12 Grams Around The World

Picoballoons and Radiosondes

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https://sf-hab.org/

The two types of Balloons Amateurs Launch

Bursting Latex Balloons

Floating Superpressure Balloons

HAB/Superpressure Balloon Comparison

	HAB (bursting)	**Superpressure**
Flight duration	~4 hours	Days to Months
Goal	High altitude	Around the world Long endurance
Altitude	Up to ~120k feet, then down	Constant at ~38k feet
Payload mass	Up to 12 lbs	10 to 20 Grams
Comms	APRS	WSPR
Payload recovered?	Yes (usually)	No
Balloon material	Latex	Multilayer plastics
Power	Batteries	Photovoltaic
Science opportunities	Short duration tests	Developing for long duration

Why Superpressure?

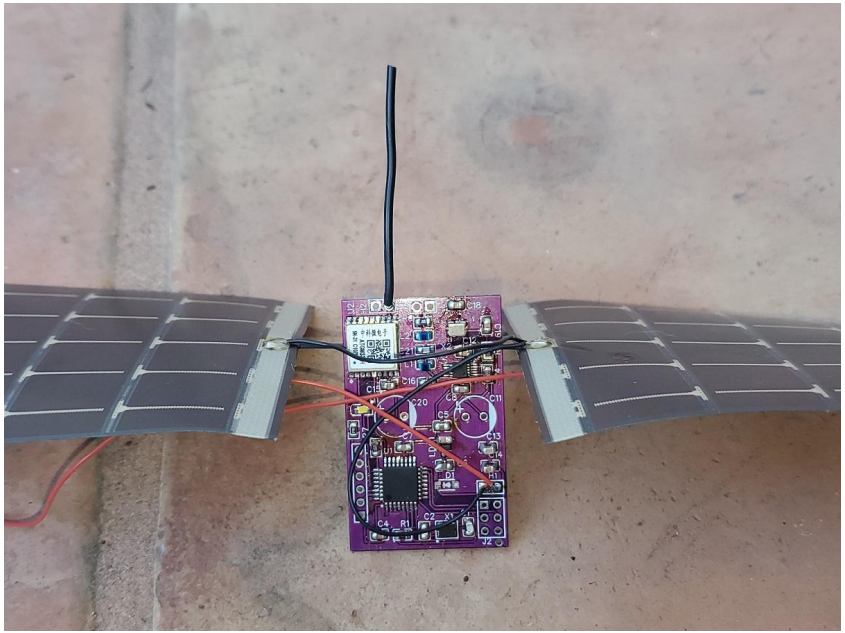
- The SF-HAB team has launched several regular bursting balloons
  - Payloads include cameras, cross-band repeater, LoRA
  - Lots of fun, but very expensive for the balloon and helium/hydrogen
- New challenges
- Pandemic project
- Try to make it around the world
  - Longest duration picoballoon is ~300 days, around the world 12 times

Superpressure Balloon Background

- Balloon material is rigid - not latex, which stretches as it ascends
- Volume of the balloon is kept constant - envelope doesn’t expand
- Analogy: Boats. Heavy steel boats float on the surface because they weigh less than the weight of the displaced water. Replace the air with water, and boat start to sink. Replace a lot of air with water, now you have a submarine. Submarines float on surface until they take on ballast (heavy water), then “float” at a particular depth. Mass of submarine = mass of displaced water.
- Bigger balloon provides more lift, more gas needed
- Balloons look empty when released

