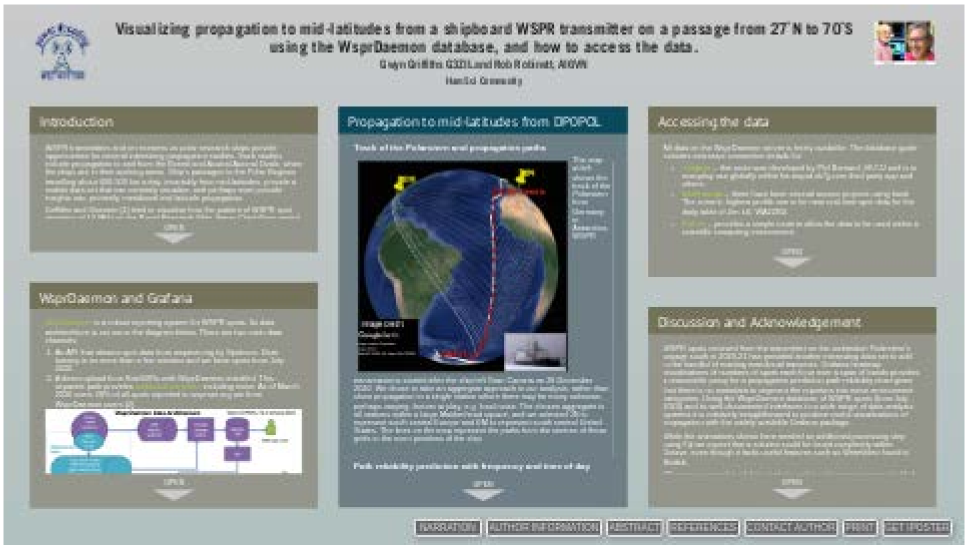
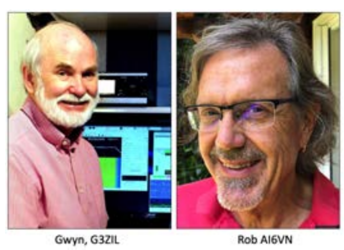
Visualizing propagation to mid-latitudes from a shipboard WSPR transmitter on a passage from 27˚N to 70˚S using the WsprDaemon database, and how to access the data.



Gwyn Griffiths G3ZIL and Rob Robinett, AI6VN

HamSci Community

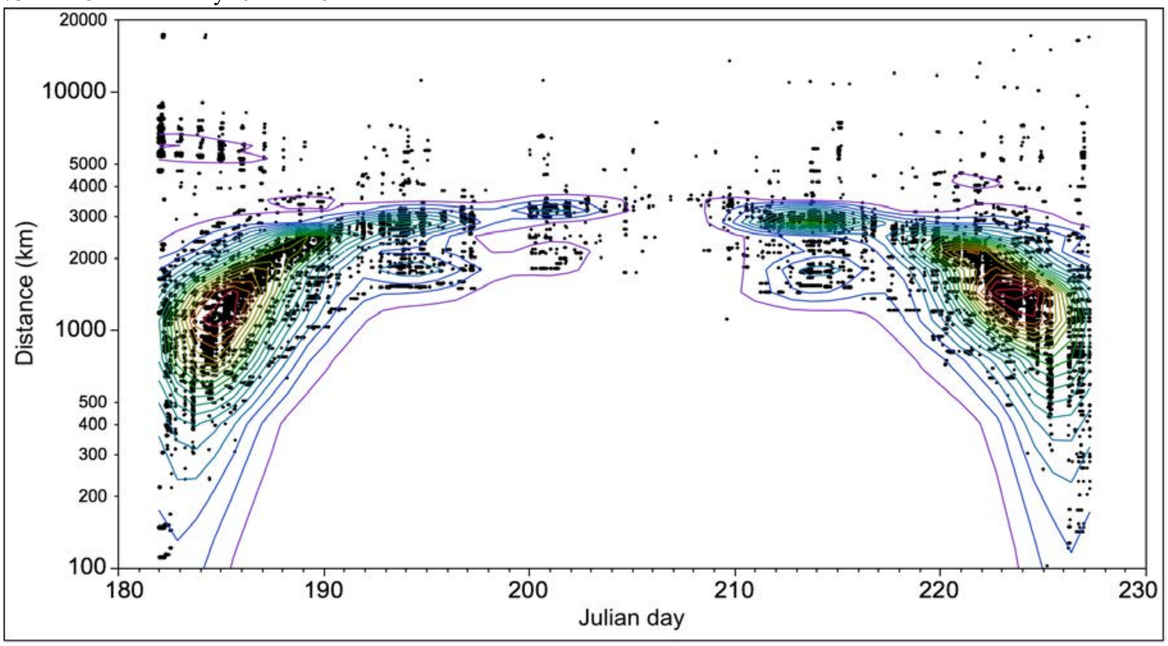


PRESENTED AT:

