Patterns in Received Noise: Methods, Observations and Questions.




Glenn N6GN Clint KA7OE Tom WO7I Dennis ND7M

Gwyn G3ZIL and Ron AI6VN will be live on the demo via Zoom

Gwyn Griffiths*, G3ZIL, Rob Robinett, AI6VN and Glenn Elmore, N6GN, with Clint Turner, KA7OEI, Tom Bunch, WO7I and Dennis Benischek, ND7M.

HamSci Community and Independent Amateurs.

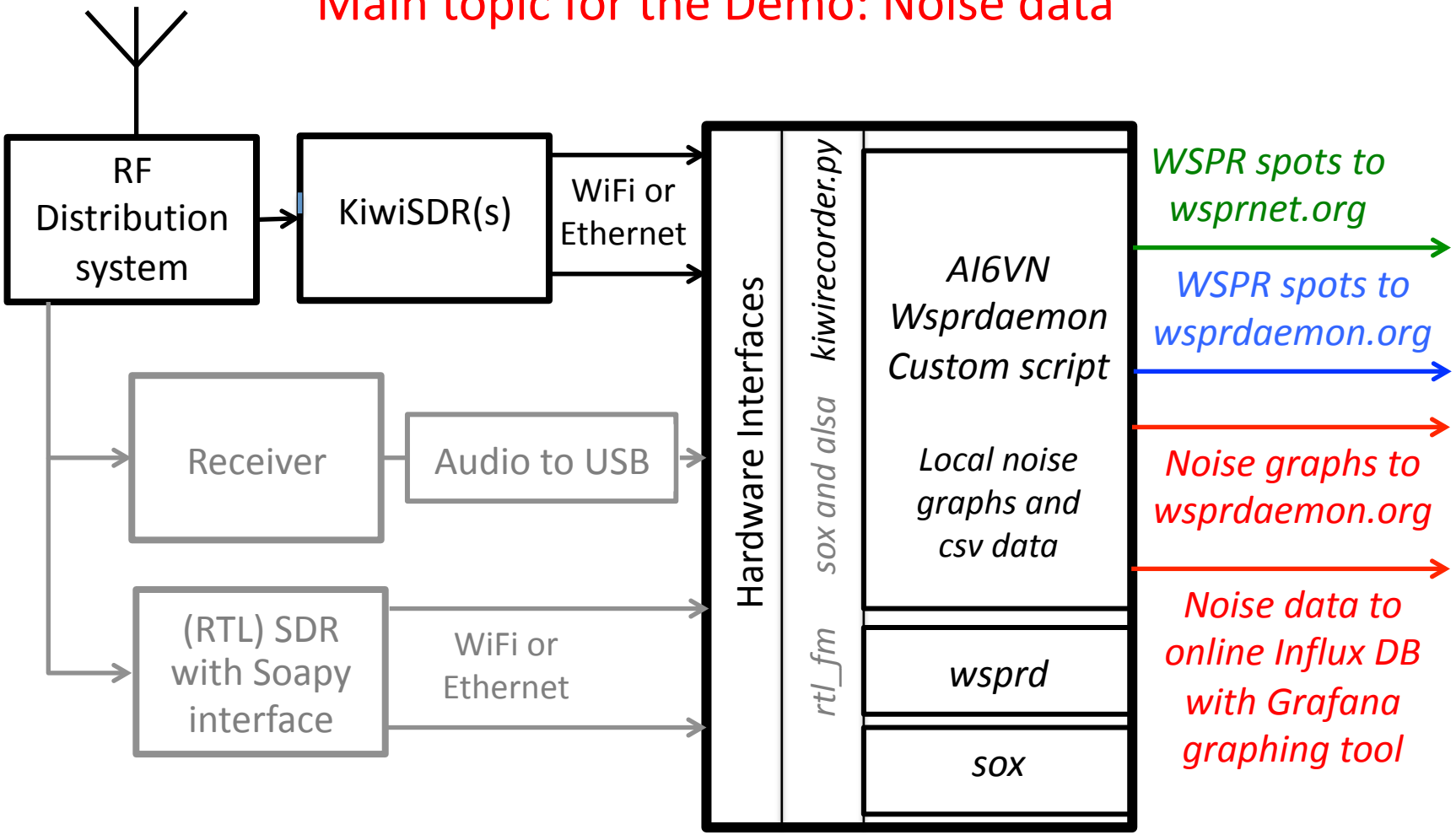
* Corresponding author: gwyn@autonomousanalytics.com

Part 1: Methods

- RF and Data Acquisition
- Key reporting stations
- Noise estimation methods
- Calibration
- Data presentation and analysis methods
- Online rolling 24hr graphs at wsprdaemon.org
- Online open access interactive graphs and data download at graphana.int8.com

RF and Data acquisition: Outline diagram

Main topic for the Demo: Noise data

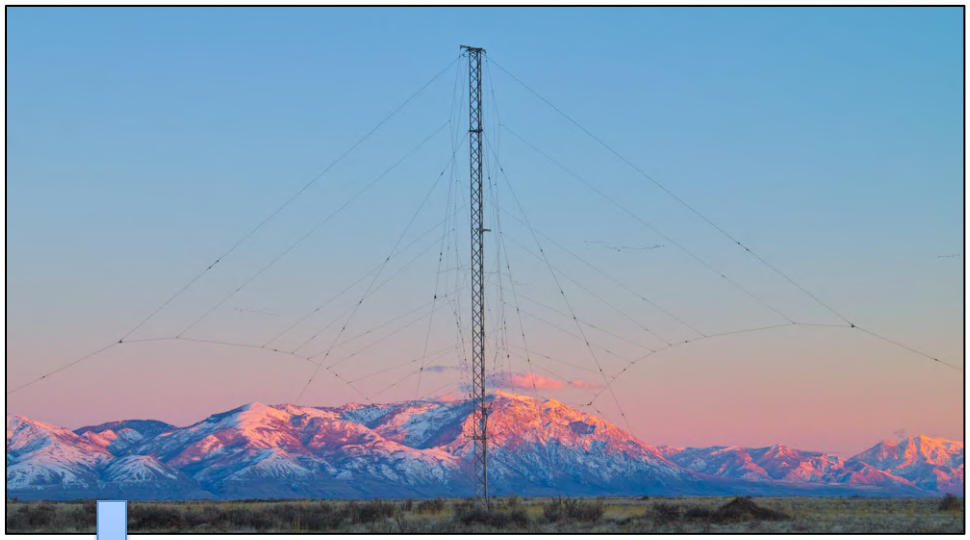


Raspberry Pi 3 or 4 or x86 server

Tested on Debian/Raspian Stretch & Buster and Ubuntu 18.04LTS

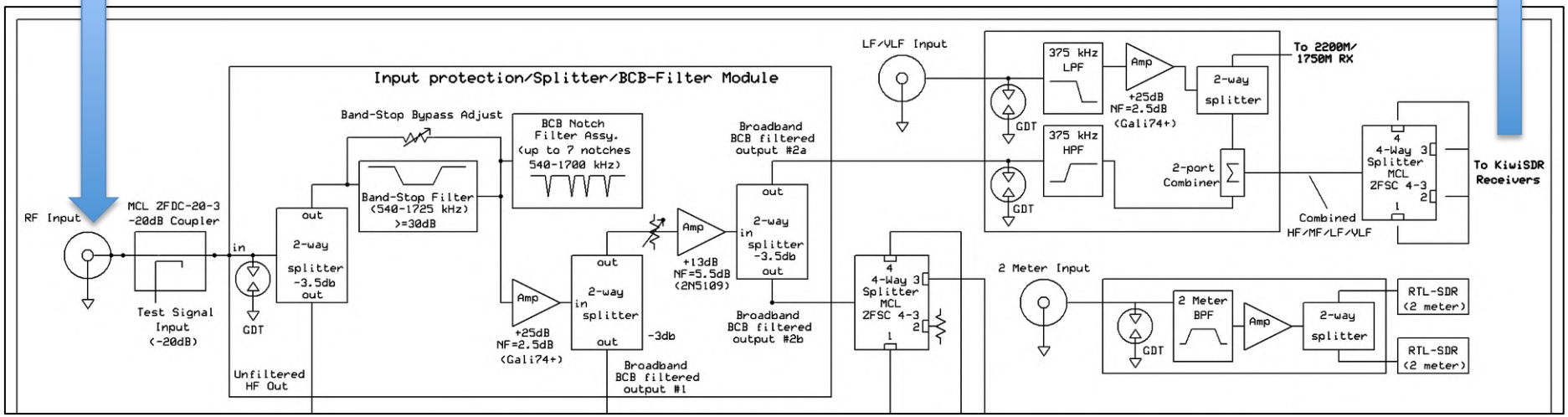
Northern Utah WebSDR system

TCI530 “omnidirectional” log-periodic antenna

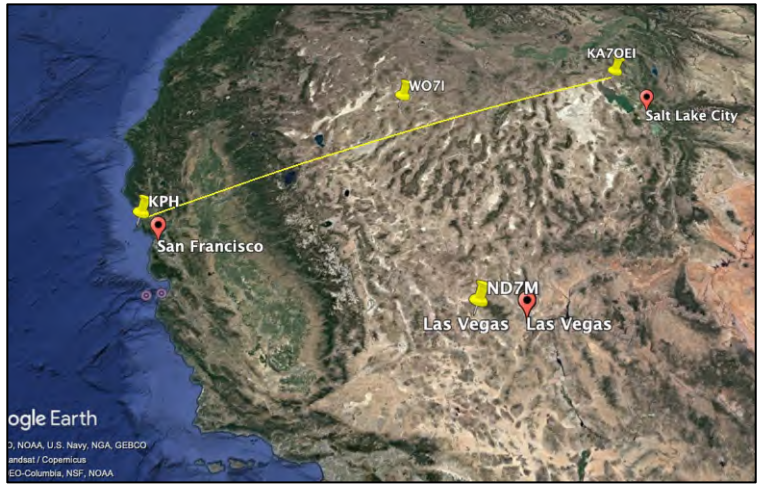


- Near Corrine, Utah, ~60km north of Salt Lake City.
- At an old HF radio research site.
- Softrock, RTL_SDR and KiwiSDR receivers.
- Details and access via https://www.sdrutah.org/

