Version 2.0 November 2020 Gwyn Griffiths gwyn@autonomousanalytics.com

WsprDaemon Timescale Databases Notes

Commands in this guide are shown in red in Courier font, and responses in blue. All the testing has been on a Raspberry Pi running Raspberry Pi OS August 2020 based on Debian 'Buster' unless otherwise noted. The author welcomes comments and corrections.

Over late summer and into fall 2020 Rob Robinett AI6VN made significant personal investments in hardware to run the WsprDaemon Timescale database. He also made arrangements for the server to be housed at a secure Internet Tier-1 colocation facility. In addition, Rob implemented a fast and secure API interface to obtain spot data from wsprnet.org. Data from wsprnet.org are now in a new Timescale database, with new data fields and some changes to existing field names. Please use this new guide and not V1 that refers to what is now a legacy system that may be taken offline at some point.

Check the WsprDaemon groups.io page at https://groups.io/g/WsprDaemon for news.

1. Introduction and Overview

1.1 WsprDaemon Data Architecture

An overview of the WsprDaemon Timescale[1] databases is shown in Figure 1.1. Despite this complexity there are straightforward routes for all types of users to gain access to the data using the methods outlined in this Guide.

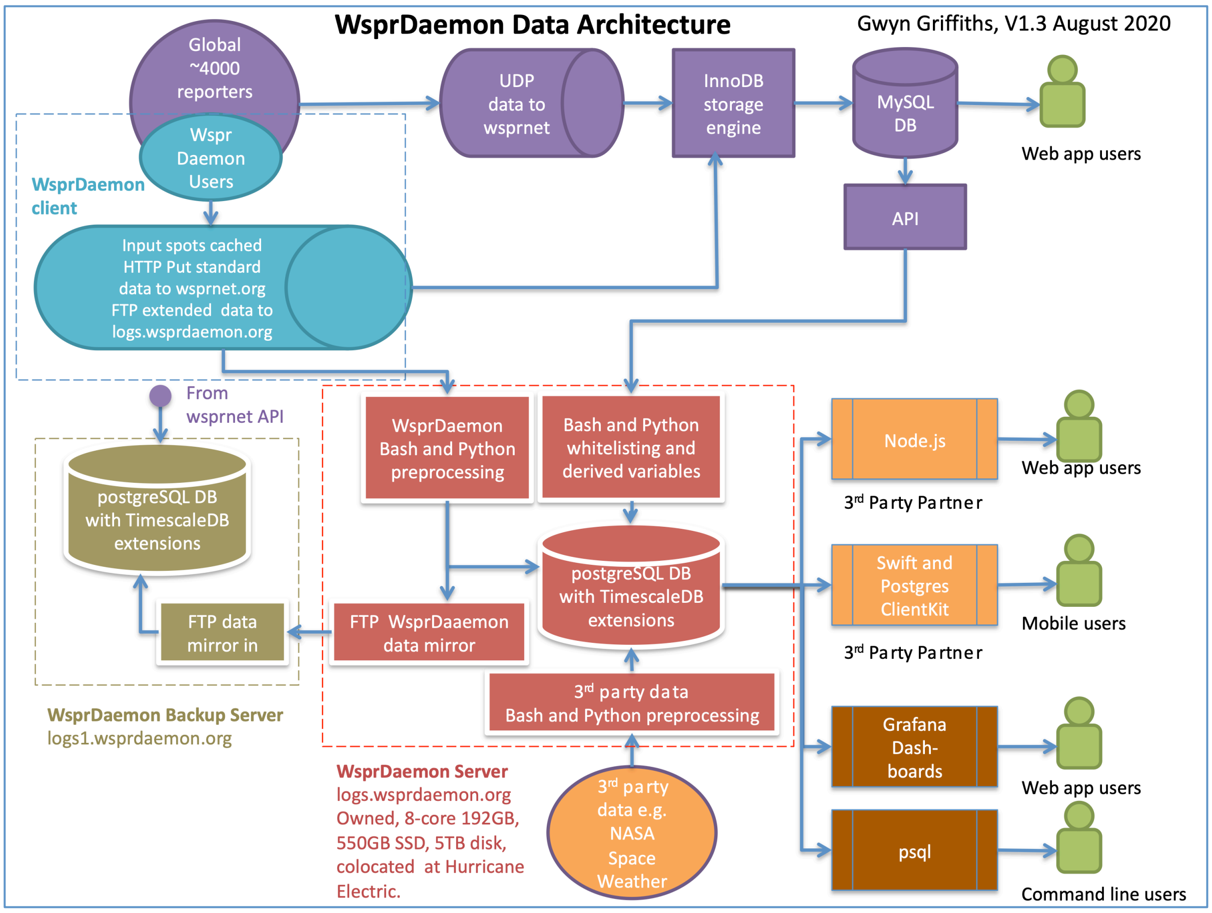

WsprDaemon Data Architecture
Gwyn Griffiths, V1.3 August 2020
Global ~4000 reporters
UDP data to wsprnet
InnoDB storage engine
MySQL DB
Web app users
API
Wspr Daemon Users
WsprDaemon client
Input spots cached HTTP Put standard data to wsprnet.org FTP extended data to logs.wsprdaemon.org
From wsprnet API
postgreSQL DB with TimescaleDB extensions
FTP data mirror in
WsprDaemon Backup Server
logs1.wsprdaemon.org
WsprDaemon Bash and Python preprocessing
Bash and Python whitelisting and derived variables
postgreSQL DB with TimescaleDB extensions
FTP WsprDaaemon data mirror
3rd party data Bash and Python preprocessing
WsprDaemon Server
logs.wsprdaemon.org
Owned, 8-core 192GB, 550GB SSD, 5TB disk, colocated at Hurricane Electric.
3rd party data e.g. NASA Space Weather
Node.js
3rd Party Partner
Web app users
Swift and Postgres ClientKit
Mobile users
3rd Party Partner
Grafana Dash-boards
Web app users
psql
Command line users

Figure 1.1 A simplified overview block diagram of the WsprDaemon data architecture.

The key points to note are:

1. The WsprDaemon data architecture currently comprises two **databases**, namely:
   a. **wsprnet** - with a data acquisition route represented in the diagram by the purple blocks - where WSPR spots forwarded by the global community of reporters to wsprnet.org are copied to our Timescale installation via an API every two minutes.
   b. **tutorial** - with a data acquisition route represented in the diagram by the cyan blocks - that accepts data from users running WsprDaemon[2] software to acquire their WSPR spots and report local noise.
2. In this guide we use postgreSQL terminology, and so, each **database** contains one or more **tables,** a full explanation of the data in each column is in Annex A, in summary:
   a. **Database wsprnet** contains a single **table** - **spots** - whose columns are shown in Table 1.1.

[1] Timescale (https://www.timescale.com/) provides extensions to the well-established postgreSQL open source database (https://www.postgresql.org/) to handle time series data efficiently.
[2] See https://github.com/rrobinett/wsprdaemon on how to obtain the software

Column	Type
wd_time	timestamp without time zone
Spotnum	bigint
Date	integer
Reporter	text
ReporterGrid	character(6)
dB	smallint
MHz	double precision
CallSign	text
Grid	character(6) N
Power	smallint
Drift	smallint
distance	smallint
azimuth	smallint
Band	smallint
version	character(10)
code	smallint
wd_band	text
wd_c2_noise	real
wd_rms_noise	real
wd_rx_az	real
wd_rx_lat	real
wd_rx_lon	real
wd_tx_az	real
wd_tx_lat	real
wd_tx_lon	real
wd_v_lat	real
wd_v_lon	real

Table 1.1 Column names and types for the table spots in database wsprnet

b. Database tutorial currently contains three tables: **kp**, **wsprdaemon_noise** and **wsprdaemon_spots**.

kp, a geomagnetic disturbance index at three-hourly intervals, is scraped each day from NOAA's Space Weather Prediction Center. The column names and types are listed in Table 1.2. The mid-latitude index, kp_mid, is from Fredericksburg, Virginia, and kp_high from College, Alaska.

Column	Type
time	timestamp without time zone
kp_mid	integer
kp_high	integer
kp_planetary	integer

Table 1.2 Column names and types for the table kp in database tutorial

wsprdaemon_noise: Users of WsprDaemon software, particularly those using KiwiSDRs, have the option of uploading estimates of local noise obtained at the same time and in the same frequency band as the decoded WSPR transmissions[3]. The column names and types are listed in Table 1.3, with full details in Annex A.

[3] Details of the noise estimation algorithms and examples in use are available in: Griffiths, G., Robinett, R. and Elmore, G., 2020. Estimating LF-HF band noise while acquiring WSPR spots. QEX, September-October 2020 and also in a detailed report available on ResearchGate.net.

```
Column     | Type
-----------+-----------------------------
 time      | timestamp without time zone
 site      | text
 receiver  | text
 rx_grid   | text
 band      | text
 rms_level | double precision
 c2_level  | double precision
 ov        | integer
```

Table 1.3 Column names and types for the table wsprdaemon_noise

wsprdaemon_spots:

WsprDaemon access additional data fields within WSJT-X's wsprd decoder, fields that are not uploaded to wsprnet.org, but are included in this table in case they may be of interest to some in the WSPR community, see Annex A for a full description