Custom Built Tracker Electronics

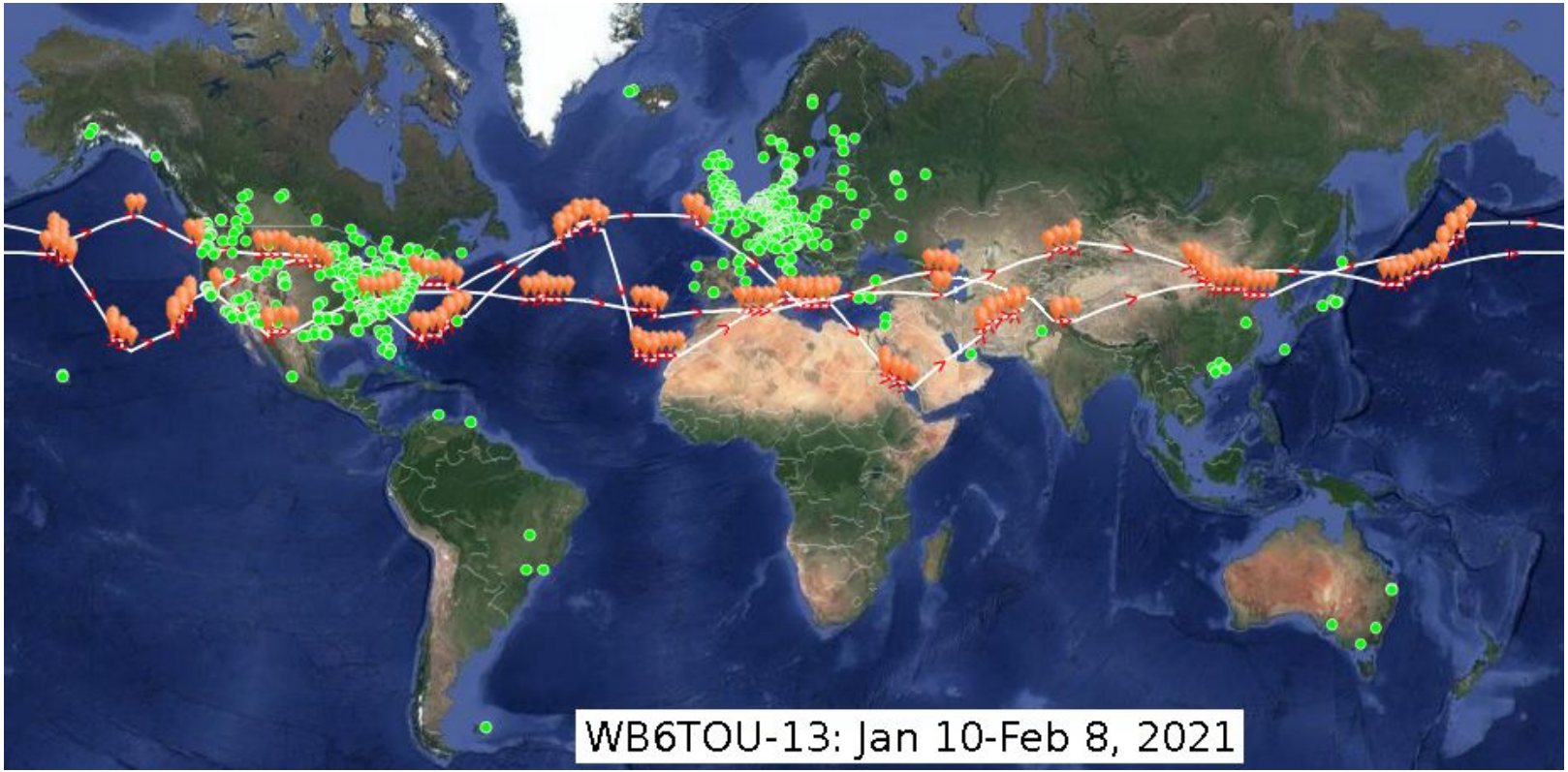
- Designed and built by Martin W6MRR
- PCB 2” by 4”, ~7 grams
- Antenna and solar bring it up to ~12 g
- ATMega328P-AU
  - UART for GPS
  - I2C for WSPR transmitter
- SI5351A with TCXO
  - 10 mW on 20 meters (14 MHz)
  - Vertical dipole
- UBlox knockoff GPS
  - ATGM336H
  - Monopole for antenna, no LNA/SAW
- Solar cells only
  - Batteries are too heavy



