What is FIS-B Decode?

FIS-B Decode (‘fisb-decode’) is a back-end system for processing FIS-B (Flight Information System - Broadcast) messages transmitted on 978 Mhz, mostly in the United States. FIS-B primarily contains meteorological information to be used in flight. This implementation roughly follows the DO-358B standard.

‘fisb-decode’ is composed of two main parts:

- The capture part of the system (‘fisb’) is a good way to explore the internal structures of FIS-B and can be used as a stand-alone system for this purpose. ‘fisb’ is a multi-level system that turns binary FIS-B messages into fully independent weather messages.
- The database part of the system (‘harvest’) creates .tif images, turns vector data into geojson, and manages the FIS-B message base using MongoDB.

‘fisb-decode’ is strictly a back-end ‘meat and potatoes’ system. It does not provide a web-based interface for humans. It is certainly possible to create front-end systems using fisb-decode, but fisb-decode is not that system.

FIS-B Decode is not designed, nor intended, to be used for any purpose other than fun exploration.

> **Warning:** FIS-B Decode is **NOT** intended for actual flight use, nor to be used as a component of a system for any flight related operations (flight planning, etc). It is strictly a fun hobby program with many bugs. It is based loosely on draft standards, not actual standards, and has not undergone any formal testing. **DO NOT USE OTHER THAN FOR FUN– NOT FLIGHT!!**

Getting things running

All the comments that follow assume you are using Ubuntu Linux version 20.04. You can, of course, use other systems, but you will need to adapt these instructions to fit them.

After putting the repository where you want it, the first thing is to add a path to the Python code by using `PYTHONPATH`. Create `PYTHONPATH` or add to it if it already exists. The best way to do this is at shell startup time by adding the lines:

```
PYTHONPATH=~/fisb-decode
export PYTHONPATH
```

to your `.bashrc` in your home directory. This is assuming you cloned ‘`fisb-decode`’ into your home directory. Change the path as needed to match your installation.

dump978-fa Setup

Unrelated to fisb-decode is FlightAware's 978. This is the program you should use to capture FIS-B packets from a radio for concurrent or later processing. There are other dump978 programs out there, but `dump978-fa` provides an arrival timestamp which is critical for fisb-decode. Read their instructions to get your radio working with `dump978-fa`.

For the initial setup, we will be using some already captured data, but at some point you will want to use your own live or recorded data. Live data is best, but works only if you are close to an airport or tower. To record data, bring a laptop with `dump978-fa` close to a tower or airport base station. Visit http://towers.stratux.me for a list of tower locations (this isn't guaranteed to be up to date, but is a good starting point). Here you can get your basic radio setup working and debugged.

What you are looking for is lines from `dump978-fa` that look like:

```
+38f18185534cbdc0058001001a4092ad19f8f8f8f8058001001a4093f26ef8f8f8f80580
001a40957526f8f8f8f8058001001a409231f4f8f8f8f8058001001a4093fb33f8f8f8f805
001001a4093fb38f8f8f8f8058001001a409231eff8f8f8f8058001001a409231f9f8f8f8f
058001001a4092ad32f8f8f8f8058001001a4095751cf8f8f8f8058001001a40923203f8f8
8f8058001001a4092ad37f8f8f8f8058001001a4092ad3cf8f8f8f8058001001a4092b5b1
f8f8f8058001001a4092b5b6f8f8f8f8058001001a40940402f8f8f8f8058001001a40923
ef8f8f8f8058001001a40923208f8f8f8f8058001001a4092b5bbf8f8f8f8058001001a409
b5c0f8f8f8f8058001001a4092320df8f8f8f8058001001a4092b5c5f8f8f8f8058001001a
092b5caf8f8f8f8058001001a409551fef8f8f8f8058001001a40940cccf8f8f8f80580010
1a409574f4f8f8f8f8058001001a4092b5cff8f8f8f8058001001a40923221f8f8f8f80580
1001a40956c0cf8f8f8f8058001001a40923226f8f8f8f8058001001a40941596f8f8f8f80
8001001a4092b5fcf8f8f8f80000000000000000;rs=43;rssi=-10.8;t=1595572682.219
```

These are FIS-B packets. Depending on the type of station you are monitoring, you will see one to four of these per second. FIS-B packets are preceded with a '`+`'.

If instead, you see smaller, sporadic packets starting with '`-`':

```
-0b28c90b386ab185446c0706013426407105c4e6c4e6c40a3a820300000000000000
;rs=43;rssi=-10.8;t=1595572682.219;
```

you are looking at aircraft sending UAT data. If this is all you are seeing, it implies that your radio setup is working, but you are not near a FIS-B ground station.

`dump978-fa` doesn't work out of the box with all radios supported by SoapySDR. I use a RSP1A and I needed to create a patch. The modulator code can also benefit with a patch if you are, like me, using a beam from 6 miles away to capture data. The `fisb-decode/misc/dump978fa` directory has these patches, as well as examples of the commands I use to capture data.

Once you are getting solid FIS-B packet reception, try to save some in a file for later processing. If you record an hours worth, you will have at least one of everything they are sending. A little over an hour will get you at least two sets of METARs. Most products are retransmitted, so you should get most items in a 15 minute interval. More data is always better, so collect as much as you can. Going during bad weather times will get you a better regional radar display.

Initial fisb-decode decoding

For all the examples that follow, we will making extensive use of fisb-decode configurations files. There are a lot of them: they are well documented, but if they are not set up for what you are trying to do, you will not get the expected result. The configuration files are guaranteed to be set with random values each time the repository is updated, so always check the values.

It is also assumed that all programs (except for a very few exceptions) are to be run from the `fisb-decode/bin` directory. So always `cd` there before running anything. I often refer to this as the `bin` directory in these instructions. All the scripts use relative paths.

A general principle is that the main programs all write into an error file if they run into problems. These error files will appear in the directory you are running the program from (`fisb-decode/bin`). So if you see an error file in the `bin` directory (like `LEVEL0.ERR`), something went wrong. These programs will also *erase* their error file at the start of execution. This is done so you can be assured that any errors occurred in the latest run of the program.

There are two main parts to 'fisb-decode'. The basic decode (also called 'fisb') and 'harvest'. There are 4 levels (0-3) of basic message decoding ('fisb'). Level 0 takes its data from `dump978-fa`. The other layers take the output from the preceding layer. The various levels do the following:

0. Performs basic decoding. Turns the message into a JSON file, which for the most part is just a translation of the FIS-B message into JSON. No special translations are performed (for the most part). *If all you want to do is to see the basic message, you can stop here*. There are also configuration settings for seeing all the reserved bits of the message (i.e. the parts you're supposed to ignore).
1. a) Processes level 0 segmented messages– where a single FIS-B message can't hold an entire payload and the total message is sent as a number of single messages. Those messages are recombined back to a single large message. b) Also, many messages are really two part messages: one containing a text portion, and the other containing a graphics portion. These are called 'Text With Graphic Overlay (TWGO)' messages. Level 1 will process these messages according to the standard (more details later).
2. Breaks apart the FIS-B message and makes a separate set of messages. So instead of a FIS-B 413 message type which groups all text-based weather reports as one, level 2 provides a message type for METARs, PIREPs, TAF, WINDs, etc. Another big part of level two is making sense of FAA times and dates. Most FAA products don't have complete timestamps. A lot of processing is performed to make sure that all dates are turned into complete ISO-8601 timestamps. Basically, level 2 gives you the message you *wish* FIS-B sent.
3. Removes duplicate messages. FIS-B, by design, frequently sends out retransmitted messages. This level will block repeats and only send out unique messages in some cases. Level 3 doesn't change any message. It just helps to

decrease the load on harvest. Because of the standard, the logic is somewhat complicated. See the level 3 source for more clarification.

'Harvest' takes the output of the above levels and stores the data in a database. All data except images are stored in the database. Images are stored in a directory. Harvest manages the database, adding new data and expiring old data.

If all you are interested in is basic FIS-B message decoding, you won't be needing anything fancier than 'fisb' level 0 or level 1. Lets start with basic level 0 decoding.

Edit `fisb-decode/fisb/level0/level0Config.py` so that the following lines match:

```
SKIP_EMPTY_FRAMES = False
DETAILED_MESSAGES = True
BLOCK_SUA_MESSAGES = False
ALLOW_SERVICE_STATUS = True
ARCHIVE_MESSAGES = False
WRITE_MESSAGE_TO_FILE = False
SHOW_MESSAGE_SOURCE = False
CALCULATE_RSR = False
DLAC_4BIT_HACK = False
ALLOW_DECODE_TEST = False
```

Next you will install some python dependencies. Install `pip3` if not already installed. On a ubuntu 20.04 system use:

```
sudo apt install python3-pip
```

From the `bin` directory type:

```
pip3 install -r ../misc/requirements-fisb.txt
```

Then type:

```
cat ../tg/tg-source/generated/tg30.978 | ./decode0
```

`tg30.978` is a local capture from my system that I use as a test group (more on test groups later). It represents around 8 minutes of live data. What you should see is a whole bunch of messages fly by. Each one looking something like:

```
{
 "rcvd_time": "2020-10-30T09:00:07.107Z",
 "app_data_valid": 1,
 "position_valid": 0,
 "station": "40.0383~-86.255593",
 "longitude": -86.255593,
 "latitude": 40.0383,
 "utc_coupled": 1,
 "transmission_time_slot": 11,
```

```
  "mso": 220,
  "mso_utc_ms": 61.0,
  "data_channel": 20,
  "tisb_site_id": "C",
  "tisb_site_id_type": "M1",
  "reserved_7_2": 0,
  "reserved_8_58": 0,
  "frames": [
   {
     "frame_type": 0,
     "product_id": 11,
     "agp_flag": 0,
     "frameheader_2_24": 0,
     "t_opt": 2,
     "month": 10,
     "day": 30,
     "hour": 8,
     "minute": 51,
     "s_flag": 0,
     "contents": {
       "record_format": 2,
       "location": "",
       "record_count": 1,
       "record_reference_point": 255,
       "product_version": 2,
       "reserved_2_58": 0,
       "records": [
         {
           "text_record_length": 240,
           "report_number": 10886,
           "report_year": 20,
           "report_status": 1,
           "reserved_5_78": 0,
           "text": "AIRMET KBOS 300851 BOSS WA 300845\nAIRMET SIERRA UPDT 1
                    FOR IFR AND MTN OBSCN VALID UNTIL 301500\nAIRMET MTN
                    OBSCN...ME NH VT MA NY PA WV MD VA NC SC GA\nFROM 60SE
                    YSC TO CON TO HAR TO 20WSW LYH TO 40WNW SPA TO ATL
                    TO\nGQO TO HMV TO HNN TO JHW TO 60SE YSC\nMTNS OBSC BY
                    CLDS/PCPN/BR/FG. CONDS CONTG BYD 15Z THRU 21Z.\n"
         }
       ]
     }
   }
 ]
}
```

This is an example of a message that has all of its bits exposed. If you are only interested in seeing how FIS-B messages are composed, you can stop here.

Moving on to levels 1 and 2, let’s update the config files.

Make `../fisb/level1/level1Config.py` match:

```
READ_MESSAGES_FROM_FILE = False
```

Make `../fisb/level2/level2Config.py` match:

```
BYPASS_TWGO_SMART_EXPIRATION = False
```

For level 1 decode type:

```
cat ../tg/tg-source/generated/tg30.978 | ./decode1
```

The only difference level 1 makes is that any segmented messages are grouped together and decoded. Also, TWGO (text with graphic overlay) messages that have text and graphic sections will have them matched up and sent. The standard dictates that the text part of TWGO messages are immediately sent and the graphics portion is stored until it has a matching text portion. When both parts are available, the graphics part can be sent out with the text part.

Level 2 messages are a totally different animal. We don't need all the extra detail level 0 can give us for these, so we will turn those features off.

Make `../fisb/level0/level0Config.py` match:

```
SKIP_EMPTY_FRAMES = True  (changed)
DETAILED_MESSAGES = False (changed)
BLOCK_SUA_MESSAGES = False
ALLOW_SERVICE_STATUS = True
ARCHIVE_MESSAGES = False
WRITE_MESSAGE_TO_FILE = False
SHOW_MESSAGE_SOURCE = False
CALCULATE_RSR = False
DLAC_4BIT_HACK = False
ALLOW_DECODE_TEST = False
```

For level 2 decode type:

```
cat ../tg/tg-source/generated/tg30.978 | ./decode2
```

You should see output that looks something like:


```
{
 "type": "METAR",
 "unique_name": "KOCQ",
 "location": "KOCQ",
 "contents": "METAR KOCQ 140715Z AUTO 00000KT 10SM OVC120 03/02 A3025
  RMK AO1\n     T00310016=",
 "observation_time": "2021-05-14T07:15:00Z",
 "expiration_time": "2021-05-14T09:15:00Z"
}
{
 "type": "TAF",
```

```
 "unique_name": "KROA",
 "location": "KROA",
 "issued_time": "2021-05-14T05:36:00Z",
 "valid_period_begin_time": "2021-05-14T06:00:00Z",
 "valid_period_end_time": "2021-05-15T06:00:00Z",
 "contents": "TAF KROA 140536Z 1406/1506 03004KT P6SM BKN090 OVC110\n
  FM141700 36004KT P6SM BKN070\n     FM150100 07003KT P6SM BKN100\n
  FM150500 34002KT P6SM SKC=",
 "expiration_time": "2021-05-15T06:00:00Z"
}
{
 "type": "WINDS_12_HR",
 "unique_name": "LCH",
 "location": "LCH",
 "issued_time": "2021-05-14T01:57:00Z",
 "valid_time": "2021-05-14T12:00:00Z",
 "for_use_from_time": "2021-05-14T09:00:00Z",
 "for_use_to_time": "2021-05-14T18:00:00Z",
 "contents": "   0805 9900+11 2413+08 3111+01 3023-12 2930-24 306638
  299148 297059",
 "model_run_time": "2021-05-14T00:00:00Z",
 "expiration_time": "2021-05-14T18:00:00Z"
}
```


There is one final level: level 3. It won't change the contents of any message– just suppress retransmitted duplicates. However, it is the final in the chain of 'levels', so it dictates whether the output goes to a file (like for harvest) or to standard output. To make sure it is working, change its configuration file `../fisb/level3/level3Config.py` to:

```
PIREP_STORE_LEVEL3 = True
PRINT_TO_STDOUT = True
WRITE_TO_FILE = False
```

For level 3 decode type:

```
cat ../tg/tg-source/generated/tg30.978 | ./decode
```

Note that we use `./decode` to decode all the levels. This is the most common case, so we don't add a '`3`' to it.

Congratulations, you now have the FIS-B message decoding working! If your only interest is to study the structure of FIS-B messages, you are done. No need to go any further. In fact, you were done at the `decode0` or maybe the `decode1` step.

If you have a continuous data feed running from `dump978-fa`, you can just pipe its output into any of the 'decode' programs we just covered. However, `dump978-fa` has a server mode that you can use instead. You can edit the `../fisb/levelNet/levelNetConfig.py` file and set the address and port number. There are equivalent network based versions of the decode programs that take their input from a network (`decode0Net`, `decode1Net`, `decode2Net`, and `decodeNet`). For a level 3 decode from the network you would use:

```
./decodeNet
```

Getting Harvest Running

Harvest takes the output from ‘fisb’ level 3 and stores it in a database, then maintains that database per the standard. Actually, that’s not 100% true. Images sent by FIS-B get made into geotiff files and stored in a directory. Everything else goes in the database.

Harvest has a more complicated setup because it requires a database and has more dependencies. Harvest (optionally) can use external location data from the FAA and World Magnetic Model to add location information to PIREPs, METARs, TAFs, and wind forecasts.

The first step in getting harvest running is to install MongoDB. Download and install the community version for your platform. Follow the installation instructions and make sure it starts up whenever you reboot. Please take note that I use **no security** with Mongo. If you want, security you can add it (add security using Mongo commands, then change `MONGO_URI` in the configuration parameters to add username and password). You should not expose the Mongo database to the internet or other places you don’t trust without adding security.

