Evaluating Sensor Health

Jonathan Callahan

Team of players

Tampa Rays Injured List – July 08

Name	Team	Pos	Injury / Surgery Date	Injury / Surgery
Shane McClanahan	TBR	SP	06/30/23	Back tightness
Andrew Kittredge	TBR	RP	06/22/22	Tommy John surgery
Shane Baz	TBR	SP	09/28/22	Tommy John surgery
Jeffrey Springs	TBR	SP	04/24/23	Tommy John surgery
Garrett Cleavinger	TBR	RP	05/07/23	Sprained knee
Drew Rasmussen	TBR	SP	05/11/23	Strained elbow flexor
Josh Fleming	TBR	SP	05/28/23	Elbow inflammation

The "team" analogy

A network of sensors is like a "team".

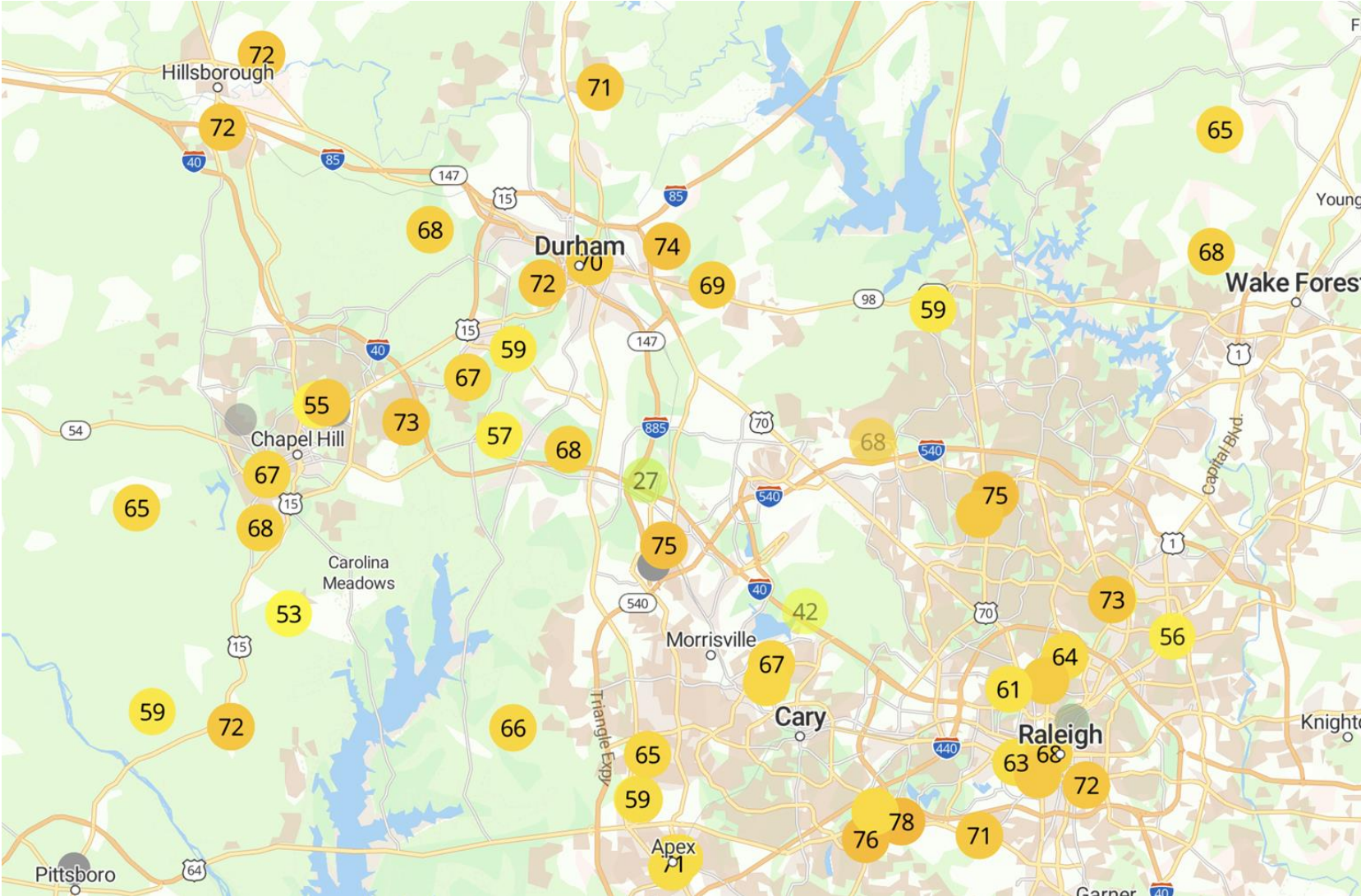When all players perform well, we get good results.