Superpressure Balloons

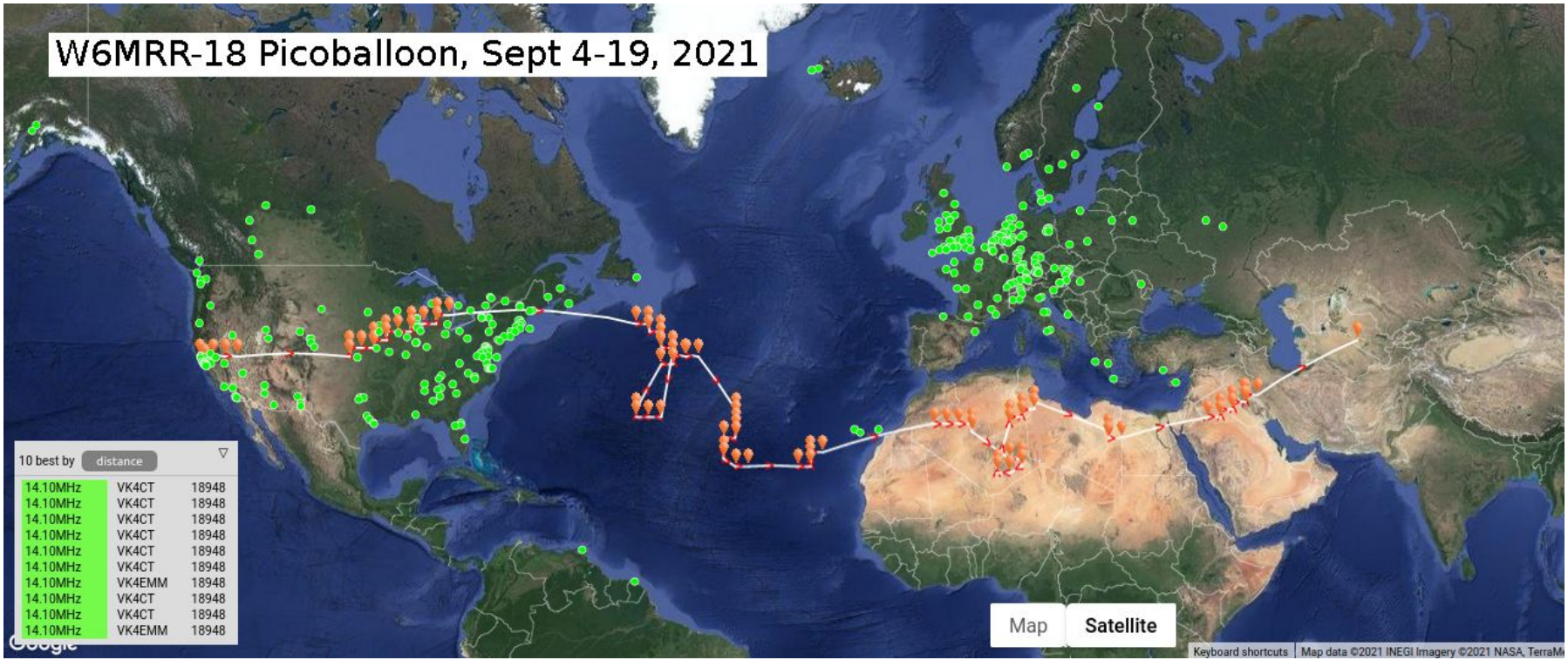
- Originally used SBS-13 balloons, $130
- Ali Express party balloons, $2 ea
  - Low quality, needs QC
  - Need two per tracker
  - ~37 grams weight per balloon
- Filled with hydrogen
  - ~7 grams (not a lot) provides ~50g lift each
- 20+ launches
- Lots more info in our Pacificon talk with David WB6TOU and Martin W6MRR