Images in harvest require GDAL and its python bindings to be installed. **HOWEVER**, If you will be using QGIS (QGIS is an open-source Geographical Information System viewing program described later), just install QGIS: **DO NOT** install `gdal-bin` or `libgdal-dev`. QGIS will install GDAL as part of its installation. If you install both QGIS and the below packages, they might conflict. The below packages are needed if you are installing on a headless server without a window system (i.e. no QGIS), or if you don’t want to install QGIS. Install the following packages (if you will not be installing QGIS):

```
sudo apt install gdal-bin libgdal-dev
```

Next you will install various python dependencies. From the `bin` directory type:

```
pip3 install -r ../misc/requirements-harvest.txt
```

Now we create the databases. There are two: `fisb` and `fisb_location`. `fisb` is the main database. `fisb_location` is optional and will contain location information from FAA sources. We will wait to discuss how to fill `fisb_location` with data later, but it doesn’t hurt to create it. To make the databases: (from the `bin` directory)

```
mongo ../db/scripts/createFisb.js
mongo ../db/scripts/createFisbLocation.js
```

You can run the above scripts anytime you want to zero out the databases.

As always, lots of config file settings.

Change `../fisb/level0/level0Config.py` (this should not change anything you already set):

```
SKIP_EMPTY_FRAMES = True
DETAILED_MESSAGES = False
BLOCK_SUA_MESSAGES = False
ALLOW_SERVICE_STATUS = True
ARCHIVE_MESSAGES = False
WRITE_MESSAGE_TO_FILE = False
SHOW_MESSAGE_SOURCE = False
CALCULATE_RSR = False
DLAC_4BIT_HACK = False
ALLOW_DECODE_TEST = False
```

Level 0 can interact with Mongo to create the `RSR` (Radio Station Reception) message, but we are not going to turn it on for now.

Change `../fisb/level1/level1Config.py` (no changes from previous):

```
READ_MESSAGES_FROM_FILE = False
```

Change `../fisb/level2/level2Config.py` (no changes from previous):

```
BYPASS_TWGO_SMART_EXPIRATION = False
```

Change `../fisb/level3/level3Config.py` (all are changes):

```
PRINT_TO_STDOUT = False
WRITE_TO_FILE = True
OUTPUT_DIRECTORY = "../runtime/harvest"
```

Change `../db/harvest/harvestConfig.py`:

```
HARVEST_DIRECTORY = '../runtime/harvest'
MAINT_TASKS_INTERVAL_SECS = 10
MONGO_URI = 'mongodb://localhost:27017/' (change this for your connection)
RETRY_DB_CONN_SECS = 60
EXPIRE_MESSAGES = True
ANNOTATE_CRL_REPORTS = True
PROCESS_IMAGES = True
IMAGE_DIRECTORY = '../runtime/images'
SMOOTH_IMAGES = False
SYNC_FILE = '../runtime/misc/sync.fisb'
IMMEDIATE_CRL_UPDATE = True
IMAGE_QUIET_SECONDS = 10
PRINT_IMMEDIATE_EXPIRATIONS = False
TEXT_WX_LOCATION_SUPPORT = False
PIREP_LOCATION_SUPPORT = False
SAVE_UNMATCHED_PIREPS = False
NOT_INCLUDED_RED = 0xEC
```

```
NOT_INCLUDED_GREEN = 0xDA
NOT_INCLUDED_BLUE = 0x96
IMAGE_MAP_CONFIGURATION = 0
CLOUDTOP_MAP = 0                          (0-4 will work, see source commer
RADAR_MAP = 0                             (0-1 will work, see source commer
```

There are basically two programs to be executed at the same time (eventually I will create `systemd` scripts for this, but at the beginning it's easier to open two windows and run each program by itself). I will assume, since this is a live system, that you are using `dump978-fa` over a network in server mode.

The first program is `decodeNetToDir`. This is the same as piping the output from `dump978-fa` to `decode`. In this case, `decode` is now configured to write its output to the directory `../runtime/harvest`, where it will store each level 2 message in its own file. The filename has a format such that reading the files in alphabetical order format will read the messages in arrival time order.

The other program is `harvest`. This reads files from `../runtime/harvest` and processes them. It also will delete processed files.

With the current configuration, images will be written to `../runtime/images`.

Next, open up 3 windows and 'cd' to `fisb-decode/bin`. In one type:

```
./decodeNetToDir
```

In the next type:

```
./harvest
```

The third window is for monitoring. Doing a directory in the `bin` directory will show you if there are any error files. `decodeNetToDir` is running the standard level 0-3 programs, so any errors will show up as `LEVEL0.ERR`, `LEVEL1.ERR`, `LEVEL2.ERR`, or `LEVEL3.ERR`. Harvest errors will be in `HARVEST.ERR`. From the monitoring directory you can check in the `../runtime` directories to look for images and files being processed (note: the files in `../runtime/harvest` are processed very quickly, so this directory will mostly look empty).

Note: When running both `decodeNetToDir` and `harvest`, and you want to stop them both, stop `decodeNetToDir` first. If you stop `harvest` first, `decodeNetToDir` will keep creating files. By stopping `decodeNetToDir` first, `harvest` will gobble up any unprocessed files and delete them, leaving the intake area clean.

If things seem to be quiet (i.e. the programs are running and no errors are being created), the next step is to run Mongo and make sure the database is filling up appropriately. Type:

```
mongo
```

```
(Mongo will babble)

> use fisb
```

`use fisb` tells Mongo the database to use. You should read up on how Mongo works, but to check the contents of a database table type into Mongo `db.<collection-name>.find().pretty()`. `collection-name` is the name of the Mongo collection (i.e. table). So to look at the METAR table, type:

```
db.MSG.find().pretty()
```

You will find that the Mongo entries look mostly like the level 2 messages except the level 2 `geometry` fields are now `geojson`. There are other changes, but those are the main ones.

Here are the collection names and what they contain:

MSG

  Holds all messages.

LEGEND

  Legend information for geotiff images.

Building Documentation

If you want to build the documentation, install sphinx. On Ubuntu 20.04 you can do this with:

```
sudo apt install python3-sphinx
```

Next, install the Python requirements from the `bin` directory as:

```
pip3 install -r ../misc/requirements-sphinx.txt
```

Then (assuming ‘fisb-decode’ was cloned in your home directory):

```
cd ~/fisb-decode/docs
./makedocs
```

The html documentation will be found in `fisb-decode/docs/build/html`. Load `index.html` in your browser to view. Sphinx is configured to link directly to the source, so this is an easy way to explore the code.

Getting RSR Running

Now that you have a basic fisb and harvest system running, we can add some improvements. The first is to get RSR or ‘Radio Station Reception’ configured. RSR basically looks at how many packets you are getting per second from a ground station, verses how many you should be getting, and turns that into a percentage. RSR is totally optional and is only really needed when running the standard body's TG06 test. If you always are using a strong signal with 100% of packets getting through, you don't need it. It is a resource hog. However, if you are like me, and using a beam antenna from 6 miles away and the reception tanks when it rains, it can be a useful indicator of signal strength.

Getting it running is a simple set of configuration changes. Update `../fisb/level0/level0Config.py` as follows (keeping other lines as before):

```
CALCULATE_RSR = True
RSR_CALCULATE_EVERY_X_SECS = 30
RSR_CALCULATE_OVER_X_SECS = 30
RSR_USE_EXPECTED_PACKET_COUNT = True
```

Stop and restart `decodeNetToDir`. Wait at least 30 seconds for the database entry to be created, then start `mongo` and have the following dialog:

```
> use fisb
switched to db fisb
> db.MSG.find({type: 'RSR'}).pretty()
{
        "_id" : "RSR-RSR",
        "type" : "RSR",
        "unique_name" : "RSR",
        "stations" : {
                "40.0383~-86.255593" : [90, 3, 100]
        },
        "insert_time" : ISODate("2021-06-09T21:42:18.134Z"),
        "expiration_time" : ISODate("2021-06-09T21:42:58.134Z")
}
```

If you see something like this, it's working. `40.0393~-86.255593` is the ground station id (basically its latitude and longitude) and `[90, 3, 100]` means you received 90 packets at an expected rate of 3 packets per second (this number can be determined by the FIS-B packet) and the percentage of packets was 100%. In the configuration file you told it to use 30 seconds of data to compute its estimate, so 3 packets a second over 30 seconds is 90 packets.

There will always be one RSR per ground station being received.

Getting Localwx Running

The next easy thing to get running is `localwx`, a simple text-based program that displays local weather on a terminal and has a curses mode for screen updates. From `bin` type `./localwx --h` and you should get:

```
usage: localwx.py [-h] [--fdc] [--airmet] [--nogairmet] [--nowinds] [--nor
                [--nounavail] [--obst] [--all] [--curses]

Display local weather from database.

For curses mode, the following keys are used (either upper or lower case)
 q - Quit
 a - Toggle AIRMETs (Will show WST, SIGMET, CWA)
 f - Toggle FDC NOTAMS
 g - Toggle G-AIRMETS
 m - Toggle METARs
 n - Toggle NOTAMS
 o - Toggle NOTAM obstructions
 s - Toggle all AIRMETs (SIGMETs, WST, CWA, AIRMETs)
 t - Toggle TAFS
 u - Toggle FIS-B Unavailable messages
 w - Toggle Wind

 <space> will update screen


optional arguments:
  -h, --help   show this help message and exit
  --fdc        Show FDC NOTAMS
  --airmet     Show AIRMETs (will show CWA, WST, SIGMET)
  --nogairmet  Don't show G-AIRMET forecasts
  --nowinds    Don't show wind forecast
  --nonotam    Don't show any NOTAMS
  --nounavail  Don't show any FIS-B Unavailable notices
  --obst       Show NOTAM obstructions
  --all        Show everything
  --curses     Show on updating display
```

As always, there is a config file to update. Edit `../db/localwx/localwxConfig.py` to see:

```
#: MONGO URI
MONGO_URI = 'mongodb://localhost:27017/'

#: List of WIND forecasts you want to get.
WINDS_LIST = ['IND']

#: List of current METARS you want displayed
METAR_LIST = ['KIND', 'KTYQ', 'KEYE']

#: List of terminal area forecasts to display.
TAF_LIST = ['KIND']

#: List of sites you want NOTAMs from.
NOTAM_LIST = ['KTYQ', 'KEYE', 'KIND', 'KI99']

#: Your lat, long. Used to determine if you are in SIGMETS, AIRMET, CWA, e
```

```
#: Configured as a tuple: (<longitude>, <latitude>).
MY_LOC = (-86.255593, 40.0383)
```

The changes you need to make should be obvious. Enter the station IDs in the appropriate places, and change `MONGO_URI` and `MY_LOC` to reflect your specifics.

When run from the command line you will get something like:

```
METAR KIND 151954Z 22007KT 10SM BKN085 BKN110 19/04 A3021 RMK AO2 SLP229
   T01940044=
METAR KTYQ 151955Z AUTO 18006KT 10SM SCT110 20/01 A3022 RMK AO2
   T02000010=
METAR KEYE 151953Z AUTO 00000KT 10SM OVC085 21/02 A3020 RMK AO2 SLP227
   T02060022=

TAF KIND 151720Z 1518/1624 21009KT P6SM BKN180
   FM160000 18005KT P6SM VCSH OVC070
   FM160800 VRB04KT P6SM VCSH BKN060
   FM161300 15005KT P6SM BKN030
   FM161700 16008KT P6SM BKN060=

WINDS IND   FT   3000    6000    9000   12000   18000   24000  30000  340
06 15/20-16/03   1909 1913+05 2320-02 3018-05 2937-18 2857-29 297145 2981
12 16/03-16/12   2612 2114+04 2314-01 2717-05 3032-18 2960-29 297645 2986
24 16/12-17/00   1807 9900+07 3011+02 2919-03 3043-15 3159-28 327744 3290

!EYE 05/004 EYE NAV ILS RWY 21 LOC U/S 2105111439-2105212000EST
!IND 05/047 IND RWY 05R/23L CLSD EXC 15 MIN PPR 3174875023 2105160500-210
!IND 05/046 IND RWY 05R/23L CLSD EXC 15 MIN PPR 3174875023 2105170500-210
!IND 05/043 IND RWY 14/32 CLSD 2105160800-2105161130
!IND 05/042 IND RWY 05R/23L CLSD 2105170500-2105170800
!IND 05/041 IND RWY 05R/23L CLSD 2105160500-2105160800
!IND 05/039 IND TWY A2, A4, A5, A7, A11, A12, B2, B5, B7, B11, B12, TWY R
  RWY 05L/23R AND TWY B, TWY B BTN TWY T AND TWY B12 CLSD 2105121858-2106

G-AIRMET
03 15/18-15/21 TURB (24000-41000 MSL)
06 15/21-16/00 TURB (24000-39000 MSL)
06 15/21-16/00 ICING (7000-18000 MSL)
```

Try running `./localwx --curses` for a continually updating version. The curses version will display the total number of TIS-B targets the ground station is tracking and the RSR in the bottom line of the screen on the far right. If the first character in the bottom line (far left) is '`*`' this means that all of the CRLs have their full reports. `localwx` is designed for a single ground station, and the full CRL report status and RSR and TIS-B targets won't be useful if you are receiving multiple ground stations.

Getting Location Working

Another optional, but useful, addition is to get location services working. Location services add longitude and latitude information to text based weather reports (METAR, TAF, WIND forecasts) and PIREPs. PIREPs are more difficult because it's often human input and the humans don't do very well at putting locations in the way they are supposed to. Also, PIREPs use bearings, and bearings are magnetic and locations are WGS84 (GPS) true coordinates. So you have to know the declination for each point. The FAA data we use doesn't always have this information.

We will need 3 files from the FAA's Aeronautical Data Delivery Service. Unfortunately, there aren't any simple links to the data, you have to navigate the website to get it. On the home page, scroll down a bit and you will see '*Explore Categories*'. In that section there will be three items of interest: '*Airports*', '*Navaids*', and '*Designated Points*'. For each of them you will follow the same procedure:

- Click on the item.
- For airports select the 'Airports' data item. For Navaids select the 'NAVAID System' item. For Designated Points select 'Designated Points',
- For each of these you will see a `Download` drop down box toward the top right of the page. Select it and under `Full Dataset` select `Spreadsheet`. This will save a `.csv` file to wherever your downloads are normally saved. This file will be called one of:
    - `Airports.csv`
    - `NAVAID_System.csv`
    - `Designated_Points.csv`

You need all three of these files. Harvest location services uses the `fisb_location` database we created earlier.

Next you need to install some World Magnetic Model software so we can calculate declinations for each point. It can be downloaded from here. You have to fill out a small survey before you can get it. Assuming you are on a Linux system, download the Linux version which is `WMM2020_Linux.tar.gz`. The World Magnetic Model is a great system, but it's one of those programs written by mathematicians who write great math software but know little about user experience. So there are some quirks to work around. Take your `WMM2020_Linux.tar.gz` and un-tar it (`tar -xvzf WMM2020_Linux.tar.gz`) in some place like your home directory. It will be placed in the `WMM2020_Linux` sub-folder. `cd` to the `WMM2020_Linux/bin` directory. There are two files we are interested in. `wmm_file` and `WMM.COF`. `wmm_file` isn't set up as an executable, so `chmod ugo+x wmm_file` to make it one. Either add the `WMM2020_Linux/bin` directory to your path, or place `wmm_file` in `/usr/local/bin` or someplace where the system will find it. It runs fine on Ubuntu 20.04 as is. If you run into issues (like you are using a Raspberry Pi), you can change the the source directory and type `make` to build from sources.

Assuming your 'fisb-decode' clone is in your home directory, and `WMM2020_Linux.tar.gz` is in the `~/Downloads` folder, the commands will look like this:

```
cd ~
tar -xvzf ~/Downloads/WMM2020_Linux.tar.gz
cd WMM2020_Linux/bin
chmod ugo+x wmm_file
sudo cp wmm_file /usr/local/bin
cp WMM.COF ~/fisb-decode/bin
```

The `WMM.COF` **HAS TO** be copied to the `fisb-decode/bin` directory. Once we are done filling the location database, you can remove it.

