last 15min
 BG4GOV3 - no spot last 15min
 BG7IBS - no spot last 15min
 BH1VCS - no spot last 15min
 BH4BWX - no spot last 15min
 CX6VM - 80m, 30m
 DD5XX - 80m, 40m
 DE1LON - 160m, 80m, 40m
 DF4XX - 160m, 80m, 40m
 DJ2BC - 160m, 80m, 40m
 DJ9IE - 160m, 80m, 60m, 40m
 DK0TE - 160m, 80m, 40m
 DK3UA - 160m, 80m
 DK8NE - no spot last 15min
 DK9IP - 160m, 80m, 40m
 DL0LBS - no spot last 15min
 DL1AXX - 40m
 DL1OD - 160m, 80m, 40m
 DL1RNN - 160m, 80m, 40m
 DL3DTH - 160m, 80m, 40m
 DL9GTB - 160m, 80m, 60m, 40m
 DO4DXA - 160m, 80m, 40m
 DQ8Z - no spot last 15min
 DR4W - 160m
 E28AC - no spot last 15min
 EA5WU - 160m, 80m, 40m
 EA8BFK - 160m, 80m, 60m, 40m

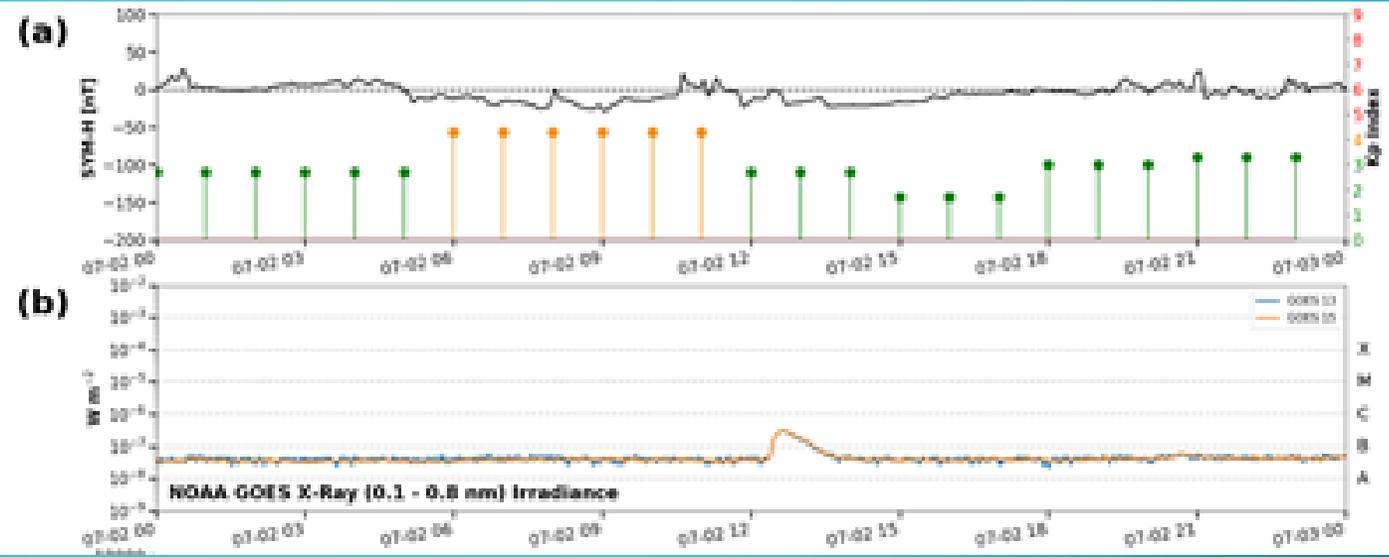
02 Jul 2017-
 03 Jul 2017
 Ham Radio Networks
 N Spots = 744196
 RBN: 21%
 WSPRNet: 79%



