Synoptic.

Sharing Earth's Data

Using Python to Retrieve Weather Observations from a Mesonet API with Application to Practical Use Cases

AMS Annual Meeting 2023

Short Course

Schedule

Introductions

Motivation & Background

– *break* –

Hands-on 1: The data Synoptic aggregates

Hands-on 2: Colab Notebook - primer

– *break* –

Hands-on 3: Colab Notebook - road wx

Hands-on 4: Colab Notebook - fire wx

– *break* –

Hands-on 5: Attendee use cases/problems

(Optional) Hands-on: Precipitation

Who is Synoptic?

- Late 1990s: Begin growing mesonet & user community
- National Mesonet Program

Synoptic.

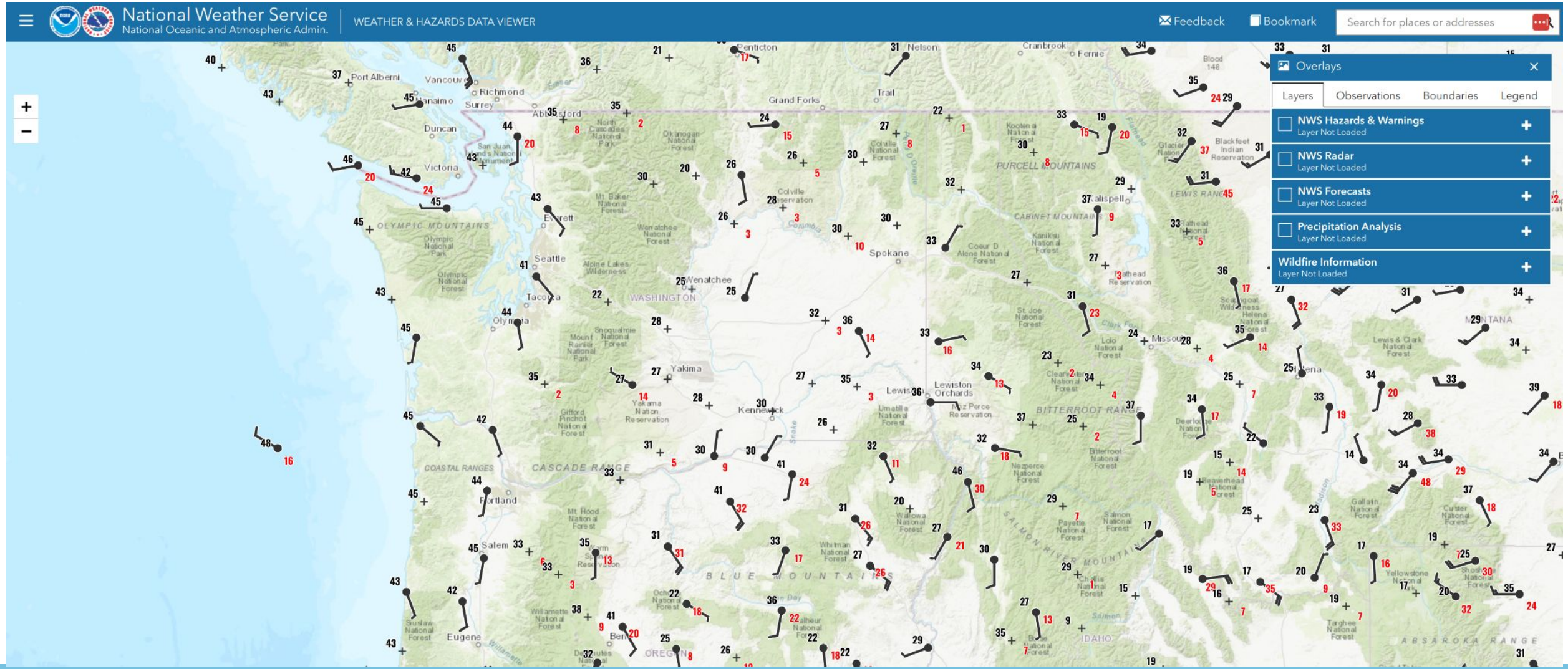
- Operational
- NMP responsibilities
- Build, maintain API
- Public Benefit Corporation

NOAA

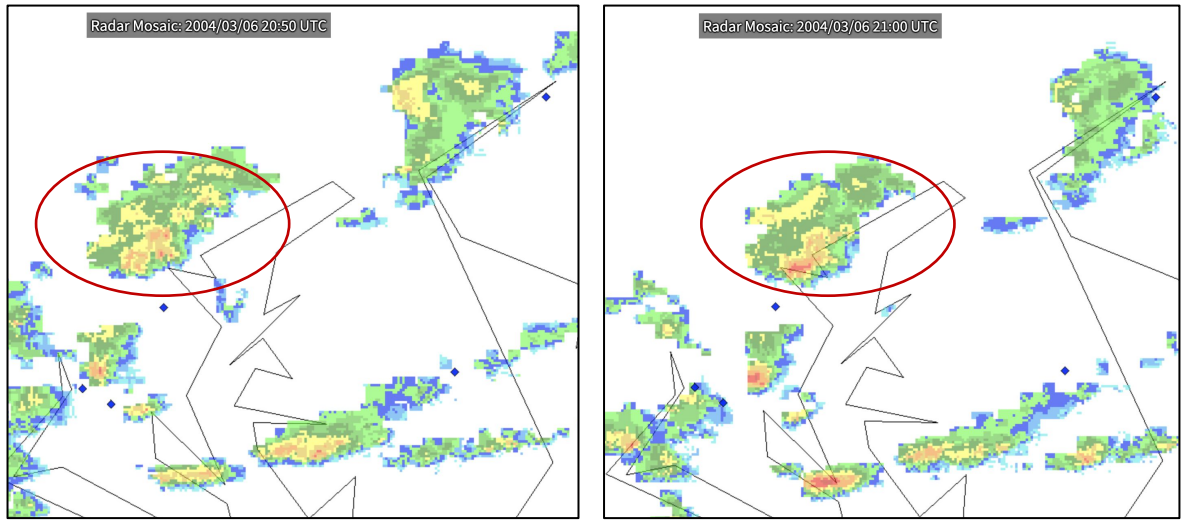
NATIONAL MESONET

NATIONAL WEATHER SERVICE

Obs available to public from Synoptic are same obs used for situational awareness by WFOs



Motivation - Why More Observations Matter



Why More Observations Matter

Measurement to Dissemination - The station

The station site needs three things:

1. Instrumentation
2. Power source
3. Communication channel (hardwire, cell modem, satellite, etc)

Measurement to Dissemination - The instruments

- Each produces an electric signal that is collected, and processed by a data logger.
- The logger will average, remember what maximum values are within a set interval.
- All or some rolling window of data is stored on the data logger.
- Data is retrieved or more commonly transmitted to some source (home computer, central network server)

Measurement to Dissemination - The data

Datetime	Temperature	Relative Humidity	Pressure	Wind Speed	Wind Direction
1/8/2023 8:00AM LST	50	40	905.7	2.0	167
1/8/2023 8:15AM LST	50	40	905.7	3.0	163
1/8/2023 8:30AM LST	51	38	905.6	3.0	168
1/8/2023 8:45AM LST	52	37	905.6	2.0	170

Say your personal weather station is sending this data to your personal computer. If we wanted to share this data so others could use it, says NWS forecasters, researchers, what kinds of questions might they have?

Measurement to Dissemination - Metadata

Datetime (Mountain Time Zone)	Temperature (° F)	Relative Humidity (%)	Pressure (mb)	Wind Speed (mph)	Wind Direction (°)
1/8/2023 8:00AM LST	50	40	905.7	2.0	167
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1/8/2023 8:30AM LST	51	38	905.6	3.0	168
1/8/2023 8:45AM LST	52	37	905.6	2.0	170

Other details that we need to provide
Location - latitude, longitude, elevation ASL, time zone
Units - of all measured variables
Other more detailed - instrumentation type, maintenance records,

Measurement to Dissemination - Transmitting

Datetime (Mountain Time Zone)	Temperature (°F)	Relative Humidity (%)	Pressure (mb)	Wind Speed (mph)	Wind Direction (°)
1/8/2023 8:00AM LST	50	40	905.7	2.0	167
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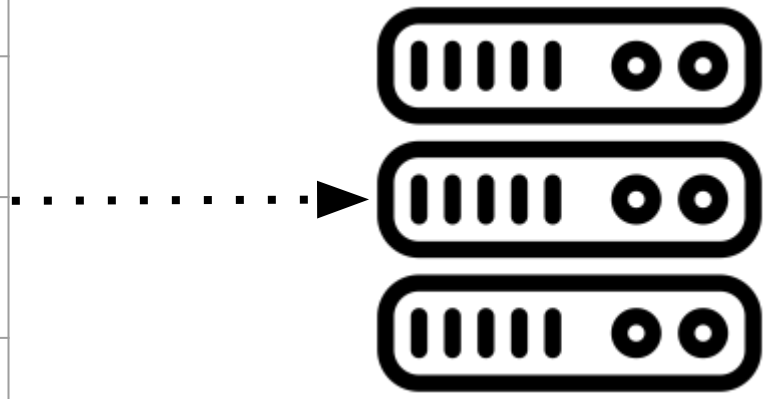