So with `WMM.COF` copied to `fisb-decode/bin` and the `.csv` files downloaded and in some directory (your choice), we can fill the database with location information. From the `fisb_decode/bin` directory type something like:

```
./locationdb <directory where .csv files are located>
```

My output with the `.csv` files in my home directory looks like:

```
./locationdb ~/
airports...



---------------------------------------------
 WMM 2020 File processing program 10 Dec 2019
---------------------------------------------



 'f' switch: converting file with multiple locations.
   The first five output columns repeat the input coordinates.
   Then follows D, I, H, X, Y, Z, and F.
   Finally the SV: dD, dI, dH, dX, dY, dZ,  and dF

 Processed 22737 lines

Caution: some calculated locations approach the blackout zone around the r
pole as defined by the WMM military specification
(https://www.ngdc.noaa.gov/geomag/WMM/data/MIL-PRF-89500B.pdf).
 Compass accuracy may be degraded in this region.
navaids...



---------------------------------------------
 WMM 2020 File processing program 10 Dec 2019
---------------------------------------------



 'f' switch: converting file with multiple locations.
   The first five output columns repeat the input coordinates.
   Then follows D, I, H, X, Y, Z, and F.
   Finally the SV: dD, dI, dH, dX, dY, dZ,  and dF

 Processed 1679 lines
```

```
reporting points...


-----------------------------------------------
 WMM 2020 File processing program 10 Dec 2019
-----------------------------------------------



 'f' switch: converting file with multiple locations.
   The first five output columns repeat the input coordinates.
   Then follows D, I, H, X, Y, Z, and F.
   Finally the SV: dD, dI, dH, dX, dY, dZ,  and dF

 Processed 1355 lines
```

You can use Mongo to check out the new collections. Be sure to `use fisb_location` as your database. The new collections are `AIRPORTS`, `DESIGNATED_POINTS` and `NAVAIDS`.

To get harvest to use this data we need to make (you guessed it) configuration changes. Edit `../db/harvest/harvestConfig.py` and change the following lines (leaving the rest unchanged).

```
TEXT_WX_LOCATION_SUPPORT = True
PIREP_LOCATION_SUPPORT = True
```

Stop any running `harvest` and `decodeNetToDir` programs. To see the changes more easily, wipe the `fisb` database (from `bin`):

```
mongo ../db/scripts/createFisb.js
```

Then start `harvest` and `decodeNetToDir`. You can run Mongo to look at the tables `METAR`, `TAF`, `WINDS_06_HR`, `WINDS_12_HR`, and `WINDS_24_HR`. Pretty much all the them will have `geojson` tags with locations. Also look at the `PIREP` table. PIREPs are tricky and not all of them (but well over 90%) will have location information associated with them.

Congratulations! You now have a complete ‘fisb-decode’ system consisting of fully functioning ‘fisb’ and ‘harvest’ sub-systems.

Other Topics

Images

Images are always geotiff files and are normally stored in `fisb-decode/runtime/images`. The image system is pretty much self-managed by

> **Getting Image Data**
>
> If you want to follow along in this section, but don’t have any image data

harvest. They are created when they arrive and removed after whatever interval the standard says they should be removed. Most images have rules that when the next one starts to arrive, the previous one gets removed. Other images, like radar, can combine old images with new images, but the older image can't be more than 10 minutes older than the newest image.

to view, don't worry. Read the Running Test Groups 28-30 section, then come back here. Be sure you are in the `bin` directory and type:

```
./harvest --test 30

<will run for a little over
 8 minutes, then type:>

cd ../tg/results/tg30/01
```

You will find plenty of `.tif` images and vector data to use in the instructions that follow.

One interesting fact about FIS-B images is that most are not rectangles. NEXRAD-CONUS is a rectangle. Some are almost rectangles. NEXRAD-REGIONAL and LIGHTNING are poly-sided shapes approximating a circle. I bring this up, because to harvest, all images are rectangles. When harvest is making an image, it looks to see what the smallest bounding box would be (i.e. biggest and smallest latitude and longitude) and that becomes the limit of the rectangle. The area of the rectangle that isn't a part of the FIS-B image is referred to (by me, FIS-B has no concept of this) as the '*not included*' portion.

FIS-B has the concept of '*no data*'. These are areas where the FIS-B system knows it doesn't have any data. Most images, other than radar, have a specific 'no data' encoding. Radar doesn't have that concept. However, to harvest, all images start out totally encoded with the 'not included' value. So if a radar image is missing a block, it will show up with the 'not included' value. 'Not included' and 'no data' are different concepts that are mostly displayed the same, but don't have to be.

There are three different ways that harvest can handle 'no data' and 'not included' values. All are controlled with the `harvestConfig.py` setting of:

```
IMAGE_MAP_CONFIGURATION = 0
```

If this value is `0`, the 'no data' and the 'not included' data show up as transparent. If you are displaying the images for casual viewing, this is the best option. A value of `2` shows the 'no data' and 'not included' values with the same color. If you were making decisions when using this data, this is the value you would want. Note that this only works within the boundaries of the image rectangle. Outside of the image file is also 'not included'. If you were building a display system, you would probably want to consider this and make everything outside of the rectangle the 'not included' color. A value of `1` is for testing and debugging. This will show 'no data' and 'not included' in different colors.

Another configuration value to consider is:

```
IMAGE_QUIET_SECONDS = 10
```

When an image arrives it pretty much arrives as a group of block messages. If you happen to be doing an image update in the middle of an image arriving, you will get only a partial image (not containing the data that didn't arrive yet). When the rest of the image shows up, the next image update will show the completed image. What this value says is to not make a new image unless there has not been any new value information for an image for the stated number of seconds. That way, you usually will always get complete images and not partial images.

If you don't like pixilated images, you can set:

```
SMOOTH_IMAGES = False
```

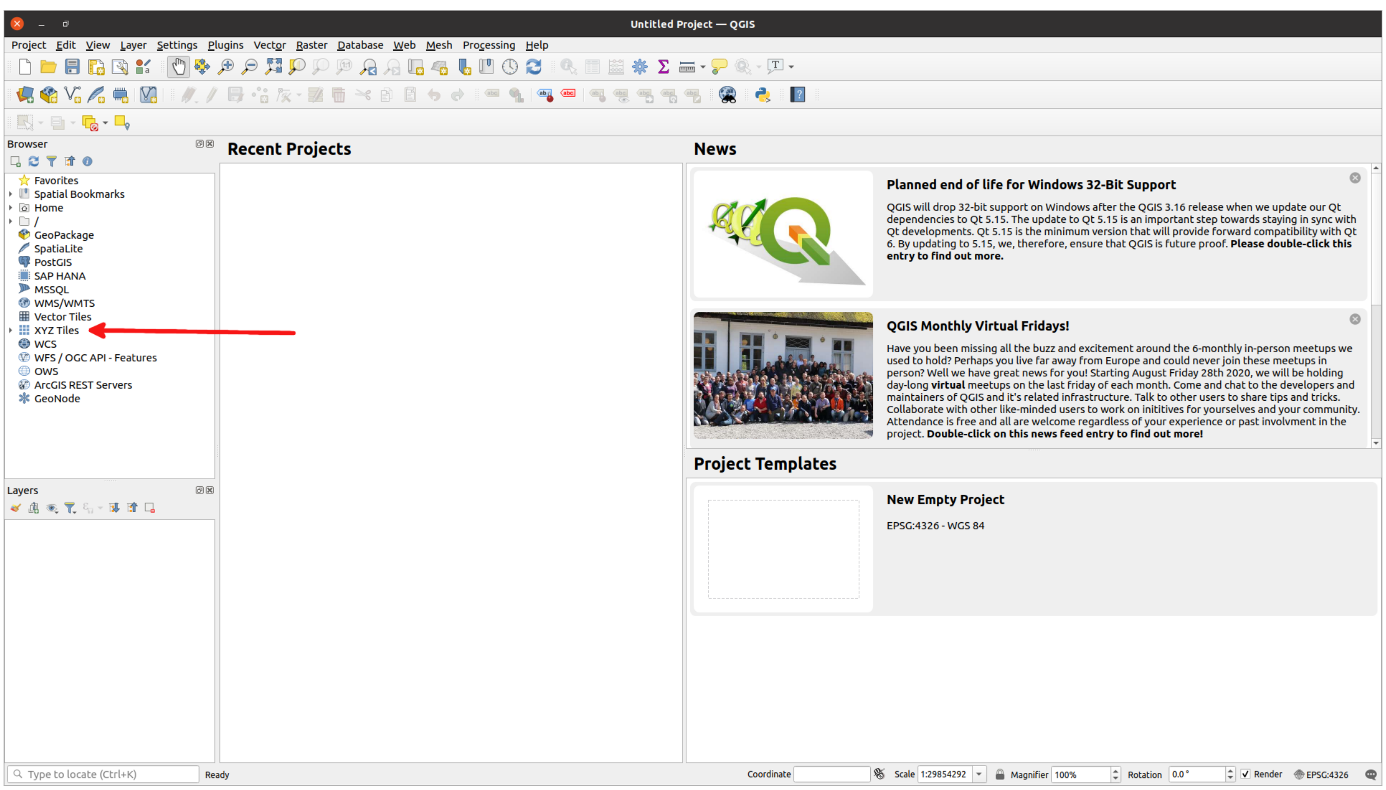
to `True`. If you do this, the images are smoothed using a bi-linear interpolation. The downside is that images are 4 times bigger.

Viewing Images

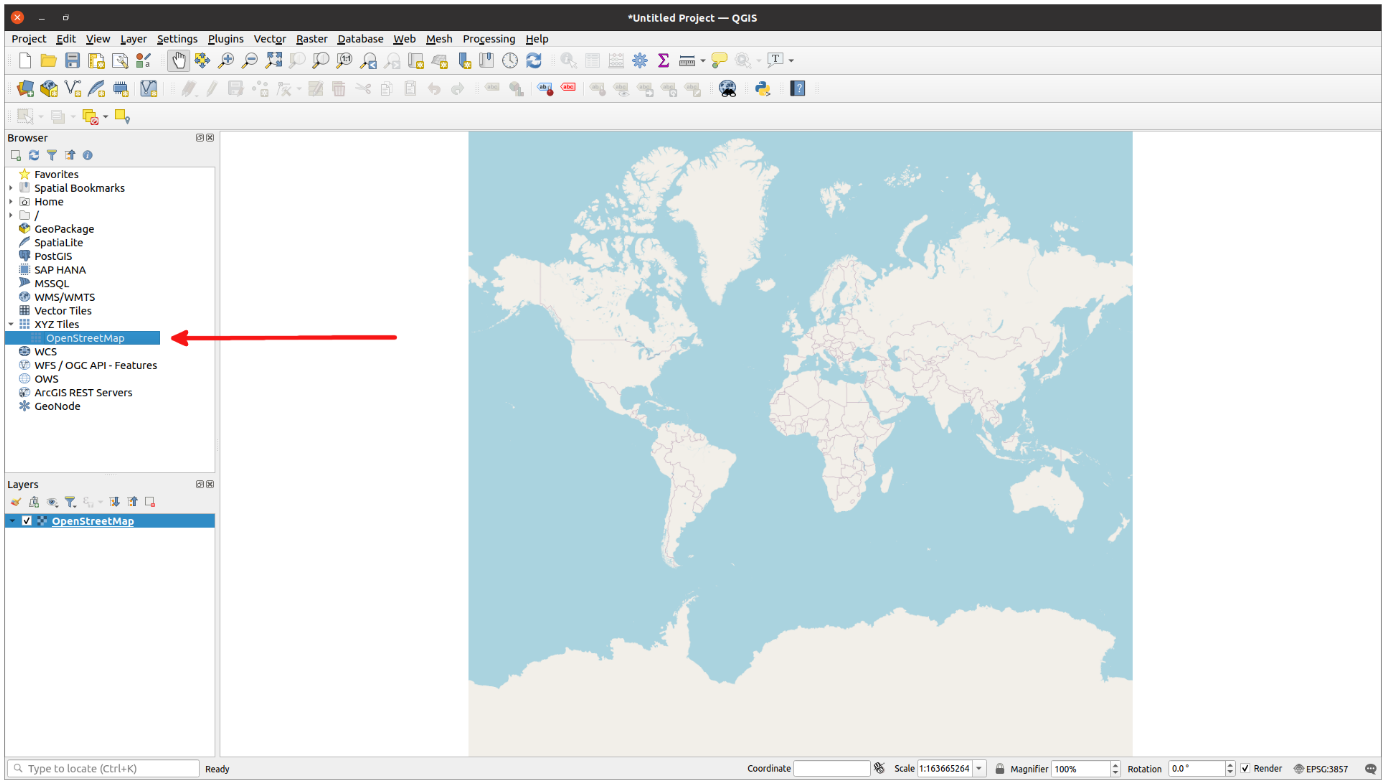
Before starting this section, let me repeat that 'fisb-decode' is strictly a back-end system for FIS-B. Looking at images and vectors at this level is just to make sure the system is working properly. A front-end system built on top of 'fisb-decode' would have a lot more options and features.

I do all my image and vector viewing using QGIS. QGIS is an excellent program, but it has a **HUGE** learning curve. It will provide you with hours of endless frustration. My goal here is to give you the minimal information to display 'fisb-decode' images and vectors using QGIS. I leave it as an exercise for you to get QGIS installed on your system.

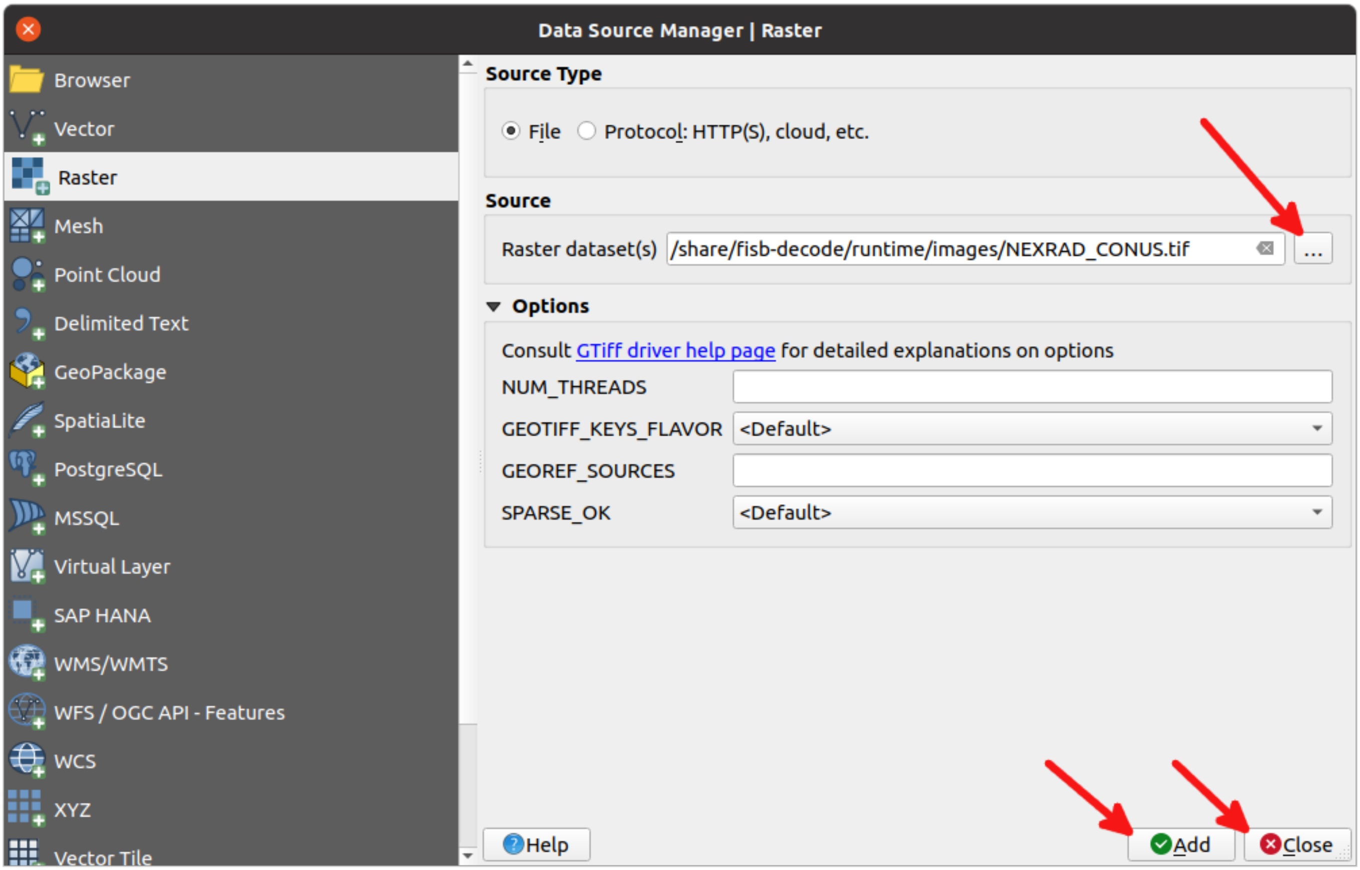
When you start QGIS you should get a screen that looks like (after a splash screen):