INTRODUCTION

WSPR transmitters and or receivers on polar research ships provide opportunities for several interesting propagation studies. Such studies include propagation to and from the Boreal and Austral Auroral Ovals when the ships are in their working areas. Ship's passages to the Polar Regions travelling about 400-500 km a day, invariably from mid-latitudes, provide a mobile data set that can certainly visualise, and perhaps even provide insights into, primarily, meridional mid latitude propagation.

Griffiths and Gloistein [1] tried to visualise how the pattern of WSPR spot reception at 10 MHz on the Royal Research Ship *James Clark Ross* varied on the ship's passage from the UK at 51˚ to Svalbard at 82˚N and back to the UK. The result below is not entirely satisfactory. Essentially a scatterplot of distance of each transmitter received at the ship and time one needs to keep in mind the variation of latitude, e.g. that the ship was on research operations at latitudes from 73˚N to 82˚N from day 192 to 219.



There were also practical limitations, for example the software used to generate the non-parametric density contours may be uncommon among the amateur community.

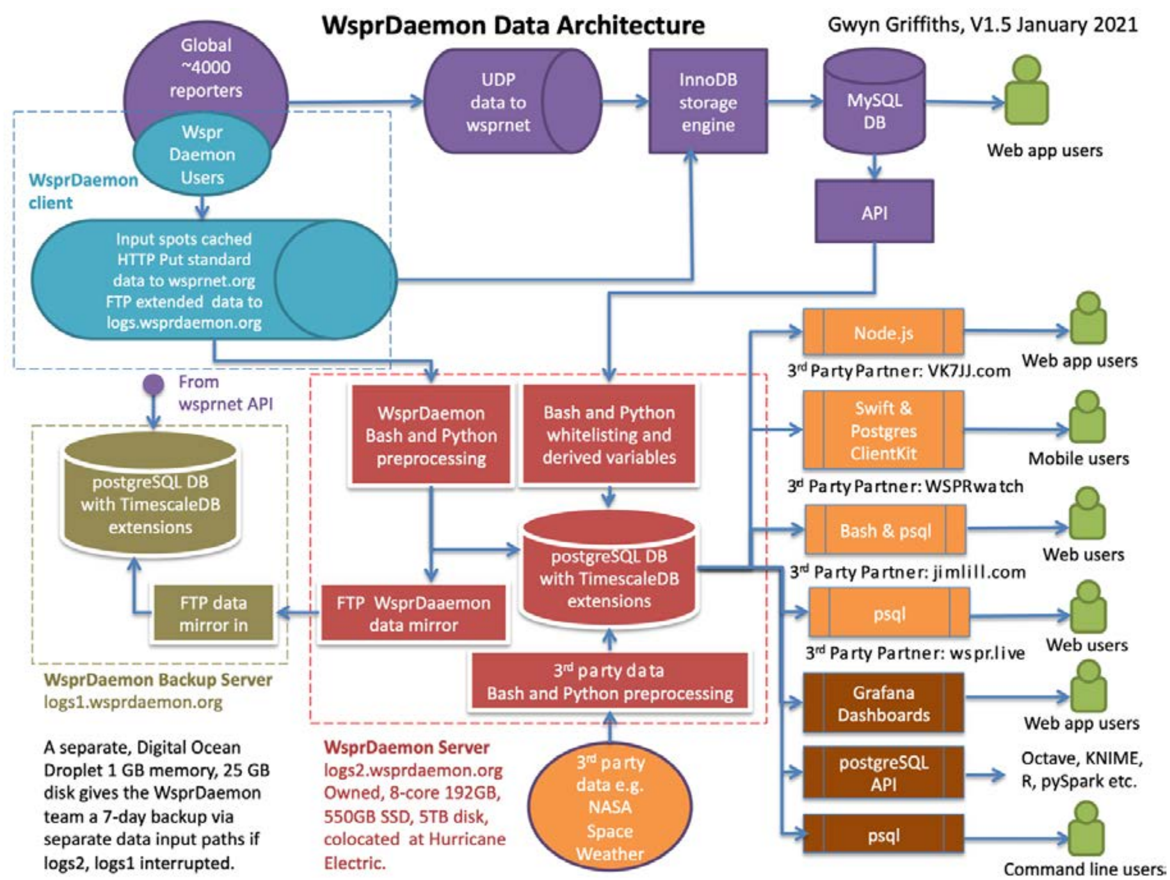
Can we do better?