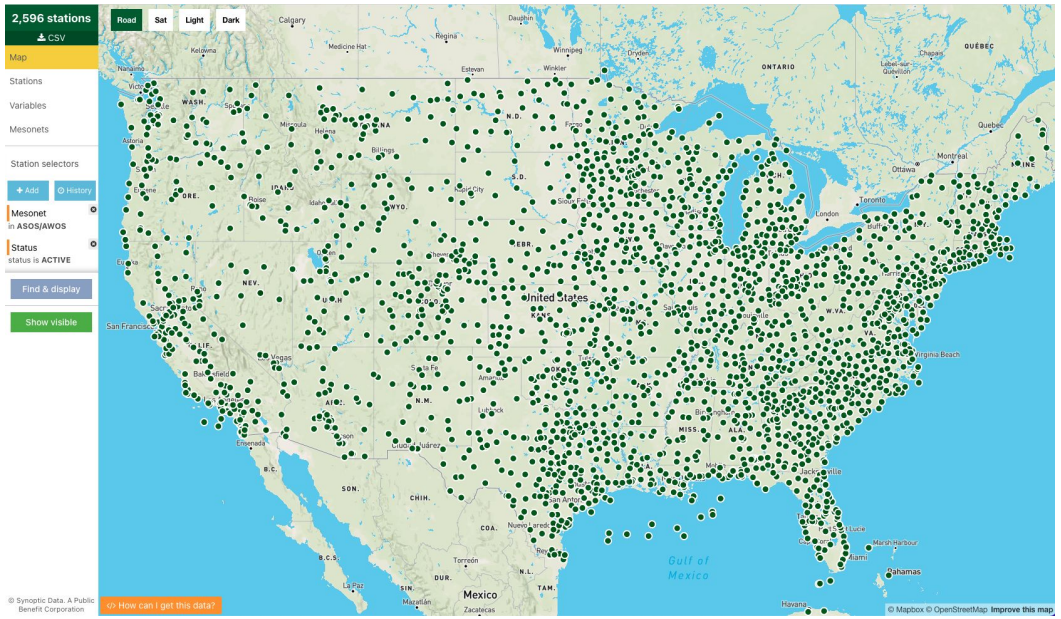
Weather observations need to be transmitted to some central server or community server, examples include

- Government network central server
- A local NWS office server
- CWOP server

Data Providers - Who are they?

Federal, state, and local governments

Monitoring conditions for transportation safety, emergency response, etc.
Data used internally and often shared publicly
Stations located at airports (ASOS/AWOS), along highways (DOTs), or across cities (e.g. Hennepin county)



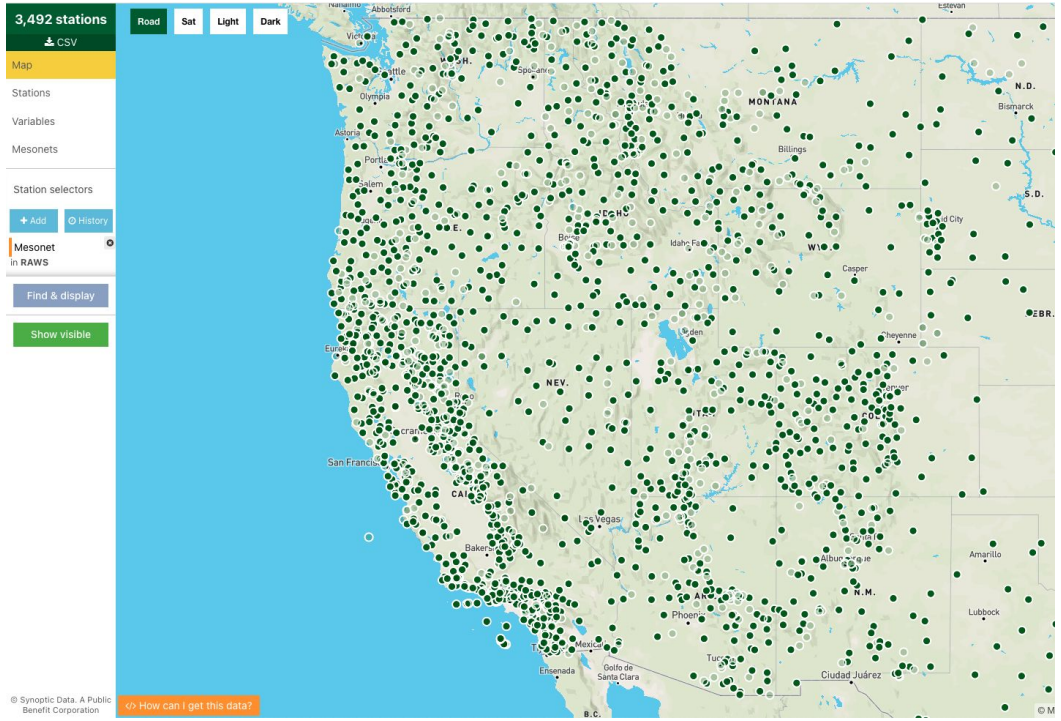
Data Providers - Who are they?

Fire Weather (RAWS, IRAWS)

Monitoring weather conditions related to fire danger, air quality, research

Data used internally and often shared publicly

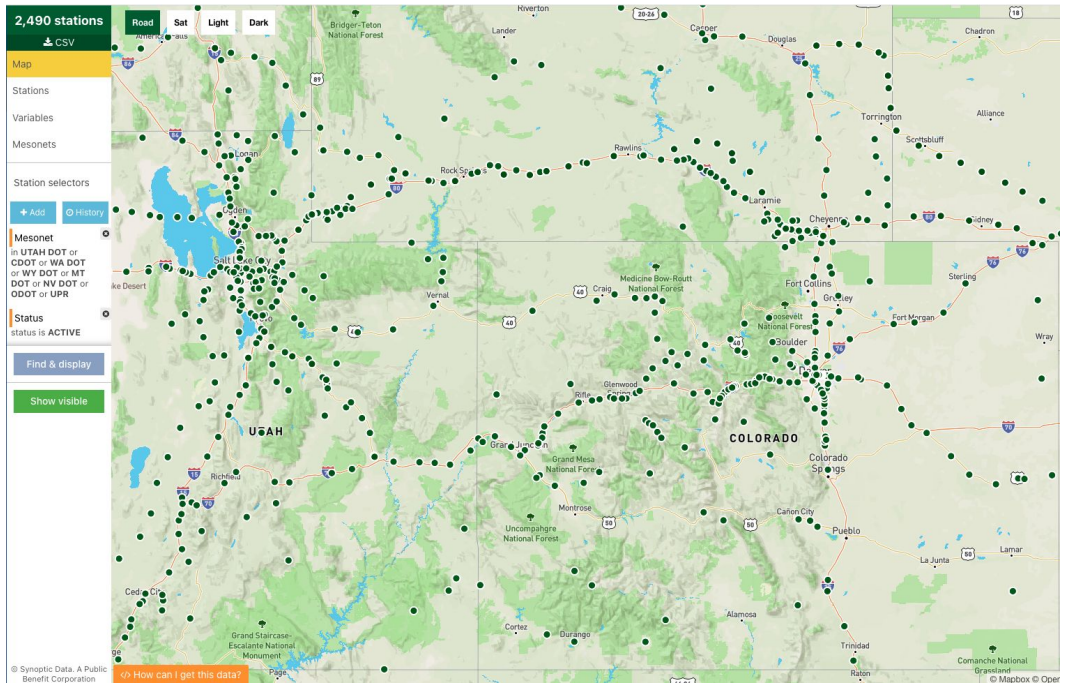
Stations located most densely across the western US in rugged terrain and fire prone areas



Data Providers - Who are they?