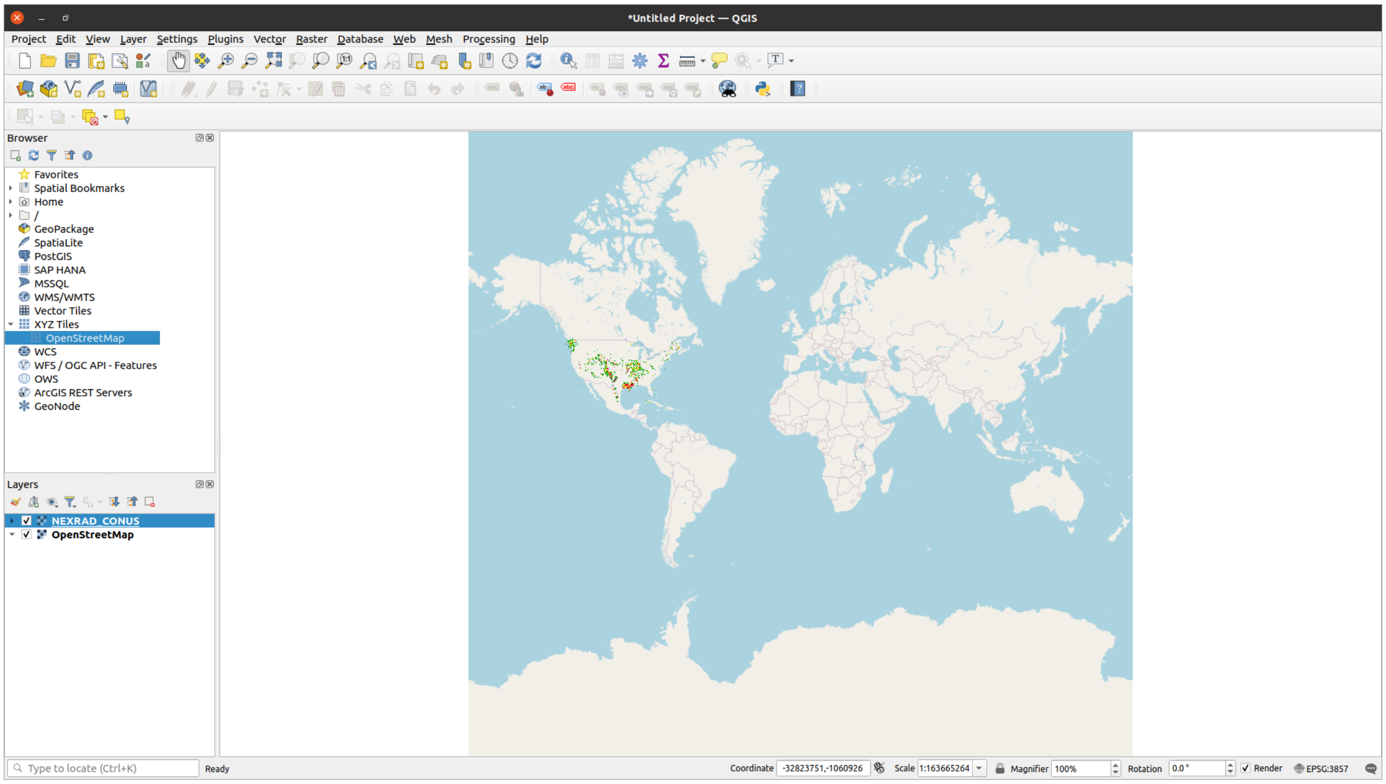
On the far left hand side, you see an item called ‘`XYZ Tiles`’. Click on the down-arrow to the left of ‘`XYZ Tiles`’ and the ‘`OpenStreetMap`’ label will appear. Double-click on ‘`OpenStreetMap`’. Your screen should now look like this:



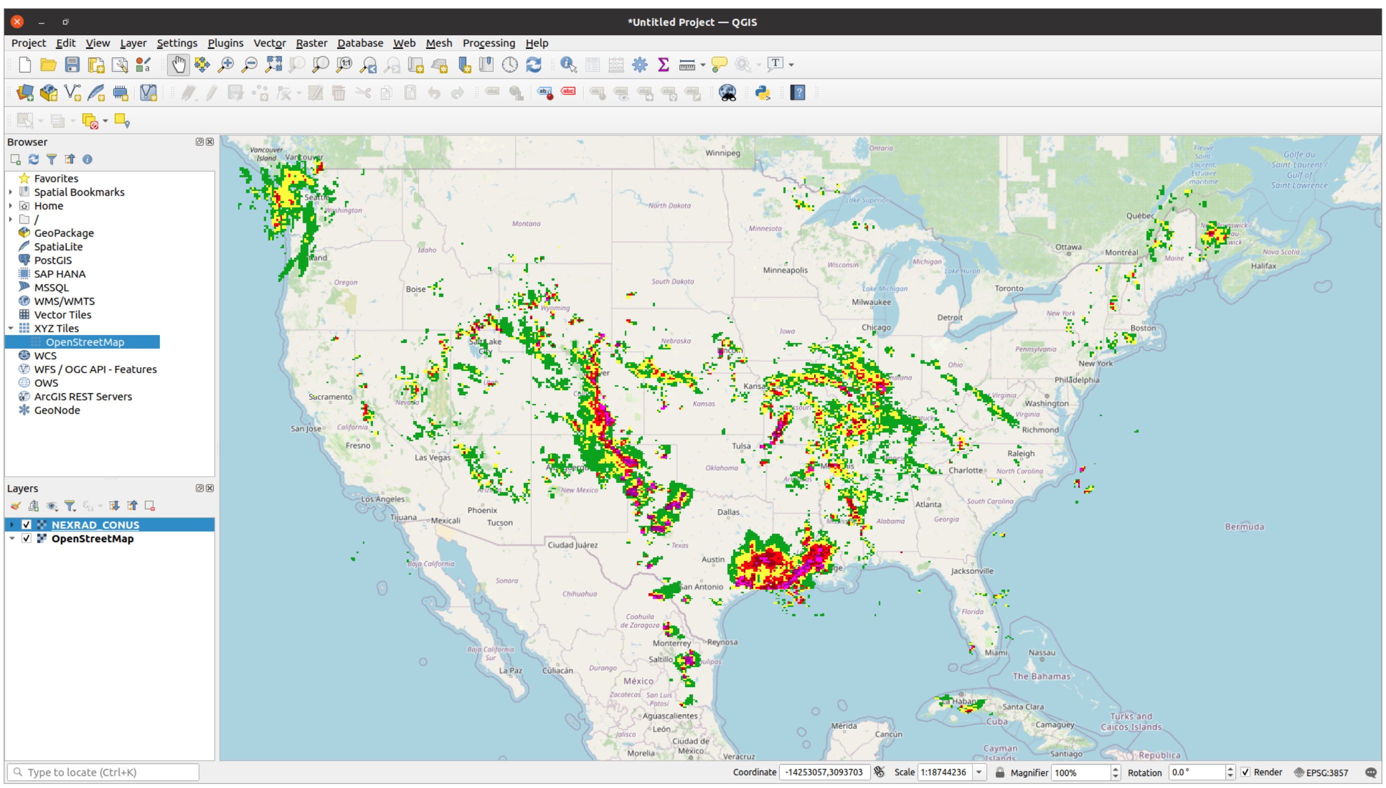
At the very top of the screen select ‘`Layer`’, then ‘`Add Layer`’, and then ‘`Add Raster Layer...`’. You will then get a pop-up window that looks like:



Under '`Source`' and to the right of '`Raster dataset(s)`' click the 3 dots '`...`' to bring up a file dialog. Find an image file in the `fisb-decode/runtime/images` directory. In this example I chose `NEXRAD_CONUS.tif`. Click the `Open` button on the top right of the file dialog and you will be returned back to the raster dialog box. Click '`Add`' in the bottom right corner (your selected filename should be in the box to the right of the '`Raster dataset(s)`' line) and then click '`Close`'. Your screen will now look something like:



Use your mouse scroll wheel to zoom in and out. Hold the left mouse button to pan. You should be able to make your screen similar to:



That's pretty much it for loading `.tif` files. Your most important box at this point is the `Layers` area at the bottom left. Right clicking on a layer will give you a number of useful options. Click the check mark next to the layer name to make the layer visible or invisible.

Viewing Vectors

Lots of messages in FIS-B generate vector data. AIRMETS, SIGMETS, WST, CWA, NOTAMS, etc. Text weather data (METAR, TAF, etc) as well as PIREPs do too if you have the location support up and running. Vector data comes in the form of points, polygons, and linestrings. FIS-B also has circles, but harvest already turned any circles into 32 point polygons.

To get started with vectors, we will take a 'vector snapshot'. From the `bin` directory type:

```
./vectordump
```

If you have any vector data, your `bin` directory will suddenly have lots of `.csv` files it. Like so:

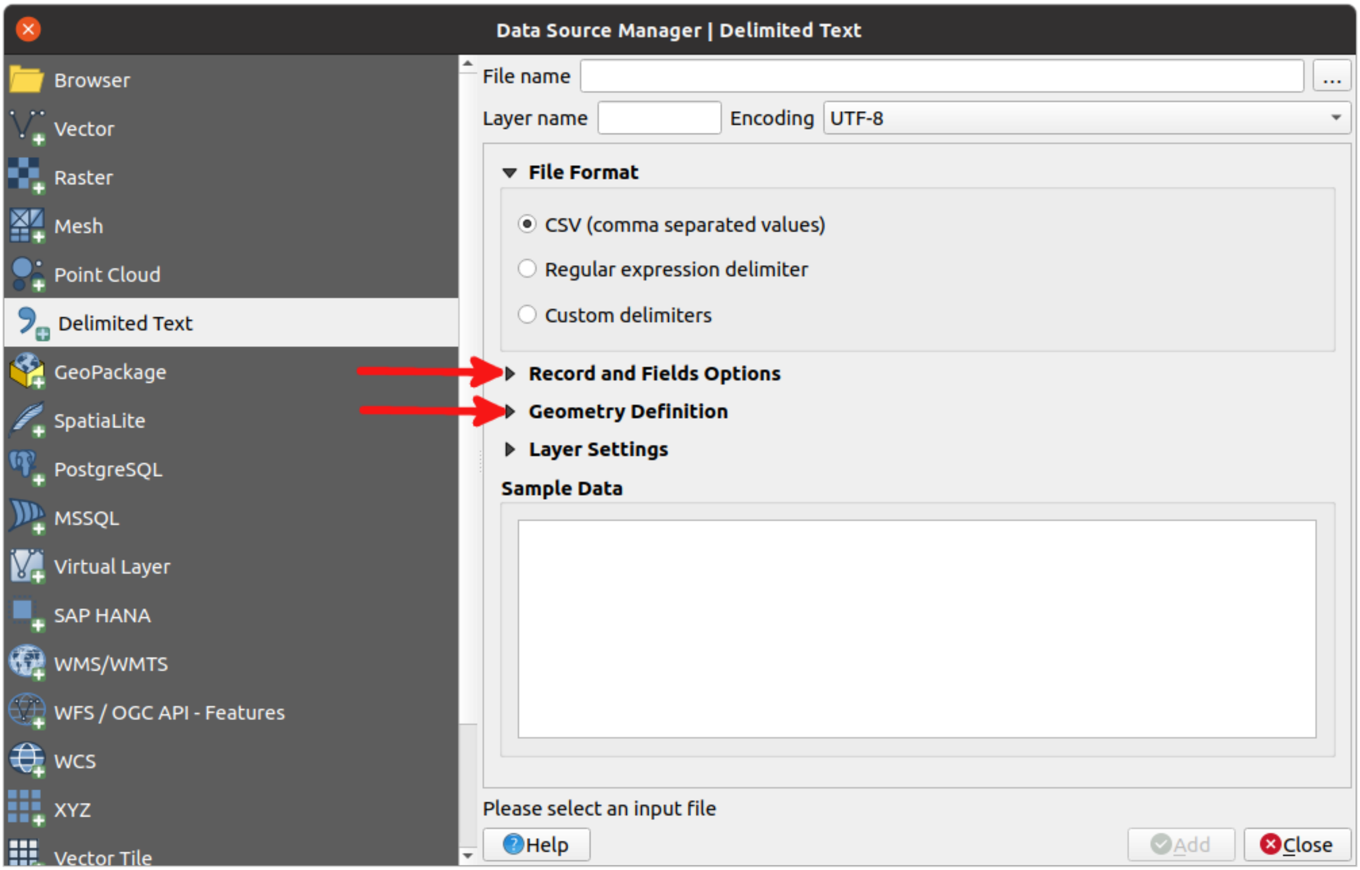
```
mbarnes@gis:/share/fisb-decode/bin$ ls
config-files-bckup decode-nopp        trickle                    V-NOTAM-D-P
config-files-rstr  harvest            trickleToDir               V-NOTAM-FDC
decode             isodate-from-secs  V-AIRMET-PG.csv            V-PIREP-PT
decode0            isodate-to-secs    vectordump                 V-TAF-PT.cs
decode0Net         localwx            V-G_AIRMET_00_HR-LS.csv    V-WINDS_06_
decode1            locationdb         V-G_AIRMET_00_HR-PG.csv    V-WINDS_12_
decode1Net         loopfiles.sh       V-G_AIRMET_03_HR-LS.csv    V-WINDS_24_
decode2            nopp2pp            V-G_AIRMET_03_HR-PG.csv    V-WST-PG.cs
decode2Net         pp2nopp            V-G_AIRMET_06_HR-LS.csv    WMM.COF
decodeNet          run-all-tests      V-G_AIRMET_06_HR-PG.csv
decodeNetToDir     tgTo978            V-METAR-PT.csv
```

Ugly huh? Doing a vector dump is something that doesn't happen very often in real life, so I just put the files in the current directory (`bin` in this case) and you should '`rm *.csv`' when you are done.

The vector files all start with `V-` then the item the vector is for. So `METAR` for METARs, etc. If there is no vector information for a particular type, a file will not be created. In this case, there is no `NOTAM_TFR` with vector data, so there is no file. The last part is either `-LS`, `-PT`, or `-PG`. These stand for *linestring*, *point*, and *polygon*, respectively. QGIS requires that each file only contains data of a single type. G-AIRMETs can contain both polygons and linestrings, but each type needs to be in a different file.

The files produced are `.csv` files and each line is its own object in something called WKT (Well Known Text) format.