WB6TOU-13: Around the World 2.5 Times



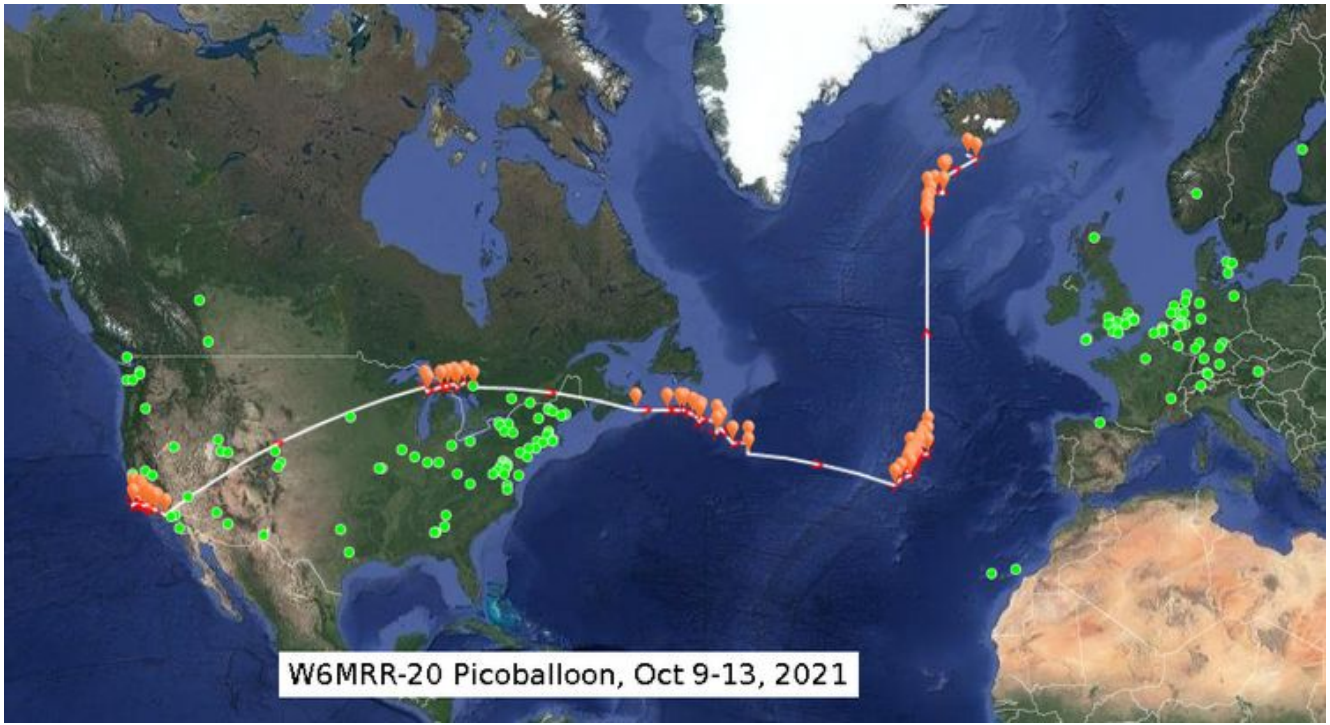
SBS-13 balloon, WB8ELK WSPR Skytracker

W6MRR-18: California to Turkmenistan



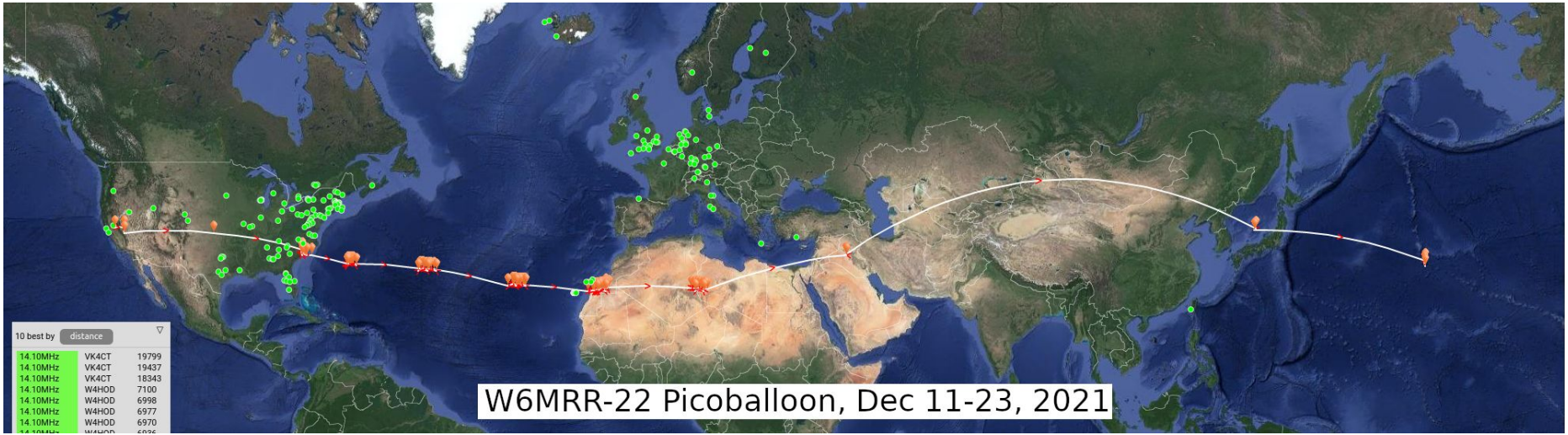
Two Ali Express balloons, custom WSPR transmitter