KiWISDR outputs



KPH Point Reyes, California

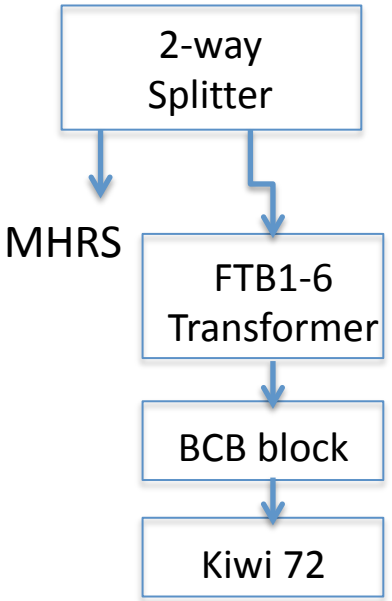


Kiwi SDRs and part of the RF distribution system at KPH, Point Reyes

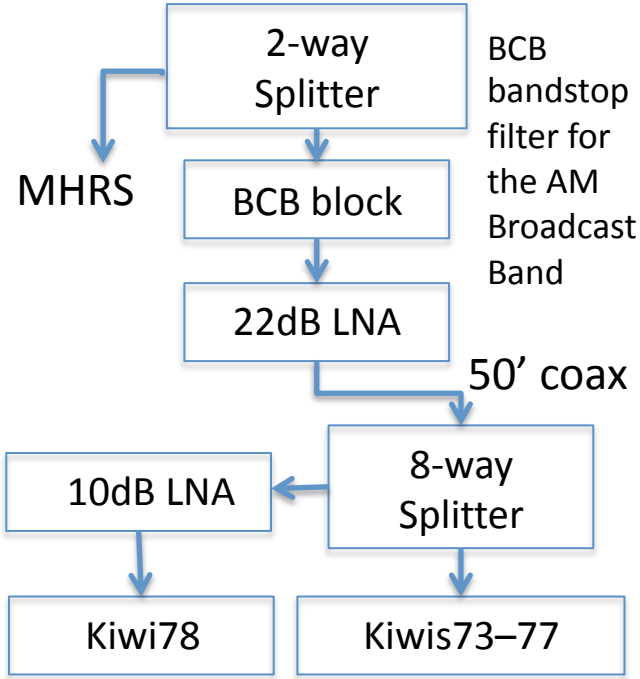
- Point Reyes, California, ~60km northwest of San Francisco, within Point Reyes National Seashore.
- Historic RCA Maritime Radio station, site chosen by Dr Harold Beverage *ca.* 1928. Facilities restored and maintained by the Maritime Historical Radio Society (MHRS), and the site by National Parks Service, to whom we are greatly indebted.
  http://www.radiomarine.org

Antennas

Marconi LF&MF



TCI-530 MF &HF

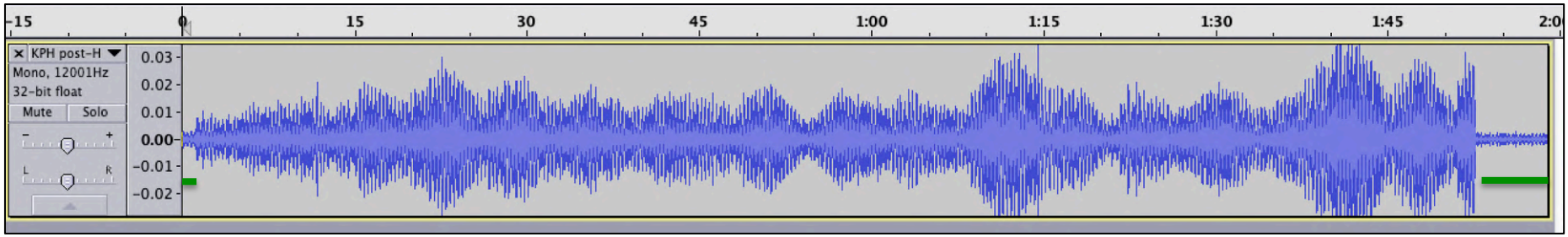


WO7I and ND7M, Nevada

WO7I, N. Nevada: 1.8 to 30MHz OCF Inverted Vee -> 30MHz LPF -> BCB -> LNA (30dB gain, NF 1.8 dB) -> Splitter -> Splitter -> two KiwiSDRs

ND7M, S. Nevada: Wellbrook ALA1530LN Magnetic Loop via 250’ Heliax -> BCB -> LNA (20dB)
-> splitter->HPF & T1-1-X65X 40-10m KiwiSDR
->LPF & T1-1-X65X 2200-60m KiwiSDR

One slide summary: RMS and FFT methods

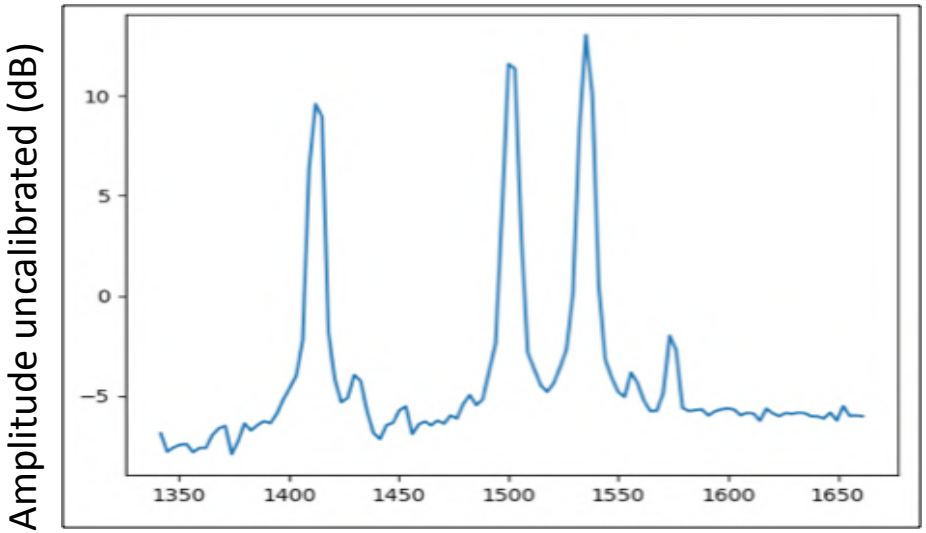


Pre

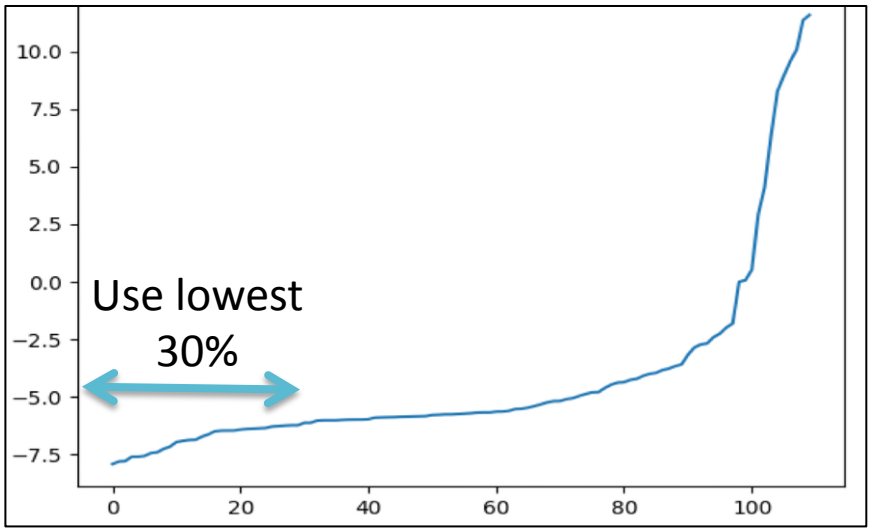
Post

RMS: Make the noise level estimate as the lower of the lowest amplitude 50ms interval either in the Pre- or Post- WSPR transmission period. Example: KPH post-Hann window on 7.04MHz at 1414-1416UTC 4 Jan2020.

FFT: Use the WSPR c2 format file and Python FFT code to derive spectral amplitude estimates. Sort into amplitude order, use sum of power in lowest 30%.



Frequency (Hz)



Frequency bin, out of 111, in Amplitude order

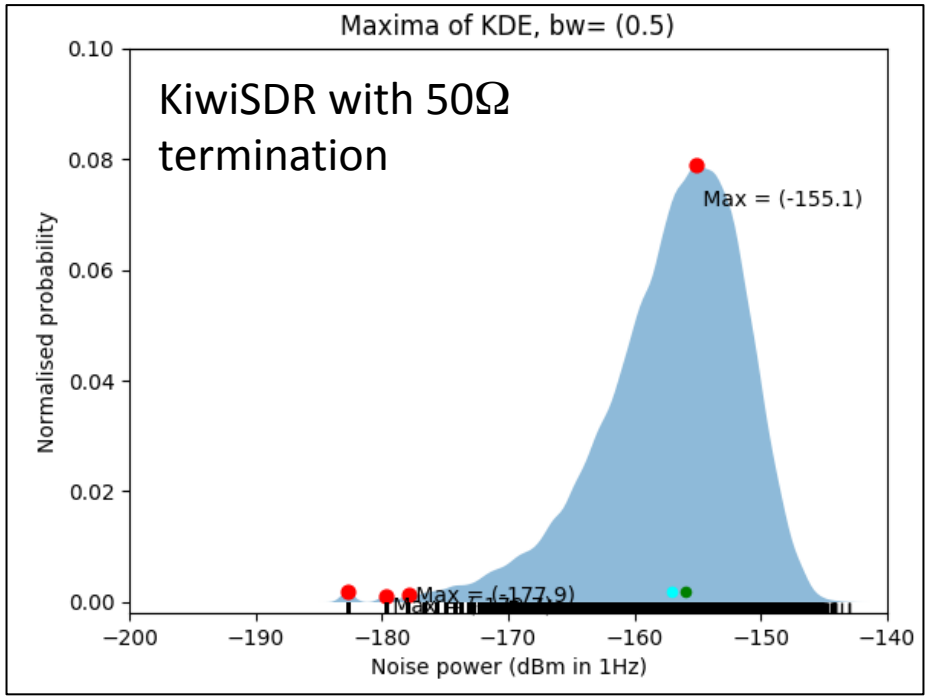
Calibration and Interpretation: RMS and FFT methods

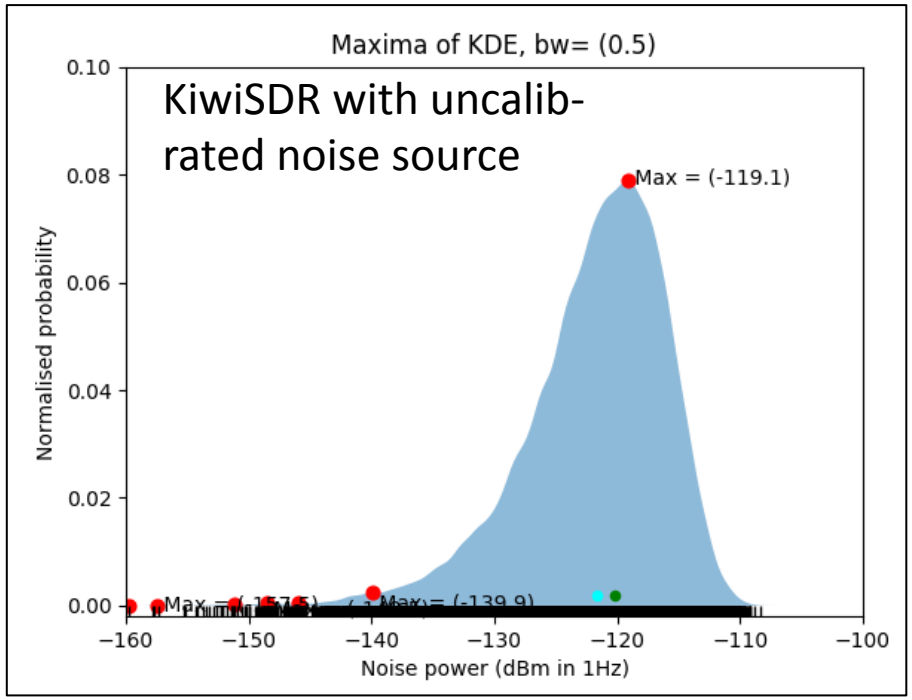
"… for this presentation calibration will be set aside as we concentrate on patterns and not absolute noise levels".

Both the RMS and FFT estimators require empirical offsets to be determined.