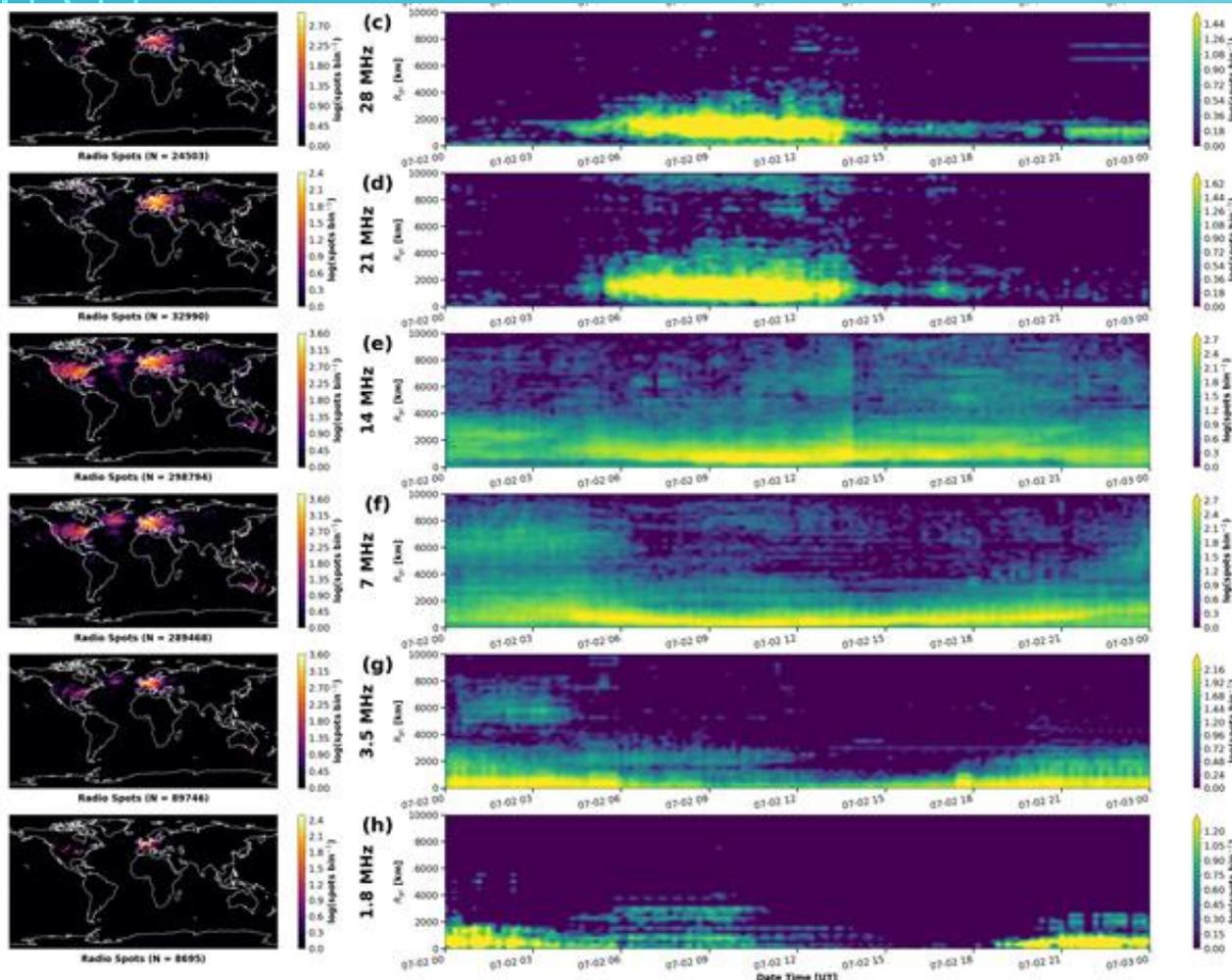


RBN-WSPRNET DAILY HISTOGRAMS

02 Jul 2017-
03 Jul 2017
Ham Radio Networks
N Spots = 744196
RBN: 21%
WSPRNet: 79%



- The RBN-WSPRNet Daily Histograms are used to monitor global high frequency (HF) ham radio communications in relation to space weather activity. The following data are shown:
 - Panel (a) shows geomagnetic activity indices derived from ground-based magnetometer data, including the SYM-H index (black line) and Kp Index (colored stems).
 - Panel (b) shows X-ray flux measurements made by the GOES satellites for monitoring solar flares.