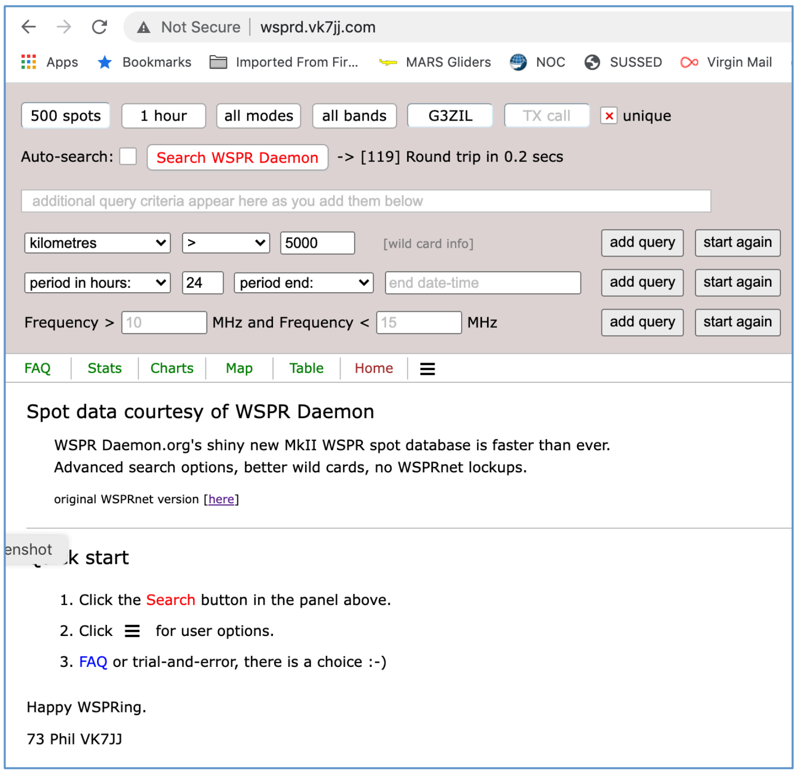
```
    Column     | Type
---------------+-------------------------------
 time          | timestamp without time zone
 band          | text
 rx_grid       | text
 rx_id         | text
 tx_call       | text
 tx_grid       | text
 SNR           | double precision
 c2_noise      | double precision
 drift         | double precision
 freq          | double precision
 km            | double precision
 rx_az         | double precision
 rx_lat        | double precision
 rx_lon        | double precision
 tx_az         | double precision
 tx_dBm        | double precision
 tx_lat        | double precision
 tx_lon        | double precision
 v_lat         | double precision
 v_lon         | double precision
 sync_quality  | integer
 dt            | double precision
 decode_cycles | integer
 jitter        | integer
 rms_noise     | double precision
 blocksize     | integer
 metric        | integer
 osd_decode    | integer
 receiver      | character varying
 nhardmin      | integer
 ipass         | integer
```

Table 1.4 Column names and types for the table wsprdaemon_spots

1.2 Paths and methods for accessing data from WsprDaemon servers

Read access to the WsprDaemon wsprnet database table **spots**, takes four main forms:

1. Using an **App** from a third-party developer, where most of the intricacies are hidden from view. These Apps provide the basic search functionality found on wsprnet.org and added graphs and tables. Currently two Apps access our wsprnet **spots** table:
   a. **wsprd.vk7jj.com**. As well as simple queries, Phil Barnard provides a form-filling advanced query option to use our postgreSQL interface, Figure 1.2.
   The time taken for each query is shown, and a running average; on 10 November 2020 the average response time over 1654 queries was 0.7 seconds.



500 spots | 1 hour | all modes | all bands | G3ZIL | TX call | ✗ unique

Auto-search: ☐ Search WSPR Daemon -> [119] Round trip in 0.2 secs

additional query criteria appear here as you add them below

kilometres | > | 5000 | [wild card info] | add query | start again

period in hours: | 24 | period end: | end date-time | add query | start again

Frequency > 10 MHz and Frequency < 15 MHz | add query | start again

FAQ | Stats | Charts | Map | Table | Home | ☰

Spot data courtesy of WSPR Daemon

WSPR Daemon.org's shiny new MkII WSPR spot database is faster than ever.
Advanced search options, better wild cards, no WSPRnet lockups.

original WSPRnet version [here]

enshot ...k start

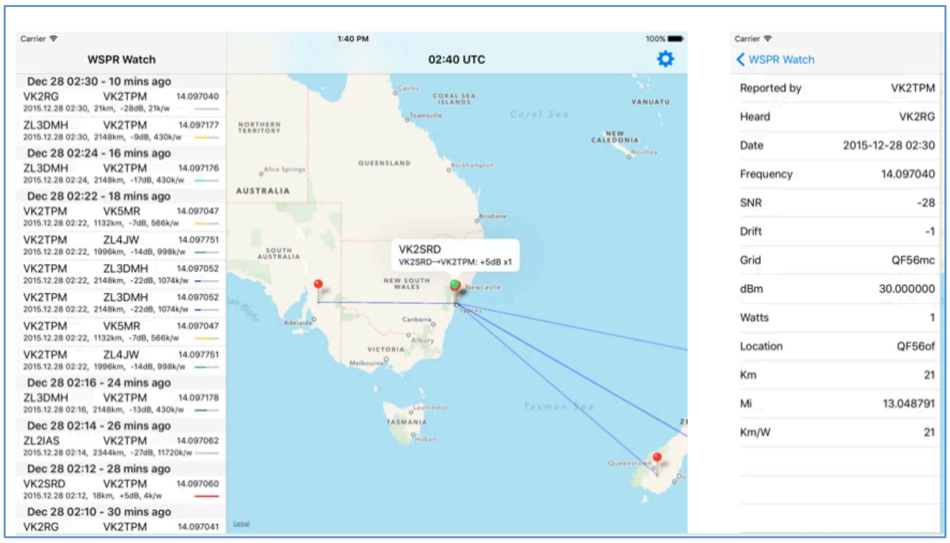
1. Click the Search button in the panel above.
2. Click ☰ for user options.
3. FAQ or trial-and-error, there is a choice :-)

Happy WSPRing.

73 Phil VK7JJ

Figure 1.2 Screen shot of the advanced search panel at wsprd.vk7jj.com

   b. **wsprwatch**, Figure 1.3, is an iOS App by Peter Marks, VK2TPM, available at https://apps.apple.com/us/app/wspr-watch/id532487317



WSPR Watch

Dec 28 02:30 - 10 mins ago
VK2RG VK2TPM 14.097040
2015.12.28 02:30, 21km, -28dB, 21k/w
ZL3DMH VK2TPM 14.097177
2015.12.28 02:30, 2148km, -9dB, 430k/w
Dec 28 02:24 - 16 mins ago
ZL3DMH VK2TPM 14.097176
2015.12.28 02:24, 2148km, -17dB, 430k/w
Dec 28 02:22 - 18 mins ago
VK2TPM VK5MR 14.097047
2015.12.28 02:22, 1132km, -7dB, 566k/w
VK2TPM ZL4JW 14.097751
2015.12.28 02:22, 1996km, -14dB, 998k/w
VK2TPM ZL3DMH 14.097052
2015.12.28 02:22, 2148km, -22dB, 1074k/w
VK2TPM ZL3DMH 14.097052
2015.12.28 02:22, 2148km, -22dB, 1074k/w
VK2TPM VK5MR 14.097047
2015.12.28 02:22, 1132km, -7dB, 566k/w
VK2TPM ZL4JW 14.097751
2015.12.28 02:22, 1996km, -14dB, 998k/w
Dec 28 02:16 - 24 mins ago
ZL3DMH VK2TPM 14.097178
2015.12.28 02:16, 2148km, -13dB, 430k/w
Dec 28 02:14 - 26 mins ago
ZL2IAS VK2TPM 14.097062
2015.12.28 02:14, 2344km, -27dB, 11720k/w
Dec 28 02:12 - 28 mins ago
VK2SRD VK2TPM 14.097060
2015.12.28 02:12, 18km, +5dB, 4k/w
Dec 28 02:10 - 30 mins ago
VK2RG VK2TPM 14.097041

< WSPR Watch

Reported by	VK2TPM
Heard	VK2RG
Date	2015-12-28 02:30
Frequency	14.097040
SNR	-28
Drift	-1
Grid	QF56mc
dBm	30.000000
Watts	1
Location	QF56of
Km	21
Mi	13.048791
Km/W	21

Figure 1.3 Screen shot of WSPRwatch, an iOS app from Peter Marks, VK2TPM

2. Using **Grafana**[4], a powerful graphing package with built-in connections to postgreSQL databases. We have a selection of Grafana Dashboards on the WsprDaemon server at logs2.wsprdaemon.org:3000 where you are welcome to use the guest userid Open and password Open. A full Guide to using Grafana with WsprDaemon data is available via the WsprDaemon website[5].
3. Using **node.js** - this is the method used by Phil Barnard, VK7JJ, to access the data, and he has kindly provided details in **Annex B** as it is clear that others are interested in this route. Questions should be directed to Phil at phil 'at' perite.com.
4. Using **psql** - a command line tool to work with a postgreSQL database. Two modes are available:
    a. **Batch command line:** This mode is useful in, among other applications, bash scripts. Care is needed to get the quotes syntax right when calling for column names with upper case letters and especially if mixed with single quotes needed with character or text data values. A simple example of a bash script used by Jim Lill, WA2ZKD is shown in **Annex C**.
    b. **Interactive mode**: The rest of this guide concentrates on **psql** in interactive mode, but in doing so, provides a rich set of postgreSQL examples that can be used with node.js, Grafana, or any other method for accessing the data where SQL is used.

There are also routes for access that enable data analysis packages to use our databases, for example:

1. Python and subsequently matplotlib, **Annex D** shows a skeleton Python script for accessing our databases and obtaining data.
2. KNIME[6], an "end to end data science" software package where the programmer builds a system by interconnecting diagrams representing pre-built modules, has a postgreSQL connector node[7] that does work with the WsprDaemon databases. With a wide range of third-party modules KNIME is a powerful option for data exploration and presentation. A trivial example is shown in **Annex E**.
3. OCTAVE is a well-established and widely used scientific and engineering data analysis package. PostgreSQL[8] is the only database system it currently connects to directly. The untested route is outlined in **Annex F**.

1.3 Installing PostgreSQL on your local computer

Note: If you already have an SQL program installed, e.g. SQLite or MySQL there may be an issue when it comes to installing PostgreSQL - unfortunately these problems may only come to light as an installation is attempted.

The notes in this section are for a Raspberry Pi, for installation on other operating systems see https://www.postgresql.org/download/ a reminder, command line inputs are in red.

```
sudo apt install postgresql libpq-dev postgresql-client postgresql-client-
common -y and write to
```

[4] See https://grafana.com/
[5] See http://wsprdaemon.org/grafana.html
[6] See https://www.knime.com/
[7]hub.knime.com/knime/extensions/org.knime.features.database/latest/org.knime.database.extension.postgres.node.connector.PostgreSQLDBConnectorNodeFactory
[8] See https://octave.sourceforge.io/database/index.html

If you intend to use Python to read from the databases on the WsprDaemon server you will need an adapter program psycopyg2 for Python3, see Annex D for an example. You will of course need Python 3 installed, and you may need pip3 if not already installed:

```
sudo apt install python3-pip
sudo pip3 install psycopg2
```

Note that you do not need an installation on your own machine of the Timescale DB extensions that are used on the WsprDaemon server alongside postgreSQL. That is, unless you intend to create your own Timescale databases.

This guide can only provide the bare essentials on using postgreSQL to query the WsprDaemon databases. Full details on postgreSQL are available online[9] and at a very useful simplified tutorial website[10].