Noise level as dBm in 1 Hz

	RMS	FFT	KDE
Terminated 22.9dB ENR Noise source	-156.0	-157.0	-155.1
Uncal. Noise source	-150.9	-151.9	-149.3
	-120.2	-121.7	-119.1





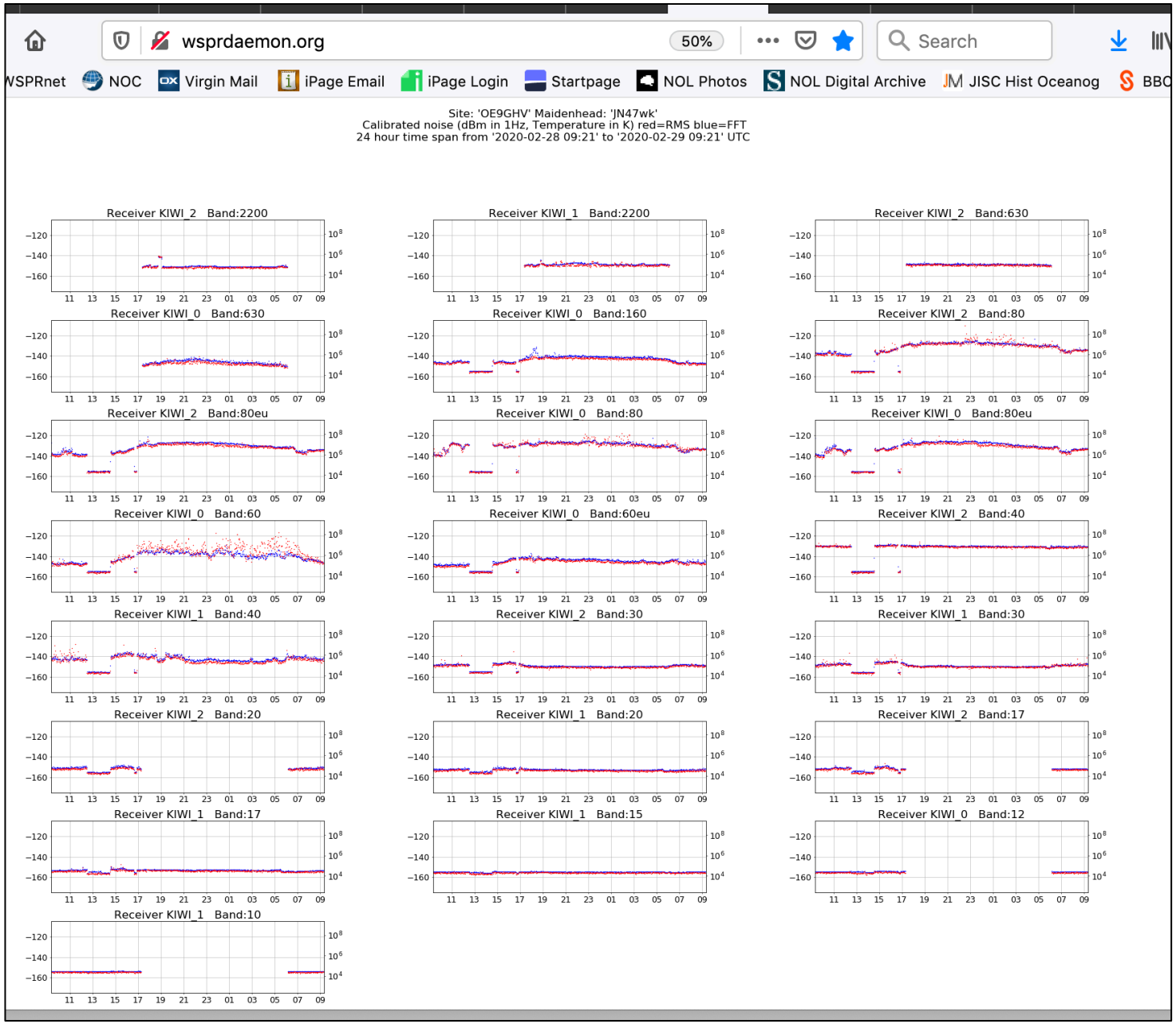
Data presentation and analysis

- Time series – Single station, rolling quick look
  – Multiband, multistation, interactive
- Derive anomalies – Differences from mean or median interpretation of time series with offsets
- Cross-correlation – Lag / lead of one of a pair or time series
  – Variation with meaningful dependent variable, e.g. time of day
- Animations – Especially using run pause, for time series and cross-correlations
- Contour graphs – e.g. noise as Z axis property using colour
- Sunrise / sunset times
- Propagation forecasts

But currently using ad hoc methods rather than a seamlessly integrated RF data analysis toolbox.

Noise graphs at wsprdaemon.org

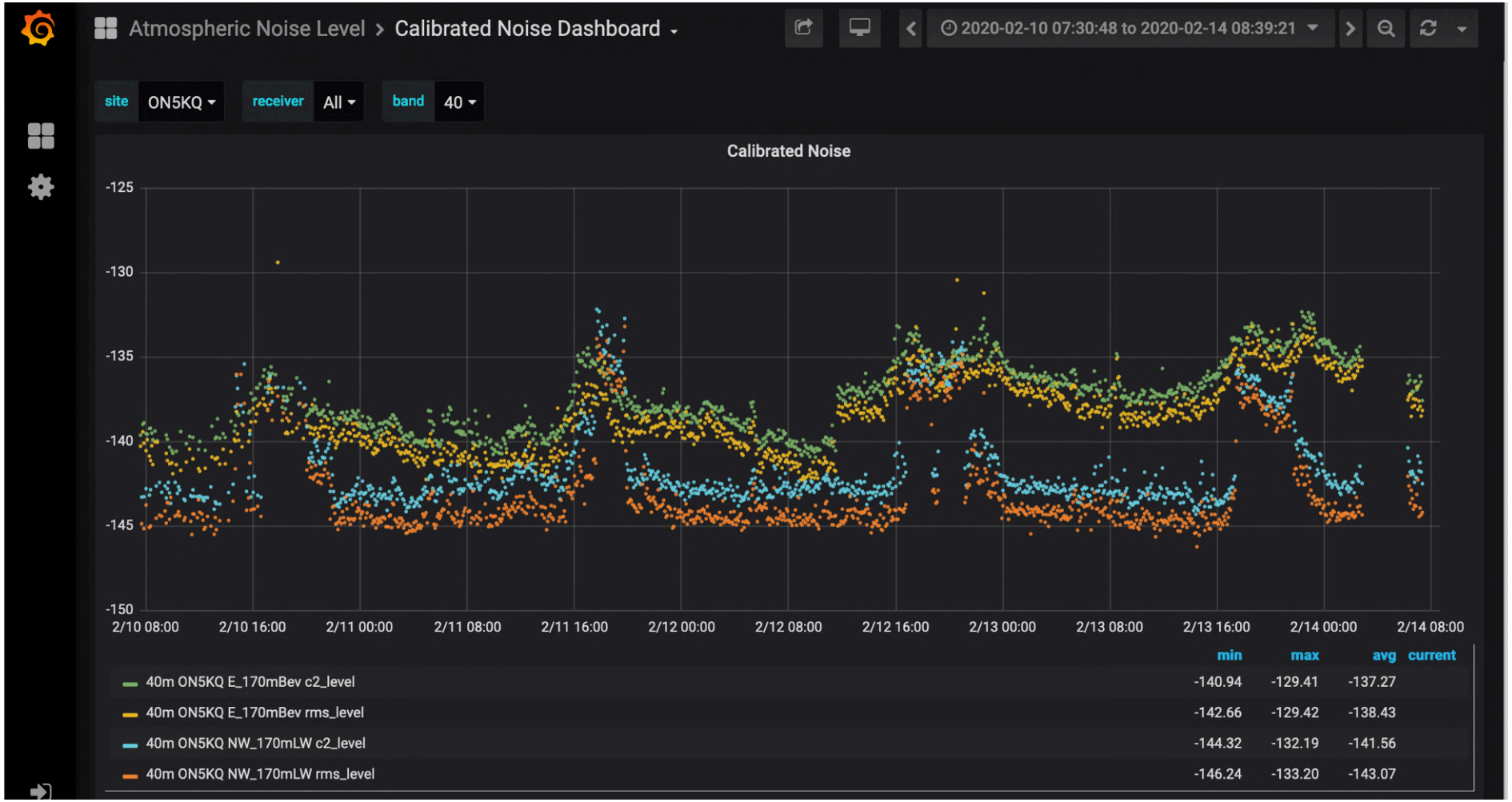
http://wsprdaemon.org



OE9GHV, rural Austria, one of several reporters from low noise locations to wsprdaemon.org

Example of RF input disconnection, showing noise level of the KiwiSDRs.

Noise data from Influx Database viewed using Grafana



http://grafana.int8.com/d/3dcOdAmWk/calibrated-noise-dashboard?orgId=1

https://grafana.int8.com/d/3dcOdAmWk/calibrated-noise-dashboard?orgId=1&from=1581319848935&to=1581669561901&var-site=ON5KQ&var-receiver=All&var-band=40

Access to the Noise Database

- Data exploration using the Grafana tool − used to search for several examples for this demonstration.
- Option 1 Data download from Grafana:
  - *Calibrated Noise – More – Export csv*
  - But, Grafana uses adaptive data decimation based on time window
- Option 2 Data download from the Influx* Database
  - Note the ‘site’, ‘receiver’, ‘band’ and time span from the Grafana view, and the access details in the line below.
  - On a computer with an Influx client installed, e.g. using Terminal :

```
influx -ssl -unsafeSsl -host 35.238.159.210 -username radio_read -password '79ESsPMy' -format 'csv' -database 'radio' -execute "SELECT * FROM atmospheric_noise WHERE site = 'KD2OM' AND band = '40' AND time > '2019-10-15T00:00:00Z' AND time < '2019-10-29T22:00:00Z' LIMIT 2000" > output_file.csv
```