The remainder of this poster explores the visualisations for reception reports of WSPR transmissions from the German Research Icebreaker *Polatstern* on her December 2020 – January 2021 voyage from Europe to Atarctica. We do this through direct access to the WSPR spots in the WsprDaemon database and its associated Grafana interface.

WSPRDAEMON AND GRAFANA

WsprDaemon (http://wsprdaemon.org/) is a robust reporting system for WSPR spots. Its data architechture is set out in the diagram below. There are two main data channels:

1. An API that obtains spot data from wsprnet.org by Spotnum. Data latency is no more than a few minutes and we have spots from July 2020.
2. A direct upload from KiwiSDRs with WsprDaemon installed. This separate path provides additional variables (http://wsprdaemon.org/wspr-field-names.html) including noise. As of March 2020 some 28% of all spots reported to wsprnet.org are from WsprDaemon users [2].

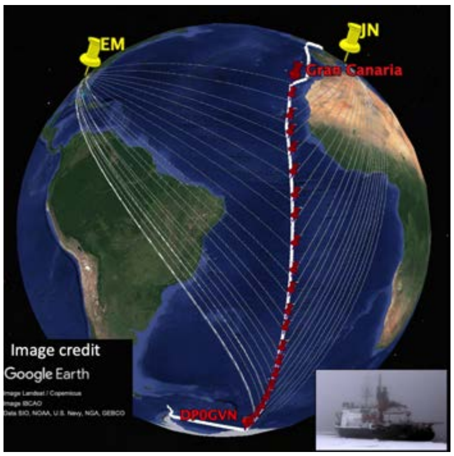


Data from these two channels are stored in a PostgreSQL database with TimescaleDB extensions. A guide (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf)to accessing the data with numerous PostgreSQL examples is available. The servers also run Grafana visualisation software and users can access prepared views, or create their own drawing on a guide (http://wsprdaemon.org/ewExternalFiles/Setting_up_Timescale_Grafana_dashboards_V2-2.pdf), or can install Grafana on their own systems.

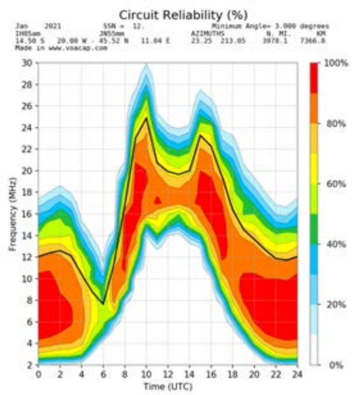
PROPAGATION TO MID-LATITUDES FROM DP0POL

Track of the *Polarstern* and propagation paths

The map at left shows the track of the *Polarstern* from Germany to Antarctica. WSPR transmissions started after the ship left Gran Canaria on 28 December 2020. We chose to take an aggregate approach in our analysis, rather than show propagation to a single station where there may be many unknown, perhaps varying, factors at play, e.g. local noise. The chosen aggregate is all stations within a large Maidenhead square, and we selected JN to represent south central Europe and EM to represent south central United States. The lines on the map represent the paths from the centres of those grids to the noon positions of the ship.