1.4 Gaining access

We have set up a universal read-only user id: wdread with password JTWSPR2008

With postgreSQL installed on your computer you can access the database **wsprnet** on the WsprDaemon server using:

```
psql -U wdread -d wsprnet -h logs2.wsprdaemon.org
Password for user wdread: JTWSPR2008
wsprnet=>
```

In this command line, the -d option connects us to Database **wsprnet**, which, as a reminder, contains the single table **spots** with data acquired via an API from wsprnet.org. The -h option declares the address of the WsprDaemon server, here it is logs2. If this changes during the currency of this Guide we will post a note on the WsprDaemon groups.io page.

The postgreSQL prompt shows the database name.

To connect directly to the **tutorial** database, with its tables **kp**, **wsprdaemon_noise** and **wsprdaemon_spots** simply change -d wsprnet to -d tutorial in the command line above.

Sections 2–4 of this guide cover navigation and use of the database using psql through a wide range of example queries.

2. WsprDaemon database navigation

Once connected to a database as in section 1.4, to list the **tables** in the **database** use \d:

```
wsprnet=> \d
                List of relations
 Schema |        Name        |   Type    |  Owner
--------+--------------------+-----------+----------
 public | spots              | table     | postgres
 public | spots_Spotnum_seq  | sequence  | postgres
 public | spots_spotnum_seq  | sequence  | postgres
```

To list the **columns** and **data types** within a **table**, use \d with the table name:

```
\d spots
```

This will output the list shown in Table 1.1. We will use these column names in our queries to table spots, most are self explanatory to WSPR users, see Annex A for a full annotated list.

There is no need to log out and then back in to work with the other database, use \c and the database name, for example, if connected to database wsprnet, to connect to database tutorial:

```
wsprnet=> \c tutorial
```

[9] See https://www.postgresql.org/
[10] See https://www.postgresqltutorial.com/

```
psql (12.2, server 12.4 (Ubuntu 12.4-1.pgdg18.04+1))
SSL connection (protocol: TLSv1.3, cipher: TLS_AES_256_GCM_SHA384, bits: 256,
compression: off)
You are now connected to database "tutorial" as user "wdread".
tutorial=>
```

There is an extensive help system, accessible via \h for a list of commands, and then \h command for specific details.

To exit use \q

3. Querying spots from the WsprDaemon wsprnet database

This section provides examples of interactive queries on table **spots** in database **wsprnet** following on from the access and database selection details in Sections 1 and 2. Virtually all examples use very simple postgreSQL expressions of the form:

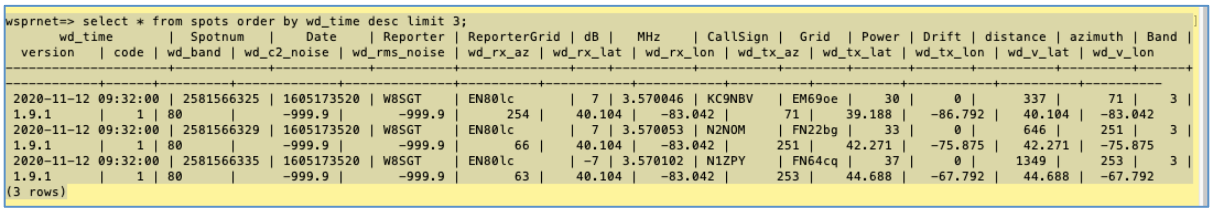
SELECT something FROM table_name WHERE one_or_more_conditions one_or_more_options;

The expression, which can span several lines, must end with a semicolon. If nothing seems to be happening, you may have forgotten the semicolon. If you forget, just type ; at the next prompt. The WHERE clause is not always needed.

To see a short example, for the last 10 records with the newest first from the table **spots** order by time desc is included as an option, and limit 3 sets how many records to output to the screen. The * signifies all fields.

First, connect to the database:

```
psql -U wdread -d wsprnet -h logs2.wsprdaemon.org
Password for user wdread: JTWSPR2008
wsprnet=> select * from spots order by wd_time desc limit 3;
```



```
wsprnet=> select * from spots order by wd_time desc limit 3;
       wd_time        |  Spotnum   |    Date    | Reporter | ReporterGrid | dB |    MHz     | CallSign |  Grid  | Power | Drift | distance | azimuth | Band |
  version    | code | wd_band | wd_c2_noise | wd_rms_noise | wd_rx_az | wd_rx_lat | wd_rx_lon | wd_tx_az | wd_tx_lat | wd_tx_lon | wd_v_lat | wd_v_lon
---------------------+------------+------------+----------+--------------+----+-----------+----------+--------+-------+-------+----------+---------+------+
-----------+------+---------+-------------+--------------+----------+-----------+-----------+----------+-----------+-----------+----------+----------
 2020-11-12 09:32:00 | 2581566325 | 1605173520 | W8SGT    | EN80lc       |  7 | 3.570046 | KC9NBV   | EM69oe |    30 |     0 |      337 |      71 |    3 |
 1.9.1       |    1 | 80      |      -999.9 |       -999.9 |      254 |    40.104 |   -83.042 |       71 |    39.188 |   -86.792 |   40.104 |  -83.042
 2020-11-12 09:32:00 | 2581566329 | 1605173520 | W8SGT    | EN80lc       |  7 | 3.570053 | N2NOM    | FN22bg |    33 |     0 |      646 |     251 |    3 |
 1.9.1       |    1 | 80      |      -999.9 |       -999.9 |       66 |    40.104 |   -83.042 |      251 |    42.271 |   -75.875 |   42.271 |  -75.875
 2020-11-12 09:32:00 | 2581566335 | 1605173520 | W8SGT    | EN80lc       | -7 | 3.570102 | N1ZPY    | FN64cq |    37 |     0 |     1349 |     253 |    3 |
 1.9.1       |    1 | 80      |      -999.9 |       -999.9 |       63 |    40.104 |   -83.042 |      253 |    44.688 |   -67.792 |   44.688 |  -67.792
(3 rows)
```

The output to the screen is paged, press the space bar for the next page, or type q to end.

A where clause lets us specify columns of interest. Note the need for double quotes for "Reporter", needed for a column name with a capital letter. Also, note the use of single quotes around 'G3ZIL' and the wd_band '30'. Reporter and wd_band columns are of type character, hence the need for single quotes. If omitted there will be an error message.

```
wsprnet=>  select * from spots where "Reporter" = 'G3ZIL' and wd_band = '30'
order by wd_time desc limit 10;
```

3.1 Export query output to a file

In this interactive mode where you are connecting to the remote logs2.wsprdaemon.org server you can download the result of a query to the current directory of your local computer using the following:

```
tutorial=>  \copy (select * from spots where "Reporter" = 'G3ZIL' and wd_band
= '30' order by wd_time desc limit 3) to 'G3ZIL_spots.csv' with csv;
COPY 3
```

The \ before the copy signifies an export to a file on the client computer. Note that the postgreSQL query must be within parentheses. There are limitations in the ability of the csv format to handle some aspects of postreSQL output, such as NULLs; full details are in the postgreSQL documentation[11].

The output of the query on the local computer is:

```
pi@raspberrypi:~ $ cat G3ZIL_spots.csv
2020-11-12 11:18:00,2581778396,1605179880,G3ZIL,IO90hw,-
8,10.140184,DJ6OI,JO41tp,23,0,768,268,10,          ,1,30,-999.9,-
999.9,80,50.938,-1.375,268,51.646,9.625,51.646,9.625
2020-11-12 11:18:00,2581778405,1605179880,G3ZIL,IO90hw,-
9,10.140157,OZ7IT,JO65df,37,0,1028,248,10,          ,1,30,-999.9,-
999.9,57,50.938,-1.375,248,55.229,12.292,55.229,12.292
2020-11-12 11:16:00,2581773016,1605179760,G3ZIL,IO90hw,-
1,10.140275,OE7WRT,JN57qg,37,0,1012,298,10,          ,1,30,-999.9,-
999.9,109,50.938,-1.375,298,47.271,11.375,50.938,-1.375
```

The wd_time format in the first column is directly usable in Excel or other spreadsheets as date time.

Simple expressions in a query

Here is an example of a search for a particular Reporter and wd_band that only lists column dB (that is, SNR) above a threshold of -10 dB, where only wd_time, CallSign and dB are requested as output (wd_time is there by default). As dB is a numeric column we can use the mathematical operator >, and no single quotes around its numeric value -10. But single quotes are needed around '40' as wd_band is a text column. And a reminder, double quotes are needed around Reporter, CallSign and dB as these column name contain capitals.

```
wsprnet=# select wd_time, "CallSign", "dB" from spots where "Reporter" =
'G3ZIL' and wd_band = '40' and "dB" > -10 limit 10;
```

3.2 Wildcards

Queries can include wildcards, where % matches zero or more characters or numbers. This example uses like and the wildcard symbol % for any Grid with characters JN for Reporter 'G3ZIL' and where wd_band = '60', remembering the quotes:

```
wsprnet=# select wd_time, "CallSign", "Grid", "dB" from spots where "Grid"
like 'JN%' and "Reporter" = 'G3ZIL' and wd_band = '60' order by wd_time desc
limit 10;
```

The _ character represents one character or number. If needed there is not like to exclude.