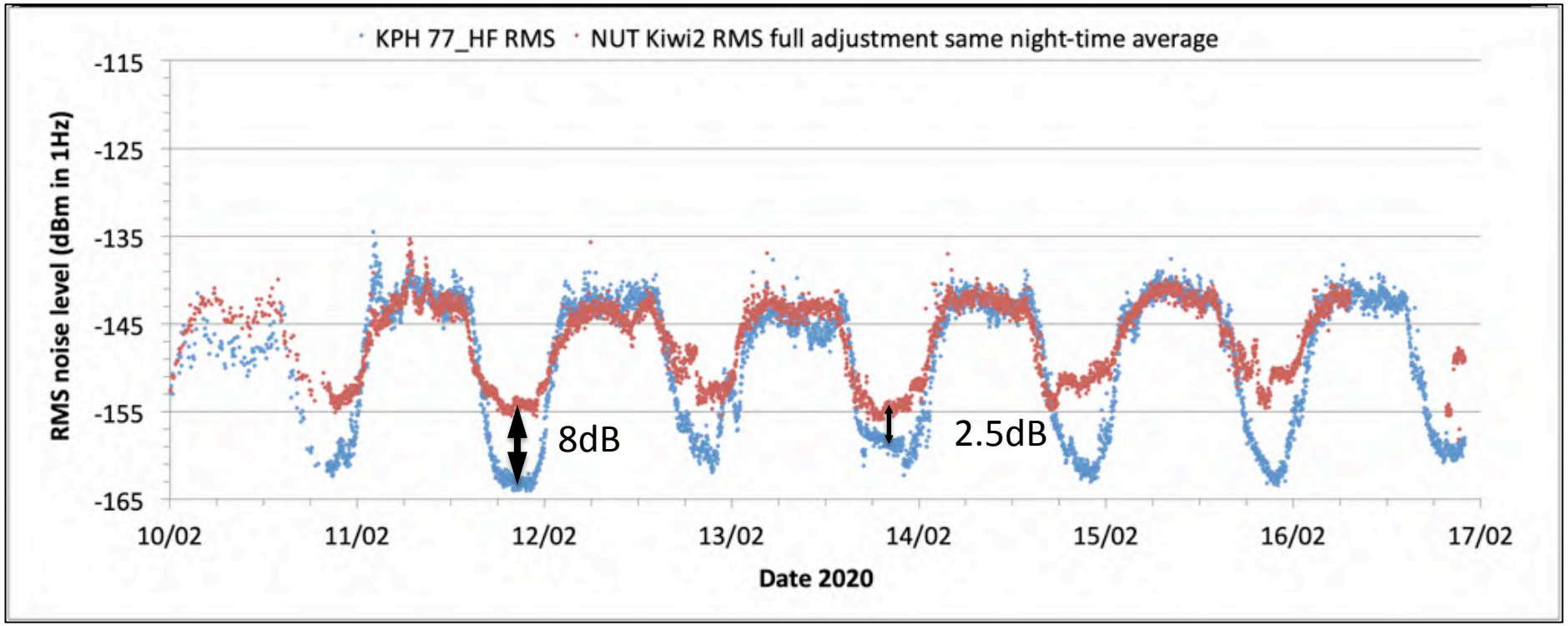
name	time	band	fft_level	grid	maidenhead	receiver	rms_level	site
atmospheric_noise	1571097720000000000.00	40	-135.179	undefined	FN12gx	OM1	-141.07	KD2OM
atmospheric_noise	1571097840000000000.00	40	-135.665	undefined	FN12gx	OM1	-140.93	KD2OM
atmospheric_noise	1571097960000000000.00	40	-139.826	undefined	FN12gx	OM1	-139.77	KD2OM

* Full details at https://docs.influxdata.com/influxdb/v1.7/introduction

Part 2: Observations

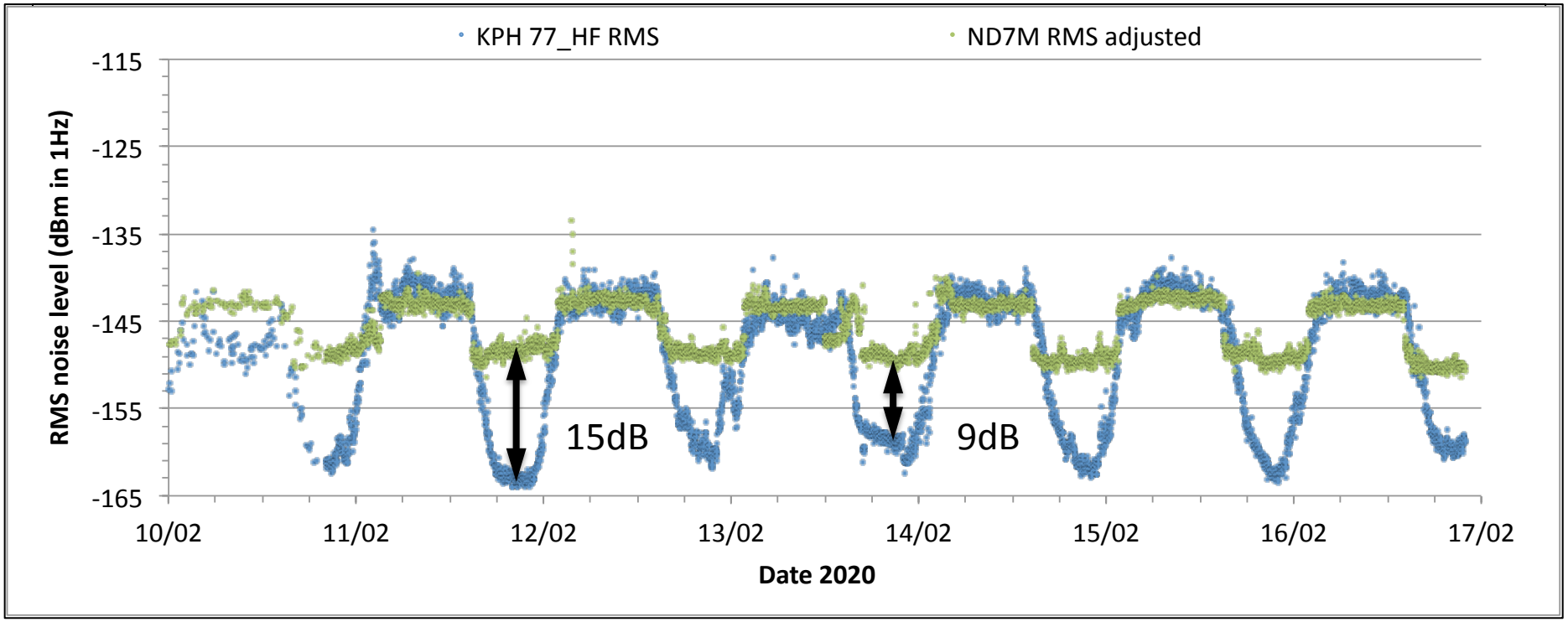
- Diurnal variability in observed noise
- Adverse impact of local noise sources
- Coherent fluctuations at stations 1000km apart
- Seasonal changes in the pattern of diurnal noise

Diurnal noise pattern example: 160m at KPH & NUT



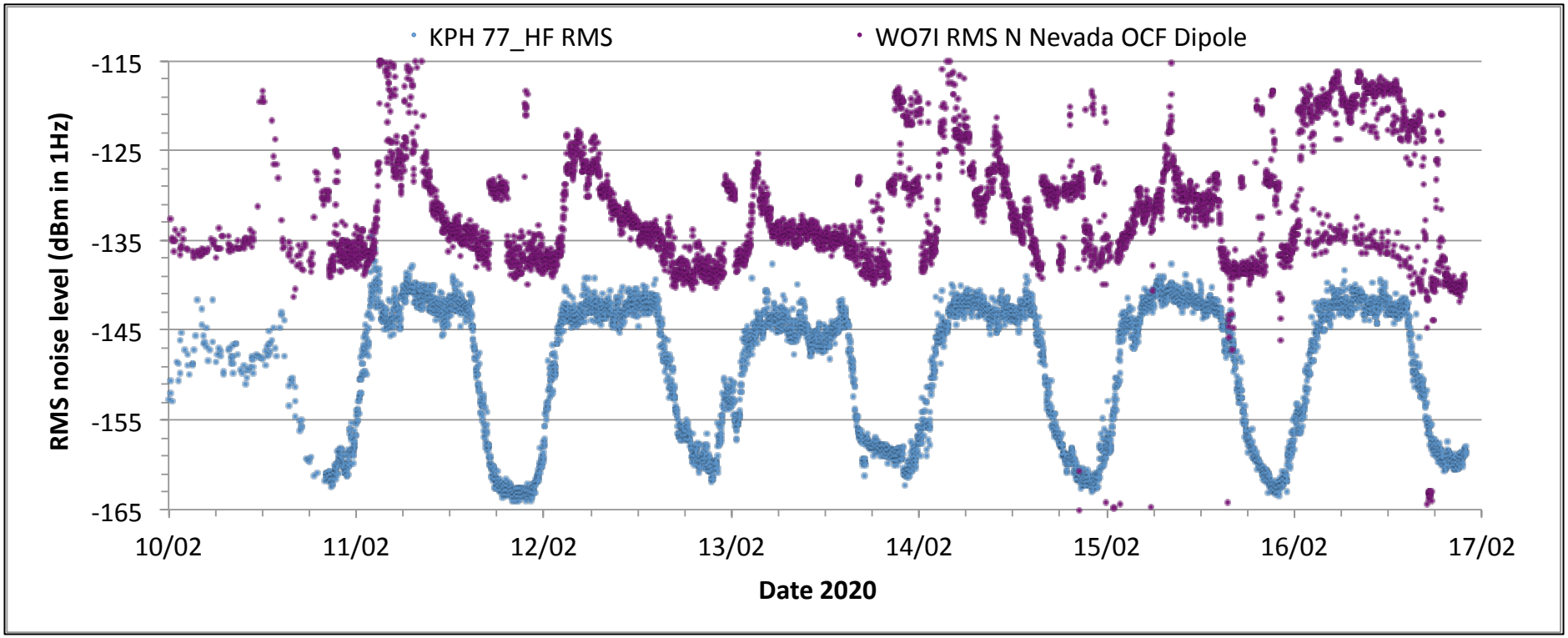
- Reduction of Northern Utah (NUT) reported noise level by 18.7dB provides a match, on average, to the night-time noise level at KPH. ***If*** *daytime local background noise representative of night time local background noise it adds 0.3dB.*
- Daytime noise level at NUT consistently higher by 2.5–8dB than at KPH, with day to day variations.
- *Has NUT been adjusted to refer to the antenna, same as KPH?*

Diurnal noise on 160m: Diagnosis at ND7M using KPH



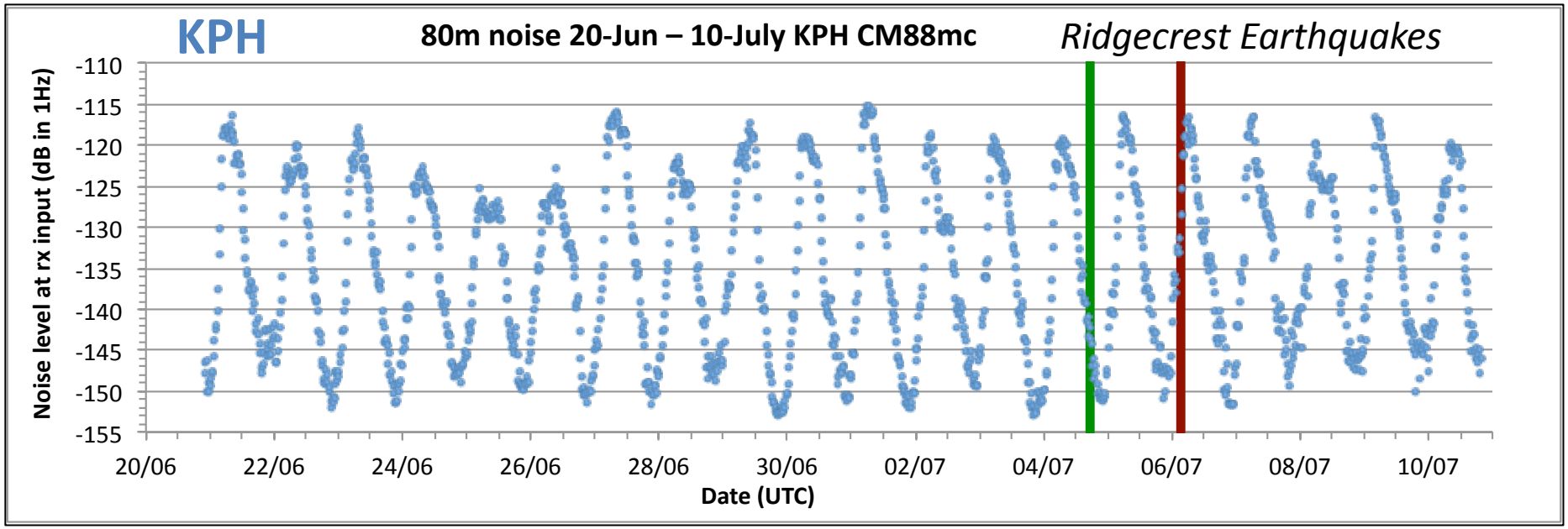
- Increasing ND7M reported noise level by 2.9dB provides a match, on average, to the night-time noise level at KPH. ***If*** *daytime local background noise representative of night time local background noise it adds 0.9dB.*
- Daytime noise level at ND7M consistently higher by 8–15dB than at KPH, with day to day variations.