Road and Railway Weather Networks

Monitoring weather conditions near and along railways and roadways
Data used internally and often shared publicly (not always easily accesible)
Stations located along highways and railways



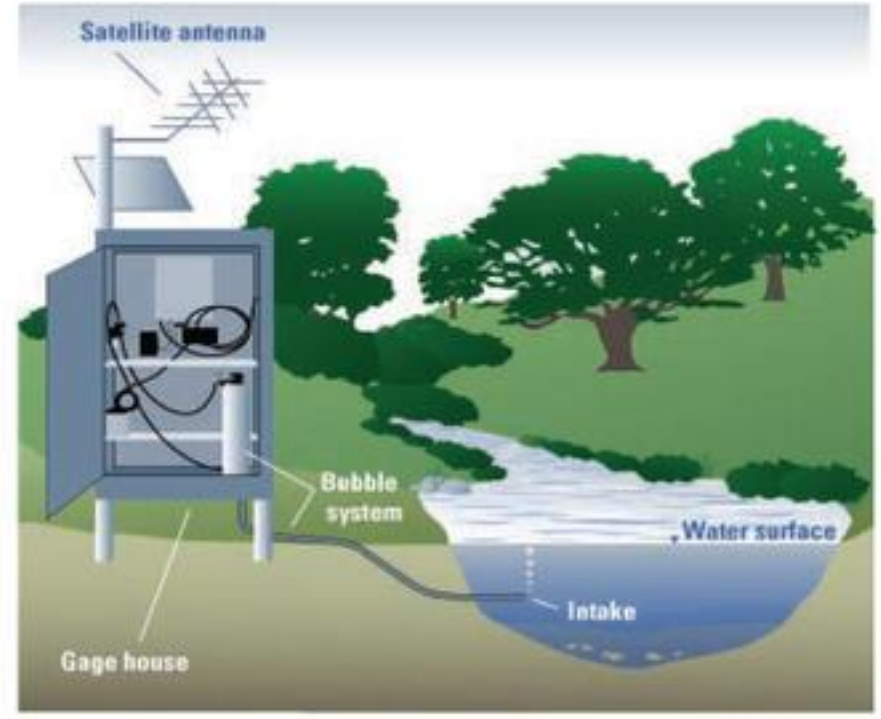
Data Providers - Who are they?

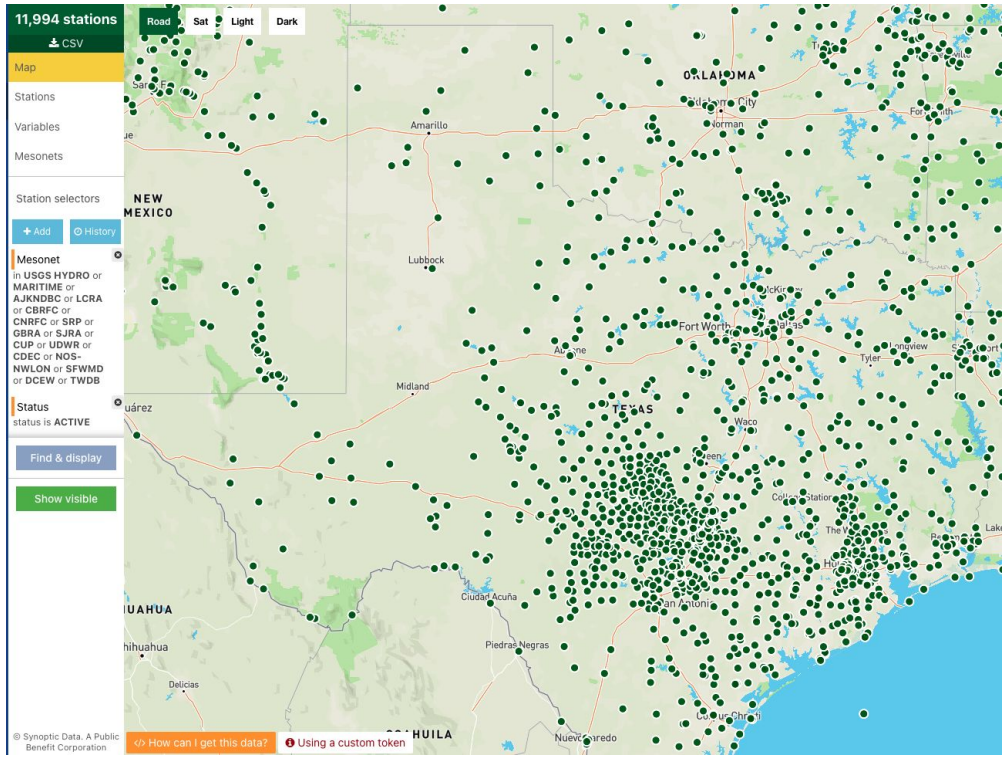
Hydrological Networks

Measuring various water-related variables such as streamflow, water level, water height

Data used internally and often shared publicly

Stations located along streams, rivers, lakes, reservoirs and coastal locations for monitoring water levels, flow, and coastal tsunami hazards





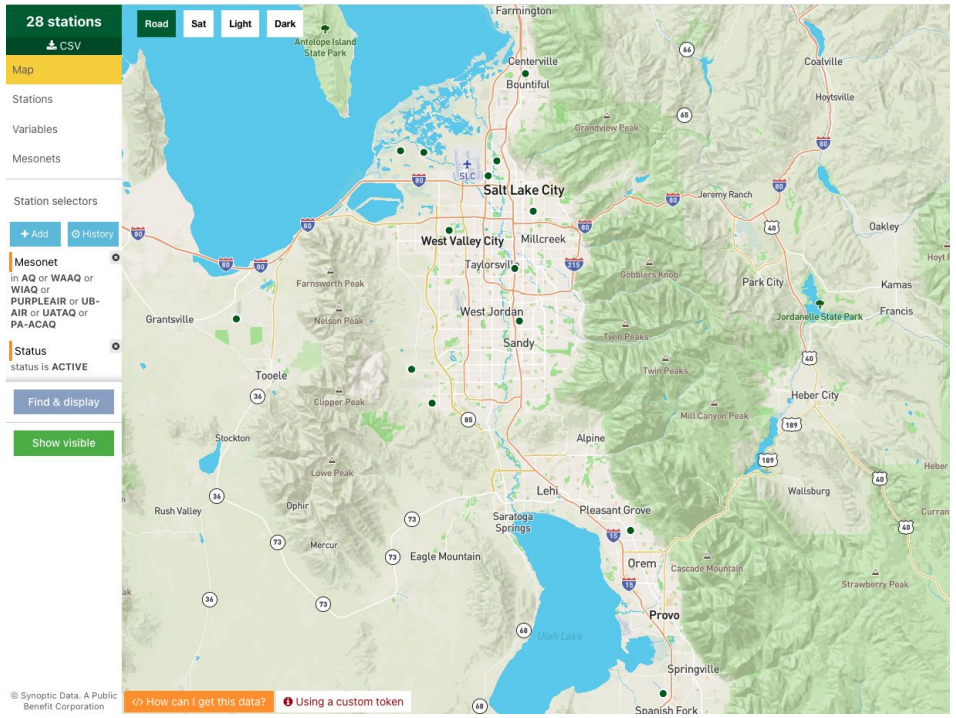
Data Providers - Who are they?

Air Quality Networks

Measuring weather and particulate matter for air quality monitoring

Data used internally and often shared publicly

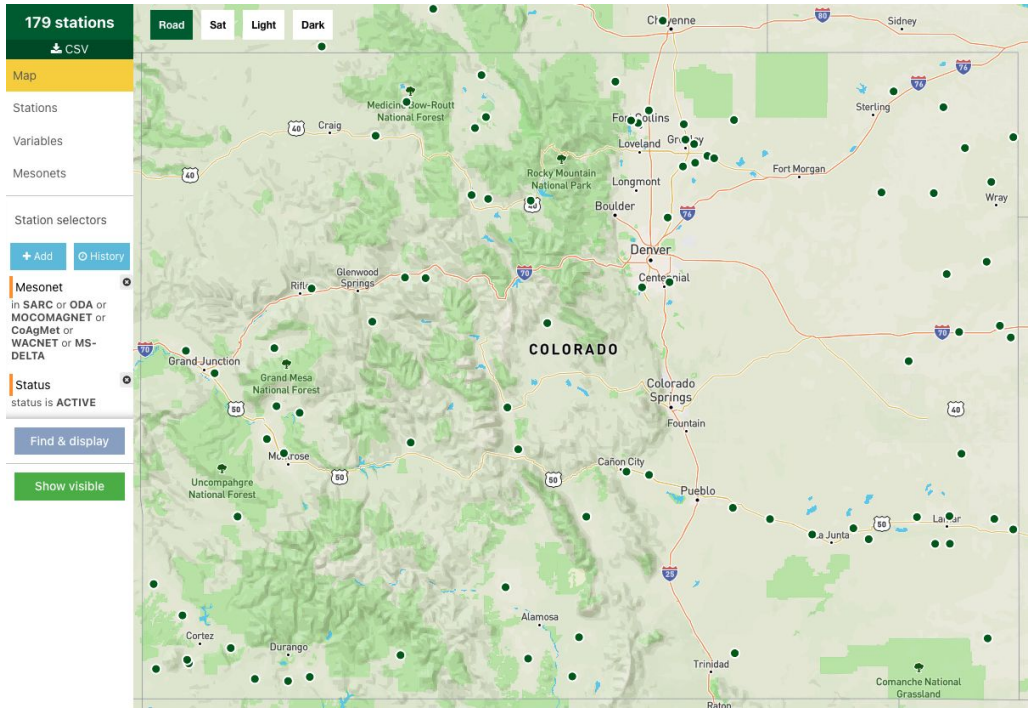
Stations typically located across certain urban corridors (more personal, home stations coming online)



Data Providers - Who are they?