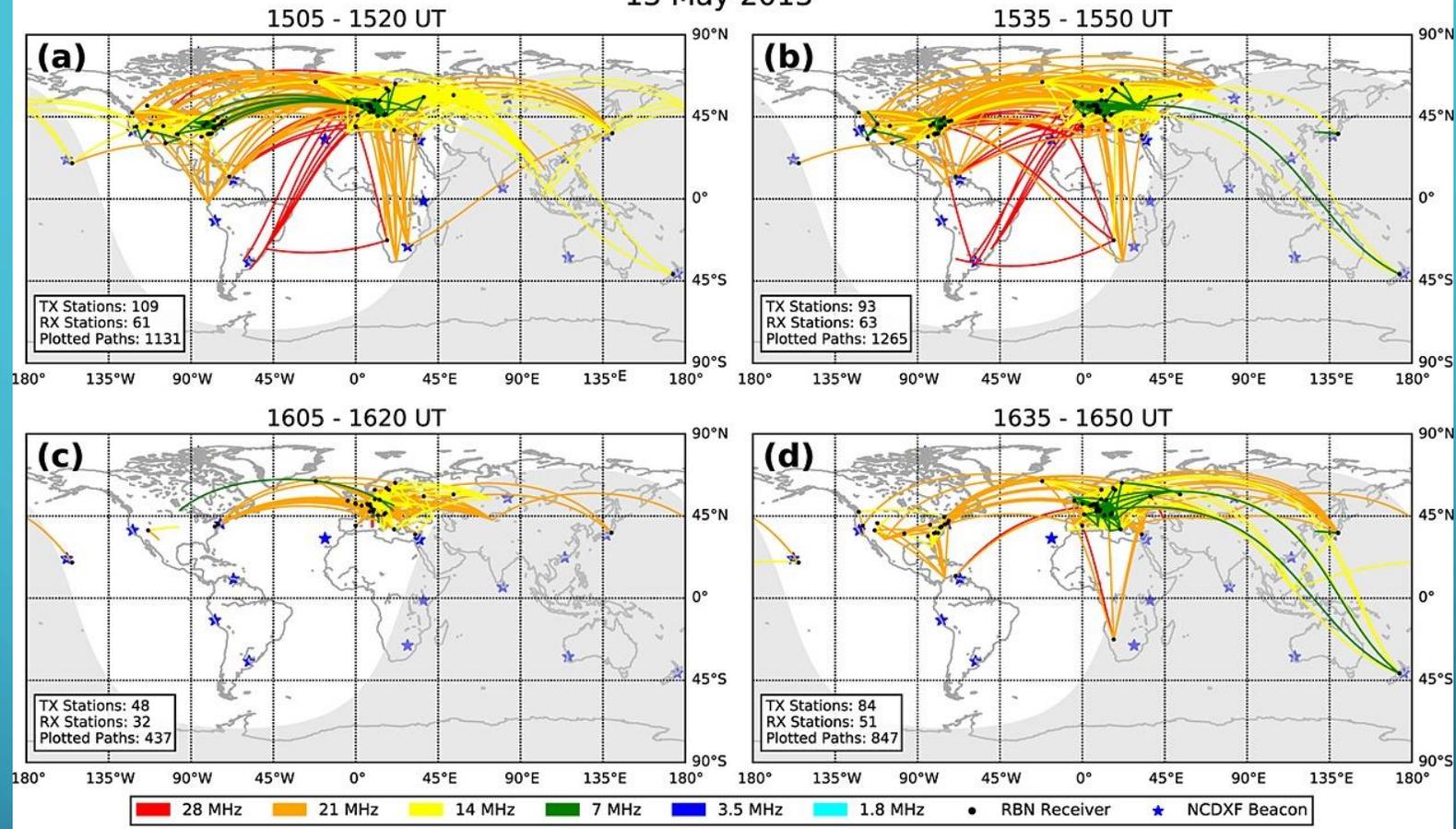


Panels (c) - (h) show density maps and histograms of ham radio spots/QSOs from the Reverse Beacon Network and WSPRNet. The data are located at the midpoint of the transmitter and receiver. Map bin sizes are 1° lat by 1° lon, and histogram bin sizes are 10 min by 250 km. When a user-reported location is not available, a lookup to a public database such as