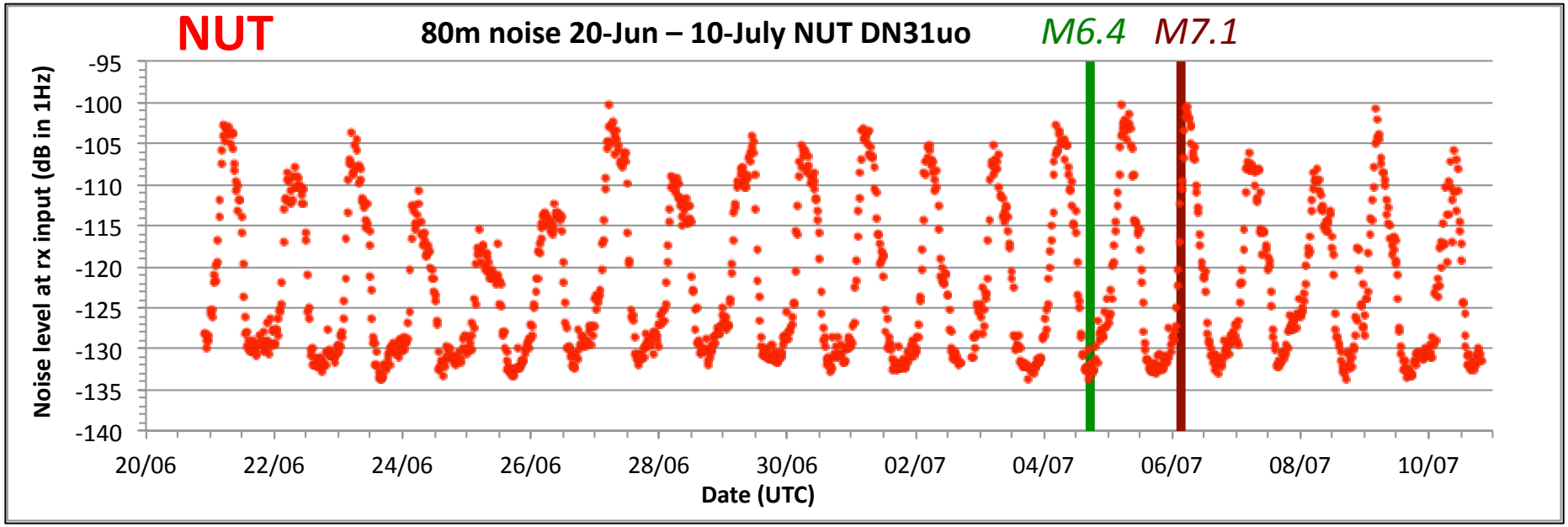
Diurnal noise on 160m: Diagnosis at WO7I using KPH



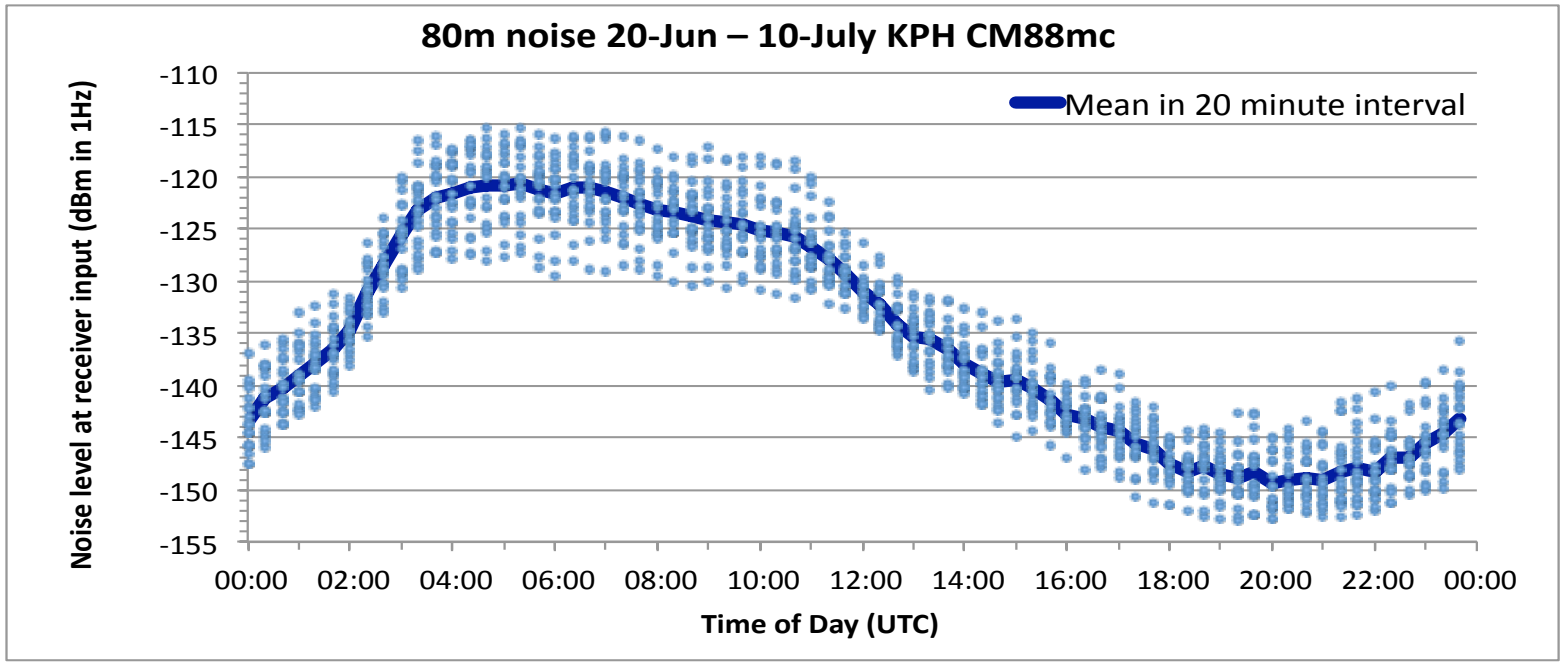
- Night time noise at WO7I on 160m too variable to match to KPH.
  Periods of intermittent high noise levels, e.g. on 16 Feb.

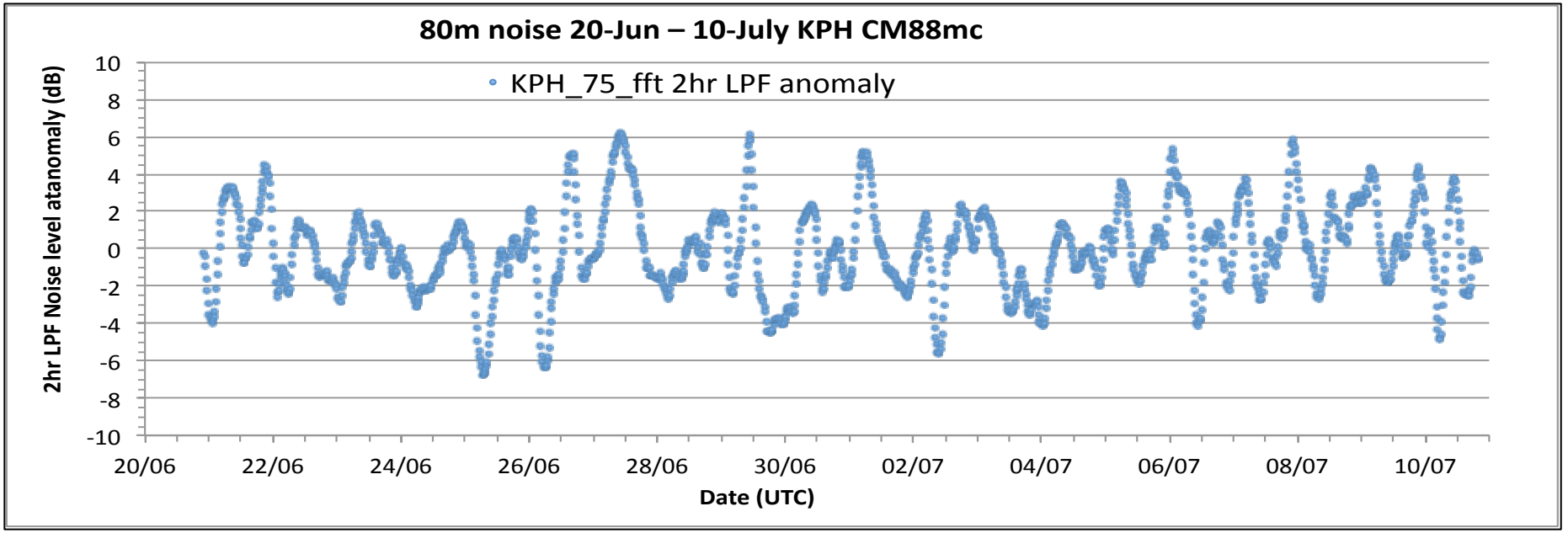
Coherent noise fluctuations: KPH & NUT 980km apart