Agricultural Networks

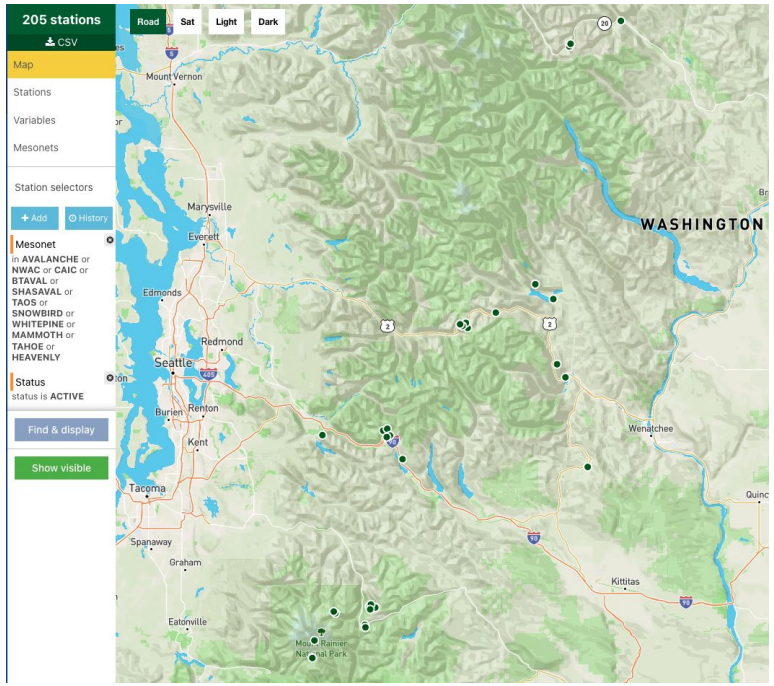
Monitoring weather conditions most impactful to agriculture (e.g. evapotranspiration
Data used internally and often shared publicly
Stations typically located in more rural and farming communities



Data Providers - Who are they?

Ski and Avalanche Networks

Monitoring weather conditions impacting on-mountain safety and avalanche conditions
Data used internally and often shared publicly
Stations located in and around ski resorts and avalanche-prone terrain



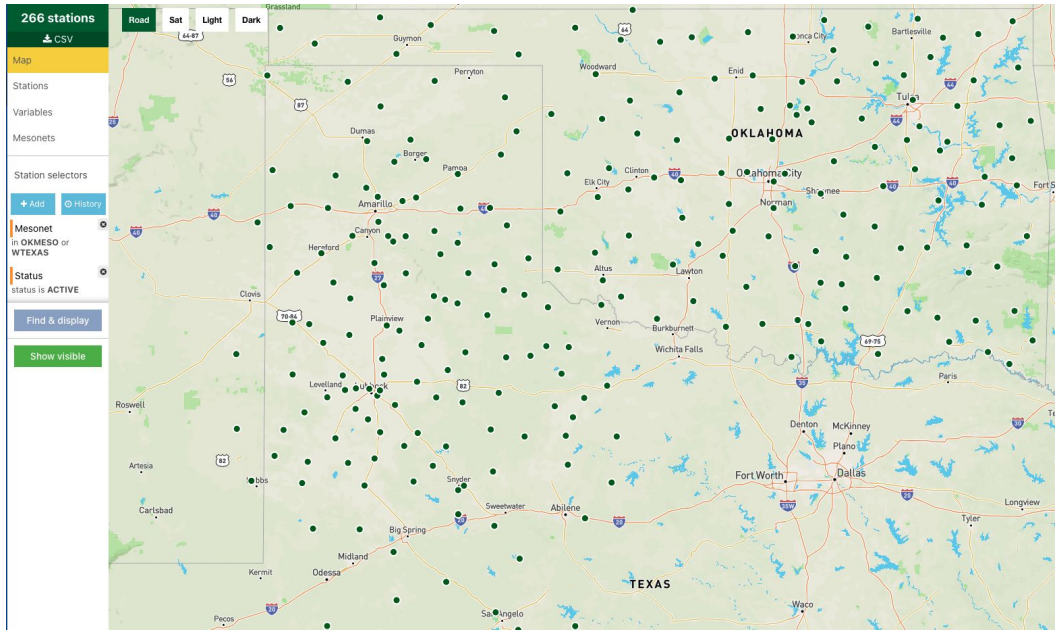
Data Providers - Who are they?

University Mesonets

Monitoring various weather conditions for situational awareness and research

Some data shared publicly, other data is restricted and requires purchase to access

Stations across states where universities have set up (Texas, Oklahoma, Kansas, Illinois, Indiana, New York, and growing!)



Data providers - Ways to get data directly from provider

Montana Mesonet API (v2) 0.0.1 OAS3

/api/v2/openapi.json

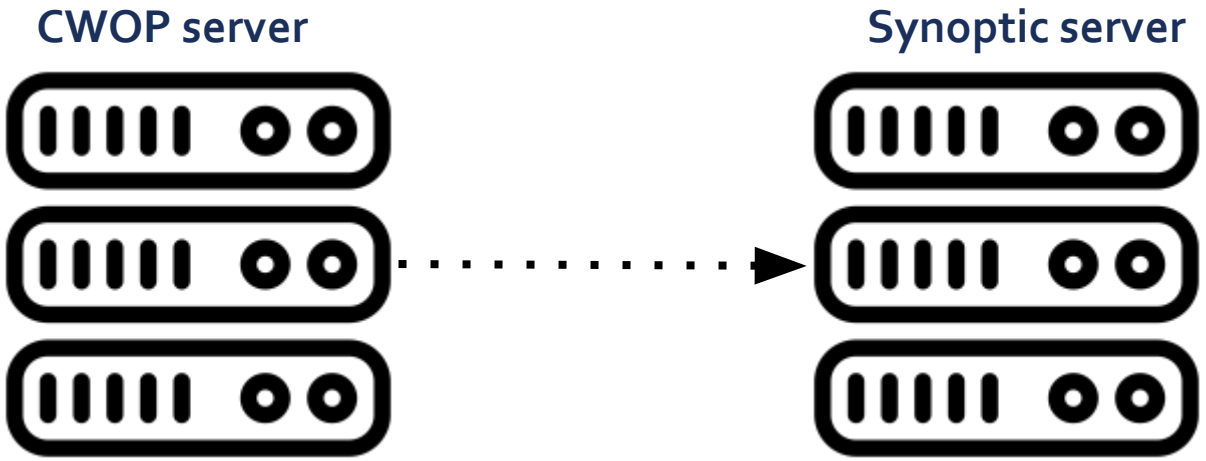
The Montana Mesonet API (v2).

mesonet.climate.umt.edu/api/v2/latest/?type=json&publ...


```
[
  - {
      station: "aceabsar",
      datetime: 1670285400000,
      Air Temperature @ 2 m [°F]: 32.18,
      Air Temperature @ 8 ft [°F]: null,
      Precipitation [in]: 0,
      Max Precip Rate [in/hr]: 0,
      Atmospheric Pressure [mbar]: 846.45,
      Relative Humidity [%]: 55.72,
      Soil Temperature @ -5 cm [°F]: 29.12,
      Soil Temperature @ -10 cm [°F]: 29.804,
      Soil Temperature @ -20 cm [°F]: 31.82,
      Soil Temperature @ -50 cm [°F]: 37.22,
      Soil Temperature @ -91 cm [°F]: null,
      Soil Temperature @ -100 cm [°F]: 42.476,
      Soil VWC @ -5 cm [%]: 15.2,
      Soil VWC @ -10 cm [%]: 17.6,
      Soil VWC @ -20 cm [%]: 18.2,
      Soil VWC @ -50 cm [%]: 17.7,
      Soil VWC @ -91 cm [%]: null,
      Soil VWC @ -100 cm [%]: 21.6,
      Bulk EC @ -5 cm [mS/cm]: 0.058,
      Bulk EC @ -10 cm [mS/cm]: 0.1,
      Bulk EC @ -20 cm [mS/cm]: 0.188,
      Bulk EC @ -50 cm [mS/cm]: 0.126,
      Bulk EC @ -91 cm [mS/cm]: null,
      Bulk EC @ -100 cm [mS/cm]: 0.325,
      Solar Radiation [W/m²]: null,
      VPD [mbar]: null,
      Wind Direction @ 10 m [deg]: 254.8,
      Wind Direction @ 8 ft [deg]: null,
      Wind Speed @ 10 m [mi/hr]: 23.287,
      Wind Speed @ 8 ft [mi/hr]: null,
      Gust Speed @ 10 m [mi/hr]: 26.373,
      Gust Speed @ 8 ft [mi/hr]: null,
      Snow Depth [in]: 0
    },
  - {
      station: "arskeogh",
      datetime: 1670284800000,
      Air Temperature @ 2 m [°F]: null,
      Air Temperature @ 8 ft [°F]: 21.02,
```