W6MRR-20: Iceland



Two Ali Express balloons, custom WSPR transmitter

W6MRR-22: California to Midway Islands



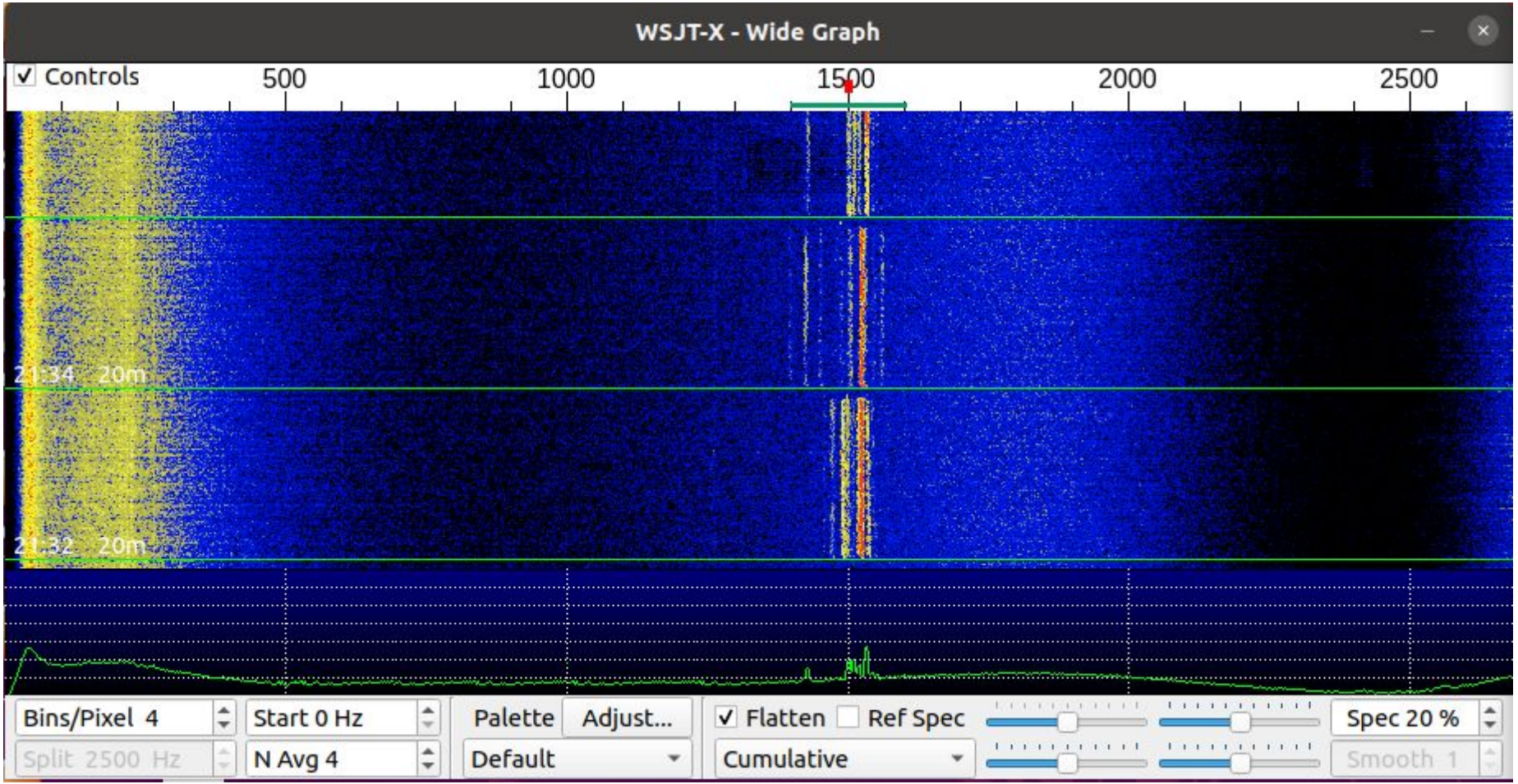
Two Ali Express balloons, custom WSPR transmitter

Balloon Communications

	Automatic Position Reporting System (APRS)	**Weak Signal Reporting System (WSPR)**
Network	ARPS.fi (APRS-IS)	WSPRnet.org
Frequency	144.390 MHz (**Line Of Sight**)	HF - typically 20 m, 14 MHz (**Skywave**)
Modulation	Binary AFSK over FM **~1200 bps**	4-ary CPFSK, 50 bits/2 minutes = **0.42 bps**
Bandwidth	10 kHz	6 Hz
Data Payload	Up to ~1,000 bits	50 bits
Power	1-10 W	10mW to 10 watts
Range	Line of sight	Beyond line of sight
Position	GPS precision	4-digit grid square (or extended 6-digit)
Telemetry	Lat/Long, + absolutely anything	Callsign, grid square, dBm