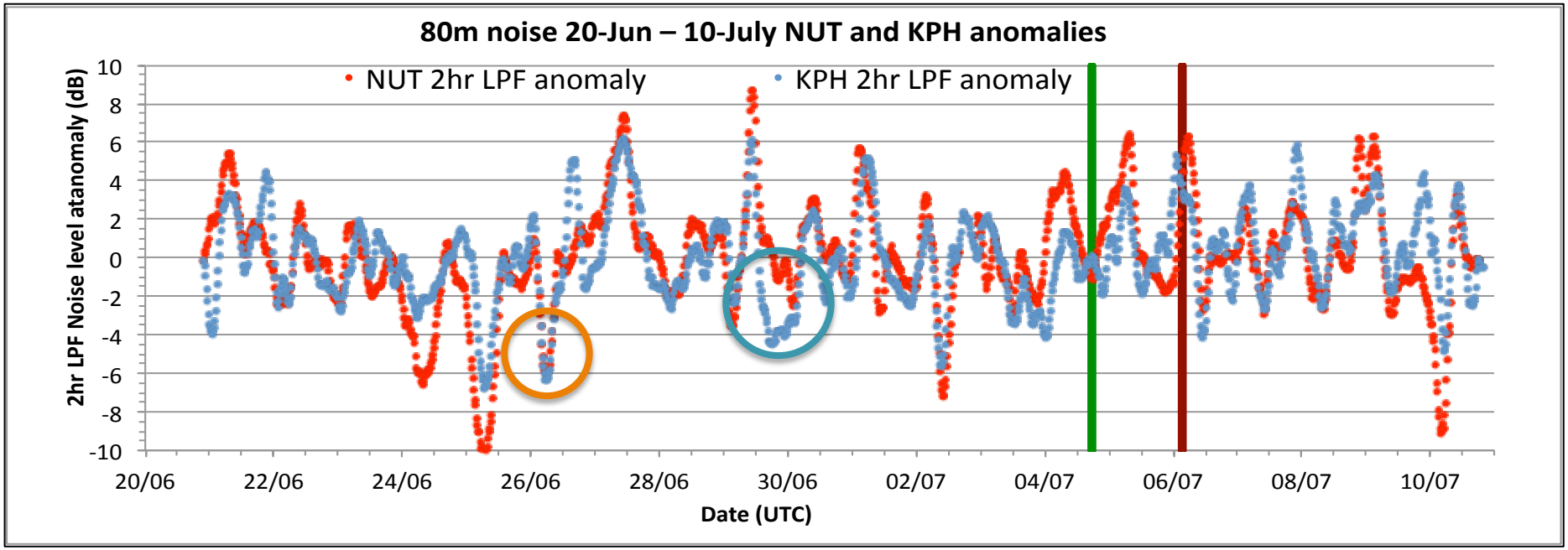


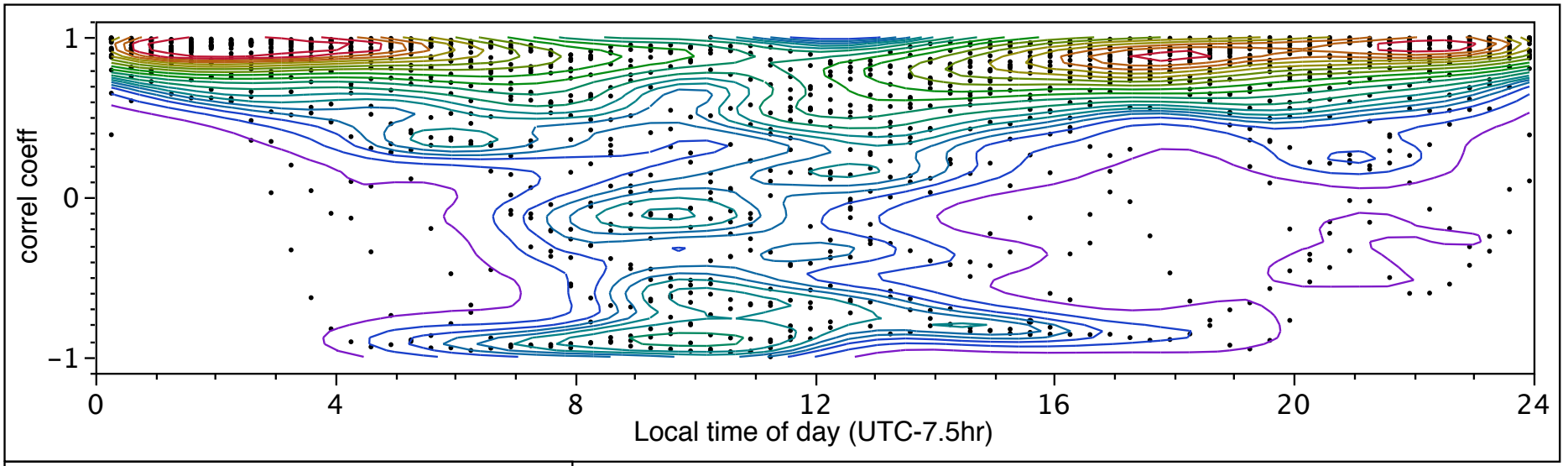
Derivation of anomaly from longer-term mean





Coherent noise fluctuations: KPH & NUT 980km apart



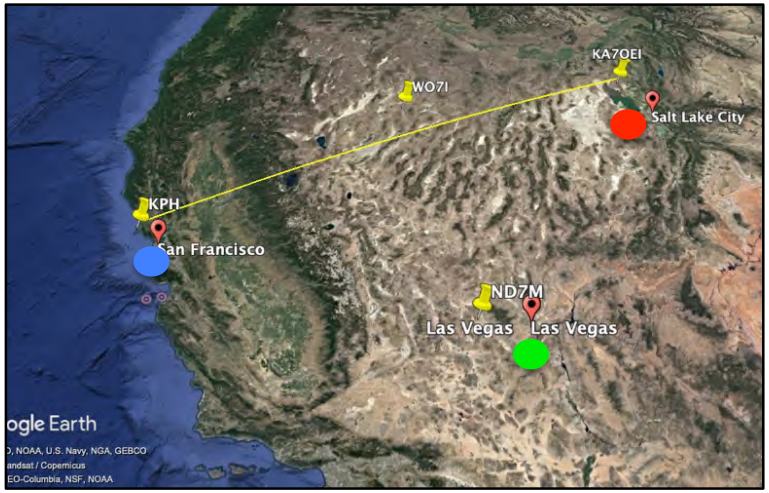


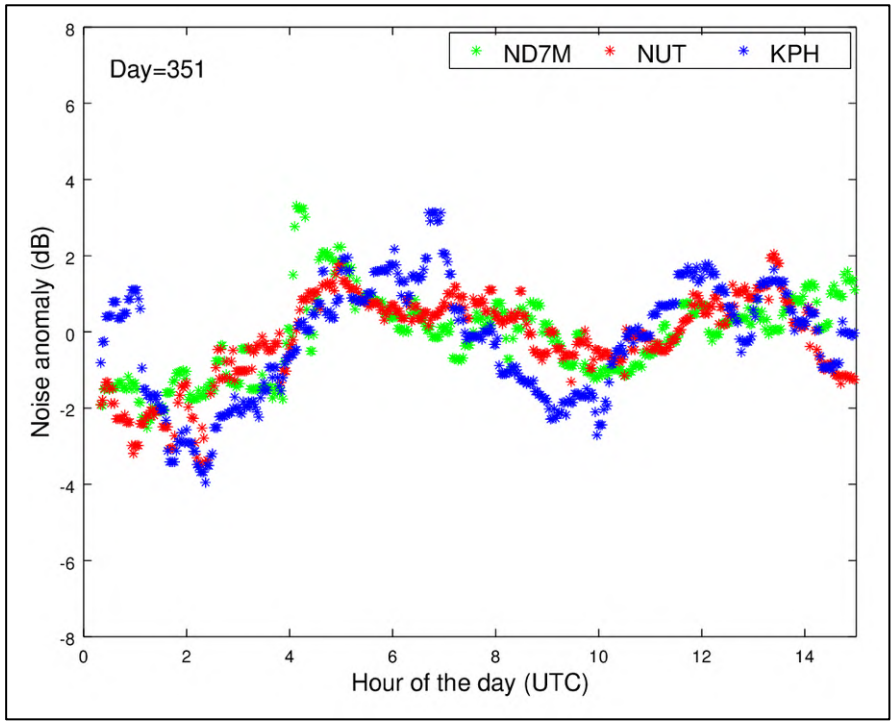
Expand observations to 3 sites: 7 Nov 19 to 3 Mar 2020

ND7M, Dennis, Parhump, S. Nevada

KA7OEI, Clint, Corrine, N. Utah

KPH, Rob et al., Point Reyes, N. Cal.





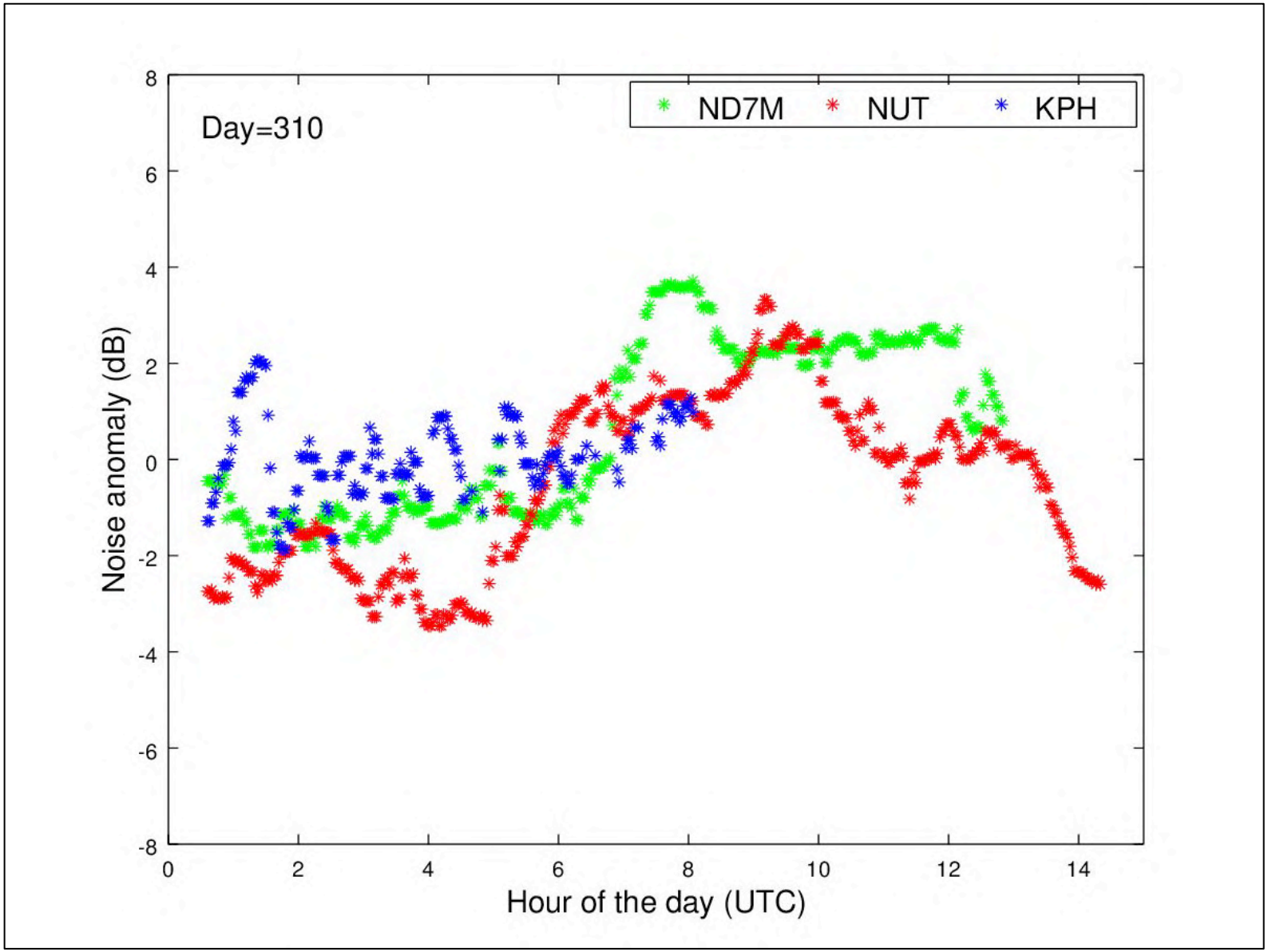
- Given raised local daytime noise levels at NUT and ND7M, restrict visualisation and analysis to between dusk and dawn.
- Given uncalibrated absolute levels, calculate and show anomalies from dusk-dawn median.