Many network providers have their own method for sharing data (API, data download, SFTP, etc)

Measurement to Dissemination - Getting to Synoptic



- One way to share data publicly is to provide the data to Synoptic Data
- This typically comes from a server that has already aggregated multiple stations (not transmitted directly from station)
- Synoptic needs 1) metadata information (units, location, network, etc) and 2) data feed (pull, push, etc)

Measurement to Dissemination - Synoptic ingest & processing

Station observations

Datetime (Mountain Time Zone)	Temperature (°F)	Relative Humidity (%)	Pressure (mb)	Wind Speed (mph)	Wind Direction (°)
1/8/2023 8:00AM LST	50	40	905.7	2.0	167
1/8/2023 8:15AM LST	50	40	905.7	3.0	163
1/8/2023 8:30AM LST	51	38	905.6	3.0	168
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Observations database

Datetime	STID	network_id	var1	var2	var3	var4	var5

Metadata database

STID	network_id	lat	lon	elevation	height_var1	height_var2	height_var3

Once station metadata is added into the metadata database, observations can flow into Synoptic to be processed (QC checks, storage) and disseminated when needed

Measurement to Dissemination - Synoptic dissemination

Observations database

Datetime	STID	network_id	var1	var2	var3	var4	var5

Synoptic Data Mesonet API

GET https://api.synopticdata.com/v2/stations/latest?&token={token}&stid=KDEN

Data stream to NOAA

Synoptic Data shares all observations regularly with NOAA through the National Mesonet Program
Observations can also be obtained by calling the Synoptic Data Mesonet API

Measurement to Dissemination - Synoptic dissemination scaled

Synoptic Data
Mesonet API

NOAA and
National
Weather Service

Enterprise,
university
customers, etc

Through robust and scalable back-end processes, Synoptic Data can ingest, process, and disseminate obs from over 100,000 stations

There are other ways to get public data!

Iowa State - https://mesonet.agron.iastate.edu/archive/
MesoWest - https://mesowest.utah.edu/
NOAA's MADIS - https://madis.ncep.noaa.gov/
NOAA NCEI - https://www.ncei.noaa.gov/access/homr/
Desert Research Institute (RAWS) - https://raws.dri.edu/

The data available from Synoptic is:

- real time
- available at low latency
- provisional
- available alongside data from 100s of other networks

Synoptic's API

REST API
- Client - server, managed through HTTP
- Stateless (no client state preserved, all necessary info is contained in the request)
- We are always waiting. Send a request, receive the data in a predictable format (JSON)


```
47 ▾      "OBSERVATIONS": {
48 ▾        "date_time": [
49            "2022-12-05T22:40:00Z",
50            "2022-12-05T22:45:00Z",
51            "2022-12-05T22:50:00Z",
52            "2022-12-05T22:53:00Z",
53            "2022-12-05T22:55:00Z"
54          ],
55 ▾        "air_temp_set_1": [
56            -6.0,
57            -6.0,
58            -6.0,
59            -5.6,
60            -6.0
61          ]
62        },
```


1. Make a request to HTTP endpoint

https://api.synopticdata.com/v2/stations/timeseries?stid=KMSO&vars=air_temp&recent=30

2. Specify your request through arguments

3. Get your data!

Synoptic's API Endpoints

https://api.synopticdata.com/v2/stations

/timeseries

/nearest

/latest

/metadata

/precip

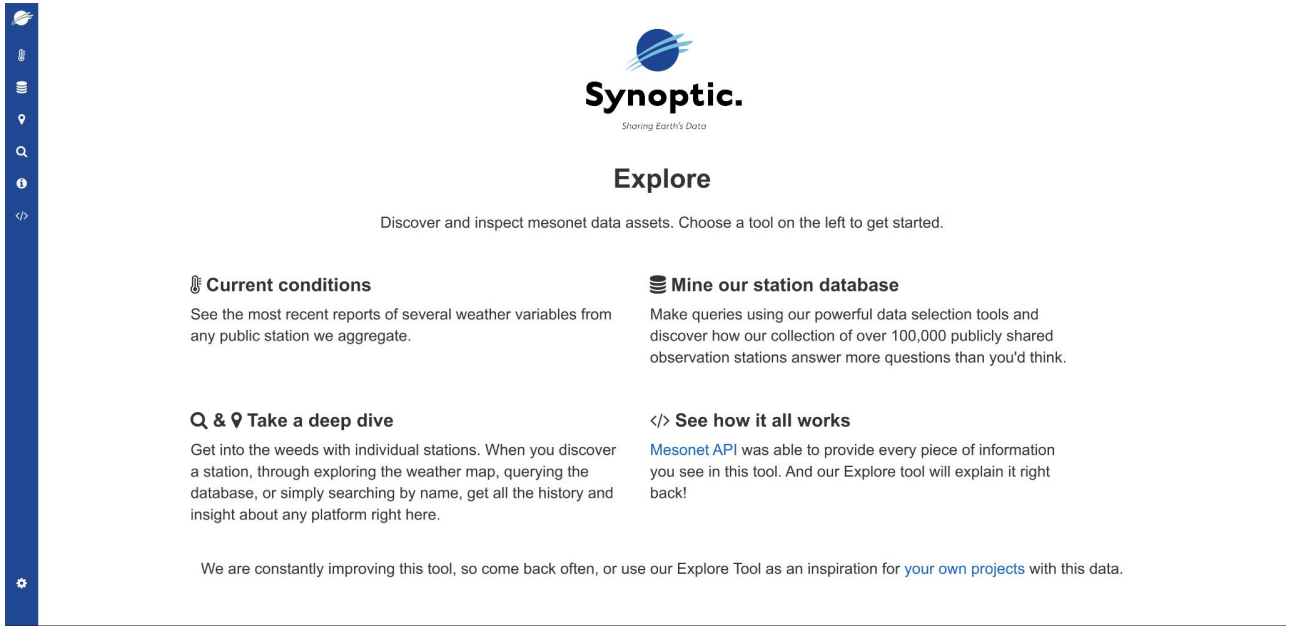
https://developers.synopticdata.com/mesonet/

Getting Started: The Synoptic Explore Tool

https://explore.synopticdata.com/

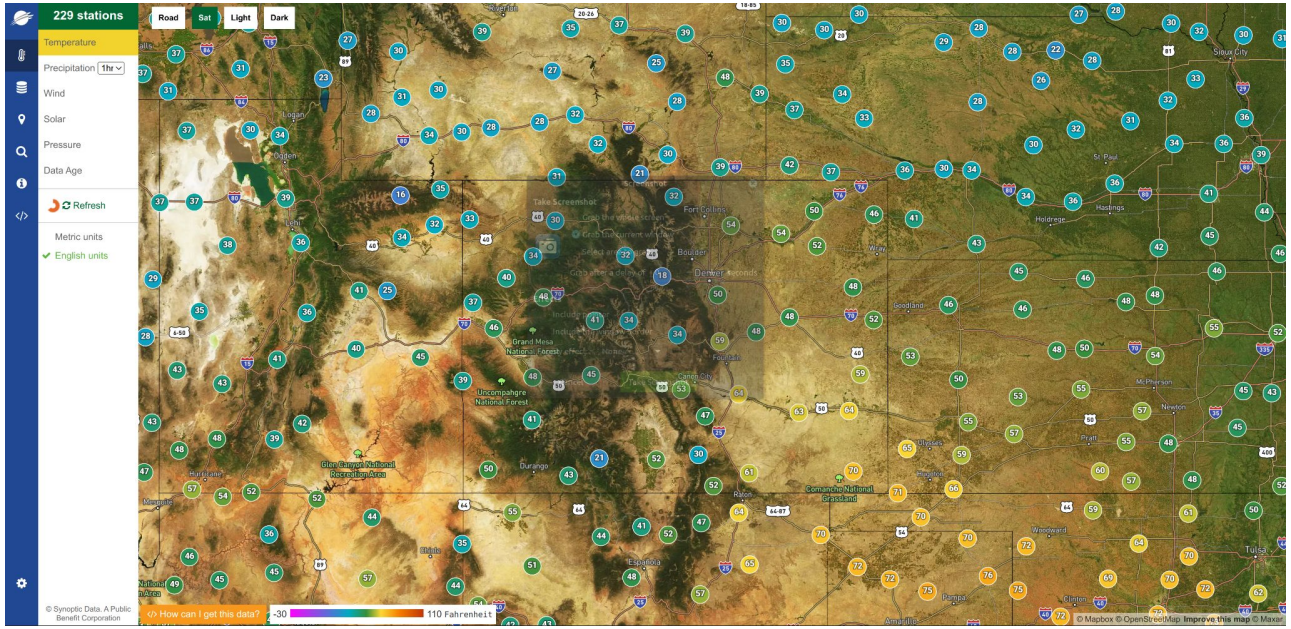
Goals:

- Familiarize with the data Synoptic aggregates
- Understand the API requests giving the data on your screen
- Familiarize with the returned JSON structure



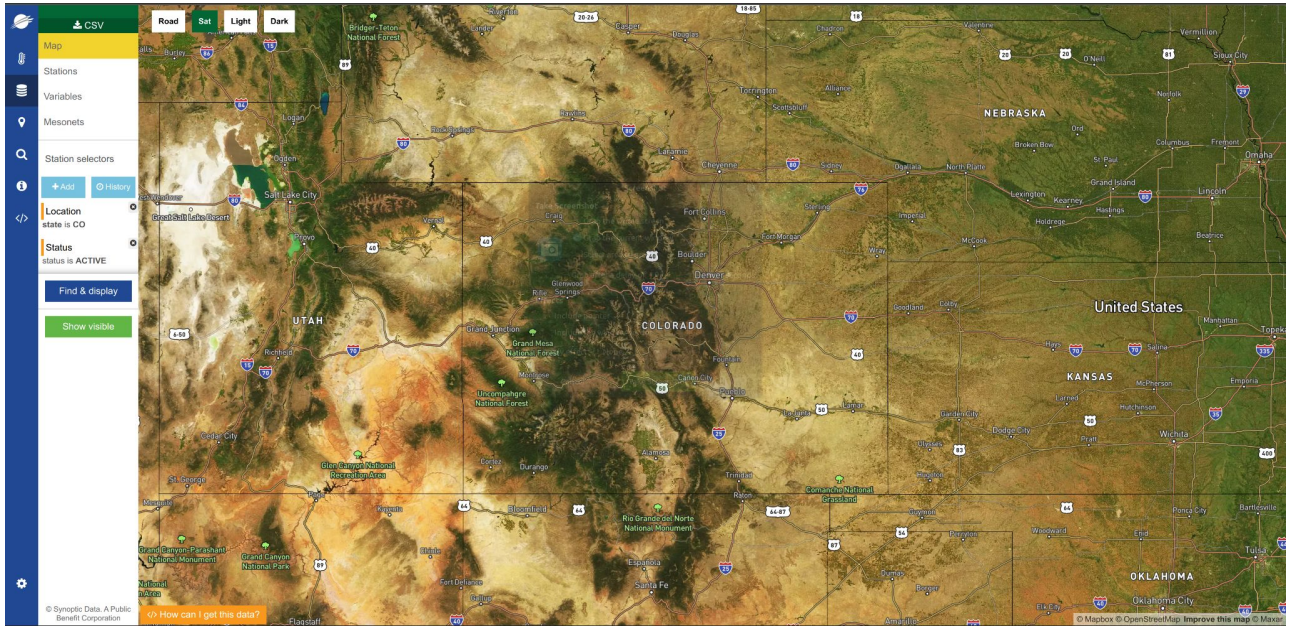
Exercise 0: Current Conditions

- Identify the network a station obs belongs to
- Zoom in/out. Additional stations appear (spacing restriction in API request for aesthetics
- Select ‘Solar’ variable – how many fewer stations appear than ‘Temperature’ variable? – Not all stations report the same variables!
- Closest station to your geographic area of interest? House?
- Precipitation – this utilizes our precip processing (will get into more detail if time allows)



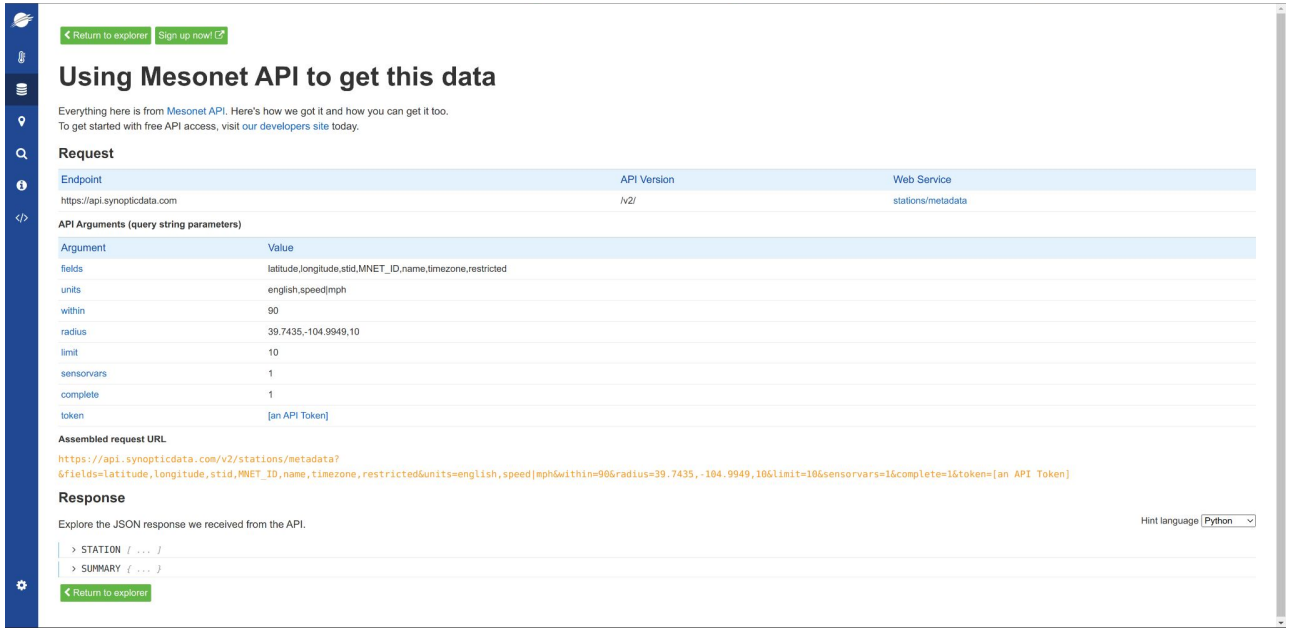
Exercise 1: Metadata Explorer

- + Add s your friend
- How many stations in your state?
- How many mesonets? Even distribution or are majority of stations in a single mesonet? COCORAHS is an outlier!
- How many stations report air temp?
- How many stations within a 10 mile radius of the AMS conference site? (39.7435,-104.9949,10)
- Update the filter to limit to the 10 nearest stations. Closest CDOT? CO006



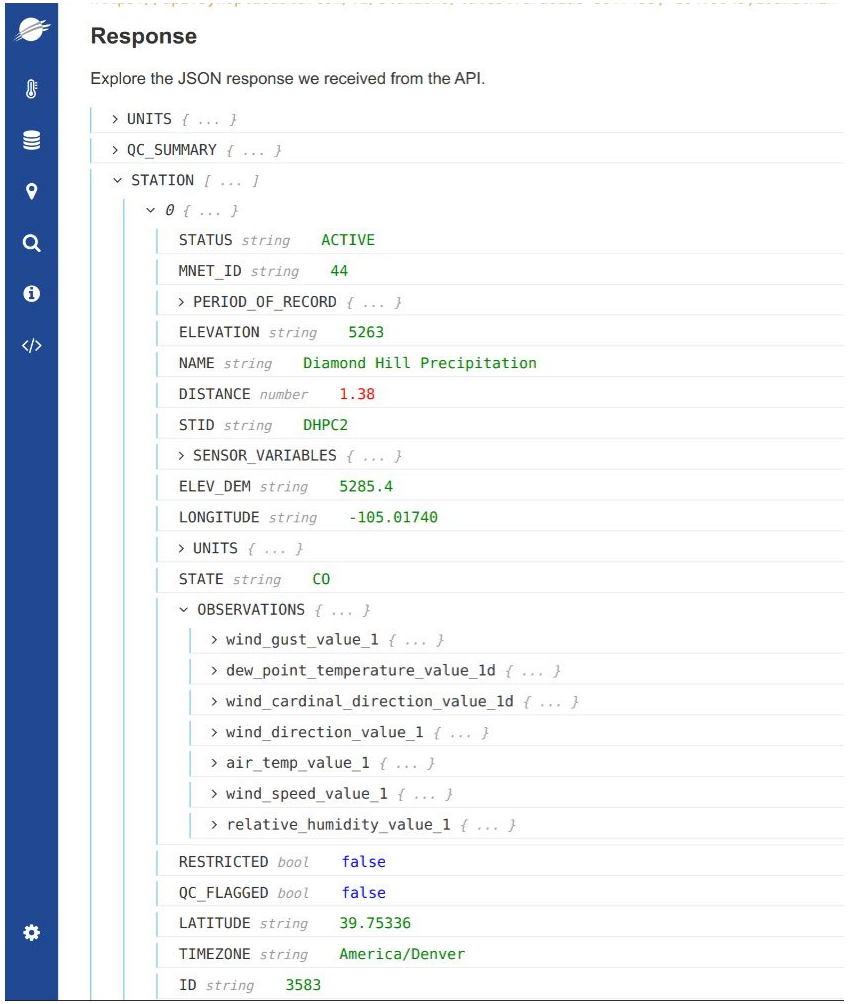
Exercise 2: Understanding the API Request

- Run through the API arguments. Some of these are relict from current conditions – that's ok.
- Web service – we're targeting the 'metadata' endpoint with our metadata discovery exercise
- Radius, limit, sensorvars, complete – API arguments for the metadata service
- Open 'Mesonet API' in a different tab. Can view all the different available arguments for the different services. We won't get into this now but this documentation is your friend
- Take a look at the request URL. Format. *Argument=Value*, separated with &
- Notice the url. We can actively change the url and it will update the Response.