Weak Signal Propagation Reporting

- Invented by Joe Taylor K1JT
- Designed to test propagation at HF
- Transmit power usually less than 10 watts
  - Our picoballoon transmits at 10 mW
  - 19,800 km max distance, circumference of earth is ~40,000 km
- Transmit duration 2 minutes, 50 bits total (162 bits), 4-ary FSK
- Occupied bandwidth is 6 Hz, WSPR band is 200 Hz wide

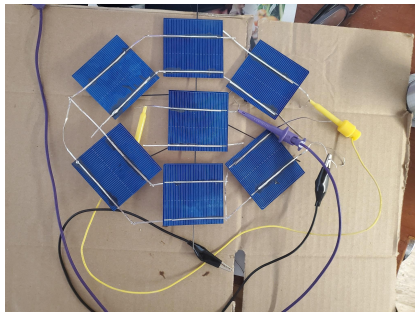


21:34 had 10 packets, 21:32 had 12 packets

Data Rates

- A few of our early picoballoons had an APRS transmitter
- Piano wire antenna straight down, no counterpoise
- High TX power (500 mW) and no real ground sometimes caused microcontroller to lock up, could only be cleared by a power cycle (nighttime)
- APRS
  - 1 watt for 1 second = 1 Joule per packet
  - 1 Joule/1,000 bits = 0.001 J/bit
- WSPR
  - 0.01 watts for ~100 seconds = 1 Joule per packet
  - 1 Joule/50 bits = 0.02 J/bit
  - 20x more energy per bit than APRS
  - Lower frequency provides skywave propogation

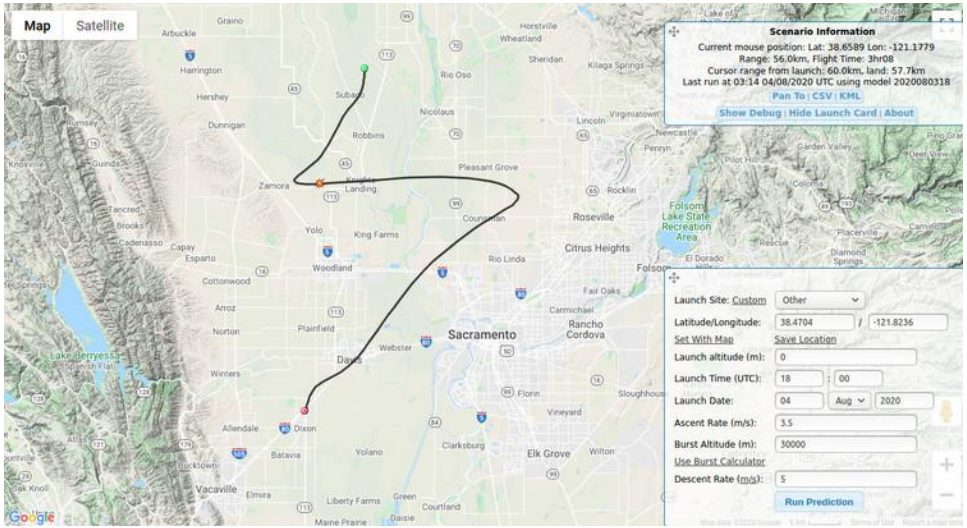
How can I get involved?



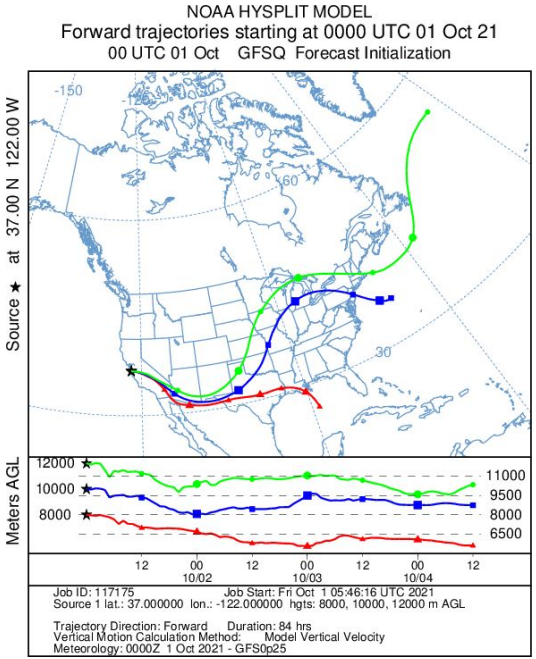
- Come to a launch
  - Launches announced on SF-HAB mailing list and SFARC Slack
  - https://sf-hab.org/
- Future picoballoon/HAB projects
  - Cameras, sensors, what would you like to fly?
  - Dual gimbal gyro inertially stabilized HAB, VLF downloader HAB
  - New balloon envelope designs, controllable altitude balloon
- Groups.io Picoballoon email list
  - https://groups.io/g/picoballoon
- Set up a WSPR receiving station
  - 95% of the time your HF station is idle
  - 20m WSPR is most popular, but all HF bands have WSPR frequencies
  - WSJT-X is the most popular decode program, also does FT8