Vectors in QGIS are trickier to display than raster (`.tif`) images. To load a vector file, start up QGIS, double click on '`OpenStreetMap`' just like you did for raster files. Now select '`Layer`' at the top of the screen. Select '`Add Layer`' and then '`Add delimited text layer...`'. You should now have a screen that looks like:

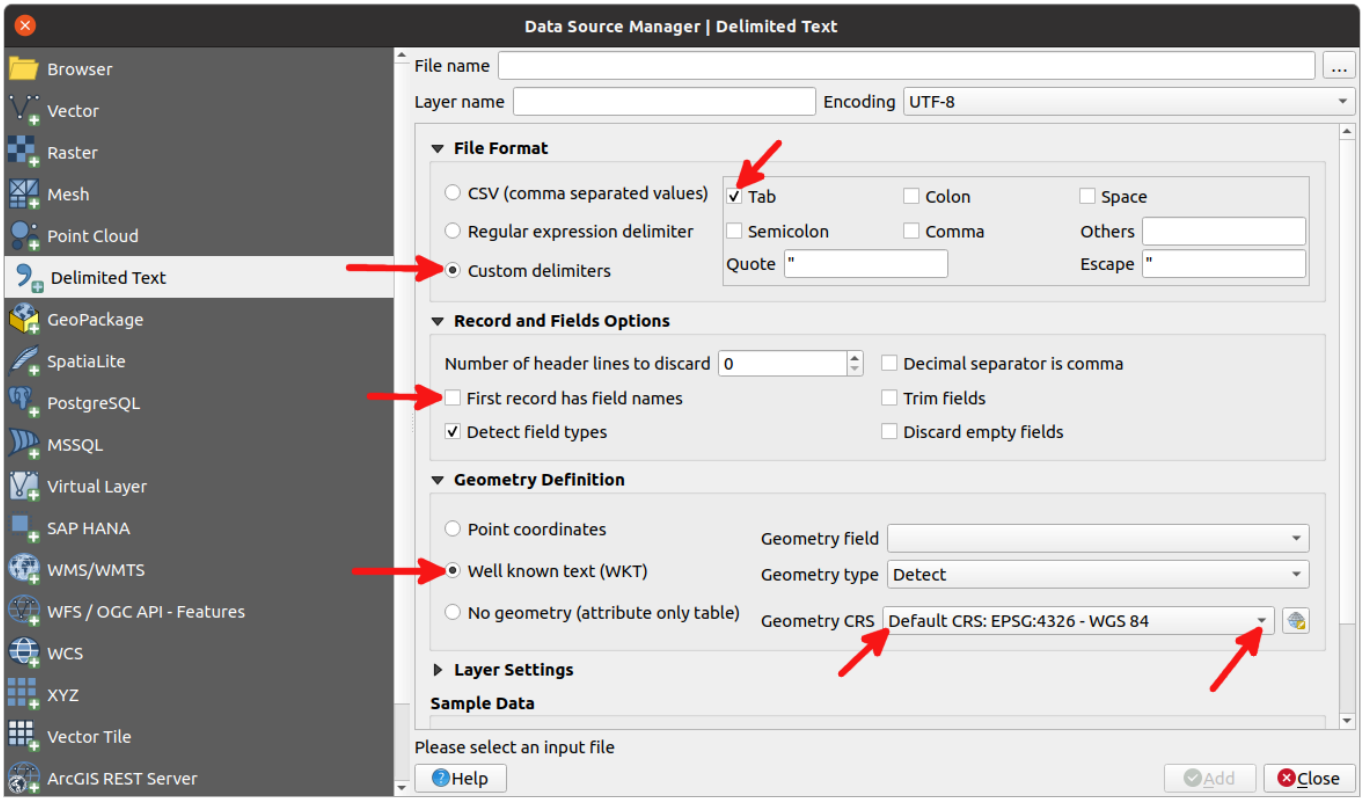


The screen you will initially see has the '`Record and Fields Options`' and '`Geometry Definition`' sections collapsed. Click of the arrows to the left of them to expand them. Don't worry about '`Layer Settings`'.

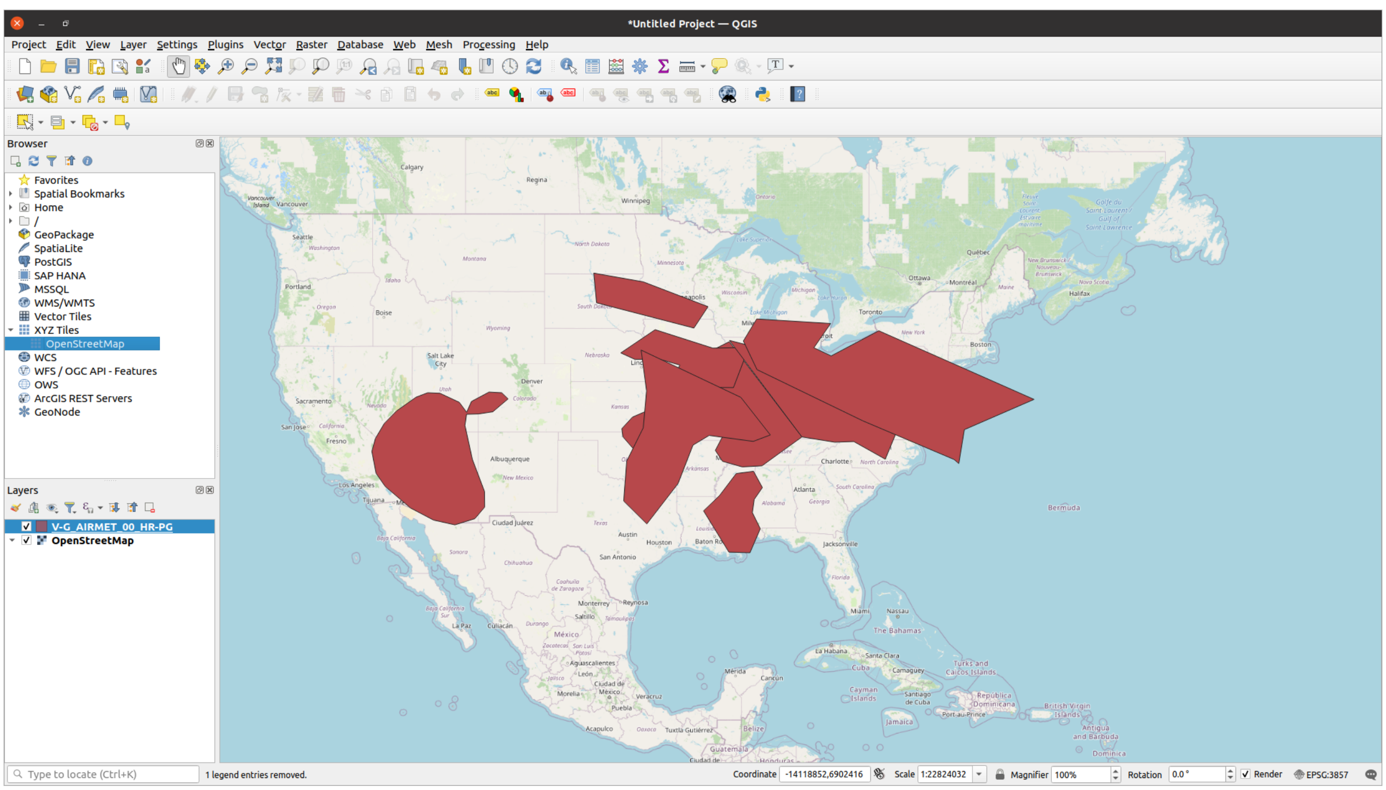
Unlike the raster screen where we didn't care about anything other than the file name, on this screen you need to make sure **EVERYTHING** on the screen below matches. Change the screen as needed. In particular make sure that:

- In '`File Format`', select '`Custom delimiters`'. Make sure '`Tab`' is selected.
- For '`Record and Fields Options`', **unselect** '`First record has field names`'.
- Number of header lines to disgard is '`0`'.
- Geometry Definition has '`Well known text`' selected and '`Geometry CRS`' is '`Default CRS: EPSG:4326 - WGS 84`' (you will need to click the drop down arrow to find this option).
- Geometry type has '`Detect`' selected.
- Don't worry about '`Layer Settings`'.

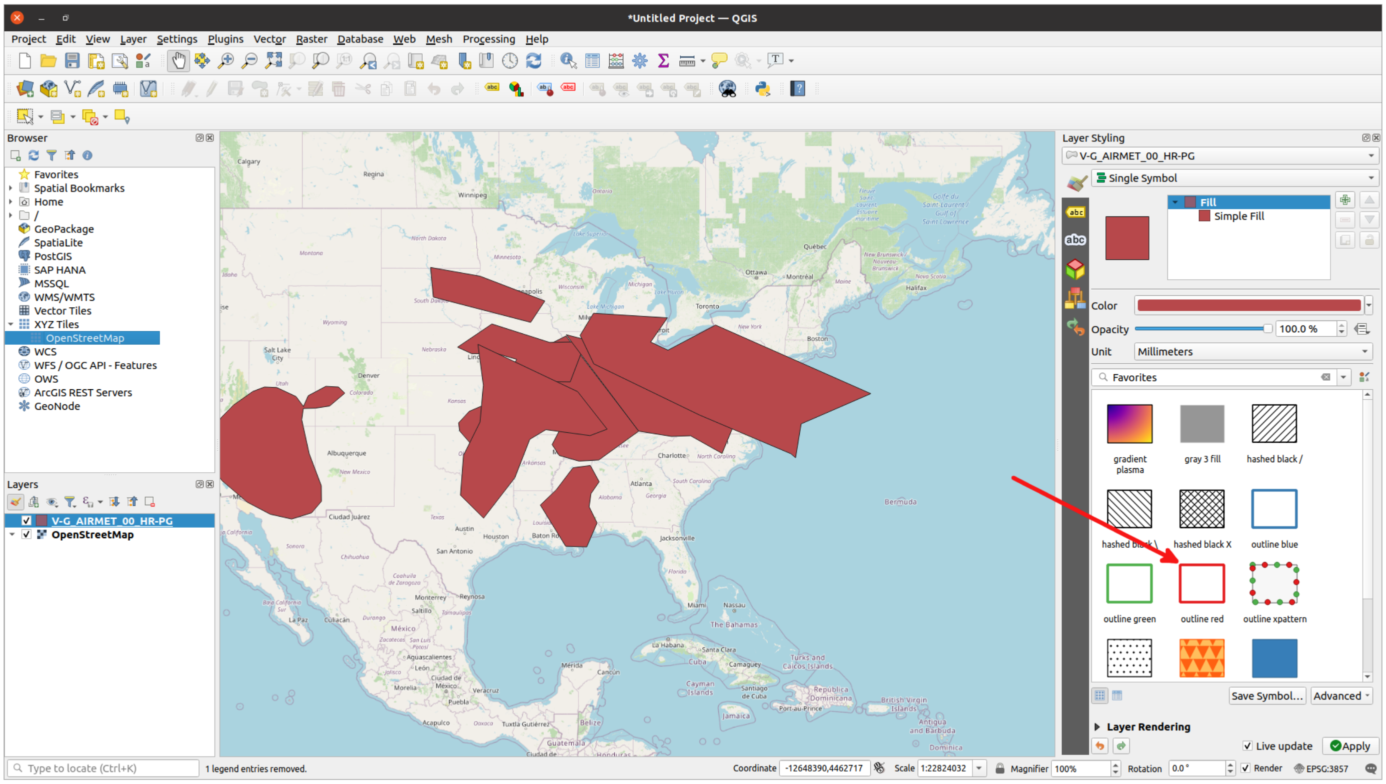
You only have to do make these changes once. From here on every time you open up a vector file, the settings will be the last settings you used. Your screen should look like:



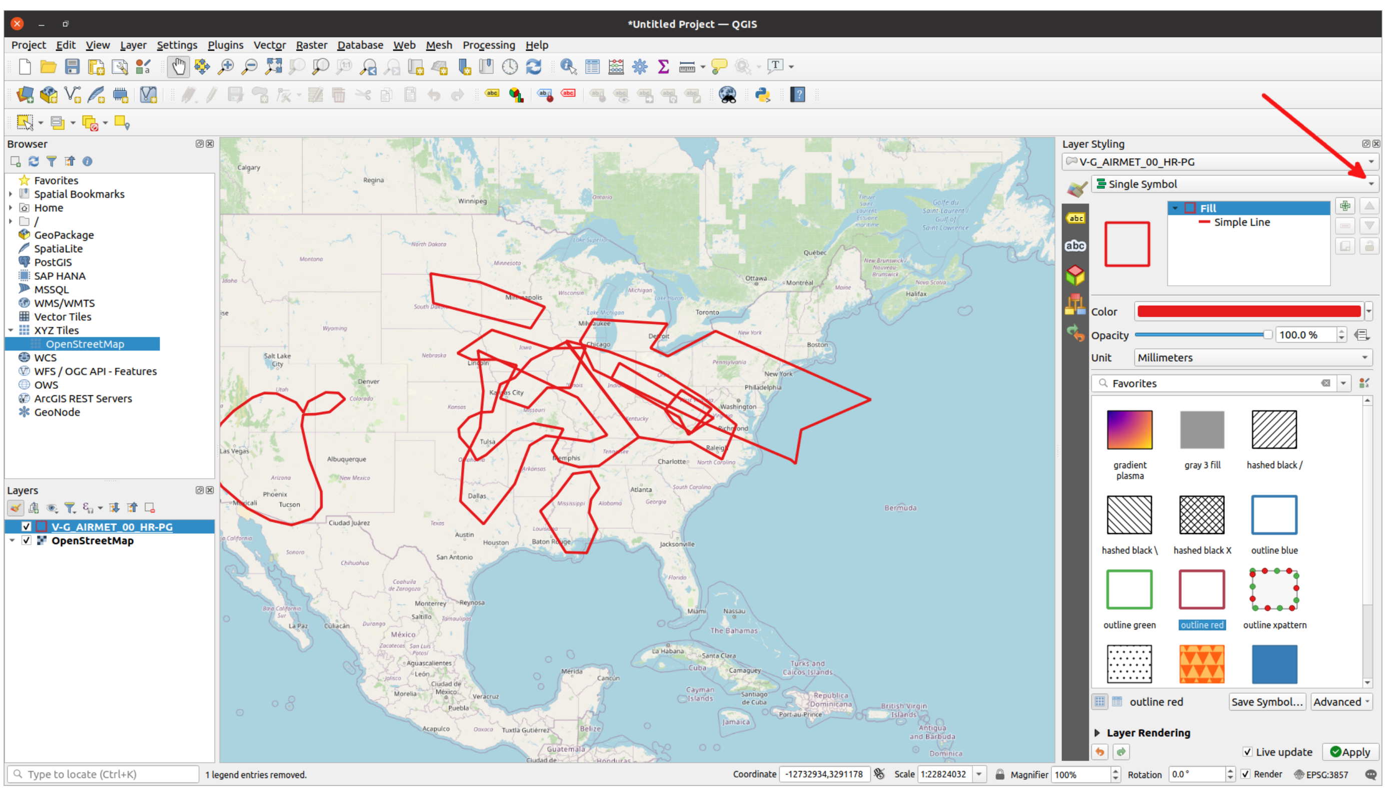
Once you changed the settings, select the filename just like you did with a raster file. Click the '`...`' for the '`File name`' field. Select the file, then click on '`Open`' at the top right of the dialog. Now click on '`Add`', then click on '`Close`'. Now your screen should resemble:



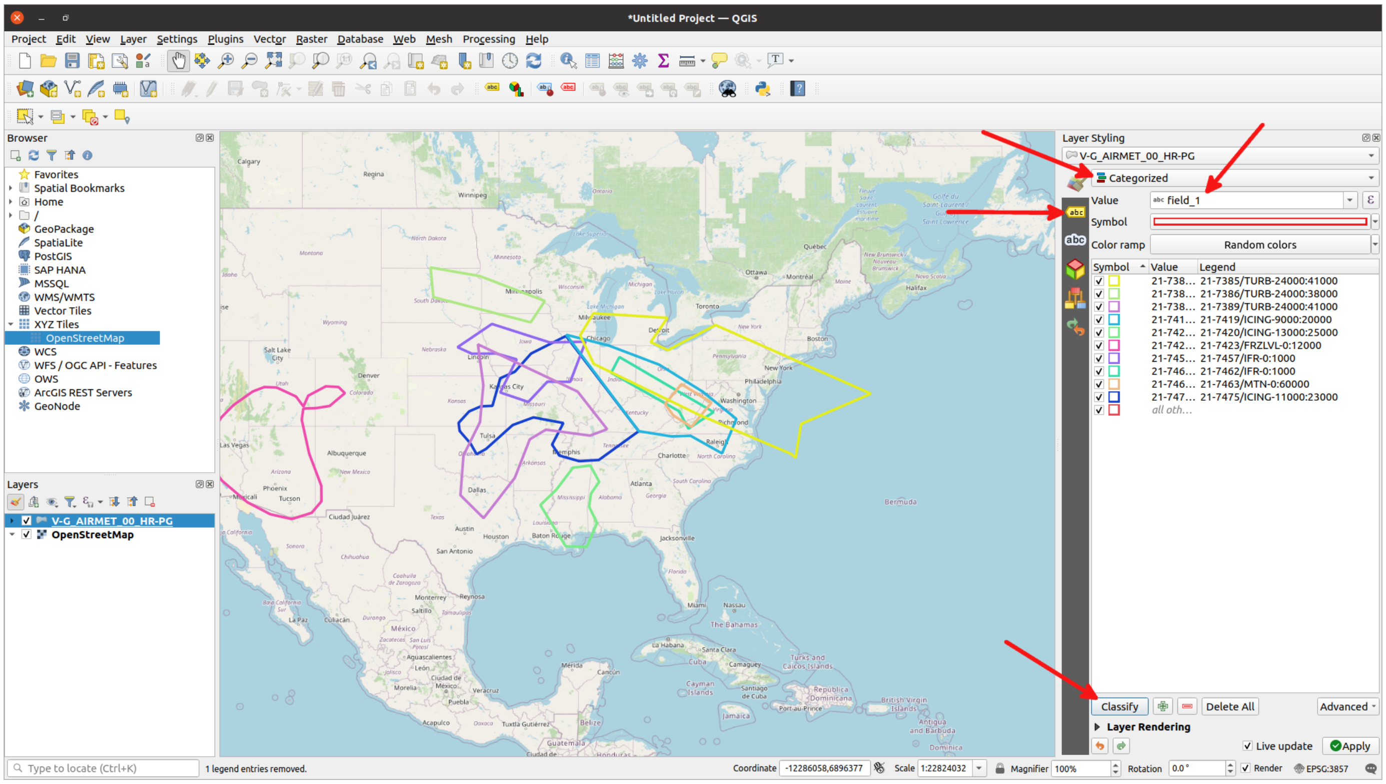
The data is there, but it's just a mass of solid color. Let's change it to an outline form. First, bring up the '`Layer Styling`' panel. In the top menu bar select '`View`' then '`Panels`' then click the check-mark next to '`Layer Styling`'. The panel will appear on the right side of the screen, but is not wide enough. Grab the left hand margin of the panel and extend it a bunch. It should look like:



Your attention from here on out is on the ‘`Layer Styling`’ panel. You should see a bunch of rectangles. Click on the one with the red border called ‘`outline red`’ (‘`outline green`’ or ‘`outline blue`’ works just as well). Now your screen should approximate:



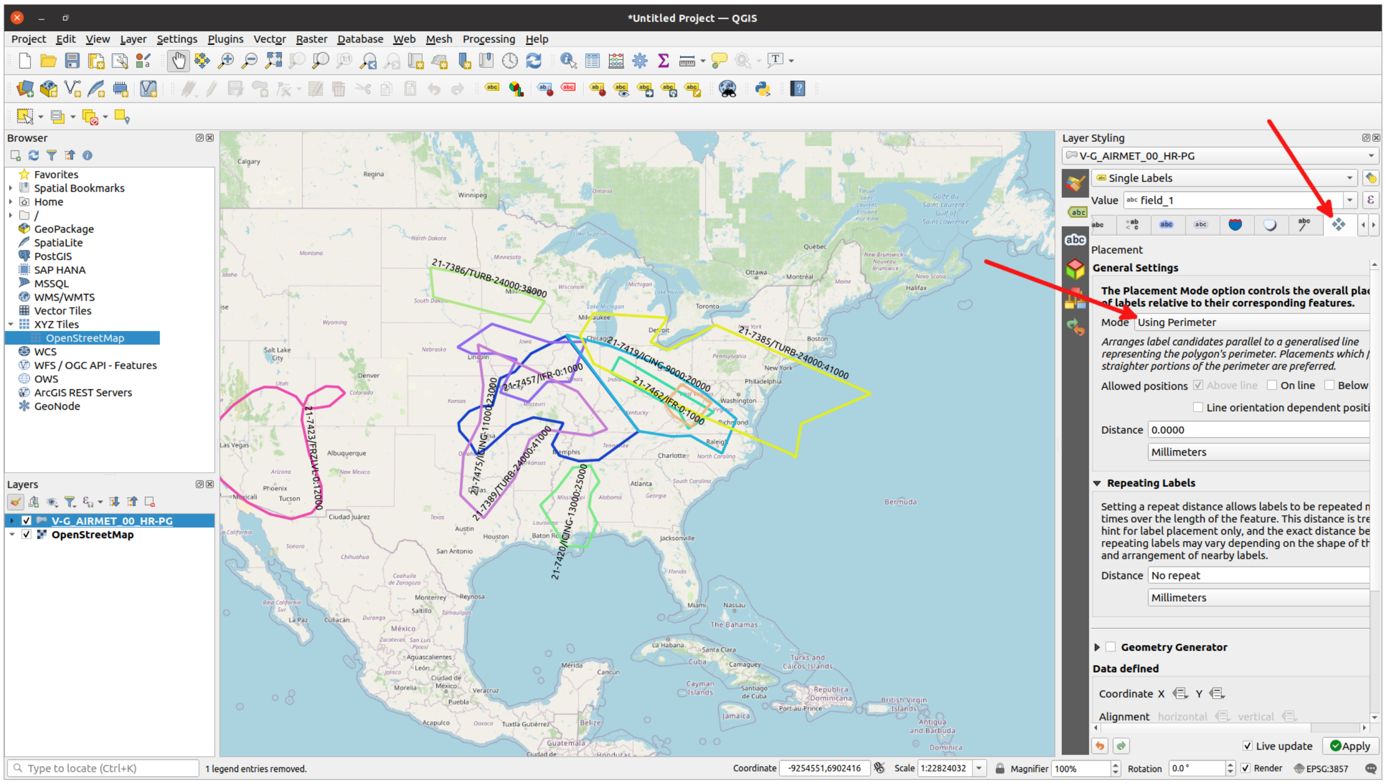
Well, we have outlines, but that didn't make things any clearer. Next let's make each outline a different color. Near the top right side is a drop-down box that has '`Single Symbol`' as its default. Click the arrow on the right side of the box and select '`Categorized`'. Once you do that, your vectors will disappear. Don't fret. Right underneath the '`Categorized`' drop-down is another one labeled '`Value`'. Click on its arrow and select '`abc field_1`'. Then, a little bit further down the right side of the screen is a button labeled '`Classify`'. Click on it. Voila! Your vectors are back, each in a different color. It should resemble:



Last step is to add some labels. On the left side of the '`Layer Styling`' panel, you will see some icons. There are two that say '`abc`'. You want the yellow top one, not the white one. Click on it. There should now be a drop-down label that says '`No Labels`'. Click its drop-down arrow and select '`Single Labels`'. Now you have labels. But they are not in the best place. You should see menu of icons underneath where it says '`Value`' with the contents '`abc field_1`'. Select the 8th icon over that is 4 green arrows pointing N, S, E, W. You should see the '`Placement`' screen. Underneath that is a drop down box labeled '`Mode`', with its value '`Around Centroid`'. Select its drop-down arrow and select '`Using Perimeter`'. There are no great label placement settings, but that's usually the best. Zooming in will usually help.

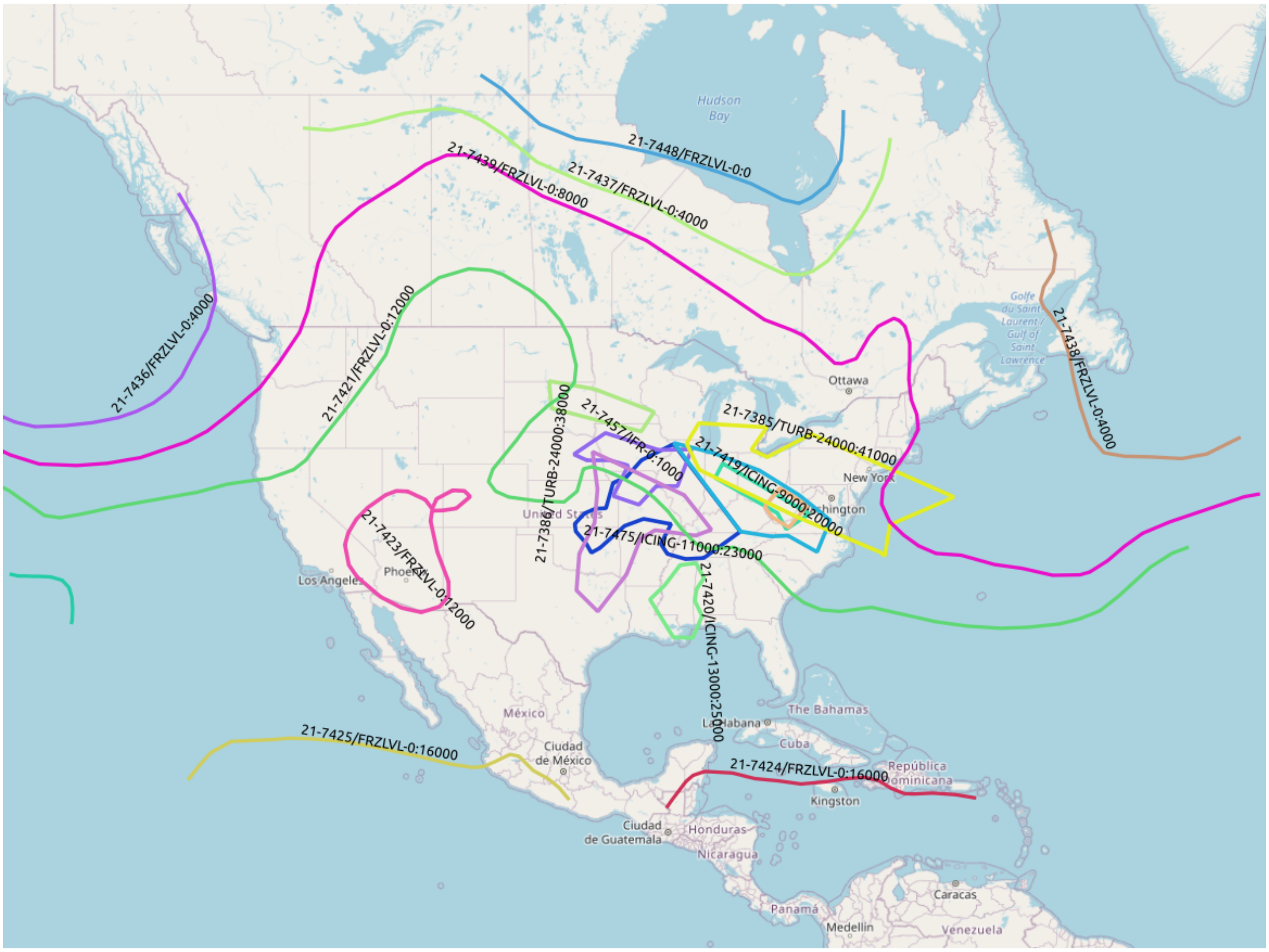
Don't worry too much about what the label says, it's meant for debugging, not general interpretation.

Your screen should mimic:



Okay, you can now load vectors into QGIS. Congrats! Try other files, such as files with linestrings (G-AIRMET) or points (NOTAM, METAR, etc).

If you ever want to save an image of a map, you can select ‘`Project`’ from the menu at the top of the screen. Then ‘`Import/Export`’ followed by ‘`Export Map to Image...`’. You can make some image adjustments, but usually I just click on ‘`Save`’. Then you can select the file format and where to save it. I added the linestring G-AIRMET that accompanied the polygon G-AIRMET and did all the steps we did above to get the following image:



Running Test Groups 28-30

A ‘*Test Group*’ is a set of FIS-B packets that are played back in real time to test various behaviors of the system. As of now, there are 30 test groups. 27 (01-27) of these come from the standard body and 3 (28-30) were created by me. We will be start the discussion about how they work and how to process them with the ones I created. We will discuss the ones from the standard body later.

The basic process is you start harvest with the option `--test n` where ‘`n`’ is the number of the test to run. Harvest starts up a sub-process that runs the program ‘`trickle`’. Trickle will fetch the correct set of FIS-B messages from a `.978` file and starts placing them in the same directory where harvest normally finds its files.

When trickle starts, it looks at the timestamp of the first message. It then calculates the difference between that timestamp and the current timestamp. That value is placed in the file `sync.fisb` which is read by harvest. Harvest then adjusts its time so that anytime the current time is needed, harvest will use the time relative to the message. It’s just like a time machine.

Trickle will ‘trickle’ the packets out at a rate that equals the rate that they arrived originally. If, at the time the packets were captured, one packet was received 3 seconds after the first, trickle will also wait 3 seconds before sending the next packet.

If you are a really astute system watcher, you will note that after trickle has finished reading packets, but before harvest does its last dump, the trickle process will become a 'zombie' process. Don't worry about this. When harvest finishes, or is terminated, the zombie process will go away. For many tests that wait around before making a final check, this might be an hour or more.

The `.978` files with the FIS-B packets are stored in the `fisb-decode/tg/tg-source/generated/` directory. The filename with packets is just the name of the test group with a `.978` extension. So test group 28's filename is `tg28.978`.

Another concept to understand with test groups is that of a '*trigger*'. A trigger is some point in time during the test run where we need to dump the contents of the system so that we can examine it later. This dump will happen in a specifically named empty directory and will be filled with a dump of all database tables, vectors, images, and anything else to create a snapshot of the system at the time of the trigger. After the run you can go back and make sure the results were what you expected.

Triggers are stored in the directory `fisb-decode/tg/triggers`. Trigger files have the same name as the test group, but are `.csv` files. They typically have one to ten lines. The trigger for test group 28 (`tg28.csv`) contains:

```
72393, 0, 1, Verify DAYTON TFR (10 and 30 nm circles)
```

`72393` tells harvest to produce a trigger dump at 72393 seconds after midnight on the day it was started. `0` is an offset. You will see numbers like `30` or `-30` here. This means to add 30 or subtract 30 seconds from the trigger time of 72393 before actually doing the trigger. We do this because instructions for many of the test groups say things like 'check for this before 72393 seconds and then check for that after 72393 seconds'. This lets us keep using the time in the instructions, but modify times slightly to accomplish the tasks. The `1` is just a sequence number. This is used to create the correct dump sub-directory. We will get to that in a moment. The string field at the end is just a message that is printed when the dump happens.

Triggers for standard body test groups are the same as above, but the comment line start with a number (or numbers) in square brackets, like `[5]` or `[7-9]`. These indicate the items number(s) in the documentation the trigger applies to.

You will also note another file in the trigger directory called `start-dates.csv`. It has one line for each test group which contains the name of the test group and the date the test is considered to have been started. These dates are used to calculate the seconds after midnight referred to in the test instructions. You may ask: 'If the FIS-B packets already have a timestamp in them, why do we need a specific start date?' And the answer is that you don't need them for non-standard body test groups (28-30). But the standard body test groups usually don't specify a start date, so I had to figure one out for each test.