Octave and Fiji processing:

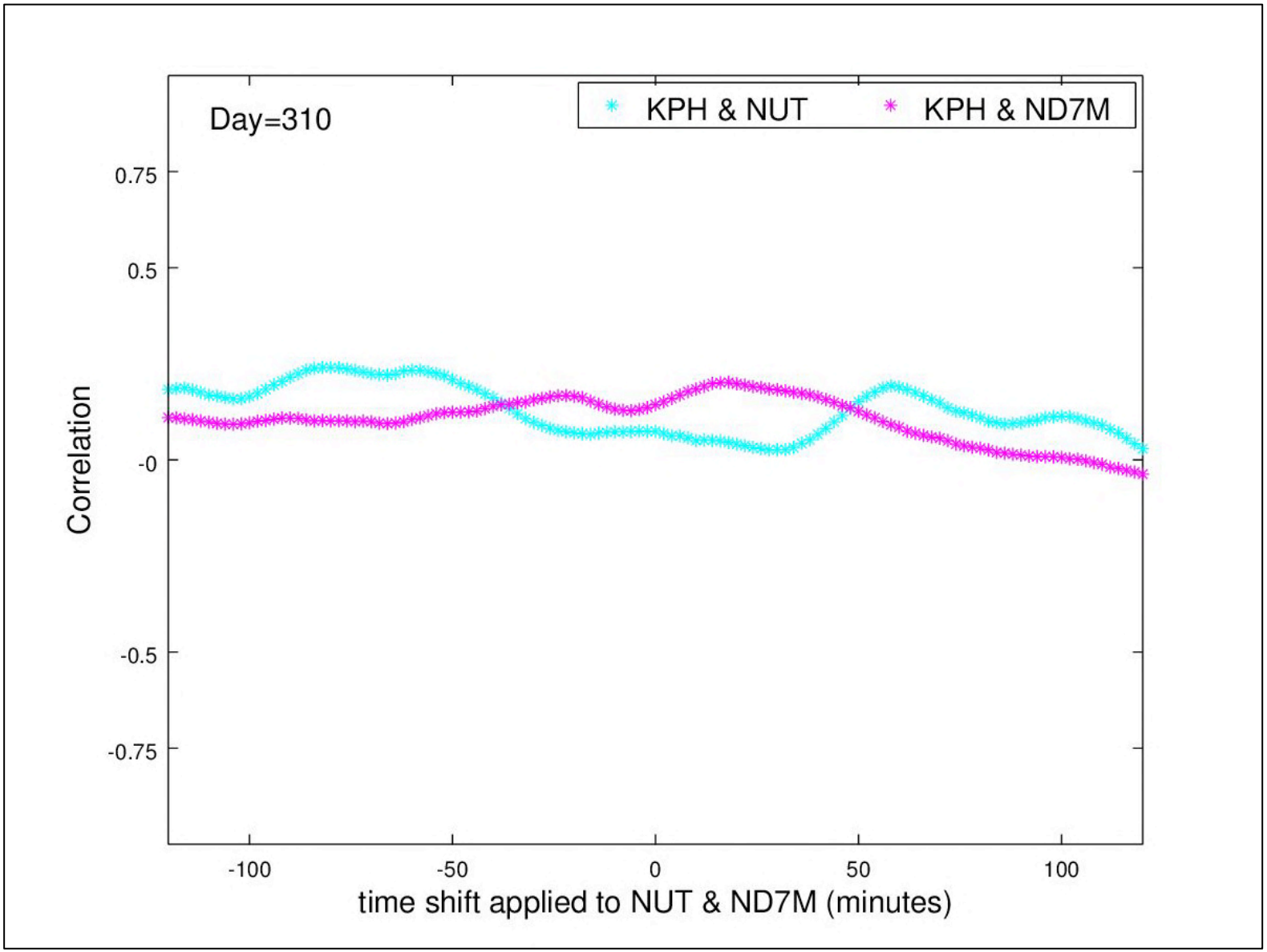
- Data to 2-minute intervals with NaNs.
- Hampel* 7-sample combined median and std. deviation filter.
- Custom script to form anomalies, plot each day between dusk and dawn, daily png file.
- Fiji (ImageJ) takes image sequence and forms into avi movie file.

* See review at /citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.605.6319&rep=rep1&type=pdf

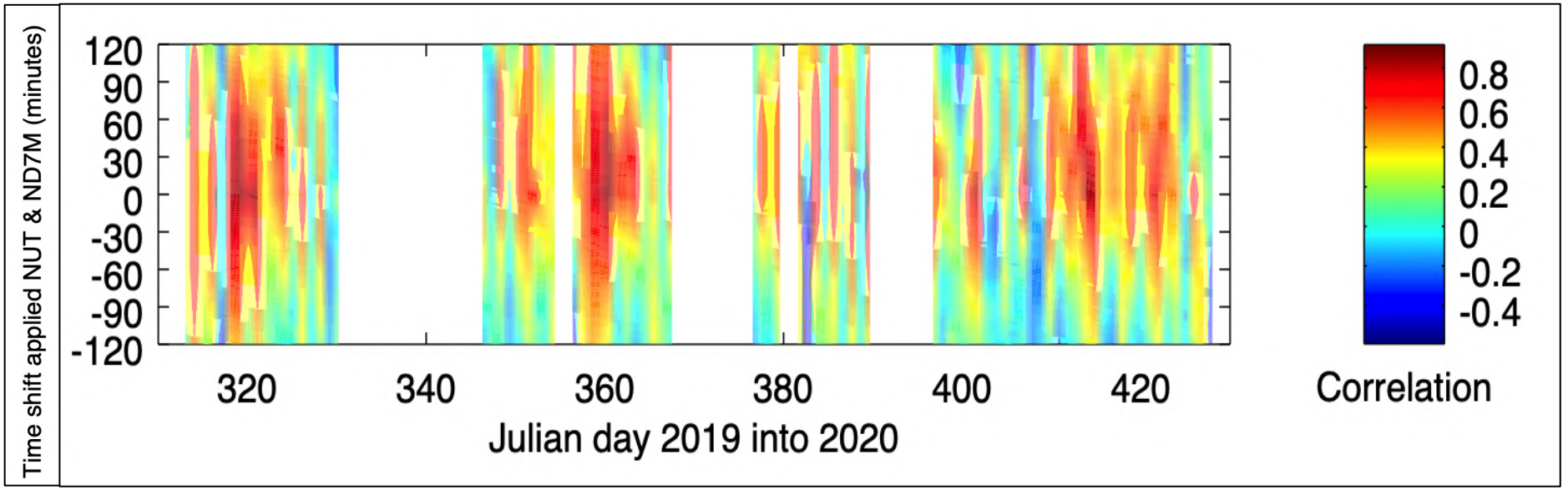
Dusk to Dawn 80m Noise Anomalies at KPH, NUT & ND7M

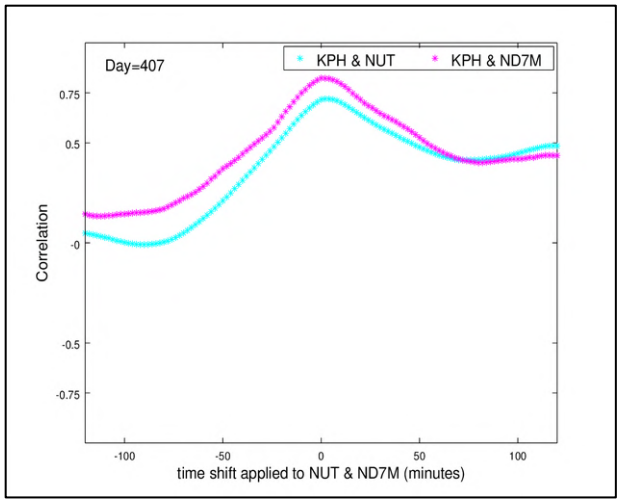


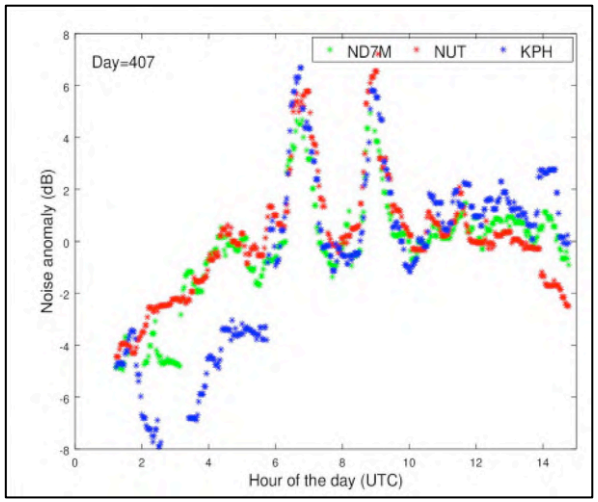
KPH & NUT and KPH & ND7M correlation profiles



Might a contour plot of correlation provide insights?



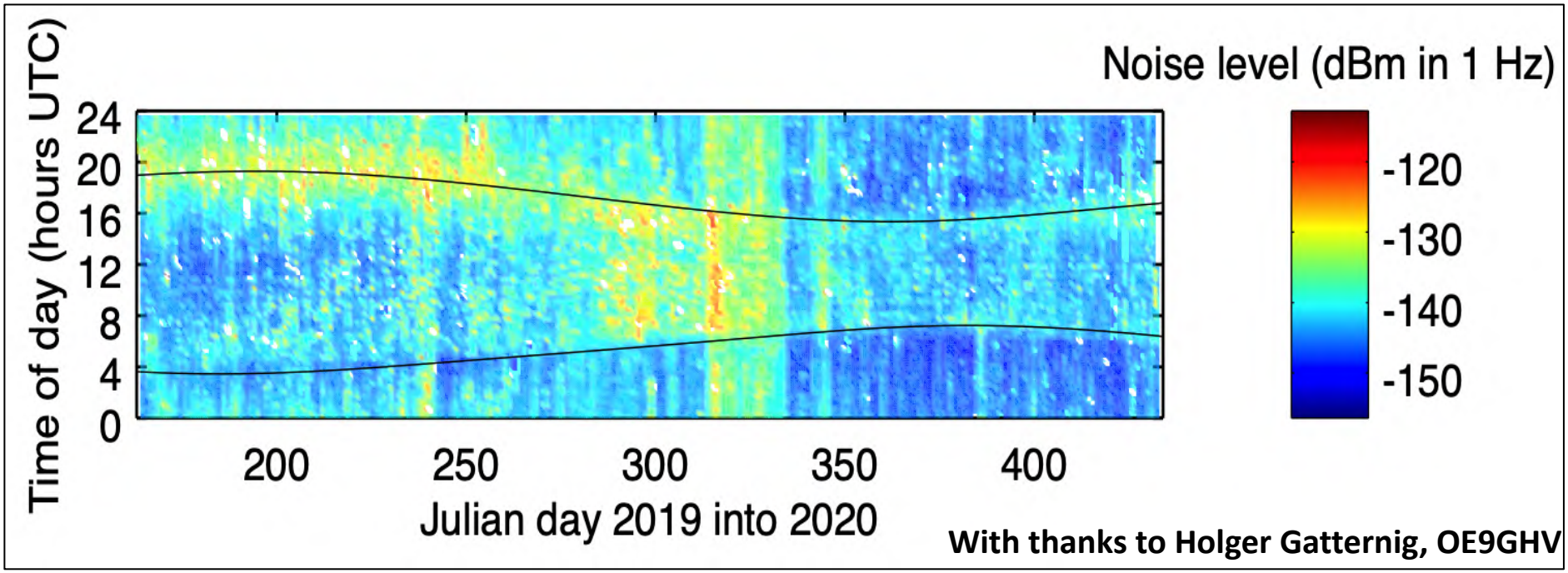




During this period, when present, the correlation generally has a broad peak. Some instances of a superimposed, or narrower, peak, e.g. Day 407 opposite, arise from coherent fluctuations over a time span shorter than dusk to dawn being present.

Day 407 correlation and time series plots, showing narrower than normal correlation peak due to the 6dB peak to peak variations of period of ~2 hours.