Flight Path Predictions

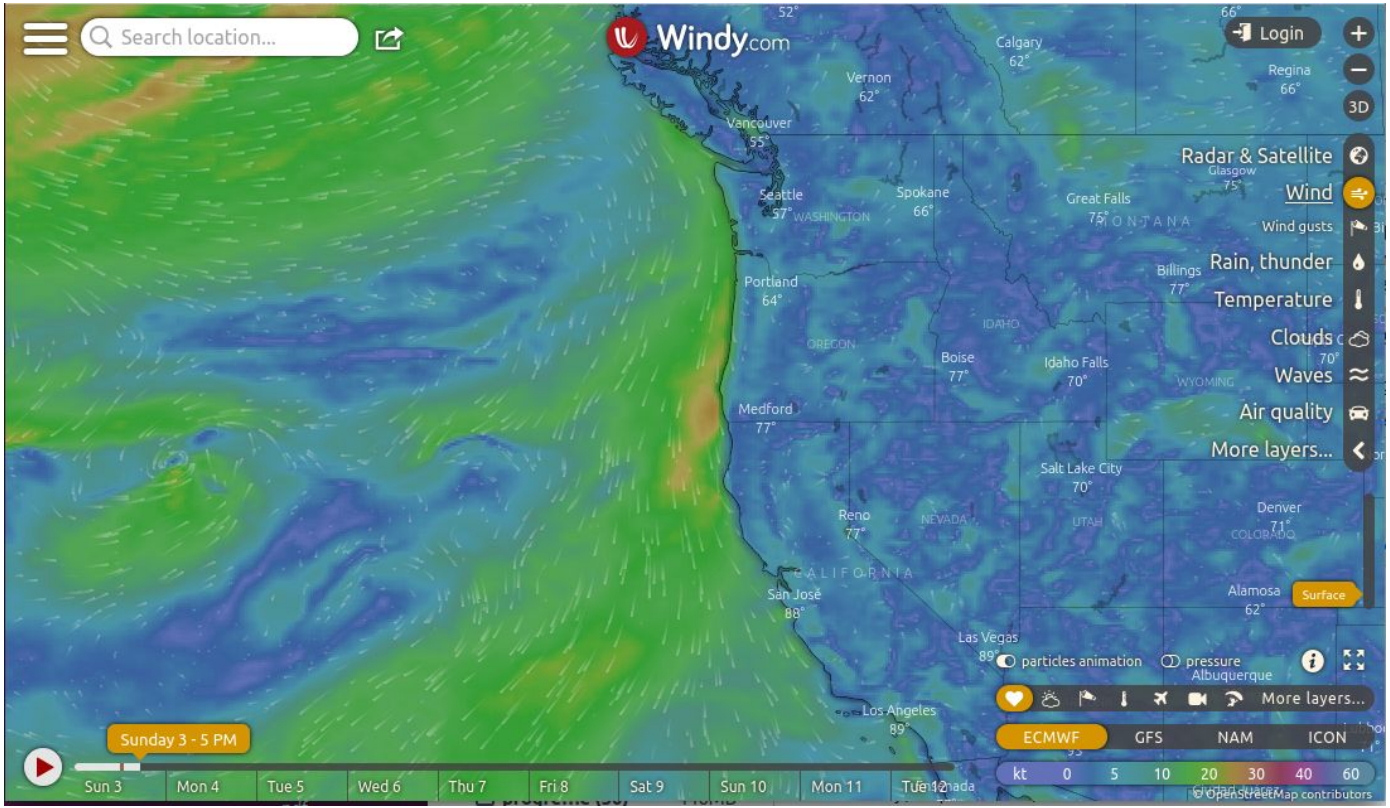
- How do you predict where a bursting Latex balloon will land?
- What direction will a superpressure Picoballoon float?
- Where is the jetstream going?