Path reliability prediction with frequency and time of day



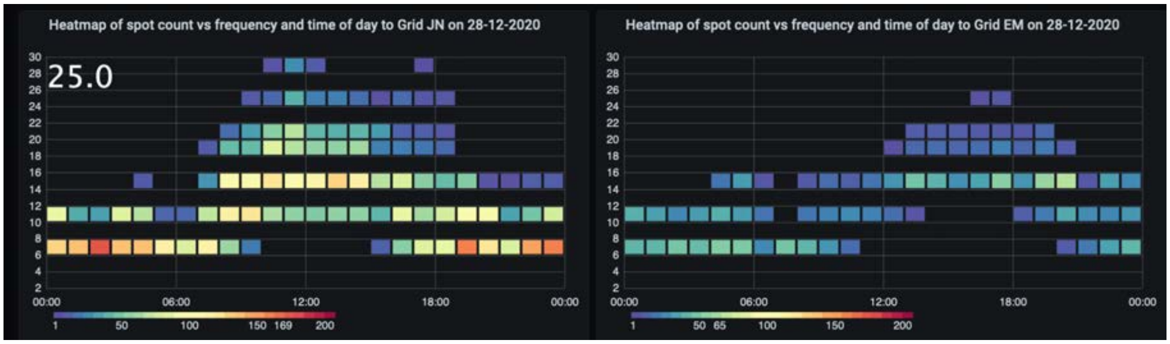
A useful form of propagation prediction graph shows path reliability, the probability, in percent, of the SNR over the path being greater than a threshold as a function of frequency and time of day. The example at left is from an online version of VOACAP (https://www.voacap.com/hf/) for a path between a receiver at grid JN and *Polarstern* at 14.5˚S and 20˚W for January 2021. This tool has settings for WSPR, here at 5 W, we chose a vertical antenna to represent the part horizontal part sloped 50 m long wire antenna on the ship. The settings are for a quiet receiver site with a dipole.

Can we reproduce this plot with WSPR data?

Grafana visualisation of path reliability from WSPR data

A WSPR spot count on each band in one-hour intervals over all reporters in our selected grid squares over a 24-hour period forms a simple proxy for path reliability. It has limitations, including not accounting for changes in the number of reporters, no knowledge of noise levels at the 50 or so reporters hearing DP0POL and no means of knowing how many reporters heard no WSPR transmissions at all.

The animation below shows our equivalent to the ITU propagation prediction path reliability graph for paths from the ship to JN (left) and EM (right). The noon latitude (˚N) is shown top left, each frame is one day, from 28 December 2020 to 17 January 2021. The main characteristics of the prediction (based on a smoothed sunspot number for January 2021) are present in these WSPR-derived plots. The dip in the predicted MUF below 10 MHz between 0300–0600 UTC is reproduced, especially with the ship north of the equator. The WSPR spots suggest that the bands at 14 MHz and above were open from morning to evening rather than with an interval of very low probability as in the prediction.

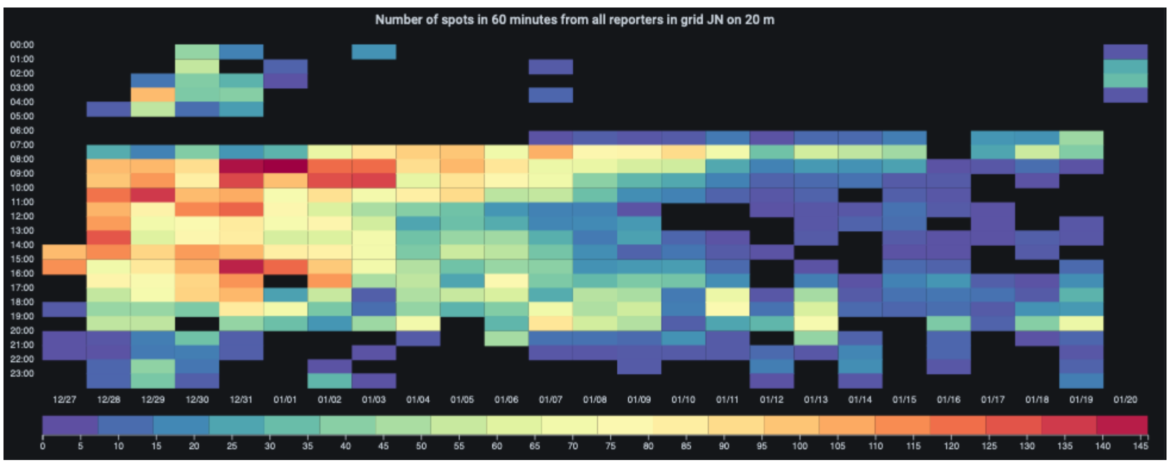


[Animated GIF generated using Fiji (https://imagej.net/Fiji) from screenshots of Grafana graphics].