This next example shows the syntax for a query where Grid can be any in EN or FN and receive ReporterGrid any in IO or JO and wd_band is 30, note the required use of parentheses around the or pairs:

```
wsprnet=#  select wd_time, "CallSign", "Grid", "Reporter", "ReporterGrid",
"dB" from spots where ("Grid" like 'EN%'or "Grid" like 'FN%') and
("ReporterGrid" like 'IO%' or "ReporterGrid" like 'JO%') and wd_band = '30'
order by wd_time desc limit 10;
```

3.3 Mathematical operations

Mathematical operations on one or more columns are allowed; column names within the mathematical expression (here "dB" - "Power" + 30) must be in double quotes as they include capitals. In this example we calculate and output the SNR normalised[12] to a transmit power of 30

[11] See https://www.postgresql.org/docs/9.2/sql-copy.html
[12] We are, of course, aware of the pitfalls of any attempt at normalisation, power may not be correctly reported and the actual radiated power and directional characteristics of the transmit and receive antennas are not often well known.

dBm (1 watt) by subtracting Power from dB and adding 30. The as gives the resulting column a name:

```
wsprnet=#  select wd_time, "CallSign", "Grid", "Power", "dB", ("dB" - "Power"
+ 30) as "Norm_SNR" from spots where "Grid" like 'FN%' and "Reporter" =
'G3ZIL' and wd_band = '80' order by wd_time desc limit 10;
```

3.4 Simple statistics and how to specify a time interval

Simple statistics can be obtained as in these examples, having done a count first to check the validity of the results. Here, as an example of how to set a time interval for the query we have chosen to span approximately local night.

```
wsprnet=#  select count("dB") from spots where wd_band = '40' and "Reporter"
= 'G3ZIL' and "CallSign"= 'K4APC' and wd_time > '2020-10-25T19:00:00Z' and
wd_time < '2020-10-26T07:00:00Z';
```

Having established that there are enough spots in the interval for meaningful statistics we form the simple arithmetic average, with round to round the avg to the nearest integer:

```
wsprnet=#  select round(avg("dB")) from spots where wd_band = '40' and
"Reporter" = 'G3ZIL' and "CallSign"= 'K4APC' and wd_time > '2020-10-
25T19:00:00Z' and wd_time < '2020-10-26T07:00:00Z';
```

This example is for max, we can also use min

```
wsprnet=#  select max("dB") from spots where wd_band = '40' and "Reporter" =
'G3ZIL' and "CallSign"= 'K4APC' and wd_time > '2020-10-25T19:00:00Z' and
wd_time < '2020-10-26T07:00:00Z';
```

We can calculate standard deviation with stddev, and here we have used trunc with 1 to give the result to 1 decimal places. We cast the result of stddev as numeric for trunc to work:

```
wsprnet=#  select trunc(cast (stddev("dB") as numeric),1) from spots where
wd_band = '40' and "Reporter"= 'G3ZIL' and "CallSign"= 'K4APC' and wd_time >
'2020-10-25T19:00:00Z' and wd_time < '2020-10-26T07:00:00Z';
```

The statistics above have been evaluated over a specific, user-set time interval. Using a Timescale extension to postgreSQL we can easily obtain statistics over a series of time intervals by using time_bucket. In this example, we've set a time_bucket of 10 minutes, aliased as ten_min, and we're calculating the median distance within each ten minute interval using the percentile_disc function with 0.5 (i.e. the median, if we were after lower quartile it would be 0.25, and 0.75 for upper quartile):

```
wsprnet=#  SELECT time_bucket('10 minutes', wd_time) AS ten_min,
percentile_disc(0.5) within group(order by distance) as """median""" FROM
spots WHERE "Reporter"= 'G3ZIL' AND  wd_band = '40' GROUP BY ten_min order by
ten_min desc limit 10;
```

3.5 Query on the azimuth angle at the receiver.

wsprnet.org calculates the azimuth at the transmitter, azimuth, as the initial bearing of the path to the receiver. However, wsprnet.org does not calculate the azimuth on arrival at the receiver. It is the arrival azimuth, wd_rx_az, that is needed if one is looking to use WSPR spot information to help evaluate the directionality of receive antennas. Except for special cases, such as receiver and transmitter on the same longitude, or where the path distance is less than a few hundred km, azimuth and wd_rx_az are not simply 180˚ apart. This example is for receiver KFS where band is '40' and we search for transmitters from azimuths between 60˚ and 90˚ where distance is between 1000 and 2000 km.

```
wsprnet=#  select wd_time, "CallSign", "Grid", distance, wd_rx_az, "dB" from
spots where "Reporter" = 'KFS' and wd_band = '40' and distance > 1000 and
distance < 2000 and wd_rx_az > 60 and wd_rx_az < 90 limit 10;
```

3.6 Query on the vertex latitude

We have added a calculation of the latitude and longitude of the position of the vertex of the great circle path between transmitter and receiver. The vertex is the most northern or southern position. In this example we select a series of parameters where the band is '40' and the vertex latitude is > 60 (i.e. above 60˚N). Where the path is predominantly north-south the vertex is most likely to be at either the receiver or transmitter. Queries on the vertex lat and lon may be informative when looking at paths that are near to, or cross, the northern and southern Auroral Ovals:

```
wsprnet=#  select "CallSign", "Reporter", wd_tx_lat, wd_tx_lon, wd_rx_lat,
wd_rx_lon, wd_v_lat, wd_v_lon, "dB" from spots where wd_band = '40' and
wd_v_lat > 60 limit 10;
```

3.7 Select only spot lines with distinct field entries

In this example we want to list only distinct (unique) CallSigns heard by G3ZIL on 40 m in the last hour, using the distinct on clause. Note the order by must match the distinct on field. This is also an example of specifying a time interval between now() and an hour ago, note that 1 hour must be in single quotes:

```
wsprnet=#  select distinct on ("CallSign") * from spots  where
"Reporter"='G3ZIL' and wd_time > now() - interval '1 hour' and wd_band='40'
order by "CallSign" limit 10;
```

3.8 Using subqueries: Order by a different column

In this example VK7JJ needed a list of distinct CallSigns as in 3.7 but required them to be ordered by wd_time - a feature not directly available in postgreSQL, as the first order by column has to be the distinct column. The solution was to use a subquery for the distinct and an outer query for the order by wd_time. Note that the output of the subquery needs an alias, here it is temp:

```
wsprnet=# select * from (select distinct on ("Reporter") * from spots where
wd_band ='40' and wd_time > '2020-11-12T08:00:00Z' and "CallSign" = 'VK7JJ'
order by "Reporter", wd_time desc) temp order by wd_time desc, "Reporter"
limit 10;
```

3.9 Use of Joins

As postgreSQL is a full relational database it provides the ability to join two or more tables.

First, we describe a variant - the 'self-join' - where a table is joined to itself, best explained using an example. Here we output wd_time, CallSign, and dB (SNR) at two Reporters for instances where both Reporters spot the same CallSign in the same two-minute interval. The from spots s1 gives us an alias s1 for one instance of our table spots and inner join spots s2 gives us a second alias s2. As G4HZX only reports on 40 there is no need to check the bands match. We use these aliases as prefixes to the column names to refer to the two instances of our single spots table:

```
wsprnet=#  select s1.wd_time, s1."CallSign", s1."dB", s2."dB" from spots s1
inner join spots s2 on s1.wd_time = s2.wd_time and s1."CallSign" =
s2."CallSign" and s1."Reporter" = 'G3ZIL' and s2."Reporter" = 'G4HZX' order
by s1.wd_time desc limit 10;
```

In this example we calculate the SNR difference for the two Reporters and make sure the bands are the same:

```
wsprnet=#  SELECT s1.wd_time, s1."CallSign", s1."MHz", (s1."dB" - s2."dB") as
"""SNR_difference""" FROM spots s1 join spots s2 on s1.wd_time = s2.wd_time
and s1."CallSign" = s2."CallSign" and s1."Reporter" = 'G3ZIL' and
s2."Reporter" = 'G4HZX' and s1.wd_band='40' and s2.wd_band='40' order by
s1.wd_time desc limit 10;
```

Using a left join lets us output those CallSigns heard by one station and not another within the same two-minute interval on a band, in this case, those heard by G3ZIL but not by G4HZX:

```
wsprnet=#  SELECT
  s1."wd_time" AS "time",
  s1.distance as km,
  s1."dB",
  s1."Reporter",
  s1."CallSign"
FROM spots s1
left join spots s2
on s1.wd_time = s2.wd_time
  and s1."Reporter" = 'G3ZIL' and s2."Reporter" = 'G4HZX'
  and s1.wd_band='40' and s2.wd_band='40'
  and s1."CallSign" = s2."CallSign"
where s1."Reporter" = 'G3ZIL' and s1.wd_band='40' and s2."CallSign" is null
order by s1.wd_time desc limit 10;
```

4. Queries from tutorial database: wsprdaemon_spots, wspraemon_noise and kp

Whereas our database wsprnet spots table contains data from all those reporting to wsprnet.org our database tutorial only contains data uploaded directly by users of WsprDaemon[13]. The four main reasons for this separate data route are:

1. Allows for immediate data upload even if wsprnet.org is down.
2. Allows for additional spot-related data columns derived from the wsprd program that are not uploaded to, or handled by, the database at wsprnet.org.
3. Allows for a 'receiver' designator, useful for sites that report spots from multiple receivers but under one reporting identifier, usually a callsign, to compare the results between different receivers and or antennas.
4. Allows for noise estimates data to be uploaded, stored and queried alongside spots data.

In addition, the tutorial database contains tables of ancillary data, currently only kp, the geomagnetic disturbance index, is available.

4.1 Table wsprdaemon_spots

The full list of data columns in table wsprdaemon_spots is shown in Annex A. While some column names are different to table spots in our database wsprnet by now the reader will be sufficiently familiar to not need a full set of examples that parallel those in section 3. Here we will concentrate on those queries that cannot be run against the wsprnet spots table.

First, connect to database tutorial:

```
tutorial=# \c tutorial
```

In this example we calculate SNR difference between two receivers and two different callsigns for a set span of spot distances reported by the first callsign, together with the tx_call, distance and azimuth at the first callsign. We are using N6GN/K and N6GN/P as the reporters, with specific receiver GN0 at N6GN/K and GN4 at N6GN/P, on 40 m and for spots between 0 and 5000 km distant.

```
tutorial=# SELECT
  s1.time AS time, s1.tx_call, s1.km, s1.rx_az,
  (s1."SNR" - s2."SNR" ) as "dB_difference"
from wsprdaemon_spots s1
join wsprdaemon_spots s2 on s1.time = s2.time
and s1."tx_call"= s2."tx_call"
```

[13] See wsprdaemon.org

```
and s1."rx_id"= 'N6GN/K' and s2."rx_id" = 'N6GN/P'
and s1."receiver"='GN0' and s2."receiver"='GN4'
and s1.band='40' and s2.band='40' and s1.km> 0 and s1.km<5000
order by time desc limit 20;
```

In this next example drawing on a parameter from the wsprd decoder not sent to wsprnet.org we find the median SNR at G3ZIL on 40 m for the past 24 hours for the spots decoded by the Fano decoder (osd_decode=0) and, when the Fano cannot produce a result, by the Ordered Statistics Decoder (osd_decode=1), with a count of spots decoded by each. There is no median function as such in postgreSQL and so we use the percentile_disc function with 0.5 (i.e. 50%). This snippet also shows the use of the filter clause, note that table wsprdaemon_spots has been aliased to a for brevity, and we've given headings for the derived variables:

```
tutorial=# SELECT osd_decode as decode_type,
       COUNT(a.osd_decode),
       percentile_disc(0.5) within group (order by a."SNR")
       filter (where osd_decode = 0) as Median_SNR_Fano,
       percentile_disc(0.5) within group (order by a."SNR")
       filter (where osd_decode = 1) as Median_SNR_Ordered_Statistics
FROM wsprdaemon_spots a
WHERE rx_id='G3ZIL' and band='40' and time > now()-interval'1 day'
GROUP BY a.osd_decode;
```

resulting in:

```
decode_type | count | median_snr_fano | median_snr_ordered_statistics
-------------+-------+-----------------+-------------------------------
           0 |  4857 |             -12 |
           1 |  1173 |                 |                            -25
```

4.2 Table wsprdaemon_noise

The full list of data columns in table wsprdaemon_noise is shown in Annex A. Details of the rms and c2 (FFT) algorithms used to estimate noise have been published in the Sept/Oct 2020 issue of QEX[14].