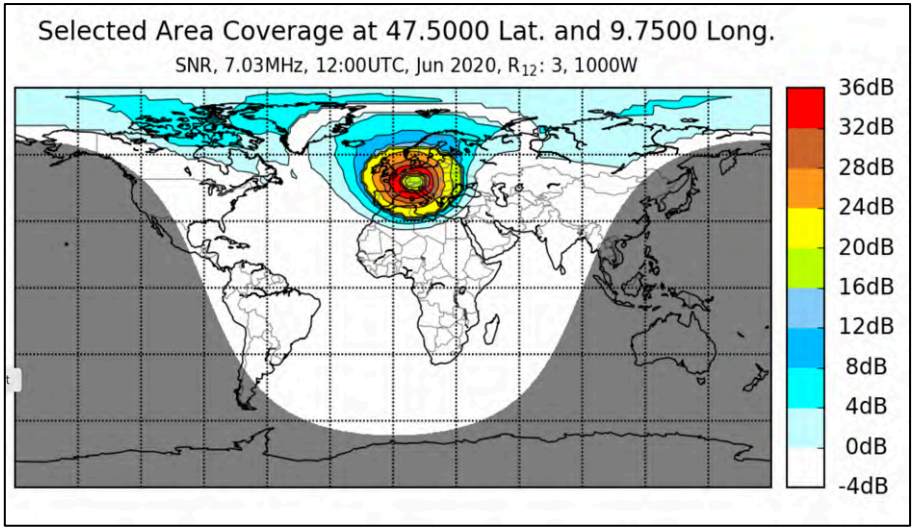
Seasonal changes in the pattern of diurnal noise

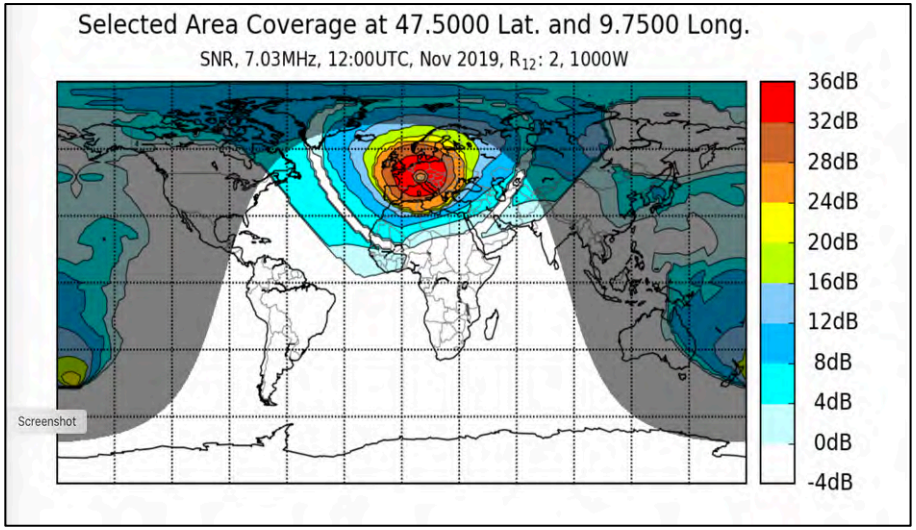


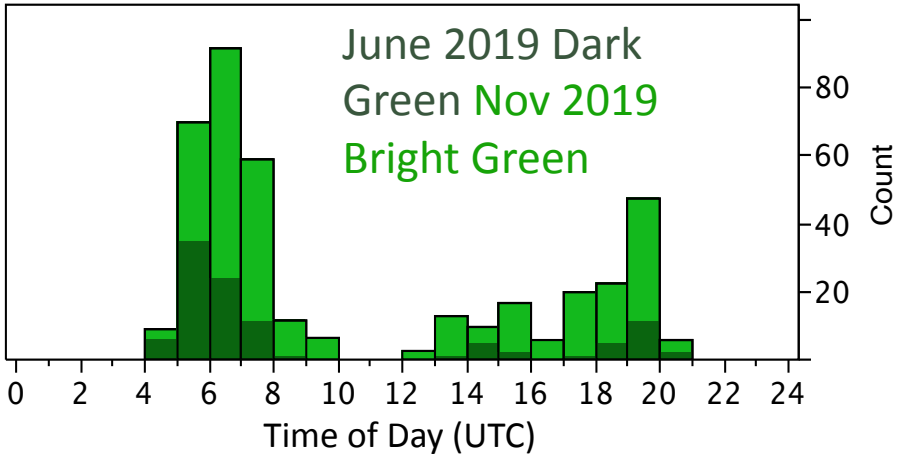
- 40m at a quiet, rural location near Alberschwende, Austria.
- KiwiSDR receiver and an 80m circumference vertical loop antenna via splitter.
- Lines at local sunrise and sunset.
- Summer mid-day minimum from D layer absorption, evening peak due to thunderstorms.
- Challenge: Maintaining a stable calibration given hardware and antenna changes.
- *Speculative: Autumn-winter daytime maximum from southern hemisphere summer evening/ night-time thunderstorms?*

Noon propagation to OE9GHV: June and November

June 2019 ITURHF Propagation model at http://www.predtest.uk/ Nov 2019







Histograms by time of day of VK/ZL 40m WSPR spots received at OE9GHV.

- Propagation model (of transmit signal from OE9GHV) does suggest paths open to the night-time Southwest Pacific at noon UTC.
- Histograms of VK and ZL WSPR spots at OE9GHV supports existence of afternoon paths to VK and ZL in November.

Part 3: Questions

- Methods
  - Are there other techniques that would improve robustness of our noise estimates?
  - Are there standard tools, e.g. Octave packages, RF-GIS that can ease the task of dealing with this data?
  - What other processing and visualisation approaches might be useful?
- Observations
  - We've not come across other projects looking at daily to seasonal LF-HF noise − what have we missed?
  - Are there pitfalls in our use of anomalies that could lead to false conclusions? If so, what could we do instead?
  - Are there numerical simulation models of LF-HF noise, with data assimilation to provide realism, that a HamSCi Community member could run and use?

Postscript

Experimental WSPR database for amateur investigations*

Experimental WSPR database for amateur investigations*

WSPR spots in
ca. 1.6million/day

Wsprnet.org database
Query by Band, tx_call, rx_id
5 fixed periods hour - 2 weeks
9 sort by options
Uniques only option
1,000 spot limit web page
10,000 limit via curl
Archive files up to previous day

Scrape of up to 10,000 spots every 3 minutes

wsprdaemon direct upload

Influx time series database
16-core 24GB 500MB SSD server

- Adds Lat, Lon for tx and rx, vertex of great circle path, FFT noise for wsprdaemon reporters.
- SQL-like flat file queries on all fields.
- Command line interface, curl, bash script inc. .mat Matlab file
- Data retention and spot download limits TBD

Example query

SELECT tx_call, tx_grid, rx_id, rx_grid, SNR FROM SPOTS WHERE tx_grid =~ /EN|FN/ AND rx_grid =~ /IO|JO/ AND band = '30' LIMIT 1000

Experience to date

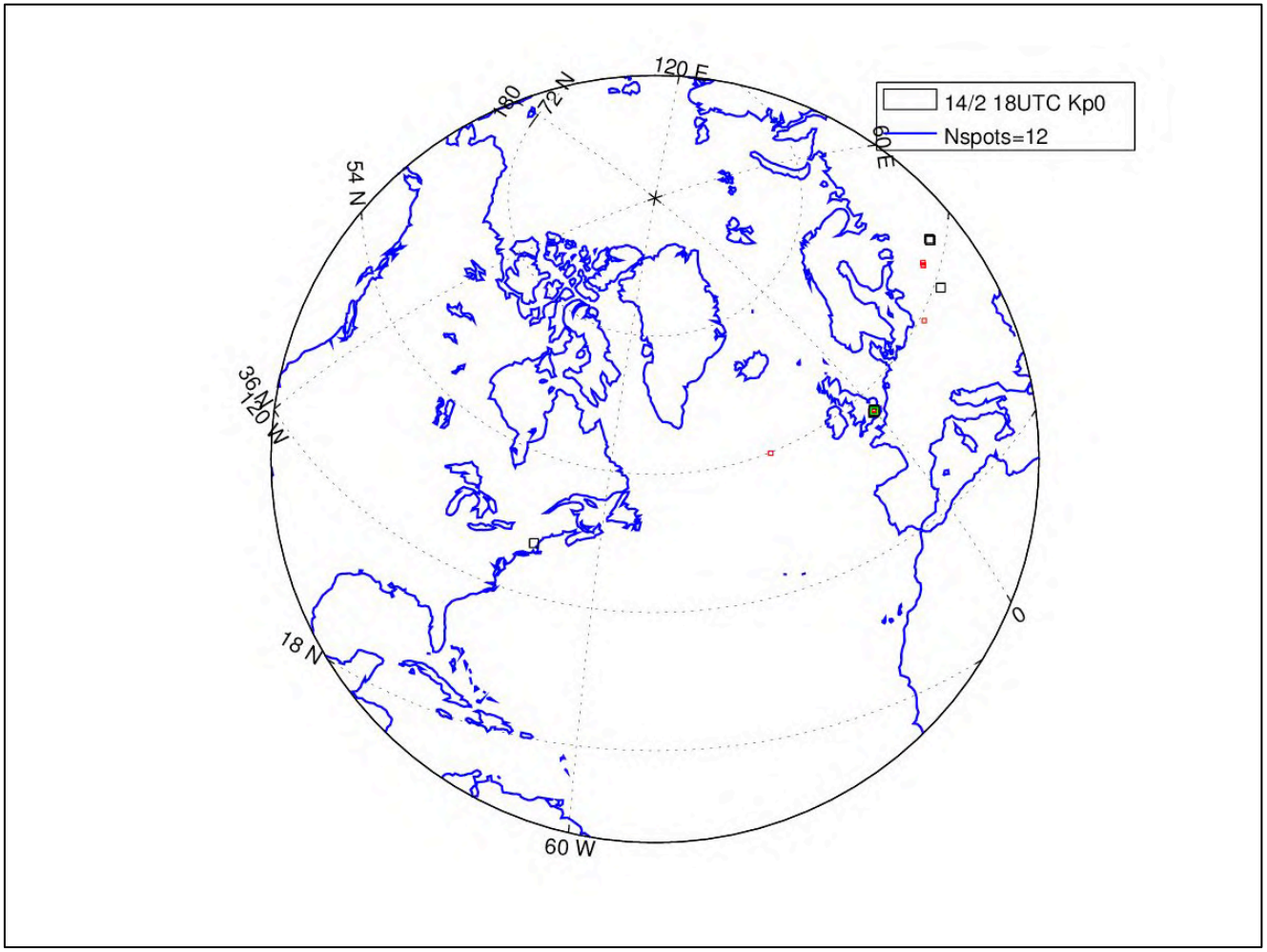
- Greatly increased appreciation of wsprnet.org!
- High series cardinality 1M (approx. number of distinct band, tx_call, rx_id combinations) can grind some queries to a halt with ~40M spots.
- Apply methods to filter wrong decodes
- Investigate other DBs e.g. Timescale

*that may also be of interest for scholarly research …

Example animations from Influx database queries

workflow

wsprnet.org → Influx DB → Query with .mat output file → Octave with m.map library hourly png files → Fiji (ImageJ) png files to avi movie



Single receiver, G4HZX, London, UK.

Band 40m.

Transmitters in black.

Great Circle path vertex in red.

Concentrating on paths crossing the N. Atlantic.

14-19 Feb 2020

Kp from nearest 3hr report

From https://services.swpc.noaa.gov/text/daily-geomagnetic-indices.txt

Western Hemisphere tx, Western Europe rx