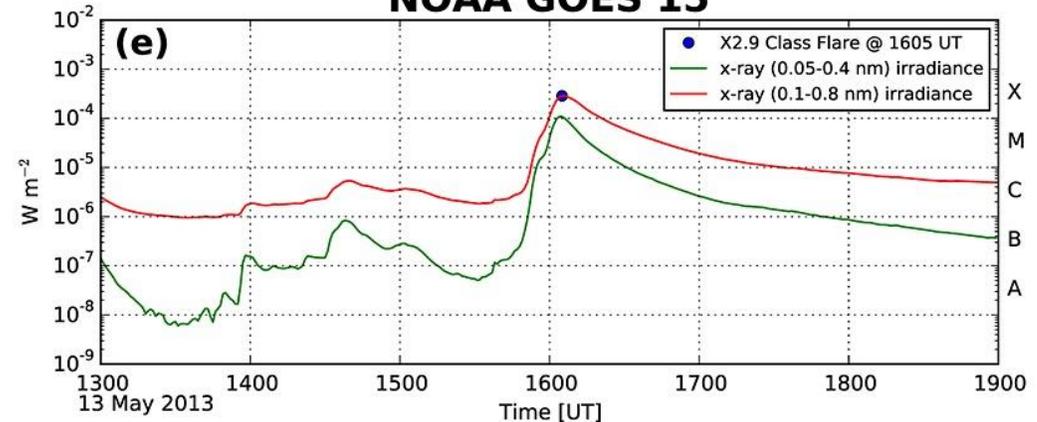
<http://qrz.com> or <http://hamcall.net> is made. If location is not provided and a database lookup is not available, the spot is discarded.

Reverse Beacon Network

13 May 2013



NOAA GOES 15



WHY IS ALL THIS IMPORTANT?



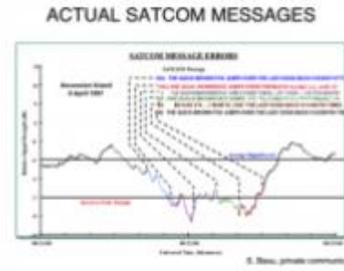
ELECTRIC POWER TRANSMISSION

The electric power grid, and consequently the power to your home and business, can be disrupted by space weather.



HF RADIO COMMUNICATIONS

Space weather impacts radio communication in a number of ways.



SATELLITE COMMUNICATIONS

Satellite communication refers to any communication link that involves the use of an artificial satellite in its propagation path.



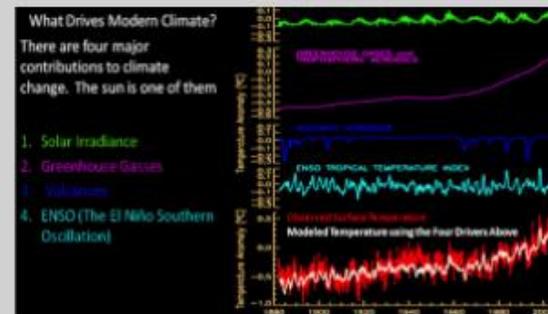
SATELLITE DRAG

Drag is a force exerted on an object moving through a fluid, and it is oriented in the direction of relative fluid flow.



SPACE WEATHER AND GPS SYSTEMS

The use of single and dual frequency radio navigation systems, like GPS, has grown dramatically in the last decade.



SPACE WEATHER IMPACTS ON CLIMATE

All weather on Earth, from the surface of the planet out into space, begins with the Sun.



BUT WHAT CAN I DO?

- Be a Data Contributor with Your Normal Ham Activities
- Consider a PSWS
- Take Advantage of Existing Resources to Make Your Ham Experience Better

REFERENCES

<https://hamsci.org/>

<https://hamsci.org/publications>

<http://wsprnet.org/drupal/wsprnet/map>

<http://www.reversebeacon.net/>

<https://pskreporter.info/pskmap.html>

<https://www.dxwatch.com/>

<https://hamsci.org/sites/default/files/publications/2020-01%20QEX%20Cowling.pdf>

<https://youtu.be/7j-2DgkHphk> (TangerineSDR explanation)

MORE REFERENCES

- Ionospheric Sounding Using Real-Time Amateur Radio Reporting Networks

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014SW001132?campaign=wlytk-41855.5282060185>

- Design of Software Defined Radio for SuperDARN Radars (Super Dual Auroral Network)

https://vtechworks.lib.vt.edu/bitstream/handle/10919/89908/Kennedy_P_S_T_2019.pdf?sequence=5&isAllowed=y

AND STILL MORE REFERENCES

- The Ionosphere and GNSS: Explained

https://youtu.be/w-5HI2b_wKE

- HF Communications – Space Weather Prediction Center

<https://www.swpc.noaa.gov/impacts/hf-radio-communications>

- Space Weather & VHF Propagation

https://spaceweather.rra.go.kr/effect/english/03_03

- Contest University – 2020 Solar Cycle Update and the HF Response to Ionospheric Storms and Traveling Ionospheric Disturbances