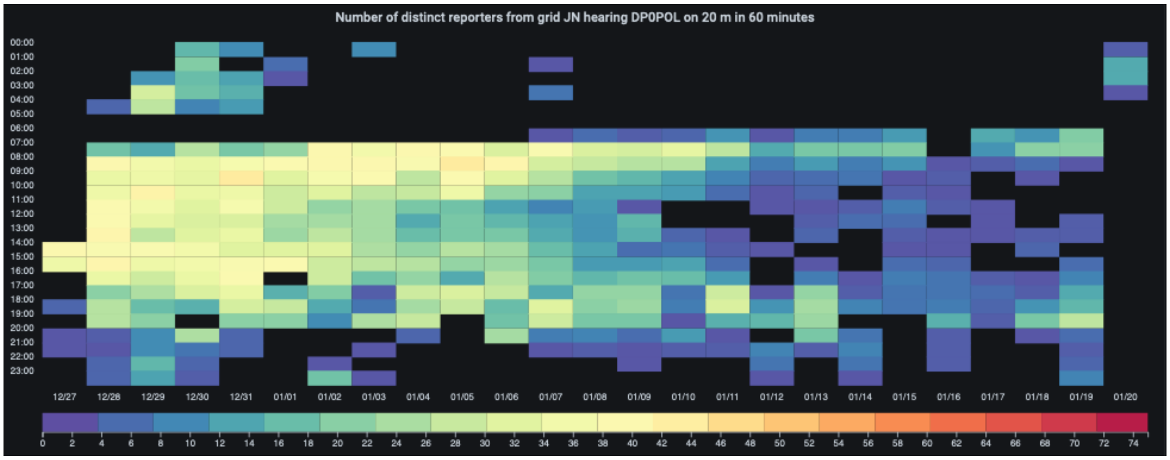
A single band, single graphic overview of path reliability

This graphic helps answer the question, "How does the hour-by-hour propagation pattern vary each day as the ship travels from Gran Canaria to Antarctica?" We arrive at our final graphic in four stages, our example band being 20 m:

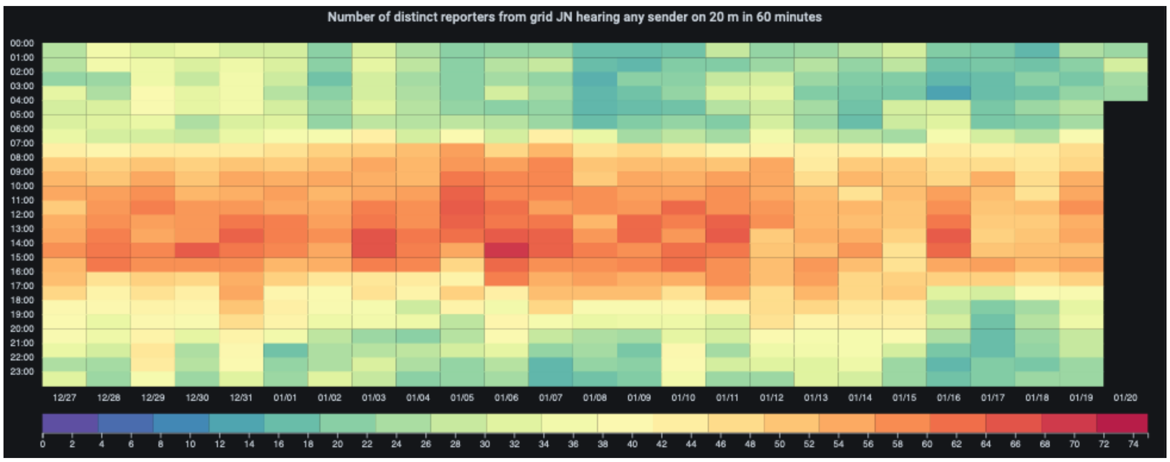
1. The number of spots received in 60 minutes from all reporters in grid JN. This is exactly analogous to the data in the animation above, and shares its limitations. Nevertheless, the gradual reduction in number of spots received is clear. The peak remains during the morning, and the MUF dip seen in the prediction is present as a black band of no spots whatever the ship's latitude.