To run test 28, from the `bin` directory type:

```
./harvest --test 28
```

Your output should look like:

```
*** Running Test 28 ***
Waiting for sync.fisb to be created by trickle.
Expect trigger events at:
  01: 2021-05-17 02:44:54-04:00  72393 -> 2020-09-18 20:06:33

(time delay here)

01:  Verify DAYTON TFR (10 and 30 nm circles)
** done **
```

Harvest tells you at the start of the run when to expect trigger events in your actual local clock time. In this case it is telling me it will produce a dump at `2021-05-17 02:44:54-04:00` local time. Since there is only one trigger, the program will stop then too. `72393` is the number of seconds past midnight on `2020-09-18` and `2020-09-18 20:06:33` is the UTC time in the past that corresponds to `72393` seconds past midnight on that date. When the trigger actually happens, it prints its associated message.

Trigger dumps are placed in the `fisb-decode/tg/results` folder. It will create a new directory with the name of the test group, then sub-folders under that with the sequence number of the trigger (`01`, `02`, etc). So in our case, when the test is done, it will have created the folder: `fisb-decode/tg/results/tg28/01`. Its directory contents will be:

```
2020-09-18-200633_72393  NOTAM_TFR.db  V-NOTAM-TFR-PG.csv
```

Every dump file will have a file with a name like `2020-09-18-200633_72393`. It just tells you the time in UTC (in the past) that the message was processed. `2020-09-18-200633` means ‘2020-09-18 20:06:33’. `72393` is as discussed previously. The contents of this file will be the text of the trigger.

For some test groups, the offset is varied either slightly ahead or behind the specified trigger time. This handles cases like ‘check before this time’, or ‘check after this time’. The trigger filename will then look like one of:

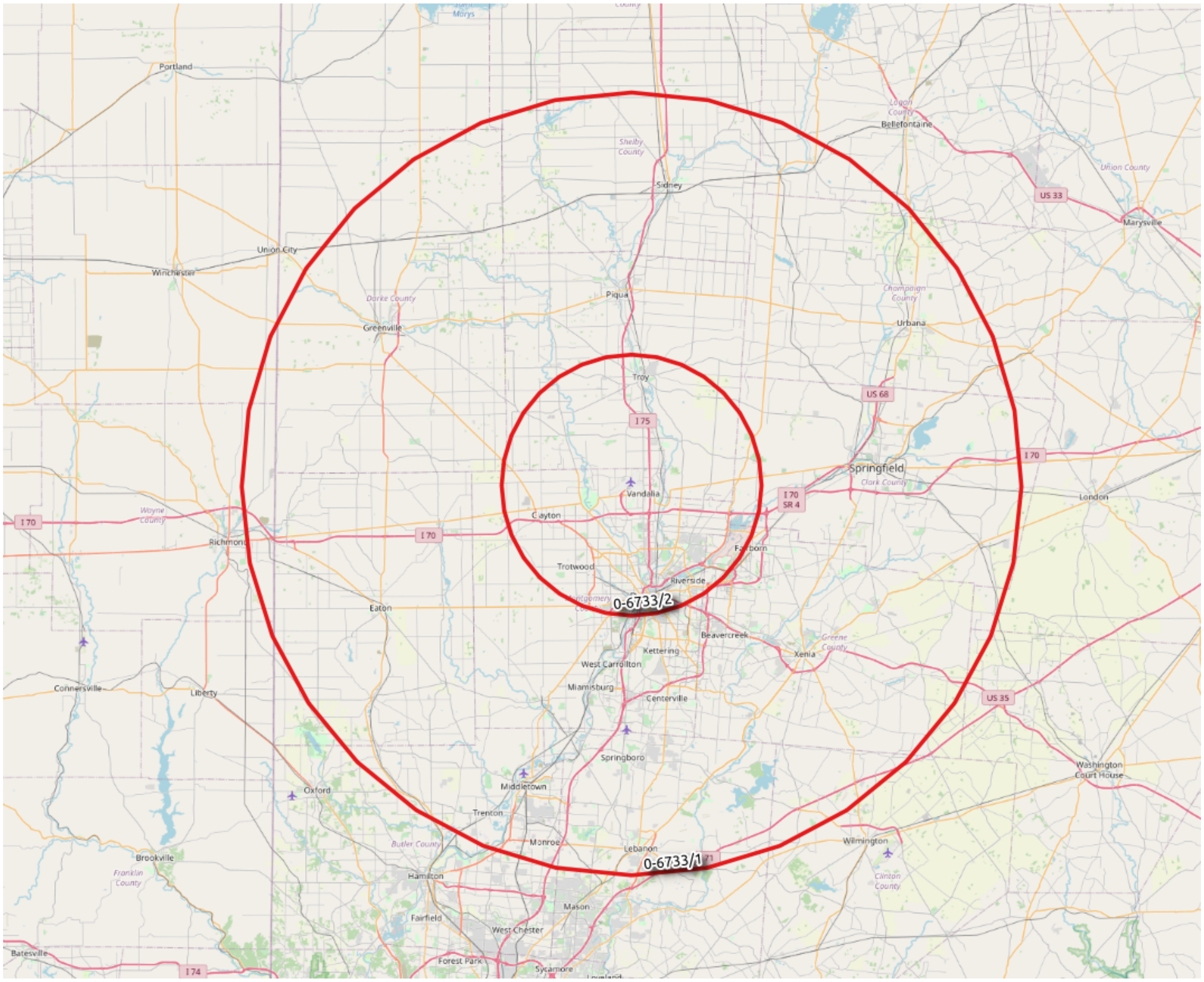
```
2020-09-18-200633_72393~72398-5
2020-09-18-200633_72393~72390+3
```

The value after the tilde is the time as noted in the documentation, followed by a positive or negative offset. This is helpful, since when you are following along with a test, it’s most useful to reference the number in the documentation.

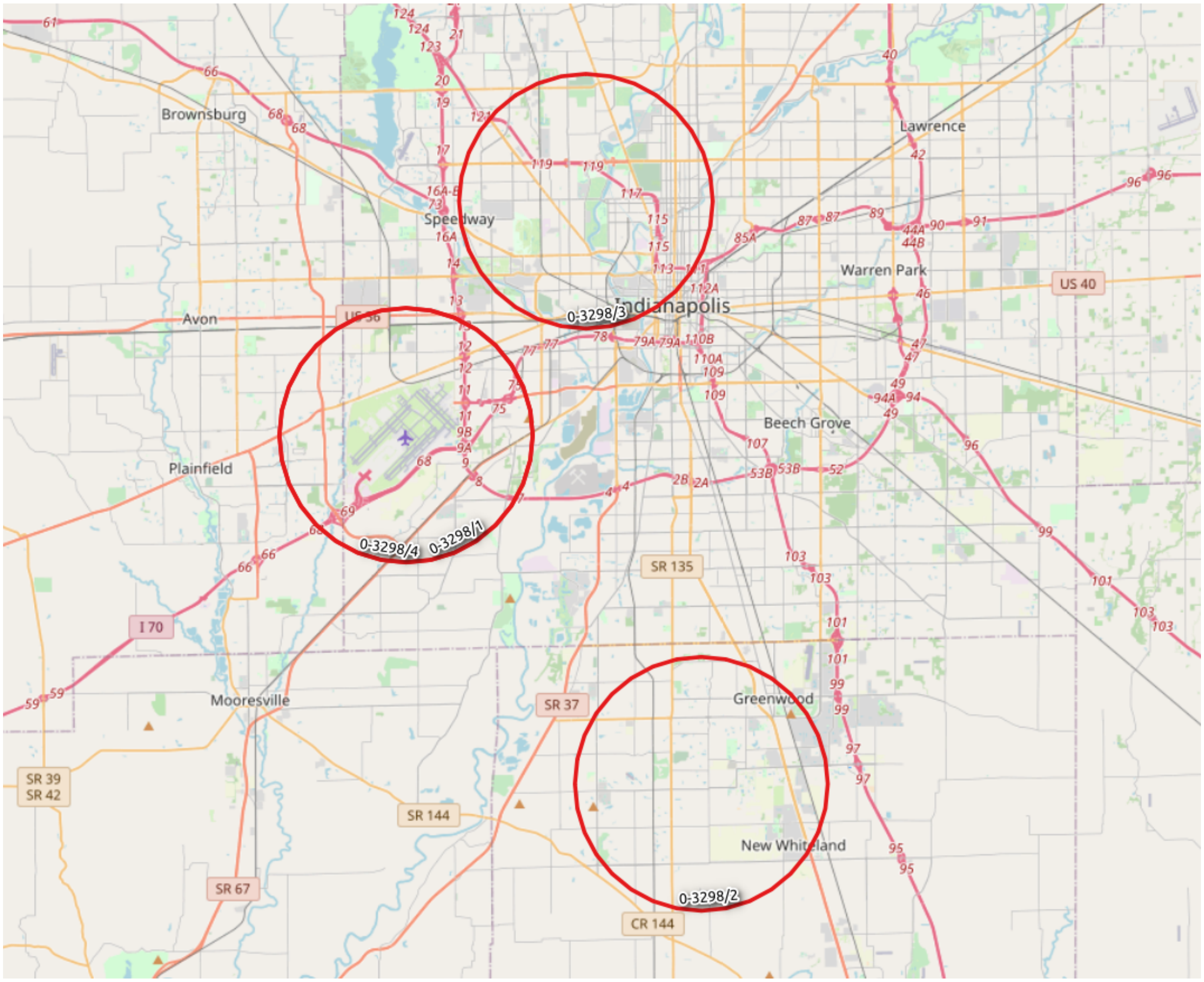
`NOTAM_TFR.db` is an augmented dump of the Mongo `NOTAM_TFR` table. Some tables that have `start_time` and `stop_time` fields have an added `status` field to tell you if the the message is `active`, `pending activation`, or `expired`. This is based on the current time of the dump.

Since this isn't normally part of the database record, we add it at the time of the dump. CRL messages will also have a `status` field added to tell you if the CRL is `complete` or `incomplete`.

`V-NOTAM-TFR-PG.csv` contains the vector information for the TFR. When displayed in QGIS it will look like:



Test group 29 is another example of a TFR. Its vector data will look like this in QGIS:



Test group 30 is a more realistic scenario. It is about 8 minutes of live data. It is the only actual example I have ever found of a CRL overflowing. A CRL can handle 138 entries before it declares overflow. An overflowed CRL can’t be declared complete even if all its reports are complete, because there are more unreported reports.

The directory `fisb-decode/tg/results/tg30/01` contains:

```
2020-10-30-0900277  ICING_10000_SEV.tif image-report.txt     TURBULENCE_2
CLOUD_TOPS.tif      ICING_10000_SLD.tif LIGHTNING_ALL.tif    TURBULENCE_24
CRL_11.db           ICING_12000_PRB.tif LIGHTNING_POS.tif    V-AIRMET-PG.
CRL_12.db           ICING_12000_SEV.tif METAR.db             V-G_AIRMET_0
CRL_14.db           ICING_12000_SLD.tif NEXRAD_CONUS.tif     V-G_AIRMET_0
CRL_15.db           ICING_14000_PRB.tif NEXRAD_REGIONAL.tif  V-G_AIRMET_0
CRL_16.db           ICING_14000_SEV.tif NOTAM.db             V-G_AIRMET_0
CRL_17.db           ICING_14000_SLD.tif NOTAM_TFR.db         V-G_AIRMET_0
CRL_8.db            ICING_16000_PRB.tif PIREP.db             V-G_AIRMET_0
G_AIRMET.db         ICING_16000_SEV.tif RSR.db               V-METAR-PT.c
ICING_02000_PRB.tif ICING_16000_SLD.tif SERVICE_STATUS.db    V-NOTAM-D-PT
ICING_02000_SEV.tif ICING_18000_PRB.tif SIGWX.db             V-NOTAM-FDC-
ICING_02000_SLD.tif ICING_18000_SEV.tif TAF.db               V-PIREP-PT.c
ICING_04000_PRB.tif ICING_18000_SLD.tif TURBULENCE_02000.tif V-TAF-PT.csv
```

```
ICING_04000_SEV.tif ICING_20000_PRB.tif TURBULENCE_04000.tif V-WINDS_06_HR
ICING_04000_SLD.tif ICING_20000_SEV.tif TURBULENCE_06000.tif V-WINDS_12_HR
ICING_06000_PRB.tif ICING_20000_SLD.tif TURBULENCE_08000.tif V-WINDS_24_HR
ICING_06000_SEV.tif ICING_22000_PRB.tif TURBULENCE_10000.tif V-WST-PG.csv
ICING_06000_SLD.tif ICING_22000_SEV.tif TURBULENCE_12000.tif WINDS_06_HR.c
ICING_08000_PRB.tif ICING_22000_SLD.tif TURBULENCE_14000.tif WINDS_12_HR.c
ICING_08000_SEV.tif ICING_24000_PRB.tif TURBULENCE_16000.tif WINDS_24_HR.c
ICING_08000_SLD.tif ICING_24000_SEV.tif TURBULENCE_18000.tif
ICING_10000_PRB.tif ICING_24000_SLD.tif TURBULENCE_20000.tif
```

This is pretty representative of what you find in a test group dump. In our case, we would need to look at `CRL_14.db` and verify that the overflow is set.

If you don’t have access to any data at all and just want to see what things look like, test group 30 is is a good example because it has about ‘one of everything’.

One file we haven’t covered is `image-report.txt`. Its contents will be similar to:

```
Current Image Report at 2020/10/30 09:00:27

NEXRAD_REGIONAL
  observation_time: 2020/10/30 08:58:00
  newest_data: 2020/10/30 08:58:00
  image age (mm:ss): 02:27
  last_changed: 2020/10/30 09:00:16
NEXRAD_CONUS
  observation_time: 2020/10/30 08:54:00
  newest_data: 2020/10/30 08:54:00
  image age (mm:ss): 06:27
  last_changed: 2020/10/30 08:56:41
CLOUD_TOPS
  valid_time: 2020/10/30 09:00:00
  image age (mm:ss): 00:27
  last_changed: 2020/10/30 08:58:51
LIGHTNING
  observation_time: 2020/10/30 08:55:00
  newest_data: 2020/10/30 08:55:00
  image age (mm:ss): 05:27
  last_changed: 2020/10/30 08:55:33
ICING_02000
  valid_time: 2020/10/30 08:00:00
  image age (mm:ss): 60:27
  last_changed: 2020/10/30 08:57:43
ICING_04000
  valid_time: 2020/10/30 08:00:00
  image age (mm:ss): 60:27
  last_changed: 2020/10/30 08:58:05

  (removed more ICING products)

TURBULENCE_02000
  valid_time: 2020/10/30 09:00:00
```

```
  image age (mm:ss): 00:27
  last_changed: 2020/10/30 08:57:14
TURBULENCE_04000
  valid_time: 2020/10/30 09:00:00
  image age (mm:ss): 00:27
  last_changed: 2020/10/30 08:57:34

  (removed more TURBULENCE products)
```

Because `.tif` files don't have obvious metadata, this file contains various image statistics at the time of the dump. Radar and lightning data can have multiple sources for an image, but the age from the oldest to the newest data can't be more than 10 minutes.

One other report not covered yet is `SERVICE_STATUS`. Service status is a report that shows what planes are being provided TIS-B services. This is the hockey puck shaped area around a plane that TIS-B is providing UAT data for. In our example, it looks like:

```
{'_id': '40.0383~-86.255593',
 'expiration_time': '2020-10-30T09:00:54+00:00',
 'traffic': ['aaf8ba', 'ac89af']}
```

Service status is provided by each ground station. So there will be one record for each station you are receiving. The `_id` value is the id of the station (a concatenation of its longitude and latitude). These messages are sent frequently, so are expired quickly (40 seconds). `traffic` is a list of ICAO numbers for each plane being followed. If there are no planes being followed, no service station packets will be created. When there are a lot of planes being followed, FIS-B will send out messages that do not list all planes, but rather a subset. Harvest keeps a list of all planes, and this message will report all current planes.