When all sensors perform well, we get good information.

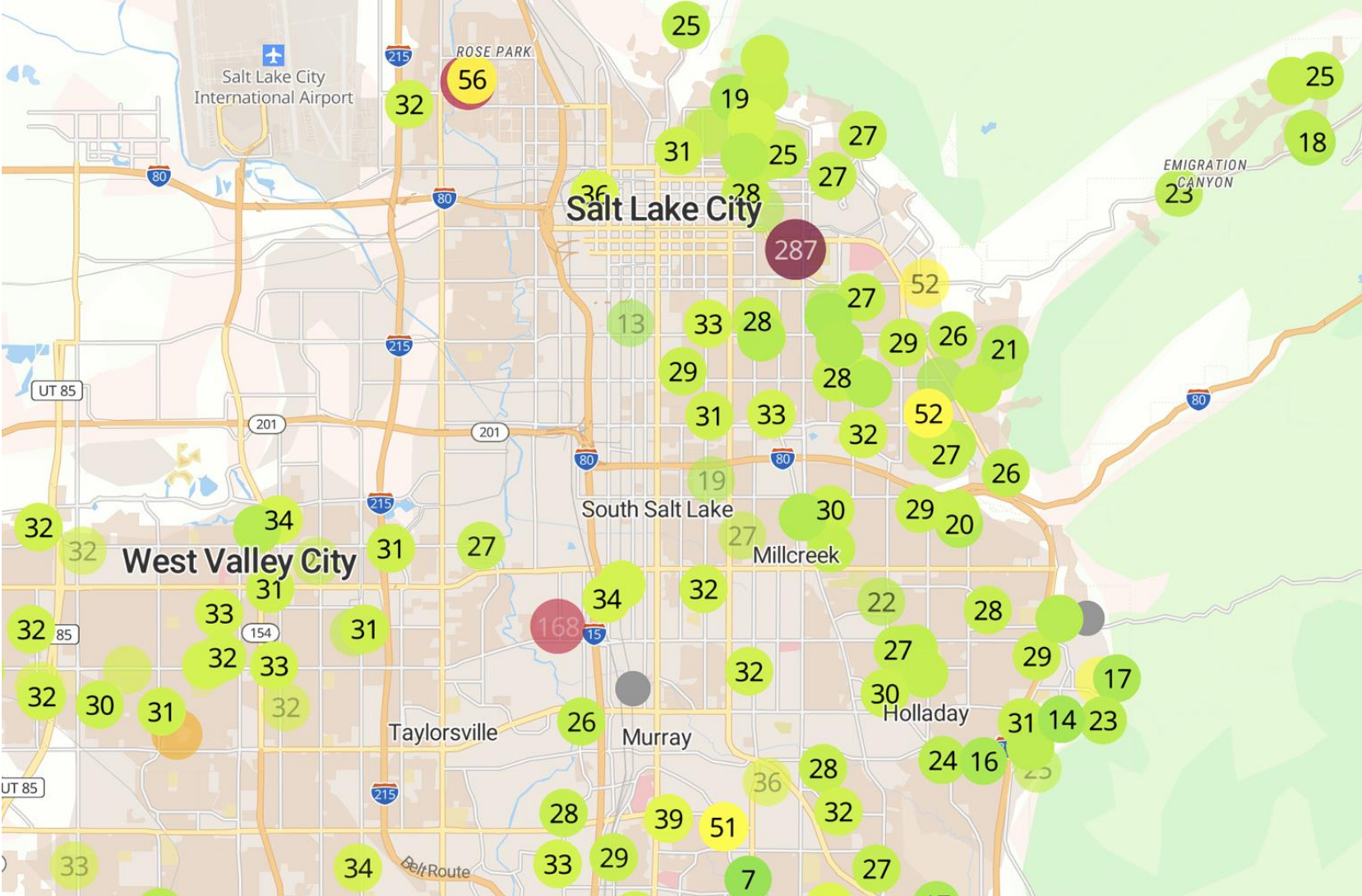When a player is sick or injured, they go on the "Injured List".