<https://www.contestuniversity.com/wp-content/uploads/2020/05/W2NAF-2020-Solar-Cycle-Update.pdf>



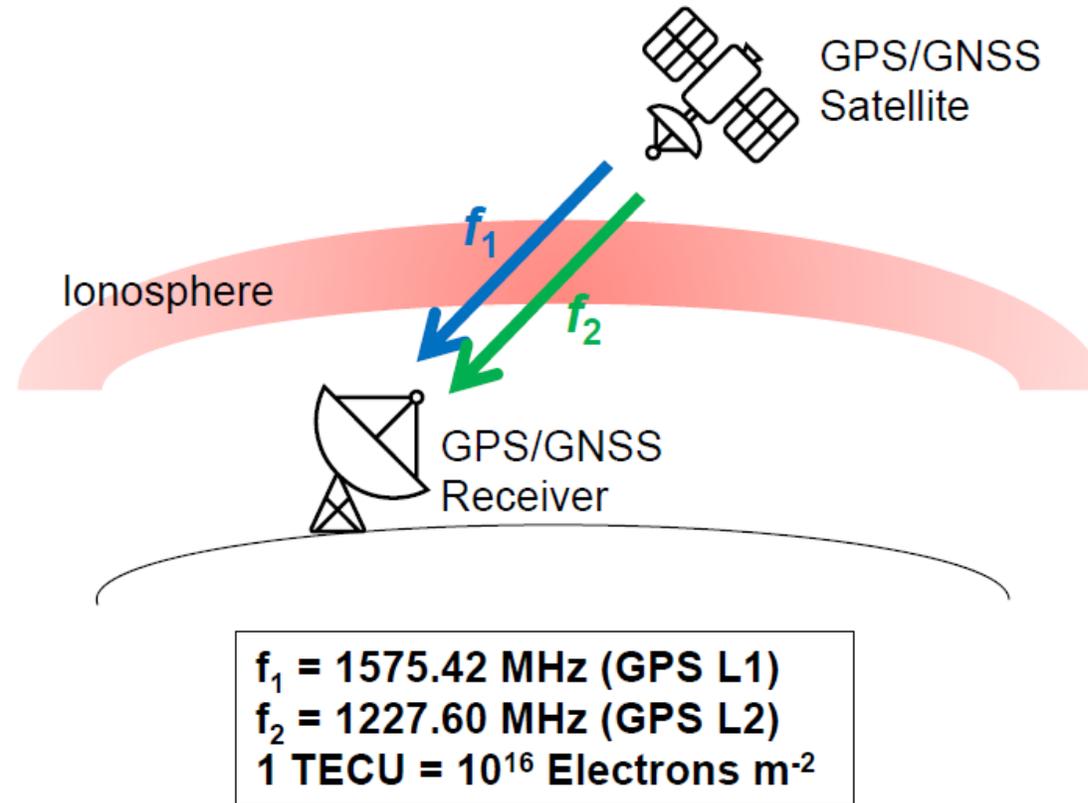
AND THE LAST REFERENCE PAGE

- N2LVI's Quick Guide to HF Propagation Using Solar Indices

https://www.qsl.net/w2vtm/hf_solar.html

What is Total Electron Content (TEC)?

- TEC is a measure of the total number of electrons between a GPS/GNSS satellite transmitter and GPS/GNSS receiver.
- It is derived from the difference in phase delay of two different frequencies passing through the ionospheric plasma.



What is Total Electron Content (TEC)?



$$I_s = \frac{1}{40.3} \frac{f_1^2 f_2^2}{f_1^2 - f_2^2} \left[\underbrace{(L_1 - L_2)}_{\text{Recorded carrier phases of the signal (converted to distance units)}} - \underbrace{(\lambda_1 n_1 - \lambda_2 n_2)}_{\text{Integer cycle ambiguities}} + \underbrace{b_r + b_s}_{\text{Instrument (satellite and receiver) bias terms}} \right]$$

↑
Slant
TEC

↑
Frequency
Terms

↑
Recorded
carrier phases
of the signal
(converted to
distance
units)