The noise time series are far more amenable to graphical presentations, e.g. using Grafana. Nevertheless, the following example is of some interest. At G3ZIL the KiwiSDR receiver G3ZIL_1 has an antenna switch board from Glenn Elmore N6GN at its input; as part of a separate noise-measurement script the antenna input is switched to a 50 ohm terminator during the interval between WSPR transmissions. In the example query below we see that the c2_level FFT noise level estimate is reading noise from the antenna, as it is an estimate of the 30% of the lowest value Fourier coefficients in, and adjacent to, the WSPR band throughout the transmission period. However, the rms estimator looks for the quietest 50 milliseconds during the gap between WSPR transmissions, in this case reading the noise level at the terminated input to the KiwiSDR - a useful systems check.

```
tutorial=# select time, c2_level, rms_level from wsprdaemon_noise where
site='G3ZIL' and receiver='G3ZIL_1' and band='40' and time > now() - interval
'10 minutes' order by time desc;
        time         | c2_level | rms_level
---------------------+----------+-----------
 2020-11-19 14:10:00 |   -131.2 |   -155.81
 2020-11-19 14:08:00 |  -131.34 |   -155.62
 2020-11-19 14:06:00 |  -131.63 |   -155.52
```

The next example is a simple count of the number of times the KiwiSDR overload counter ov is greater than 0:

[14] Gwyn Griffiths, Rob Robinett and Glenn Elmore "Estimating LF-HF band noise while acquiring WSPR spots". QEX, ARRL, Sept-Oct 2020.

```
tutorial=# select count (ov) from wsprdaemon_noise where site='G3ZIL' and ov
>0 and time > now()-interval'1 day';
count
-------
     1
```

and in contrast, for KA7OEI-1, Northern Utah:

```
tutorial=# select count (ov) from wsprdaemon_noise where site='KA7OEI-1' and
ov >0 and time > now()-interval'1 day';
count
-------
  1047
```

Annex A. Description of data within columns of tables in wsprnet and tutorial

For ease of reference the column names ane types are repeated here. As a reminder:

- If the Column name contains a capital letter, e.g. Reporter, postgreSQL requires it to be within double quotes, e.g. WHERE "dB" > 10
- If the Type is text or character postgreSQL requires it to be within single quotes, e.g. WHERE "Reporter"='G3ZIL'. Note that column wd_band is of type text, as our initial thought was to have entries for 60 and 60eu and 80 and 80eu but this has not been implemented, thus use WHERE wd_band='80'.

Database wsprnet - table spots:

```
Column       | Type
-------------+----------------------------+
wd_time      | timestamp without time zone
Spotnum      | bigint
Date         | integer
Reporter     | text
ReporterGrid | character(6)
dB           | smallint
MHz          | double precision
CallSign     | text
Grid         | character(6) N
Power        | smallint
Drift        | smallint
distance     | smallint
azimuth      | smallint
Band         | smallint
version      | character(10)
code         | smallint
wd_band      | text
wd_c2_noise  | real
wd_rms_noise | real
wd_rx_az     | real
wd_rx_lat    | real
wd_rx_lon    | real
wd_tx_az     | real
wd_tx_lat    | real
wd_tx_lon    | real
wd_v_lat     | real
wd_v_lon     | real
```

Columns with data from wsprnet.org

wd_time	UTC time of the start of the two minute interval for a WSPR cycle and is in the format 2018-11-19 18:30:00
Spotnum	An unique identifier assigned by wsprnet to an incoming spot as they are received at wsprnet.org.[15]
Date	Unix epoch format in seconds, `1604915400` use converter, e.g. at https://www.epochconverter.com/ to convert to human readable date.
Reporter	Identifier as provided by the uploader of the WSPR data, e.g. KD0J, and may include a suffix such as /A, /P etc.

[15] Do not assume Spotnum to increment uniformly with time, a spot that arrives late, e.g. an Internet outage at the reporter, will have a Spotnum issued at the time it is received at wsprnet.org, and not related to the time the spot was decoded.

ReporterGrid	Maidenhead grid locator of the Reporter. It will be 6 characters if wsprnet.org has that information.
dB	Signal to noise ratio (SNR) as estimated within the decoder within WSJT-X
MHz	Frequency in MHz as seen at the receiver by adding the measured audio frequency to the 'dial' frequency for the selected band, reported to 6 decimal places, i.e. 1Hz.
CallSign	Identifier for the transmitting station, as decoded from the WSPR transmission.
Grid	Maidenhead grid locator of the Reporter. It will be 6 characters if wsprnet.org has a record for that CallSign.
Power	Power reported by the transmitting station in dBm. 30 dBm = 1 Watt.
Drift	Drift of the transmitted signal in Hz over the duration of the WSPR message seen by the receiver (which may also drift).
distance	Distance in km calculated from the receiver and transmitter grid squares. Accuracy will be best with two 6-character locators.
azimuth	Azimuth in degrees of the receiver as seen at the transmitter assuming a great circle short path. Clockwise from north.
Band	This is the band designator assigned by wsprnet.org as the frequency in MHz as an integer except that 136 kHz is listed as -1. Note that there are spurious entries, e.g. 49 with 7074, 41 with 2 (out of 238 million spots).
version	Where available, the version of the WSJT-X software in use.
code	A mode designator code: 1 is 'standard' WSPR2 and the new mode FST4W-120, 2 is WSPR15 and FST4W-900, 4 is FST4W-300 and 8 is FST4W-1800.

columns of data derived during preprocessing by WsprDaemon server from the above.

wd_band	Determined from the frequency by WsprDaemon preprocessing software, expressed in metres for 2200 - 2 metres, with 70cm and 23cm as 70 and 23. Where an appropriate band cannot be determined it is listed as 9999 (26,057 in 238 million).
wd_c2_noise & wd_rms_noise	These two noise fields are set to absent data currently, i.e. -999.0.
wd_rx_az	Azimuth in degrees of the incoming signal at the receiver assuming a great circle short path from the transmitter. Clockwise from north.
wd_rx_lat	Latitude in degrees of the receiver calculated from Grid. Negative is south. These numeric latitude and longitude fields allow for numeric SELECT statements in postgreSQL queries.
wd_rx_lon	Longitude in degrees of the receiver calculated from the rx_grid. Negative is west.
wd_tx_lat	Latitude in degrees of the transmitter calculated from the tx_grid. Negative is south.
wd_tx_lon	Longitude in degrees of the transmitter calculated from the tx_grid. Negative is west.
wd_v_lat	Latitude in degrees of the vertex of the great circle path between receiver and transmitter. The vertex is the most northerly, or southerly, point on the path. There are, of course, instances where the vertex is at the receiver or transmitter.

	This is calculated by WsprDaemon and can be useful when studying paths that are near to or within the polar Auroral Ovals.
wd_v_lon	Longitude in degrees of the vertex of the great circle path between receiver and transmitter.

Database tutorial table wsprdaemon_noise

```
  Column    | Type
-----------+----------------------------
 time       | timestamp without time zone
 site       | text
 receiver   | text
 rx_grid    | text
 band       | text
 rms_level  | double precision
 c2_level   | double precision
 ov         | integer
```

time	UTC time of the start of the two minute interval for a WSPR cycle and is in the format 2018-11-19 18:30:00
site	Usually the callsign of the reporting station, e.g. N6GN.
receiver	It is not uncommon for WsprDaemon users to use more than one receiver. In some cases they may use a separate site name e.g. N6GN/K to distinguish different receivers and or different antennas. In other cases, this receiver column allows the user to use a secondary identifier of their own choice, e.g. N6GN has used GN0, GN1, GN2, GN3. As styles and usage vary, and there is no metadata available, users of this table should consult the reporting station for details.
rx_grid	Maidenhead grid locator of the Reporter. It should be 6 characters.
band	The band in metres; a text column that includes separate entries for 60, 60eu, 80 and 80eu. At least one site uses the noise estimation capability to estimate the signal level of standard frequency stations, including WWVB, CHU-3, WWV-10. For a full list use:

```
select distinct band from wsprdaemon_noise;
```

rms_level	Noise estimate from the wsprdaemon RMS algorithm, essentially the RMS value of the quietest 50ms within the gap between WSPR transmissions. Units are dBm in 1Hz, however the absolute value will depend on the offset calibration provided at the receiver (same goes for c2_level).
c2_level	Noise estimate from the wsprdaemon FFT algorithm using the c2 decimated samples file produced by wsprd.
ov	For the KiwiSDR a count of the number of ADC overload events within the two-minute reception interval.