When a sensor is sick injured, it should go on the "Injured List".

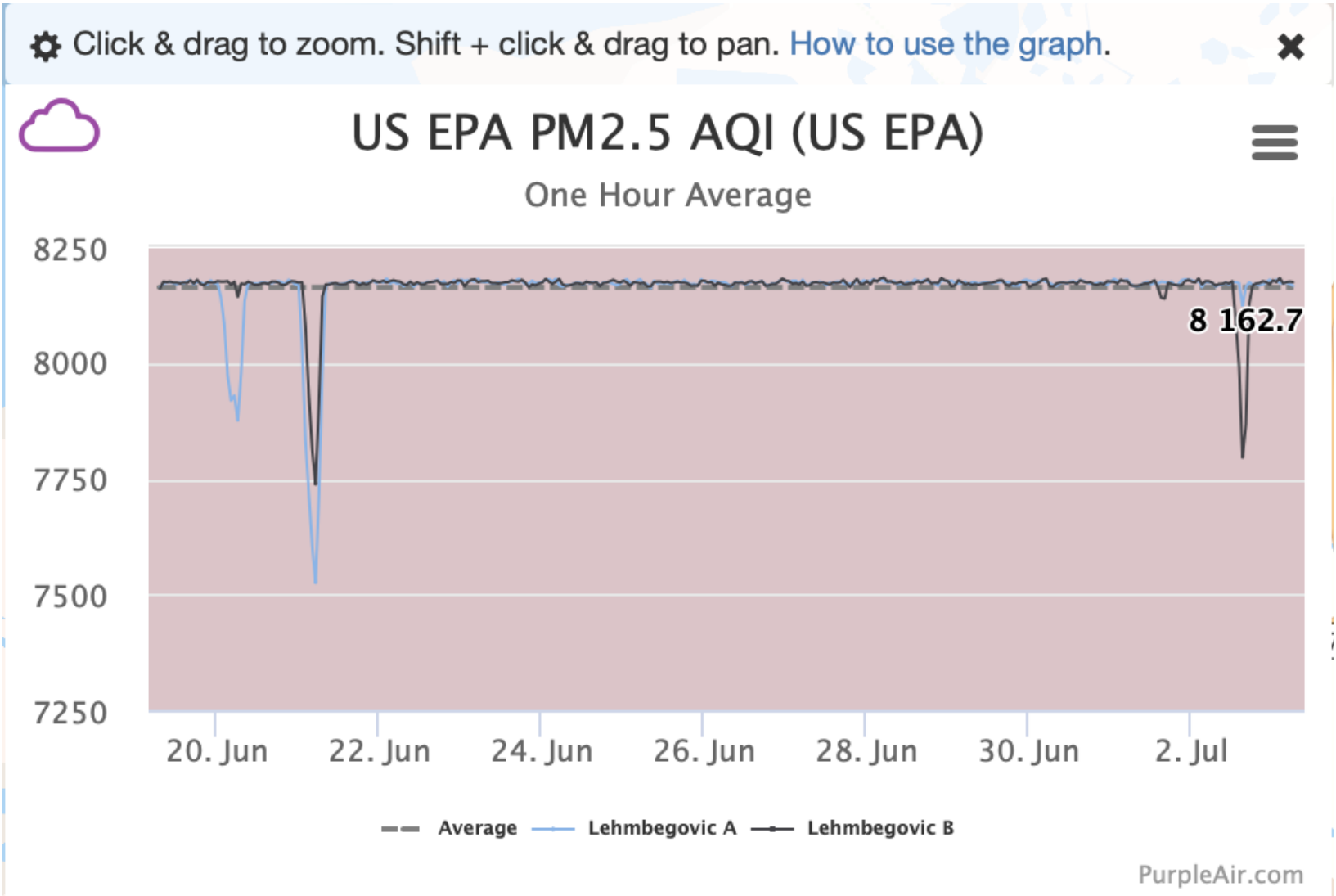When players or sensors get better, they rejoin the team.