Exercise 3: Understanding the JSON return structure

- Structure of the metadata request. STATION, SUMMARY and values will be key value pairs in the JSON dictionary.
- Change the endpoint in the url from ‘metadata?’ to ‘latest?’. Eliminate ‘limit=10’ and replace it ‘within=90’. Now showing data from all stations in radius that have reported within the last 90 minutes
- SUMMARY – returned many tens stations in not much time
- UNITS – all vars returned & default units
- QC_SUMMARY – by default Range check is applied
- STATION – list of stations with data
  - OBSERVATIONS – the data
- We can make similar requests to other endpoints



Python:

From request to using the data

1. Data Request
   `urllib.request`
   - standard library, (`requests` easy parameter integration, but pip-installed)

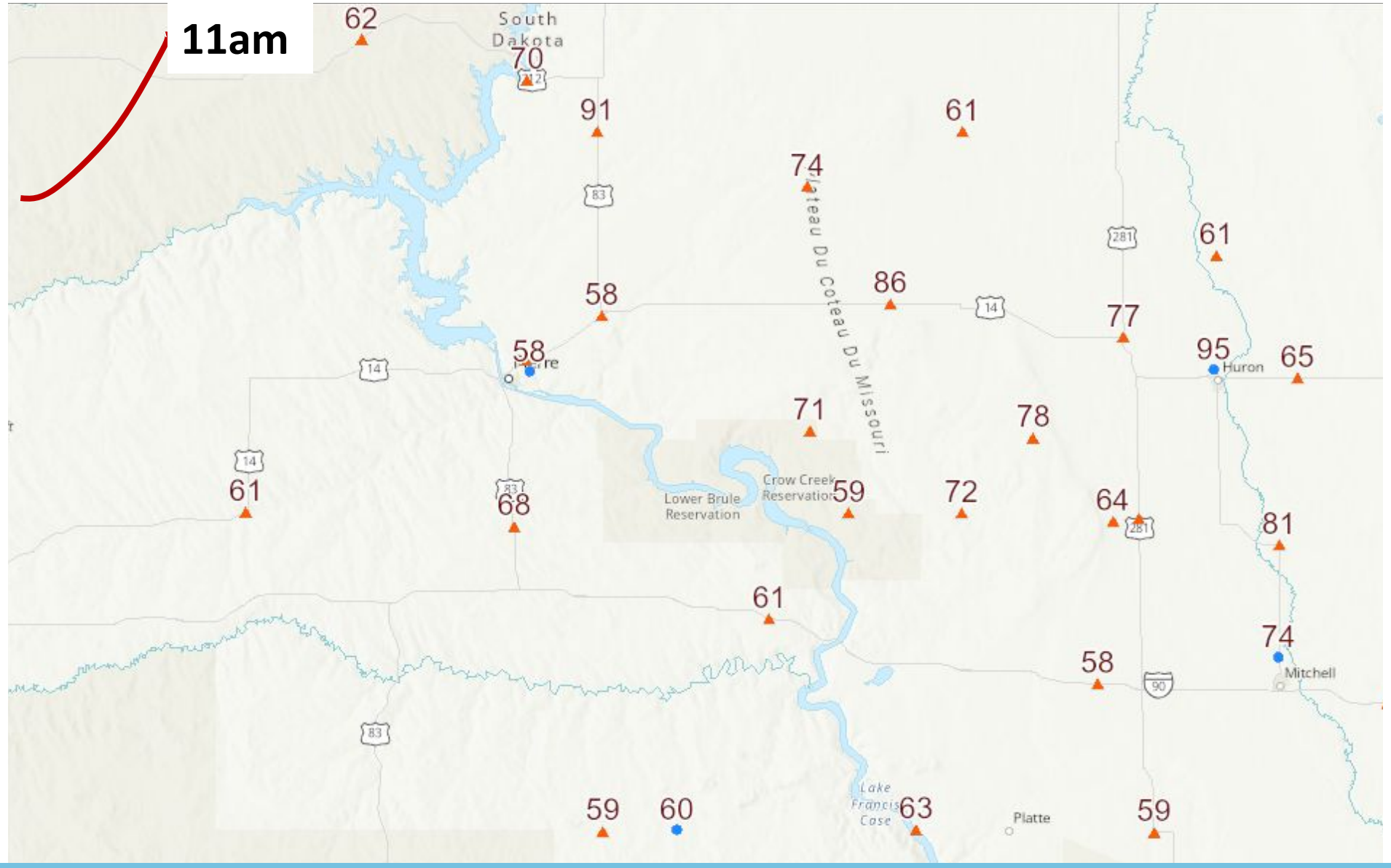
2. Initial parsing
   `json`

3. Workable data structure
   `pandas`

** This is not exclusive **

Northern Plains Derecho – July 5, 2022

Northern Plains Derecho – July 5, 2022



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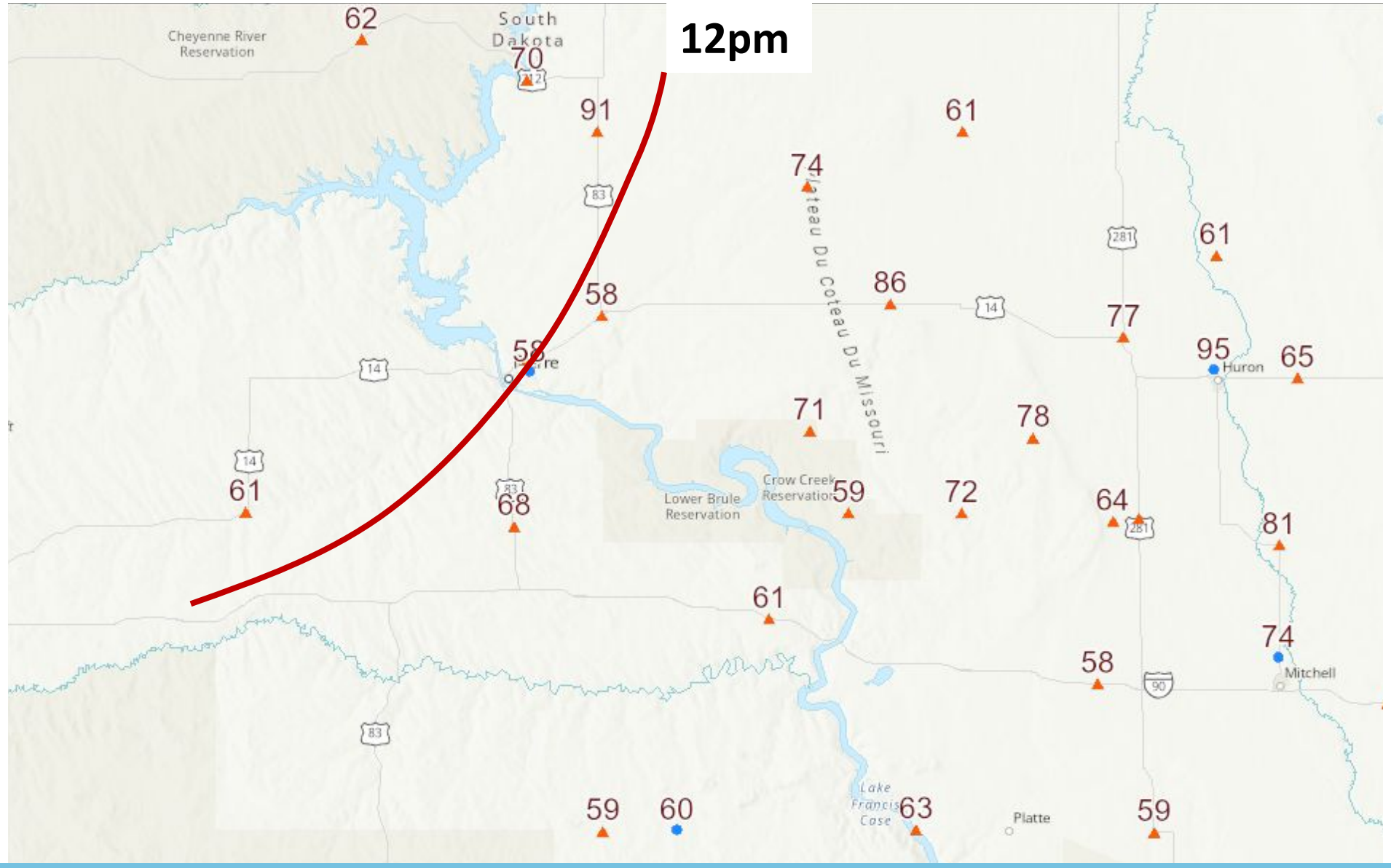