Database tutorial table wsprdaemon_spots

This was our first table of WSPR spots and we chose column names that seemed appropriate, but have ended up being different to the spots table in our wsprnet table (which we implemented later with names requested by the wsprnet administrators). Nevertheless, the data fields should be easily understood from the names and reference to the wsprnet spots table described above, until the sync_quality column. Sync_quality and subsequent columns and fields available within the wsprd decoding program but not sent to wsprnet.org. As the WsprDaemon program does have access to these fields and there is no impediment to their transmission to, and incorporation in, the wsprdaemon_spots table they are included in case they may be of interest.

```
    Column      | Type
---------------+-------------------------------
 time           | timestamp without time zone
 band           | text
 rx_grid        | text
 rx_id          | text
 tx_call        | text
 tx_grid        | text
 SNR            | double precision
 c2_noise       | double precision
 drift          | double precision
 freq           | double precision
 km             | double precision
 rx_az          | double precision
 rx_lat         | double precision
 rx_lon         | double precision
 tx_az          | double precision
 tx_dBm         | double precision
 tx_lat         | double precision
 tx_lon         | double precision
 v_lat          | double precision
 v_lon          | double precision
 sync_quality   | integer
 dt             | double precision
 decode_cycles  | integer
 jitter         | integer
 rms_noise      | double precision
 blocksize      | integer
 metric         | integer
 osd_decode     | integer
 receiver       | character varying
 nhardmin       | integer
 ipass          | integer
```

sync_quality	Our conjecture: A measure of how well the incoming sync symbol sequence is synchronised to the sync vector sequence timed by the receiver's clock. The raw variable is on a scale of 0 to 1 (but was recorded as the integer of 10 times the raw value in V2.1), hence care needs to be taken if comparing across versions.
dt	This is the time difference between the actual start of the audio signal presented to wsprd and 2 seconds past an even minute as perceived by the clock at the receiver. wsprdaemon records the full 10ms resolution value. There are (possibly at least) four main causes for a non-zero reading: 1. A time offset from UTC in the clock at the transmitter. 2. A time offset from UTC in the clock at the receiver. 3. A delay (latency) at the transmitter between the clock-commanded start of transmission and the actual transmission. 4. A delay (latency) at the receiver between the clock-commanded start of reception and the actual audio file start.
decode_cycles	This is the number of cycles taken for the Fano (default) or Jelinek (if selected) decoder to produce an output. The default maximum number of cycles is

	10,000, but can be set with the -C option on calling wsprd. In practice the most common value for decode_cycles (mode) is 1; for example, decode_cycles was 1 for 10212 out of 13285 spots for KD2OM on 40m, which is about 77%. This field may also be refered to as Fano iterations-per-bit.
jitter	Applied as a fine adjustment to the well-known dt time shift value. Centred on zero, values are in steps of 8 between -64 and +64. and are tried in the sequence 0, -8, 8, 16 etc. For 91092 spots at KD2OM 85645 i.e. 94% jitter was 0, 1.5% were at -8 and 1% at +8, and all allowed values to +/-64 were present. While no unit is given, it is certainly time, and quite likely to be the sampling interval, that is 1/375Hz or 0.26667 seconds, making each step of 8 equivalent to 0.021333 seconds.
blocksize	A parameter controlling the detection of individual symbols in the wsprd demodulator. Allowable values are 1, 2, 3, units are symbols. A value of 1 signifies that the first try using non-coherent detection of individual symbols was successful (sufficient), this is equivalent to the original wspr demodulator. Blocksizes of 2 and above means that that many symbols are decoded at once; from the source code, "Longer block lengths require longer channel coherence time". Most of the time blocksize will be 1, as an example, of 90271 spots at KD2OM 88214 were blocksize 1, 1575 at 2 and 482 at 3.
metric	This is an output from the Fano (default) or Jelinek (if selected in the call to wsprd.c) decoder. In Information Theory, metric is a measure of the "closeness of a path to the received sequence". The distribution of metric for 92513 spots at KD2OM is shown below. There is a broad asymmetric distribution at about 570. The singular peak at 810 is because that value is when the Fano (or Jelinek) algorithm has failed. In that case, the Ordered Statistic Decoder (OSD) is executed. It will come up with its decode, and if accepted, the osd_decode flag (see below) will be set to 1. This happened (osd_decode flag set to 1) in 98.8% of instances when metric was 810 in this test case with KD2OM spots.
osd_decode	Flag, either 0 or 1. If 0 then either the Fano (default) or the stack (Jelinek, only if wsprd is called with option -J) decoding algorithms have been used to decode. These algorithms can end without a decode being produced. If 1 then the Ordered Statistics Decoder (OSD) has been used. This decoder will always produce a decode - but of course it can be wrong. Therefore, wsprd only accepts an OSD decode if the tx_call it produces is already in the hash table having been decoded previously by the Fano or Jelinek algorithms.
receiver	A user-supplied designator, exactly as used in the wsprdaemon_noise table.
nhardmin	A count of the hard errors from the Fano (default) or the stack (Jelinek, only if wsprd is called with option -J) decoding algorithm. Not yet clear what it means if the Ordered Statistics Decoder (OSD) has been used.
ipass	A flag determined by user set options and the number of passes required to effect a decode. If wsprd is called with option -s (which it is not in wsprdaemon) this is the single pass (now very old) mode, so ipass can never be greater than 1, but (I think) can still be 1 if only a single pass was needed. If option -B was set (which it is not in wsprdaemon) then block demodulation is disables, only single-symbol noncoherent demodulation is used, and npass can take the values 1 or 2. Otherwise, npass may take a value of up to 3.

Annex B Accessing the WsprDaemon database using node.js

This Annex is a note on how to use node.js to access the wsprnet database table spots on the WsprDaemon server courtesy of Phil Barnard, VK7JJ, phil 'at' perite.com to whom we are

The code examples provided assume a working knowledge of node.js and its package manager NPM.

1. Open an ssh connection in the terminal you use to connect to node.js
2. Use NPM to install the pg package https://www.npmjs.com/package/pg - documentation of the pg package with examples: https://node-postgres.com/
3. The three sample scripts provided with this doc. all accept a simple postgres text query.

The pgclient and pgpool scripts are able to be run directly in a terminal via ssh and return their results to the console. pgweb is for use with the node express web server module.

Database access details as required by db_config are available from WSPR Daemon.

NOTE: the script files are bundled as .txt files but need to be changed to .js before being run.

pgclient.js

A pg client is designed to be used for normal day to day personal queries of the db and is fine for a personal web server.

Each client query connects to the db, authenticates, passes the query to the db and receives either an error message or a JSON results.rows string and then disconnects from the db.

The overhead is inconsequential and queries are fast and efficient, there is no persistent connection. The client_query function is as straightforward as possible with direct access to errors and results.

pgpool.js

For use with a heavy duty server. A pool of of pre-authenticated clients is assigned by the WSPR Daemon db server when the node.js server starts and is used for the life of the node server.

The pool.query method runs a query on the first available idle client and returns its result. Each client is released back into the pool automatically.

Authentication occurs with the pool assigned as the web server starts up. The pool is only released when the server is shut down.

The pool_query function is as straightforward as possible with direct access to errors and results.

pgweb.js

For use with a public facing web server and assumes the use of node express.

The web_query function is effectively copied and pasted from http://wsprd.vk7jj.com

Express (code not included) accepts Javascript fetch queries from the browser and calls the web_query function for each query.

The web_query function takes two arguments, a query string and a response object passed to it by express. It returns JSON stringified results.rows and errors to the web client using promises with a catch.

A zip folder with these notes and the three script files can be downloaded from

http://wsprdaemon.org/VK7JJ_node_pg_how_to.zip

Annex C Bash script to read basic spot data from database wsprnet table spots

This bash script was written in conjunction with Jim Lill WA2ZKD to access spots data for his real-time WSPR spots analysis website http://www.jimlill.com:8088/

Invoked as the script name with two arguments, the unique, wsprnet.org assigned, Spotnum at which to start listing (SPOTNUM_START) and the number of rows required (N_SPOTS) it returns the latest N_SPOTS rows to the standard output. Bash variable query_1 is formed within a string with single quotes allowing double quotes internally for the column names with upper case letters. Bash variable query if formed from concatenating ${query_1}, the required start spotnum ${SPOTNUM} and number of rows in variable ${N_SPOTS} in an expression with double quotes that does not upset the quoting within ${query_1} itself, and uses a \ to escape the double quotes around the column name Spotnum.

Jim Lill added the awk lines to decode the type of WSPR transmission from the code data. This decode to transmission type is only valid for spots after around 19 October 2020 when the code column was repurposed by the wsprnet.org team to indicate the new modes in WSJT-X V2.3.0-rc1.

```
#!/bin/bash

WSPRDAEMON_TIMESCALE_HOST="logs2.wsprdaemon.org"
SPOTNUM_START=$1
N_SPOTS=$2

query_1='select wd_time, "CallSign", "MHz", "dB", "Grid", "Power","Reporter",
"ReporterGrid", code, "Spotnum" from spots where "Spotnum" > '
query="${query_1} ${SPOTNUM_START} order by "\""Spotnum"\"" asc limit
${N_SPOTS};"

PGPASSWORD=WA2ZKD psql -U wdjim -d wsprnet -h ${WSPRDAEMON_TIMESCALE_HOST} -A
-F, -t -c "$query" 2> wdquery.log | \
awk -F, 'BEGIN { OFS="\t" }
         $9 == 1 { $9 = "WSPR2" }
         $9 == 2 { $9 = "WSPR15" }
         $9 == 4 { $9 = "FST4W-300" }
         $9 == 8 { $9 = "FST4W-1800" }
         { printf ("%s %-12s\t %.6f\t %s\t %s\t %s\t %-12s\t %s\t %s %s\n",
$1, tolower($2), $3, $4, $5, $6, $7, $8, $9, $10)}'
```

Use and output:

```
Gwyn-2:desktop gxg$ ./getspots.sh 2596339190 3
2020-11-17 22:08:00 w3ts          0.475629 -7   FN10ml    37   WB3AVN
      FM19og    WSPR2     2596339191
2020-11-17 22:08:00 g8axa         7.040068 -22  JO01bi    27   SM0JZT
      JO89ul    WSPR2     2596339192
2020-11-17 22:08:00 kk4df         10.140182     -22  EM85pf   27    WO7I
      DN10cw    WSPR2     2596339193
```

Typical time taken for 10000 rows into a file:

```
Gwyn-2:desktop gxg$ time ./getspots.sh 2596339190 10000 >test.csv
real 0m2.332s
user 0m0.135s
sys  0m0.062s
```

Annex D Skeleton of a Python script to read the WsprDaemon wsprnet database

This skeleton shows how to use the adapter psycopg2 on a local computer to read data from the logs2.wsprdaemon.org wsprnet database table spots and send to the standard output. This script needs psycopyg2 and postgreSQL to be installed (see section 1).

The line select_sql in the example ts_spot_read_1.py can be changed to whatever query you wish to use. However, as it stands, the line cannot contain a column name with a capital letter as that would need double quotes that would conflict with the required double quotes around the entire select_sql line. The way around this is to split the sql declaration into two or more lines, with the line needing an upper case column name in single quotes and then concatenating the lines into a single query line, as in the example ts_spot_read_2.py.