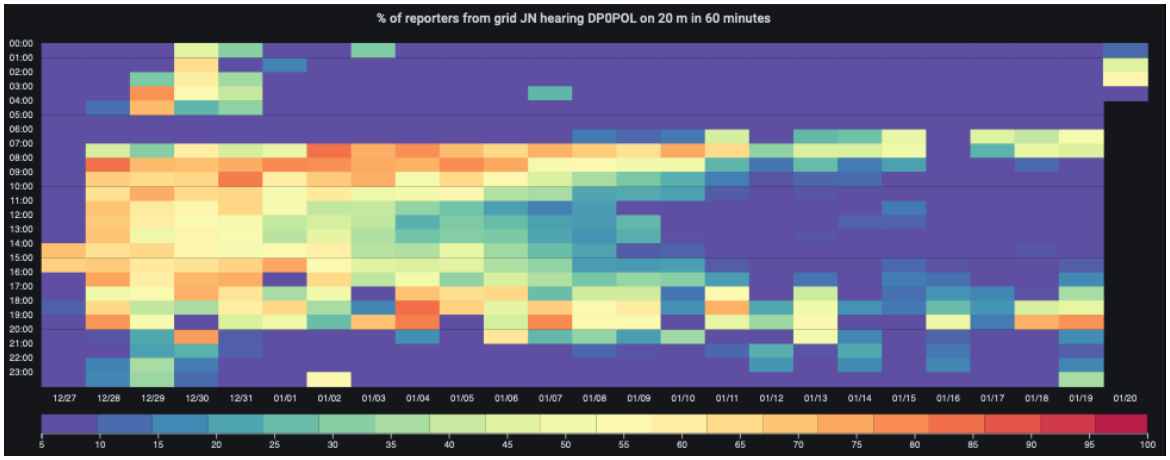
2. The number of distinct reporters from grid JN hearing DP0POL within each 60-minute interval. At most this is about 50. There is a clear reduction as the ship travels south, with many intervals showing fewer than 10, and then fewer than 4 reporters. What we have is a 'self-selecting' cohort of reporters where those at lower noise locations continue to hear DP0POL well into the southern hemisphere and during the middle of the day. We know of several reporters in grid JN with stations at remote cabins in very low noise locations. Around 0700 –0900 UTC and 1800–2000 UTC our assumption is that propagation is such that stations in less favoured locations also contribute spots.



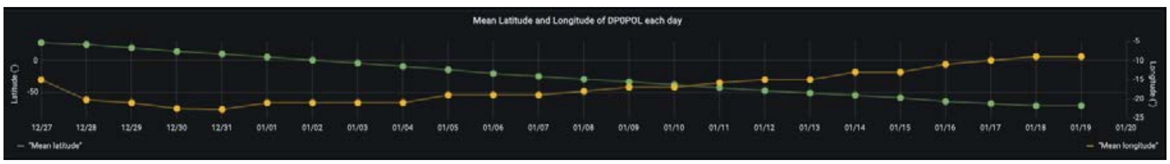
3. The number of distinct reporters from grid JN hearing any WSPR station within each 60-minute interval. This is as close as we can get to an estimate of the number of WSPR receiving stations in grid JN. While it may indeed be true that there are more stations with their receivers active from 0700–1700 UTC one should not make that assumption for it may be that there are just no transmitters within propagation range. A detailed analysis could, for example, look at how many of the spots outside 0700–1700 UTC were from local transmitters received via ground wave.



4. Percent of reporters reporting any transmission in a 60-minute interval that hear DP0POL within that interval. This is essentially the data in the second graph divided by the data in the third, and is, perhaps, as close as we can get to a path reliability graphic with WSPR data without site-specific metadata for each receiver. The morning propagation path at around 0800 UTC consistently gives a high percentage reception reports. Openings with signals strong enough to be decoded above the noise level of the average station are also possible during the early evening, and indeed with a notable opening on 18–19 January with the ship furthest south.



For reference the graph below shows the 0000 UTC latitude (green, left hand axis) and longitude (yellow, right hand axis) each day of the passage south.



The following is the SQL code entered in Grafana to produce the graphic, "Percent of reporters reporting any transmission in a 60-minute interval that hear DP0POL within that interval." $__timeGroupAlias sets the aggregation window as 60 minutes, while

wd_time between $__timeFrom() and $__timeTo()

sets the overall time window for the graphic. The code calculates the percentage from:

$$x = 100 * (sum(DP0POL)/(sum(All) + 0.1))$$

where the 0.1 is a simple expedient to avoid a divide by zero error.