Network of sensors

Network with injured sensors

Sensor showing 287 belongs on the Injured List!

Click & drag to zoom. Shift + click & drag to pan. How to use the graph.

US EPA PM2.5 AQI (US EPA)
One Hour Average

8 162.7

Average — Lehmbegovic A — Lehmbegovic B

Take Home Message

Sensors, like athletes, sometimes get sick or injured and need to go on an Exclusion List.

Luckily, low cost sensors allow us to have a deep roster.

It's OK to put 2-10% of sensors on an Exclusion List.

So, how do we measure sensor health?

Similar Concepts

Fitness Metrics

Key Performance Indicators

State-of-Health Metrics

Human Fitness Metrics

Fitbit:

- Breathing Rate
- Heart Rate Variability
- Skin Temperature
- Oxygen Saturation
- Resting Heart Rate

Combine them to create a Fitness Index.

Sensor State-of-Health metrics (daily)

- % reporting
- % valid (good QC flag)
- % "stuck" (repeated values)
- 2-channel R^2 (*for PurpleAir*)

Other

- ¿¿ % big jump ??
- ¿¿¿ agreement w/ neighbors ???

Automated filtering of unhealthy sensors

1) Create algorithms to detect failures: "state-of-health" metrics

2) Test algorithms against many sensor time series

3) Create a multi-metric, overall state-of-health index

4) Define a threshold for pass/fail

5) Only show data from sensors that have recently passed.

State-of-Health (SoH) Index

Multi-metric index of individual SoH metrics, calculated daily

We reviewed lots of PurpleAir data, tried lots of combinations

One good version:

1. If the A or B channel **pctReporting** is < 50, index = 0
2. Otherwise, index = **AB_RSquared**
3. Poor/Fair/Good: <0.2 / 0.2-0.8 / >=0.8