Both skeletons are invoked with a single argument, the number of rows to return, as in the two examples below.

```
pi@ZIL-Kiwi:~ $ cat ts_spot_read_1.py
#!/usr/bin/python
# ts_spot_read.py    Gwyn Griffiths March 2020
#  See https://wiki.postgresql.org/wiki/Psycopg2_Tutorial  for further details

import psycopg2
import sys

N_RECS=sys.argv[1]
select_sql="SELECT * from spots ORDER BY wd_time DESC LIMIT " + str(N_RECS)
print(select_sql)

try:
        # connect to the PostgreSQL database
        print("about to connect")
        conn = psycopg2.connect("dbname='wsprnet' user='wdread'
host='logs2.wsprdaemon.org' password='JTWSPR2008'")
        # create a new cursor
        cur = conn.cursor()
        cur.execute(select_sql)
        rows = cur.fetchall()
        for row in rows:
          print row
        # close communication with the database
        cur.close()
except:
        print ("Unable to connect to the database")
finally:
        if conn is not None:
            conn.close()

pi@ZIL-Kiwi:~ $ python ts_spot_read_1.py 2
SELECT * from spots ORDER BY wd_time DESC LIMIT 2
about to connect
(datetime.datetime(2020, 11, 14, 15, 52), 2587640089L, 1605369120, 'AF5WW', 'EM10ck',
-26, 14.096998, 'W8ARD', 'EN80mb', 37, 0, 1716, 236, 14, '2.1.0      ', 1, '20', -999.9,
-999.9, 47.0, 30.438, -97.792, 236.0, 40.062, -82.958, 40.062, -82.958)
(datetime.datetime(2020, 11, 14, 15, 52), 2587640094L, 1605369120, 'AF5WW', 'EM10ck',
-25, 14.097078, 'K6IA', 'DM26he', 23, 0, 1751, 106, 14, '2.1.0      ', 1, '20', -999.9,
-999.9, 296.0, 30.438, -97.792, 106.0, 36.188, -115.375, 36.188, -115.375)

pi@ZIL-Kiwi:~ $ cat ts_spot_read_2.py
#!/usr/bin/python
# ts_spot_read.py    Gwyn Griffiths March 2020
#  See https://wiki.postgresql.org/wiki/Psycopg2_Tutorial  for further details

import psycopg2
import sys

N_RECS=sys.argv[1]
# example of how to construct the sql line where one needs to double quote a column
name
# use single quotes for that part
select_sql_1='SELECT * from spots where "Reporter"='
select_sql_2=select_sql_1 + " 'G3ZIL' ORDER BY wd_time DESC LIMIT " + str(N_RECS)
print(select_sql_2)

try:
        # connect to the PostgreSQL database
        print("about to connect")
        conn = psycopg2.connect("dbname='wsprnet' user='wdread'
host='logs2.wsprdaemon.org' password='JTWSPR2008'")
        # create a new cursor
        cur = conn.cursor()
        cur.execute(select_sql_2)
        rows = cur.fetchall()
        for row in rows:
          print row
        # close communication with the database
        cur.close()
except:
        print ("Unable to connect to the database")
finally:
        if conn is not None:
            conn.close()
```

```
pi@ZIL-Kiwi:~ $ python ts_spot_read_2.py 2
SELECT * from spots where "Reporter"= 'G3ZIL' ORDER BY wd_time DESC LIMIT 2
about to connect
(datetime.datetime(2020, 11, 14, 15, 50), 2587637638L, 1605369000, 'G3ZIL', 'IO90hw',
-18, 10.14029, 'LY3LT', 'KO24  ', 23, 0, 1806, 268, 10, '          ', 1, '30', -999.9,
-999.9, 67.0, 50.938, -1.375, 268.0, 54.5, 25.0, 54.5, 25.0)
(datetime.datetime(2020, 11, 14, 15, 50), 2587637647L, 1605369000, 'G3ZIL', 'IO90hw',
-28, 10.14023, 'OH6FSG', 'KP23  ', 20, -1, 2085, 240, 10, '          ', 1, '30', -
999.9, -999.9, 38.0, 50.938, -1.375, 240.0, 63.5, 25.0, 63.5, 25.0)
pi@ZIL-Kiwi:~ $
```

Annex E KNIME example

While Grafana[16] is a very good data presentation package for WSPR-associated data it lacks, natively and through third-party extensions, many of the data analysis and graphing features that some users may need. KNIME is a data analysis and graphing package with serious scientific and engineering ambitions. Like Grafana it has capabilities from built-in and third-party extensions (nodes in KNIME terminology). The author is grateful to Brett Rider (G4FLQ) for an introduction to KNIME.

There's a very useful series of tutorials[17] online on installation and first steps and KNIME itself has extensive guides[18] and documentation. For now, here is a trivial example that gives a flavour of KNIME. If KNIME is of real interest to you please get in touch with the author.

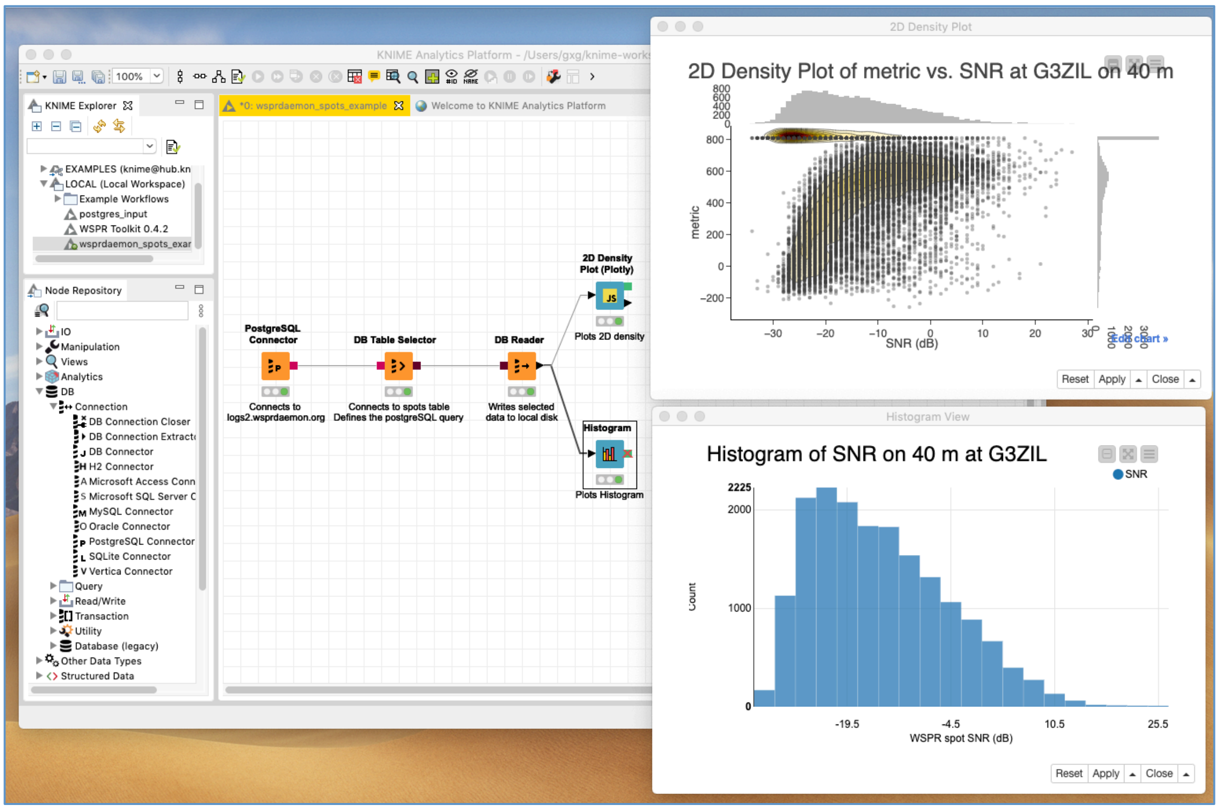


Figure D.1 Example screenshot of a KNIME workbench.

Figure D.1 shows an example KNIME Workbench with a workflow connecting to the WsprDaemon database tutorial, wsprdaemon_spots table, to produce the two graphs shown. The KNIME Explorer block, top left, shows KNIME projects stored locally; bottom left is Node REpository where you can find nodes (functional blocks) for various purposes (e.g. inputting, processing, graphing etc.) either in the basic KNIME package or online. The large window with a grid is the Workflow Editor. There are other windows but they have been closed for clarity.

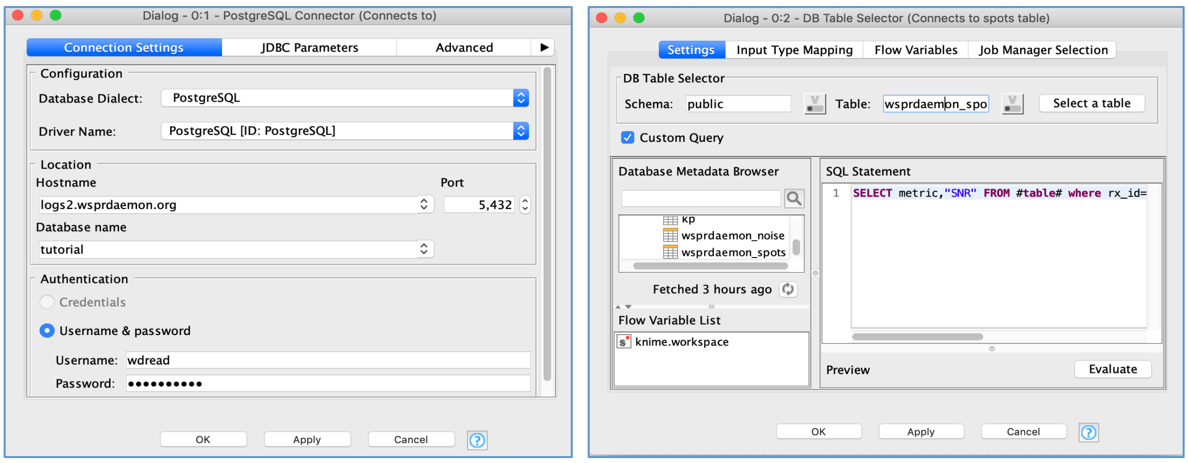
Leftmost in the Workflow Editor is the PostgreSQL Connector - this has been dragged to the Editor from the Node Repository on the left from folder DB, sub-folder Connection. Next, open the DB Query sub-folder and drag DB Table Selector to the Editor, click and drag from the output (red box) of the PostgreSQL Connector to the input of the DB Table Selector - this is the standard method to connect nodes.

[16] See wsprdaemon.org/grafana.html for an outline and link to a Guide on Grafana & WsprDaemon
[17] See http://marcoghislanzoni.com/blog/2016/04/27/knime-for-beginners-part-1/
[18] docs.knime.com/2018-12/analytics_platform_workbench_guide/index.html is a good place to start

Next we need the DB Reader node from folder DB sub-folder Read/Write, and connect to the DB Table Selector. In this example we will simply show two types of plot, a 2D Density Plot using the Plotly library and a simple Histogram. We've found the Histogram node in the Node Repository folder Views, sub-folder JavaScript, and the 2D Density Plot in the KNIME Labs, JavaScript Views, Plotly sub-folder. This type of plot, with shading and non-parametric density contours is a useful type of plot, and one not available via Grafana.