Backing Up and Restoring Config Files

Running the test groups from the standard body requires many configuration file changes. Provided are a couple of simple scripts for backing up and restoring all your config files. These are simple `tar` scripts and will work fine on most Linux systems. They provide a simple method for switching between various configurations.

From the `bin` directory, to backup or restore your configuration files type:

```
./config-files-backup <filename to store compressed tar file>
./config-files-restore <compressed tar file to restore from>
```

For example, to save the config files into my home directory I might type:

```
./config-files-backup ~/STABLE-051721.tgz
```

It is better to provide a full path for both of these commands. If instead, I had typed:

```
./config-files-backup STABLE-051721.tgz
```

The file would have placed in the `..` directory, or `fisb-decode`.

To restore the config files (**wiping out** any existing config files (be careful here)) I would type (also from the `bin` directory):

```
.config-files-restore ~/STABLE-051721.tgz
```

I would highly suggest backing up your config files before trying to run the test groups from the standard body. We will be making large changes to the config files.

Running Test Groups 01-27

On to the final frontier! The standard body provides a set of 27 test groups which you can get from their web site. The basic process is to go to the store section, make an account, find the latest set (DO-358B currently), put them in your cart, and “purchase” them (as of now, they are free). You get a link and can download them. They come as a zip file.

The zip file you will get is definitely not friendly to Linux. The normal `zip` tools didn’t work for me. You will need to use the `7zz` program from 7-ZIP. Linux downloads can be found here.

7zz will be happier if you rename (or make a copy of) the file you downloaded to a new filename without any spaces in the name.. Do this before running the following procedure. From the `bin` directory (and assuming a Linux system that has `7zz` installed (and you removed spaces from the filename)), you can run:

```
./install-imported-tg <your tg-file without spaces>
```

As a check, each `TGnn` directory in `fisb-decode/tg/tg-source/imported` should have at least one `.csv` file, a `bin` directory whose contents are `<number>.bin` files (all 432 characters in length), and a `.pdf` file. Before performing a test, you will want to read the `.pdf` file.

The next step is to take all this and turn it into a form fisb-decode can use.

Change your directory back to `bin` (i.e. `fisb-decode/bin`) and type:

```
./tgTo978
```

After a few seconds or so it will complete and it will have created new `.978` files in `fisb-decode/tg/tg-source/generated`.

One of the test groups has some serious issues with it and needs to be patched. From the `bin` directory type:

```
patch ../tg/tg-source/generated/tg13.978 -i ../misc/tg13.patch
```

Now you are ready to run the tests. Well, almost.

We will now be making some pronounced changes to the configuration files. Up to this point, we have been gradually adding features to ‘fisb’ and ‘harvest’. Now we do the opposite, and remove all the advanced features. I highly suggest you look at the previous section and do a backup of the config files. The configuration for testing is only really used for testing, so once you make all the changes, you probably want to make a backup of the testing configuration. You might be switching back and forth occasionally between a normal config and a test config, so having backups of both sets is a good idea.

What follows are changes to the config files for testing (referenced to the `bin` directory). Items not listed don’t need to be changed.

`../fisb/level0/level0Config.py`

```
SKIP_EMPTY_FRAMES = True
DETAILED_MESSAGES = False
BLOCK_SUA_MESSAGES = True
ALLOW_SERVICE_STATUS = False
ARCHIVE_MESSAGES = False
WRITE_MESSAGE_TO_FILE = False
SHOW_MESSAGE_SOURCE = False
CALCULATE_RSR = True
RSR_CALCULATE_EVERY_X_SECS = 1
RSR_CALCULATE_OVER_X_SECS = 10
RSR_USE_EXPECTED_PACKET_COUNT = False
MONGO_URI = 'mongodb://localhost:27017/' ( *set for your system* )
DLAC_4BIT_HACK = True
GENERATED_TEST_DIR = '../tg/tg-source/generated'
ALLOW_DECODE_TEST = True
```

`../fisb/level1/level1Config.py`

```
SEGMENT_EXPIRE_TIME = 60
TWGO_EXPIRE_TIME = 720  # 12 Hours
EXPUNGE_CHECK_MINUTES = 30
READ_MESSAGES_FROM_FILE = False
```

`../fisb/level2/level2Config.py`

```
METAR_EXPIRATION_MINUTES = 120
FISB_EXPIRATION_MINUTES = 20
PIREP_EXPIRATION_MINUTES = 76
PIREP_USE_REPORT_TIME_TO_EXPIRE = False
TWGO_DEFAULT_EXPIRATION_TIME = 61
BYPASS_TWGO_SMART_EXPIRATION = True
```

`../fisb/level3/level3Config.py`

```
PIREP_STORE_LEVEL3 = False
PRINT_TO_STDOUT = False
WRITE_TO_FILE = True
OUTPUT_DIRECTORY = "../runtime/harvest"
```

`../fisb/trickle/trickleConfig.py`

```
INITIAL_DELAY = 10
SYNC_DIRECTORY = '../runtime/misc'
```

`../db/harvest/harvestConfig.py`

```
HARVEST_DIRECTORY = '../runtime/harvest'
MAINT_TASKS_INTERVAL_SECS = 10
MONGO_URI = 'mongodb://localhost:27017/' ( *set for your system* )
EXPIRE_MESSAGES = True
ANNOTATE_CRL_REPORTS = True
PROCESS_IMAGES = True
IMAGE_DIRECTORY = '../runtime/images'
SMOOTH_IMAGES = False
SYNC_FILE = '../runtime/misc/sync.fisb'
TG_START_DATES = '../tg/triggers/start-dates.csv'
TG_TRIGGER_DIR = '../tg/triggers'
TG_DIR = '../tg'
IMMEDIATE_CRL_UPDATE = True
IMAGE_QUIET_SECONDS = 0
PRINT_IMMEDIATE_EXPIRATIONS = False
TEXT_WX_LOCATION_SUPPORT = False
PIREP_LOCATION_SUPPORT = False
SAVE_UNMATCHED_PIREPS = False
NOT_INCLUDED_RED = 0xEC
NOT_INCLUDED_GREEN = 0xDA
NOT_INCLUDED_BLUE = 0x96
IMAGE_MAP_CONFIGURATION = 1
CLOUDTOP_MAP = 0
RADAR_MAP = 0
```

You are now ready to run the tests. Running all the tests will take a little under 26 hours. Most of the process is like watching paint dry. The tests have to wait to make sure that certain data is still there after a certain length of time, or maybe the data needs to be deleted. Lots of waiting. Running the test is exactly like for you did for tests 28 through 30. To run test 1 type (from `bin`):

```
./harvest --test 1
```

When you start a test it will tell you how many dumps will be done, and at what time they will occur (both in your local time and in message time). The last dump is always the time the test will complete.

Be sure to read the `.pdf` file that comes with each test. It will tell you what the test should do and the output to expect. The tests are based on end user experiences, and ‘fisb-decode’ is a back-end system, so none of the ‘experience’ parts (i.e. updating screen with image age, image legends, etc) will apply.

You can run all the tests at once by typing:

```
./run-all-tests
```

Then take a break for 26 hours. If there are any errors detected when running this command the error files will be placed in the `../tg/results/tg<nn>` folder, where `<nn>` is the number of the test. `tg15` is the only test where an error is expected and normal.

Debugging Test Groups with `./decode-test`

Sometimes debugging test groups can be difficult. There is a set of scripts which will take the messages from a test group and add comments to the messages, showing the timestamp when they were received and when any dump was done. Before using these commands you need to make a change in `fisb-decode/fisb/level0/level0Config.py`. Make sure you have already installed all the harvest dependencies previously, and set the `ALLOW_DECODE_TEST` parameter as follows:

```
ALLOW_DECODE_TEST = True
```

The general format is:

```
./decode-test <test number>
```

`decode-test` is the output from ‘fisb’ level 3. There is also `decode0-test`, `decode1-test` and `decode2-test` that will use the other ‘fisb’ levels.

Output from test group 28 (which is basically 4 segmented messages) looks like:

```
./decode-test 28
#-----------------------------------------------------------
# PACKET: 2020-09-18T20:05:32.128Z
#
#-----------------------------------------------------------
# PACKET: 2020-09-18T20:05:32.174Z
#
#-----------------------------------------------------------
# PACKET: 2020-09-18T20:05:32.247Z
#
#-----------------------------------------------------------
# PACKET: 2020-09-18T20:05:33.046Z
#
{
  "type": "NOTAM_TFR",
  "unique_name": "0-6733",
  "contents": "NOTAM-TFR 0/6733 211945Z PART 1 OF 6 OH..AIRSPACE
```

```
    DAYTON, OHIO..TEMPORARY FLIGHT RESTRICTIONS. SEPTEMBER 21, 2020
    LOCAL. PURSUANT TO 49 USC 40103(B)(3), THE FEDERAL AVIATION
    ADMINISTRATION (FAA) CLASSIFIES THE AIRSPACE DEFINED IN THIS
    NOTAM AS 'NATIONAL DEFENSE AIRSPACE'. PILOTS WHO DO NOT ADHERE
    TO THE FOLLOWING PROCEDURES MAY BE INTERCEPTED, DETAINED AND
                      <lines deleted>
    ZID PART 2 OF 6 OH..AIRSPACE DAYTON, OHIO..TEMPORARY FLIGHT
    REGULATIONS, AIRCRAFT FLIGHT OPERATIONS ARE PROHIBITED WITHIN AN
    AREA DEFINED AS 30 NM RADIUS OF 395408N0841310W (DQN131010.7)
    SFC-17999FT MSL EFFECTIVE 2009211945 UTC (1545 LOCAL 09/21/20)
    UNTIL 2009220000 UTC (2000 LOCAL 09/21/20). WITHIN AN AREA
    DEFINED AS 10 NM RADIUS OF 395408N0841310W (DQ(INCMPL)",
  "station": "40.0383~-86.255593",
  "number": "0/6733",
  "start_of_activity_time": "2020-09-21T19:45:00Z",
  "end_of_validity_time": "2020-09-22T00:00:00Z",
  "geometry": [
    {
      "type": "CIRCLE",
      "altitudes": [
        18000,
        "MSL",
        0,
        "MSL"
      ],
      "start_time": "2020-09-21T19:45:00Z",
      "stop_time": "2020-09-22T00:00:00Z",
      "element": "TFR",
      "coordinates": [
        -84.218445,
        39.90097
      ],
      "radius_nm": 30.0
    },
    {
      "type": "CIRCLE",
      "altitudes": [
        18000,
        "MSL",
        0,
        "MSL"
      ],
      "start_time": "2020-09-21T19:45:00Z",
      "stop_time": "2020-09-22T00:00:00Z",
      "element": "TFR",
      "coordinates": [
        -84.218445,
        39.90097
      ],
      "radius_nm": 10.0
    }
  ],
  "expiration_time": "2020-09-22T00:00:00Z"
}
```

```
#=================================================================
# TRIGGER (1): 2020-09-18T20:06:33.000Z (72393)
# Verify DAYTON TFR (10 and 30 nm circles)
#
```

In the example, the first three packets appear blank because they are segmented messages. If you wanted to view them you could use `./decode0-test 28`.

The concept behind `decode-test` is that you can generate a 'screenplay' of the event and follow along. It won't tell you if harvest is doing anything wrong, but you can see all the data clearly and when it arrived. It is usually best to save the output from `decode-test` in a file and search for the items you have questions about. The square brackets at the beginning of trigger comment lines will refer you to the item number in the documentation that the trigger refers to.

Notes about Individual Tests

When running test groups from the standard body, it is important to read its associated `.pdf` file. Unfortunately, some are easier to understand than others. All of the times in the test groups have an associated trigger time in a trigger file. Triggers are not part of the standard test groups and were created by me. They are found in `fisb-decode/tg/triggers`. To check if the test completed properly, you need to look at its documentation and match the times against the trigger. The documentation is not always written in a logical order. There are times where something requiring trigger 2 is described long after other later trigger have been described.

Most tests do not need any clarification. Here are ones that do:

TG13

> Worst. Test. Ever. There is a patch that needs to be applied before running this test (see instructions above). This test uses 'fantasy' TFR-NOTAMs, SIGMETs, and AIRMETs that do not in any way resemble what the FAA would send. So, if your system, like 'fisb-decode', checks for sane data, this test fails out of the gate. The patch will make the feeble attempts at data passable. The instructions are confusing– the pictures make it look like the graphics appear in a sequential fashion. In reality, the graphics pretty much happen all at once. All other test groups, except this one, will stop sending packets and then have a final check. Nope. There are two minutes of useless packets after the final check. For no purpose.

TG15

> You will get a `LEVEL0.ERR` file. That's actually the whole purpose of the test– to catch bogus data.

TG19

> With `BYPASS_TWGO_SMART_EXPIRATION` set to `True` (the normal test setting), the NOTAM-TFRs will persist, even though the contents are expired. This is acceptable

for the test. In actual use, you would set `BYPASS_TWGO_SMART_EXPIRATION` to `False`, and this issue would resolve (same applies to **TG20**).

TG20

With `BYPASS_TWGO_SMART_EXPIRATION` set to `True`, at trigger 8, various reports which are shown as not present will still be present. The status of all of these reports are expired, but since we need to keep them around for an hour after the last time they were sent (per the standard), the message will not have expired (even though the parts are expired). This is expected behavior.

TG25

This TG is the 'master class' of all test groups. Extremely well constructed, tests lots of concepts not tested in other groups. Tests many realistic edge-cases. I understood lots of concepts much better after struggling to get this TG working.

Messages stuck in the system

At the ground station I normally use, messages sometimes get 'stuck' in FIS-B. In my case, there are two WST messages that have been there for over a year. Usually level 2 will generate an error message if the message dates make no sense. As of now, there is code to ignore these messages, both at the message level and at the CRL level. If this becomes a more common problem, it would be better to create a system to read these from a file and ignore them.

Using Stratux as a data source

If you have a Stratux box, you can use it as a data feed. In the `bin` directory there are the scripts `decodeStratux` and `decodeStratusToDir`. They work exactly like `decodeNet` and `decodeNetToDir`. `decodeStratux` will dump level 3 messages to the terminal, and `decodeStratusToDir` will send them to a directory for processing by harvest. There are a few things to consider:

- You need to have a somewhat accurate time set. Plus or minus 30 seconds, or even a minute, is fine. Stratux may not provide a time (it might if it has a working GPS, but GPS is not manditory, or it might be intermittant). Having a time source such as a real time clock, internet source, or even setting the date and time by hand, are required. 'fisb-decode' has lots of logic to take FAA partial times and make them complete times, but it needs a little help from a clock source.
- Always start Stratux first (and let it boot up) before starting `decodeStratux`. Stratux serves as the DHCP provider and `decodeStratux` needs to know its assigned address, which can't happen until Stratux is running.
- Internally, Stratux uses another version of dump978 to capture FIS-B packets. It converts its output to Garmin GDL 90 format, which `decodeStratux` receives. The data then gets converted back to dump978 format for processing. The FIS-B data will have no associated time. 'fisb' level 0 will use the local clock UTC time as the message received time.

Using a Raspberry Pi

A Raspberry Pi in pretty much any configuration will run the ‘fisb’ code without any problems. ‘Harvest’ is database bound, and therefore filesystem dependent. Using lots of different Pi models, nothing beats a Pi 4 with an external SSD. 4GB memory is fine for ‘harvest’ and ‘fisb’. I run Ubuntu 20.04 64-bit (needed by Mongo) with full GNOME window system, including QGIS, and have had no problems. With a Kingston 240GB A400 SATA drive in an Inateck 2.5 USB 3.0 (UASP support) enclosure, the system has been rock solid. Such was not the case when running with SD cards. Speed is not the same as your desktop, but not annoyingly slow either.

Running ‘fisb’ and ‘harvest’ (with MongoDB) does not use very many resources. On a 4GB Pi, available memory is more than 3GB at all times and system run times are always under 5%.