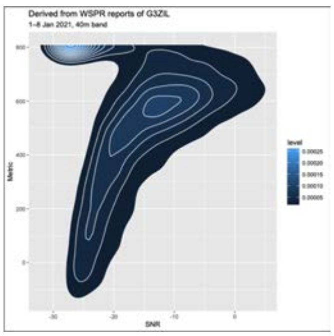
```
SELECT
$__timeGroupAlias(wd_time,60m),
100*cast(count(distinct("Reporter")) filter (WHERE wd_band = '$band_m' AND
"ReporterGrid" like concat('$Reporter_Grid','%') and "CallSign"='DP0POL') as double precision)/
(cast(count(distinct("Reporter")) filter (WHERE wd_band = '$band_m' AND
"ReporterGrid" like concat('$Reporter_Grid','%')) as double precision)+0.1) as "spot_count"
from spots where wd_time between $__timeFrom() and $__timeTo()
GROUP BY 1
```

ACCESSING THE DATA

All data on the WsprDaemon server is freely available. The database guide includes extensive connection details for:

- **node.js** (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=19)– this route was developed by Phil Barnard, VK7JJ and is in everyday use globally within his wsprd.vk7jj.com third party app and others.
- **bash script** (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=20) – there have been several access projects using bash. The current, highest profile one is for near real time spot data for the daily table of Jim Lill, WA2ZKD.

- Python (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=21) – provides a simple route to allow the data to be used within a scientific computing environment.



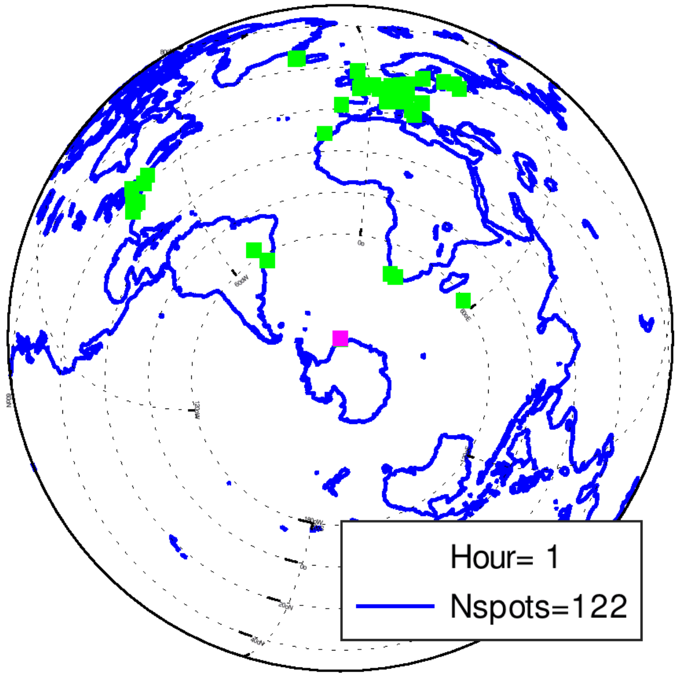
R (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=27)– Andi Fugard M0INF has shared an extensive set of examples with details on how to connect to the WsprDaemon database on their website (https://inductivestep.github.io/WSPR-analysis/).

R has an extensive range of graphs, as in this example, a scatterplot with non-parametric density countours. This uses the extended data set uploaded by the WsprDaemon program to show 'metric' against SNR. The peak at 810 comprises those spots decoded by the Ordered Statistics Decoder after the Fano decoder did not produce a spot.

- PySpark, Scala and a 'Big Data' approach (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=32) - Greg Beam KI7MT has proposed a 'Big Data' approach. The basic modules required are in place (March 2021) with further developments expected. There will be shared on his github (https://github.com/KI7MT/wspr-analytics) site.

- Clickhouse (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=34) - is a special case, in that it is a database in its own right. Columnar-oriented and with along-column, data-type optimised compression it provides a compact and fast solution for column-oriented queries. The WsprDaemon server hosts Arne's wspr.live Clickhouse database and provides near-real time spot data updates. This Clickhouse database contains all WSPR spots from 2008.

- Octave (http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_and_APIs_V2-1.pdf#page=23) - We regularly access the WsprDaemon database using Octave [Octave V6.0, Mac and Windows 10 versions tested] to produce graphs, maps and animations that are beyond the capability of Grafana. In this example we have used the m_map (https://www.eoas.ubc.ca/~rich/map.html) package to plot locations of stations hearing DP0POL on 40 m on a Great Circle map and to produce an animation. The animation has one frame per hour from 0000–2359 UTC on 19 January 2021 when *Polarstern* was in the vicinity of 70.5˚S 9˚W - marked by the magenta square. The annotation shows the hour (UTC) and the number of spots received within the hour. Where the number of spots received is under 10 most of these were from the nearby station DP0GVN, whose marker is covered by the DP0POL marker.



[*Animated GIF generated using Fiji (https://imagej.net/Fiji) from png file hourly maps from m_map and Octave]*.