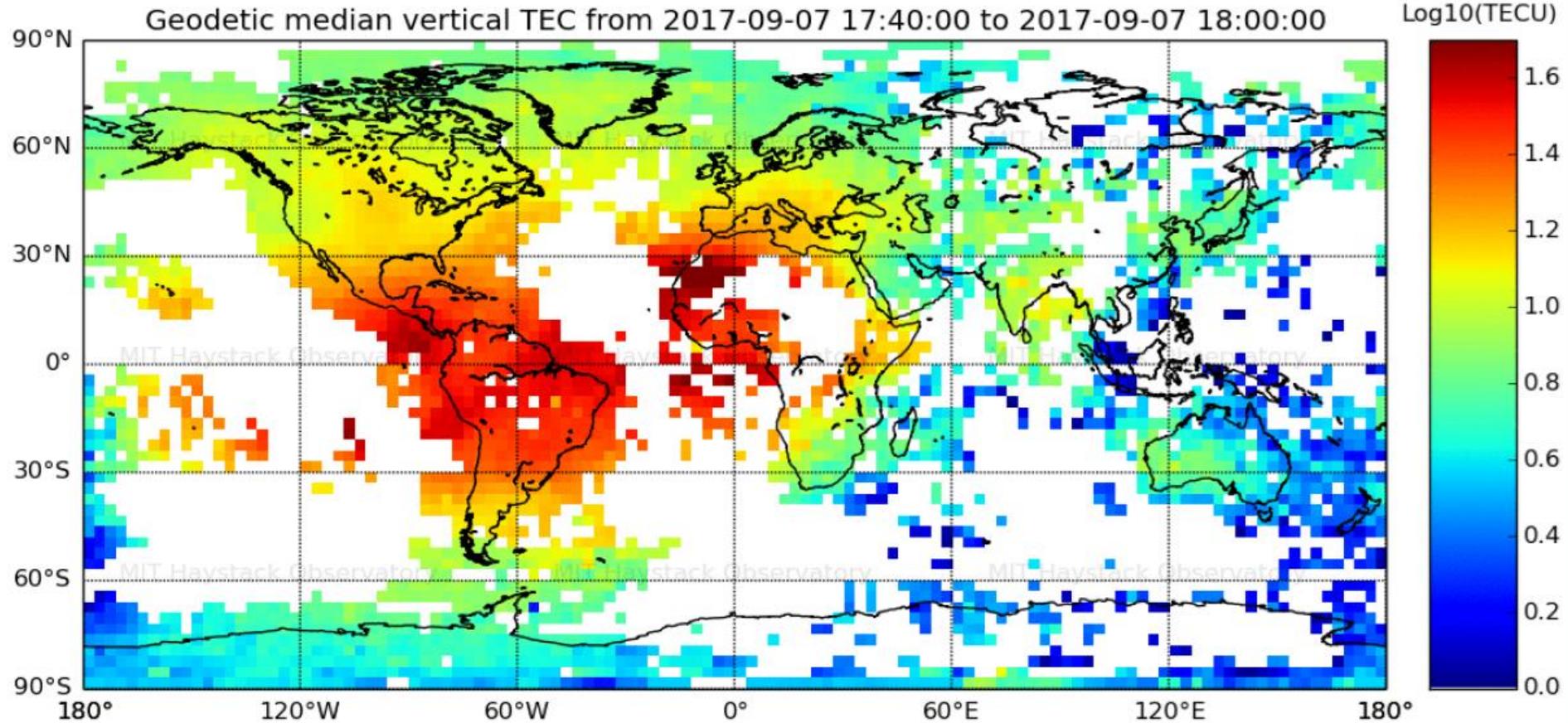
↑
Integer cycle
ambiguities

↑
Instrument
(satellite and
receiver) bias
terms

$f_1 = 1575.42$ MHz (GPS L1)
 $f_2 = 1227.60$ MHz (GPS L2)
 1 TECU = 10^{16} Electrons m^{-2}

[Tsugawa et al., 2007, [doi:10.1029/2007GL031663](https://doi.org/10.1029/2007GL031663)]

What is Total Electron Content (TEC)?



© 2017 MIT Haystack Observatory

© MIT Haystack Observatory / Anthea Coster

[Rideout and Coster, 2006, [doi:10.1007/s10291-006-0029-5](https://doi.org/10.1007/s10291-006-0029-5)]

What is an Ionospheric Storm?



- An ionospheric storm is the specific response of the ionosphere to dynamic features in the solar wind that trigger geomagnetic disturbances throughout the coupled magnetosphere ionosphere system.