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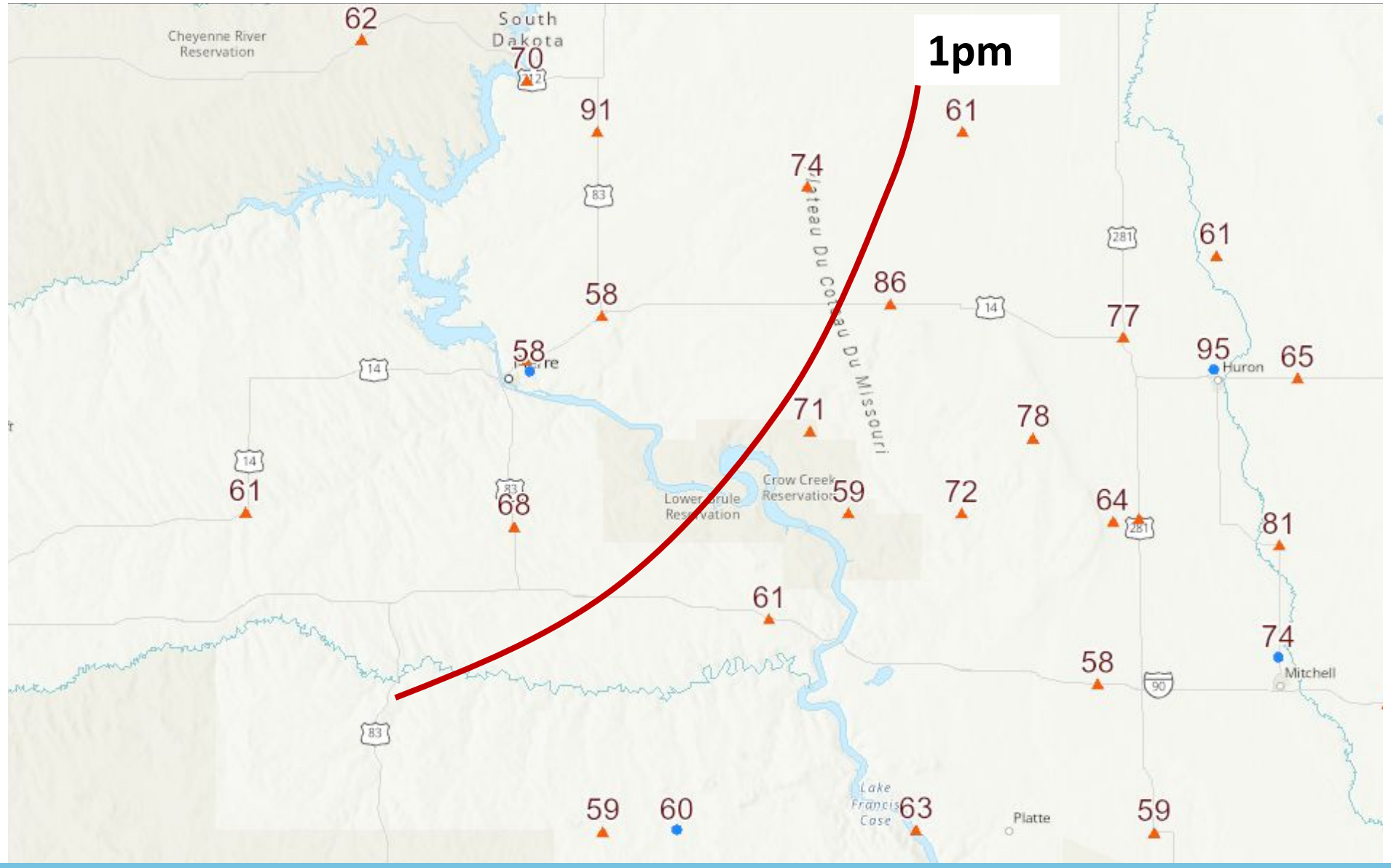

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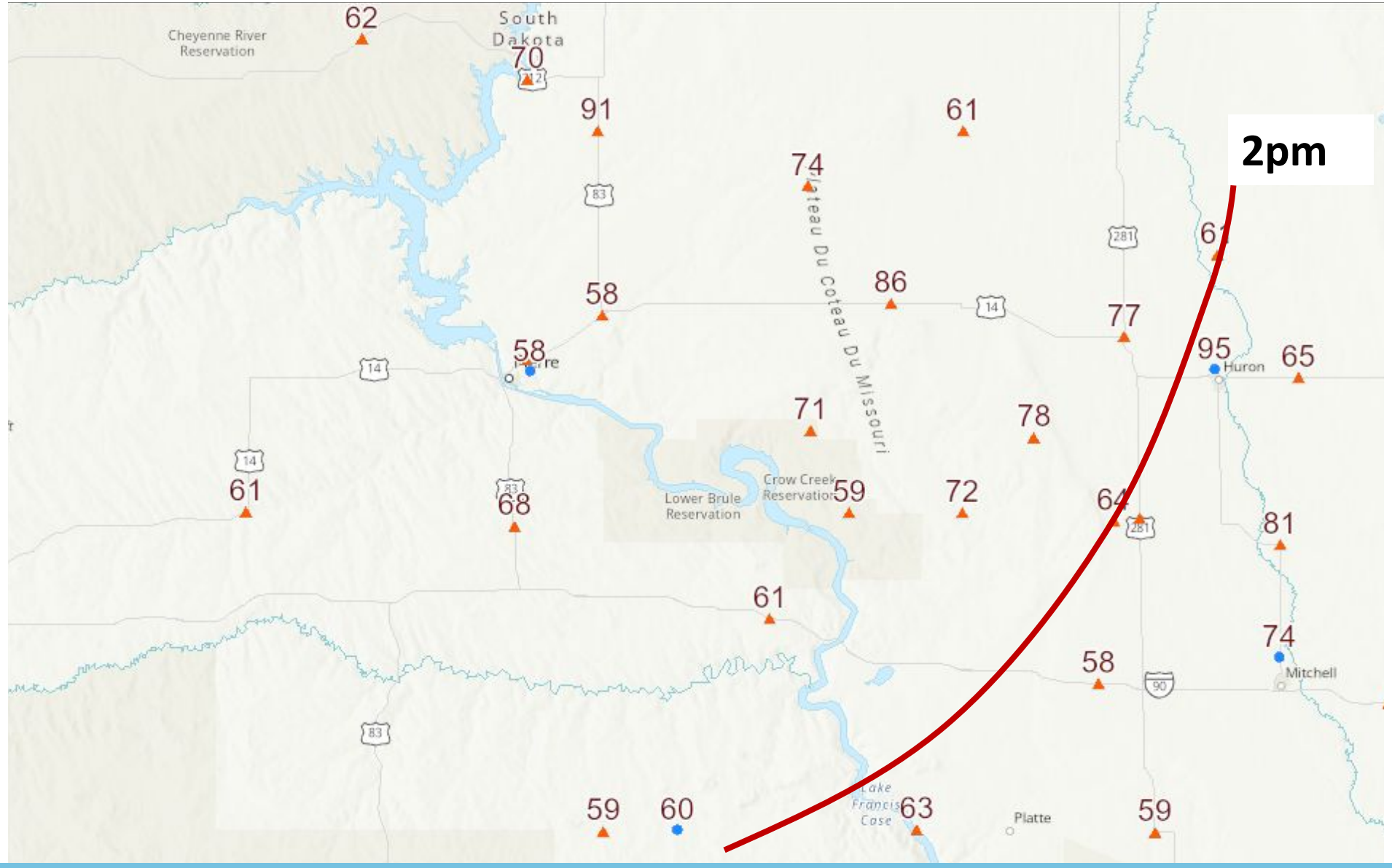

We also have a tool for simple csv download.

Less customizable than API:

Grab single station data for:

- Window of time
- Specified units
- Selected (or all) variables