DISCUSSION AND ACKNOWLEDGEMENT

WSPR spots received from the transmitter on the icebreaker *Polarstern*'s voyage south in 2020-21 has provided another interesting data set to add to the handful of existing meridional transects. Grafana heatmap visualisations of numbers of spots each hour over a span of bands provides a reasonable proxy for a propagation prediction path reliability chart given that there is no metadata to segment the reporters into noise environment categories. Using the WsprDaemon database of WSPR spots (from July 2020) and its well-documented interfaces to a wide range of data analysis systems it is relatively straightforward to produce useful visualizations of propagation with the widely available Grafana package.

While the animations shown here needed an additional processing step using Fiji we expect that a solution could be found completely within Octave, even though it lacks useful features such as WriteVideo found in Matlab.

Whatever your preferred data analysis and graphing environment it is likely to be straightforward to access the WsprDaemon database; the examples provided show what is possible for a range of languages and packages.

Acknowledgement

We are grateful to Christian Reiber DL8MDW for information and discussions concerning DP0POL and to Glenn Elmore N6GN for comments on the poster and for testing the Octave Windows 10 route. Track of the *Polarstern* courtesy Alfred Wegener Institute at https://www.awi.de/fileadmin/user_upload/MET/PolarsternCoursePlot/psobsedat.html.

AUTHOR INFORMATION

Gwyn Griffiths, G3ZIL

Gwyn Griffiths, G3ZIL, was first licensed in 1970 as GW3ZIL. He spent his career developing instruments for marine scientists, becoming UK National Oceanography Center's Chief Technologist and Professor of Underwater Systems at Southampton University. Since retiring in 2012 he has returned to amateur radio, concentrating on using WSPR and data analysis to understand HF band noise and minimize its impact on reception.

Rob Robinett, AI6VN

Rob Robinett, AI6VN, is CEO and Founder of Mystic Video, a Silicon Valley developer of professional TV broadcasting products. After a 40-year hiatus he resumed his interest in amateur radio in 2017 with a particular interest in optimizing RF receiving systems. He has deployed SDR and WSPR receive systems at the historic KPH receive site and a second set at a rural location on Maui. He conceived WsprDaemon and a robust reporting tool for WSPR users with a firm basis for easy access by others.

ABSTRACT

Visualising propagation to mid-latitudes from a shipboard WSPR transmitter on a passage from 27˚N to 70˚S using the WsprDaemon database, and how to access the data.

Gwyn Griffiths, G3ZIL and Rob Robinett, AI6VN

WSPR transmitters and or receivers on polar research ships provide opportunities for several interesting propagation studies. Such studies include propagation across the Boreal and Austral Auroral Ovals with the ship working in the Polar Regions, or, as in this case, on mid-latitude propagation with the ship on transit. On RV Polarstern's voyage from Gran Canaria (27.5˚N) to Neumayer III station, Antarctica (70.5˚S) from 27 December 2020 – 18 January 2021 a WSPR transmitter (DP0POL) operated on all bands 160–10 metres. Heatmaps of the number of spots received in Europe and North America each hour, each day, and on each band have been generated from the WSPR data held on the WsprDaemon server. These spot-count heatmaps, proxies for circuit reliability, clearly delineate the diurnal variation in band opening times and how those diurnal variations vary systematically over a 100˚ span of latitude on the voyage south. However, quantitative assessment of the spot numbers needs care; the number of reporters receiving spots changes with time and distance. Furthermore, there were far fewer distinct reporters for the LF and upper HF bands (11 for 160 m and 14 for 10 m compared with 447 for 40 m and 473 for 20 m). The heatmaps of SNR show several intriguing features, including steps from no decodes to SNRs some 10 dB above the WSPR decoding threshold as bands open and close. A Grafana dashboard is available for all to explore at http://logs1.wsprdaemon.org:3000/d/QGlNSz-Gk_2 Other ways to obtain WSPR data from the WsprDaemon database are outlined, including using Octave, R, Python, PySpark and Clickhouse. A worked example shows how to use Octave to generate a time sequence of great circle maps, as a movie, of where WSPR spots from DP0POL were received on the voyage from 27.5˚N to 70.5˚S.

REFERENCES

[1] Griffiths G. and Gloistein, M., 2018. Maritime Mobile WSPR Pole to Pole. RadCom, 94(9): 38–42.

[2] Personal communication, Phil Barnard, VK7JJ, March 2021.