Naturally, this graphical representation hides the real detail, which the user can't really escape from. Thus, right-clicking the PostgreSQL Connector node (same for the others) brings up a list of options of which the top is Configure, a tabbed series of options and input fields necessary for the node to function in your application. Figure D.2 left shows the left-most Configure tabs of the PostgreSQL Connector node. Here we've specified the hostname, database name and provided username and password. A right click followed by menu option Execute should turn the node Traffic Light from yellow to green on a successful connection.

Figure D.2 right shows the left-most Configure tabs for the DB Table Selector node, here we select the table name from a pull down list (after the Connector Node has successfully connected) and this is where we enter the SQL we wish to run. The DB Reader node is configured and executed in a similar way.



Configuration
Database Dialect: PostgreSQL
Driver Name: PostgreSQL [ID: PostgreSQL]

Location
Hostname: logs2.wsprdaemon.org
Port: 5,432
Database name: tutorial

Authentication
○ Credentials
● Username & password
Username: wdread
Password: ••••••••••

DB Table Selector
Schema: public
Table: wsprdaemon_spo
☑ Custom Query

kp
wsprdaemon_noise
wsprdaemon_spots

knime.workspace

SQL Statement
```sql
SELECT metric,"SNR" FROM #table# where rx_id=
```

Figure D.2 Configuration screens (the left-most tabs) for left: postgreSQL Connector and right: DB Table Selector.

In the 2D Density Plot node the Options tab sets the X and Y columns to plot, the General Plot Options tab lets you annotate the axes and set the image dimensions in pixel - each image will appear in a separate Chromium (by default) web browser window. The Control Options tab enables a plethora of user interaction facilities with the plot; even more options are available via a separate online package if you tick the "Enable link to Plotly editor" box (and even more options if you subscribe to their service).

To see the plots, right click a plot node and select option Execute and Open Views. After a few moments (there is a % progress bar under the node) a graph should appear in a separate browser window. The easiest way to save the graphics image is via File Print in the Browser menu and select Save as pdf as the destination option.

For each node the option at the bottom provides more information. For the Connector node it is the postgreSQL connection details; for the Table Selector node it gives the Table and column data type details and the query; for the DB Reader it gives a listing of row number and the data requested in the SQL statement, the Spec tab gives lower and upper bounds for each column.

This is just the briefest of introductions to KNIME.

Annex F Octave route

The author would be very pleased to hear from anyone that has tried and failed or succeeded with implementing the postgreSQL package with Octave on Ubuntu.

The latest package release can be found at: octave.sourceforge.io/database/index.html

Ubuntu

Installation instructions are at: wiki.octave.org/Database_package. However, Glenn Elmore N6GN found this approach to work when trying pkg install within Octave did not:

```
sudo apt-get update -y
sudo apt-get install -y octave-struct
```

However, despite having the necessary pg_config file in directories:

```
/usr/lib/postgresql/12/bin/pg_config
/usr/bin/pg_config
```

and using addpath() to point to pg_config the database package would not install within Octave via

```
pkg install -forge database
```

Windows 10

Glenn Elmore N6GN found the following approach, within Octave V4.4, worked

```
pkg install -forge struct
pkg install -forge database
```

MacOS

The author is running Octave V6.0 [this is needed for features that make generating a video from single image frames a one-script process]. The macOS version is available as a dmg file at:

https://github.com/octave-app/octave-app/releases/tag/v6.0.90-rc1

Noting the dependencies at octave.sourceforge.io/database/index.html, the step within Octave:

```
pkg install -forge struct
```

runs, although with warnings. However, the step:

```
pkg install -forge database
```

initially failed as it could not find the pg_config file (postgreSQL API).

This was corrected by copying the 'missing' pg_config file from a postgreSQL directory to the directory where the pkg script was looking, i.e.

```
cp /usr/local/Cellar/libpq/13.1/bin/pg_config  /Applications/Octave-
6.0.90.app/Contents/Resources/usr/Cellar/octave-octave-
app@6.0.90/6.0.90/bin/pg_config
```

The pkg install -forge database script now ran, although with warnings, nevertheless the database package installed and could be loaded using the following command at the Octave prompt:

```
>> pkg load database
```

Octave script to demonstrate database connection

The following Octave script connect_wd_wsprnet.m sets the connection parameters as variables for the pq_connect line to return the latest row from the spots table and then prints it as a data structure struct:

```
% Bare bones Octave script to demonstrate access to the WsprDaemon
% wsprnet database table spots % Gwyn Griffiths G3ZIL November 2020
% Tested on Matlab V4.4 and on V6.0
% Follow notes at wiki.octave.org/Database_package and
octave.sourceforge.io/database/index.html
% for database package installation notes
% load the installed database package pkg load database;
% set up default connection parameters
dbname="wsprnet";
host="logs2.wsprdaemon.org";
port="5432";
user="wdread";
password="JTWSPR2008";

% connect to the database
conn = pq_connect (setdbopts ("dbname", dbname, "host", host, "port", port,
"user", user, "password", password));

% get the latest single row into datastructure spots

struct = pq_exec_params (conn, "select * from spots order by wd_time desc
limit 1;");

spots=getfield(struct,'data');   %produces cell array

% close the connection
pq_close(conn);
% print out the structure, which has the column names etc and the data
struct

% print out the cell array
spots
```

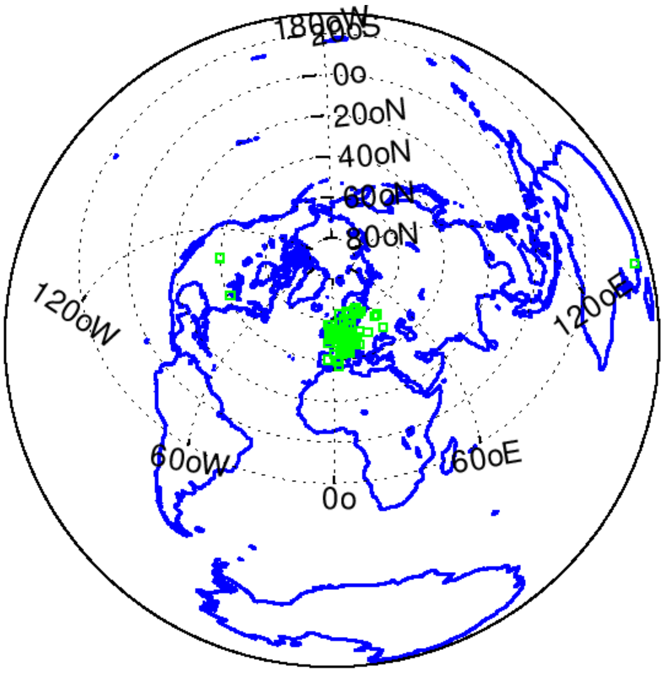
The octave script below access the WsprDaemon wsprnet database table spots and uses the m_map toolkit[19] to plot, on a great circle map, the locations of spots heard in the last hour. It reads in the band, but does nothing with it, but it does show how a character column representing numbers should be handled. [*There looks to be an issue with m_grid in Octave V6.0 due to use of char(176) for the degree sign ° causing a UTF-8 error; it was fine in Octave 4.4. If you are confident, you can change occurrences of char (176) in m_grid to char(111), lower case o, which is what I did here*].

```
% Program to illustrate Octave connection to WsprDaemon wsprnet database
table spots
% with a postgreSQL query that shows how to handle double quotes around upper
case
% together with the simple use of the m_map package to draw a great circle
world map and plot
% location of stations heard
% Gwyn Griffiths G3ZIL 17 November 2020  V1.0
% This version using Octave 6.0 on a macbook pro

% m_map package available from https://www.eoas.ubc.ca/~rich/map.html
%
% load the installed database package
pkg load database;

% set up connection parameters
dbname="wsprnet";
host="logs2.wsprdaemon.org";
```

[19] See https://www.eoas.ubc.ca/~rich/map.html

```
port="5432";
user="wdread";
password="JTWSPR2008";

% connect to the database
conn = pq_connect (setdbopts ("dbname", dbname, "host", host, "port", port,
"user", user, "password", password));

% get the last hour of time, lat, lon and band of stations heard by G3ZIL
from spots
% into datastructure struct
% Note how we deal with escaping the double quotes, e.g. around "Reporter"
% which is different to Bash, here we do not need to end previous text with "

struct = pq_exec_params (conn, "select wd_time, wd_tx_lat, wd_tx_lon, wd_band
from spots where \"Reporter\"=\'G3ZIL\' and wd_time > now() -interval \'1
hour\' order by wd_time desc;");

% convert the data parts of the structure into a cell array
spots=getfield(struct,'data');   %produces cell array

% close the connection
pq_close(conn);

% for loop to move the data from the cell array into individual variable
vectors
n_spots=rows(spots);           % number of rows in the dataset, i.e. in last
hour
for i=1:n_spots
    t_lat(i)=spots{i,2};       % same ordering as in the postgreSQL select
    t_lon(i)=spots{i,3};
endfor

% as the band values are of type character we need to convert to decimal
band=base2dec(spots(:,4),10);

% plot lat and lon of stations heard using the m_map toolbox
% in m_proj use the azimuthal equidistant, i.e. great circle map lat and lon
specify
% the centre of the map 'rad' specifies the radius in degrees, 180 would be
all globe
% m_coast gives us a simple coastline, m_grid gives lat lon gridlines
% the function m_ll2xy changes rectangular coordinates lat lon to thos
suitable for the projection
% the line function plots the data with the style parameters given
% print saves the graphics file

m_proj('azimuthal equidistant', 'lon',[-1], 'lat', [50], 'rad', [160], 'rec',
'circle');
m_coast('linewidth',1,'color','b');
m_grid('ytick', [-20 0 20 40 60 80], 'fontsize', 12);
[M,N]=m_ll2xy(t_lon, t_lat);
line(M,N, 'linestyle', 'none',
'marker','square','markersize',3,'color','green');
print( gcf, '-dpng', fullfile(sprintf('map.png')));
```

See example map output below.



Annex G Links to postgreSQL APIs or notes for a selection of other languages/systems

C#

http://zetcode.com/csharp/postgresql/

Haskell

https://hackage.haskell.org/package/postgrest

Kotlin

https://github.com/JetBrains/Exposed

Lua

https://keplerproject.github.io/luasql/manual.html

R

https://db.rstudio.com/databases/postgresql/

Spark

https://www.cdata.com/kb/tech/postgresql-jdbc-apache-spark.rst

Swift 5 or later

https://github.com/codewinsdotcom/PostgresClientKit