Ended up tossing out 10-15% of sensor-days in 2019

Distribution of SoH Index by month for Washington

Distribution of SoHIndex values for 140 sensors in Washington state
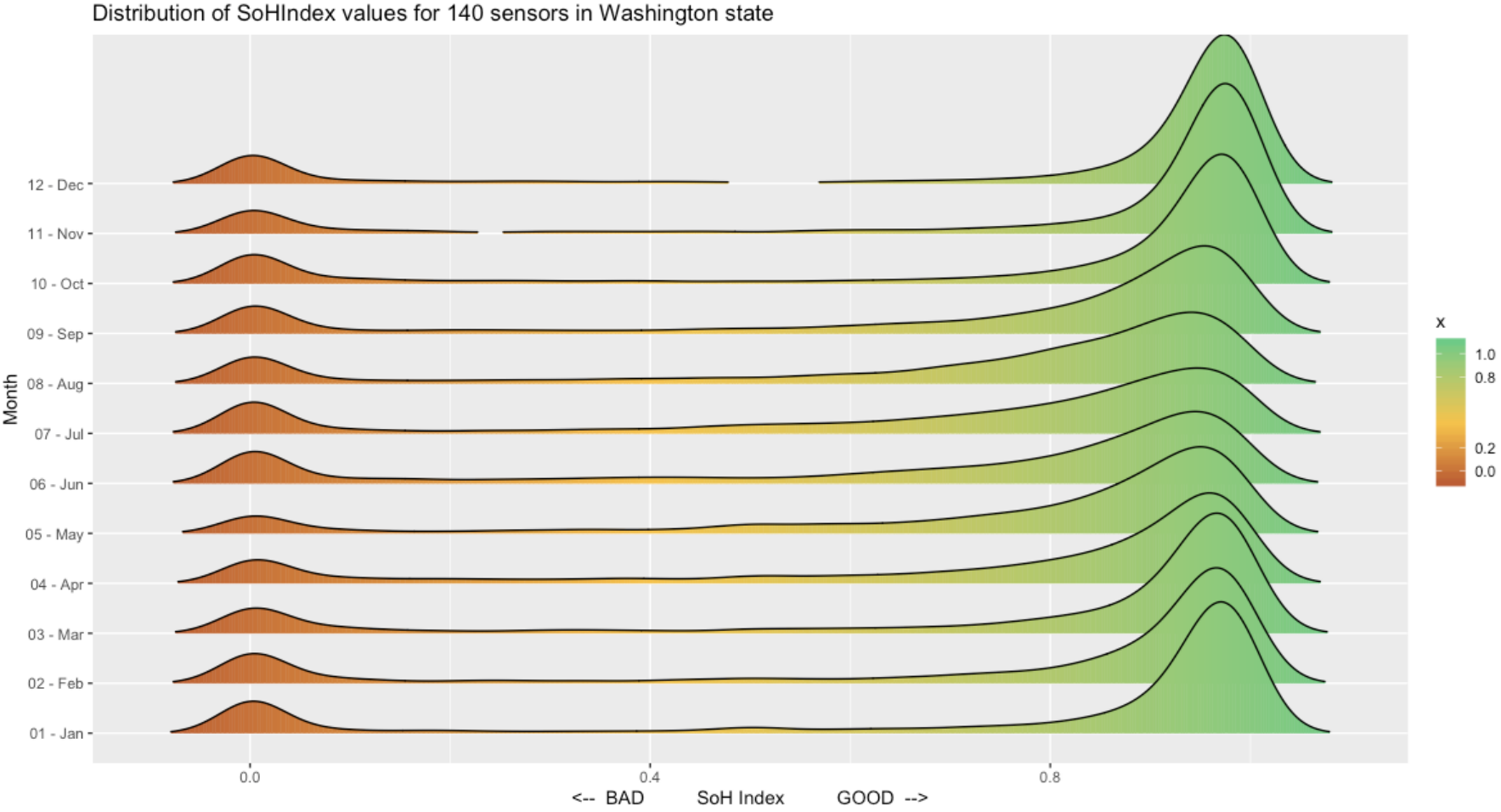
Epilogue -- Why do sensors fail?

Why do sensors fail -- `pctReporting`

- Improper installation
- Sensor gets removed
- Internal power supply failure
- Public Safety Power Shutoff
- Local wifi goes down
- Aggregation site goes down
- Squirrel chews through power cable
- 14 year-old boy with soccer ball knocks power cable loose
- ...

Why do sensors fail -- `pctValid`

- Firmware upgrade mistakes
- Particle counter malfunction
- Amplifier malfunction
- Aggregation site data QC
- Spider nest blocks air inlet
- 14 year-old boy with paint sprayer damages sensor
- ...

Why do sensors fail -- `pctStuck`

- Data handling mistakes
- Particle counter malfunction
- Amplifier malfunction
- Aggregation site data processing error
- Schmutz covers light detector
- 14 year-old boy with garden hose damages sensor
- ...

Why do sensors fail -- `AB_RSquared`

- Data handling mistakes
- Particle counter malfunction (fan?)
- Amplifier malfunction
- Aggregation site data processing error
- Water condenses inside only one particle detector
- 14 year-old boy plugs up one intake port to see what will happen
- ...

Take Home Messages

Low-cost, electronic devices sometimes fail.

Low-cost sensors are … low cost.

Deploy lots of sensors and prepare to exclude some.

Use State-of-Health metrics to create daily index.

Exclude sensors based on their SoH Index value.