[Thomas et al., 2016, [doi:10.1002/2015JA022182](https://doi.org/10.1002/2015JA022182)]

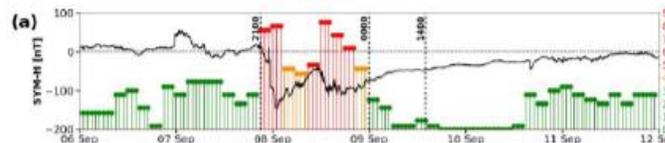
- Storm time variations in electron densities are typically characterized as
 - Positive: Increase in electron density
 - Negative: Decrease in electron density

[Matsushita, 1959]

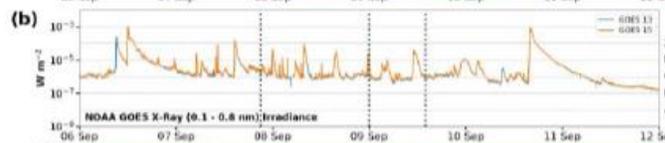
Global Response to Geomagnetic Storm



06 Sep 2017-
12 Sep 2017
Ham Radio Networks
N Spots = 3849836
RBN: 22%
WSPRNet: 78%



$Kp_{max} = 8+$
 $SYM-H_{min} = -146 \text{ nT}$



8 Sept 2100 UT

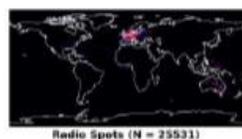
- Storm Onset

9 Sept 0000 UT

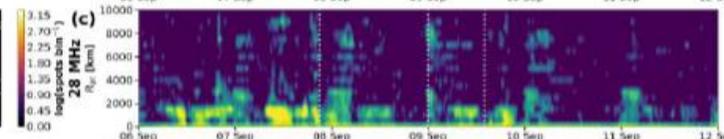
- Geomagnetic Quiet

9 Sept 1400 UT

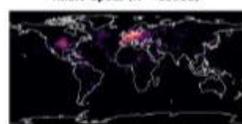
- Radio Recovery



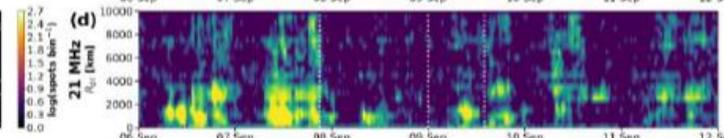
Radio Spots (N = 25531)



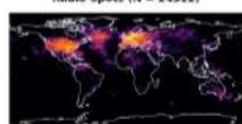
28 MHz



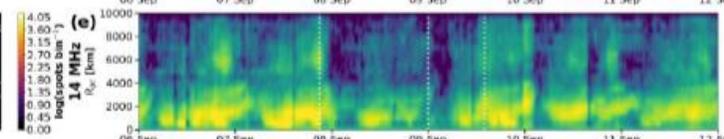
Radio Spots (N = 24312)



21 MHz



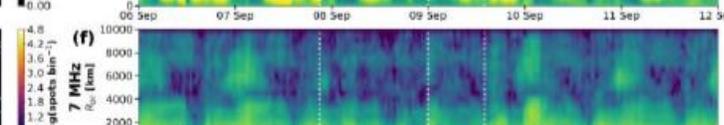
Radio Spots (N = 1349263)



14 MHz



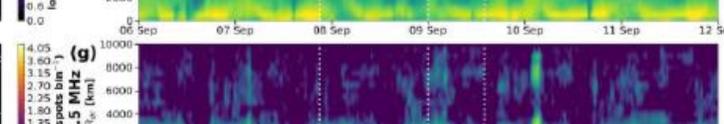
Radio Spots (N = 1918443)



7 MHz



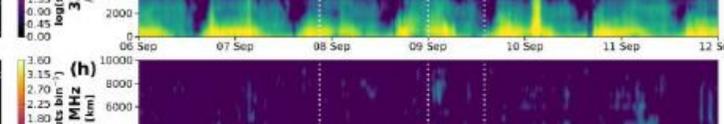
Radio Spots (N = 434245)



3.5 MHz



Radio Spots (N = 97942)



1.8 MHz

6 Sept 2017 12 Sept 2017

[Frissell et al., 2019, doi:[10.1029/2018SW002008](https://doi.org/10.1029/2018SW002008)] 500 km × 30 min bins

nathaniel.frissell@scranton.edu (W2NAF)