https://predict.habhub.org/

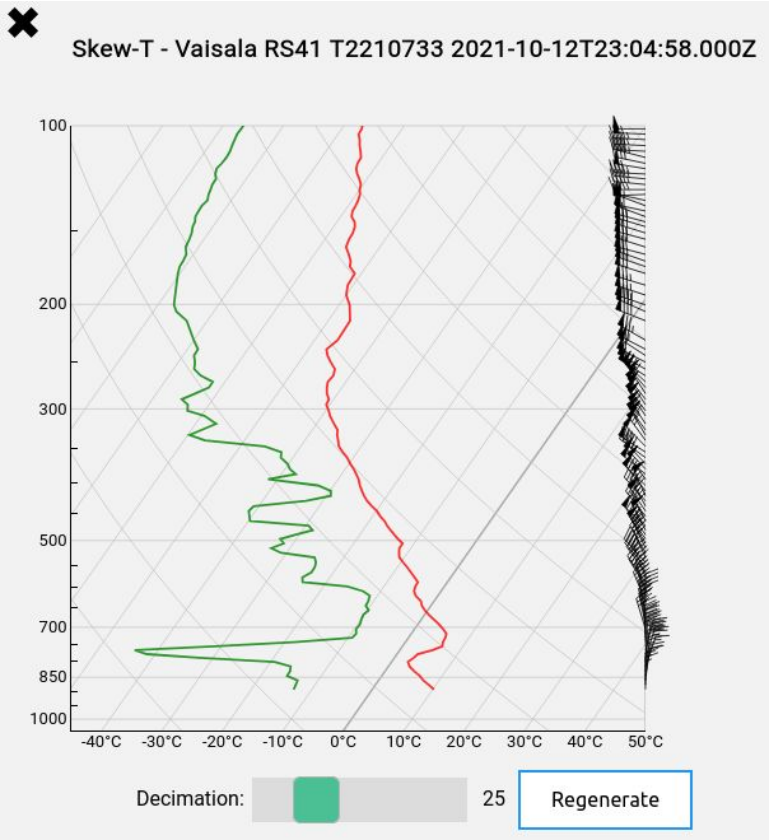


Where do these maps come from?



This data comes from Radiosondes

- Radiosondes directly measure the upper atmosphere wind, temperature, humidity, and pressure from ground up to ~30k meters (~100k feet)
- This data gets fed back into the Global Forecast System (GFS) model
- GFS is used for weather predictions, volcanic ash, manned “hot air” balloons, wildfire smoke movement



Skew-T plot from Oakland radiosonde

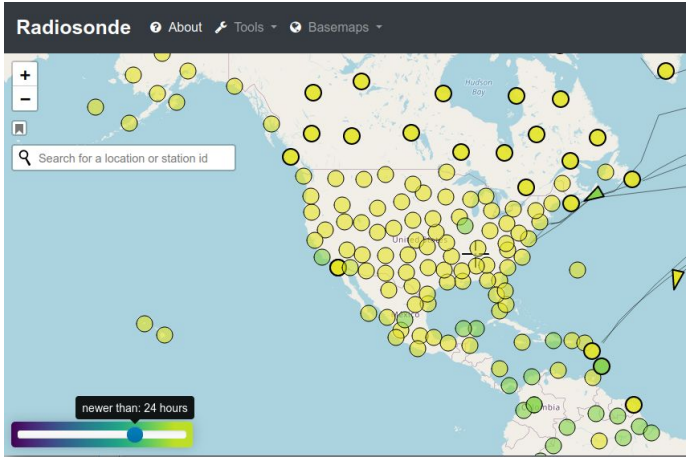
Radiosondes Directly Measure Upper Atmosphere Winds

- Small disposable transmitters on latex balloons
- Launched twice per day from ~1300 sites worldwide
- Our local radiosonde station is at the Oakland Airport
- Not amateur radio, but ham-adjacent at ~403 MHz or ~1680 MHz
- Vaisala RS41: 60mW, 403 MHz, 4800 baud GFSK, 84g (~3oz)

Vaisala RS41-SGP

Typical Radiosonde Flight

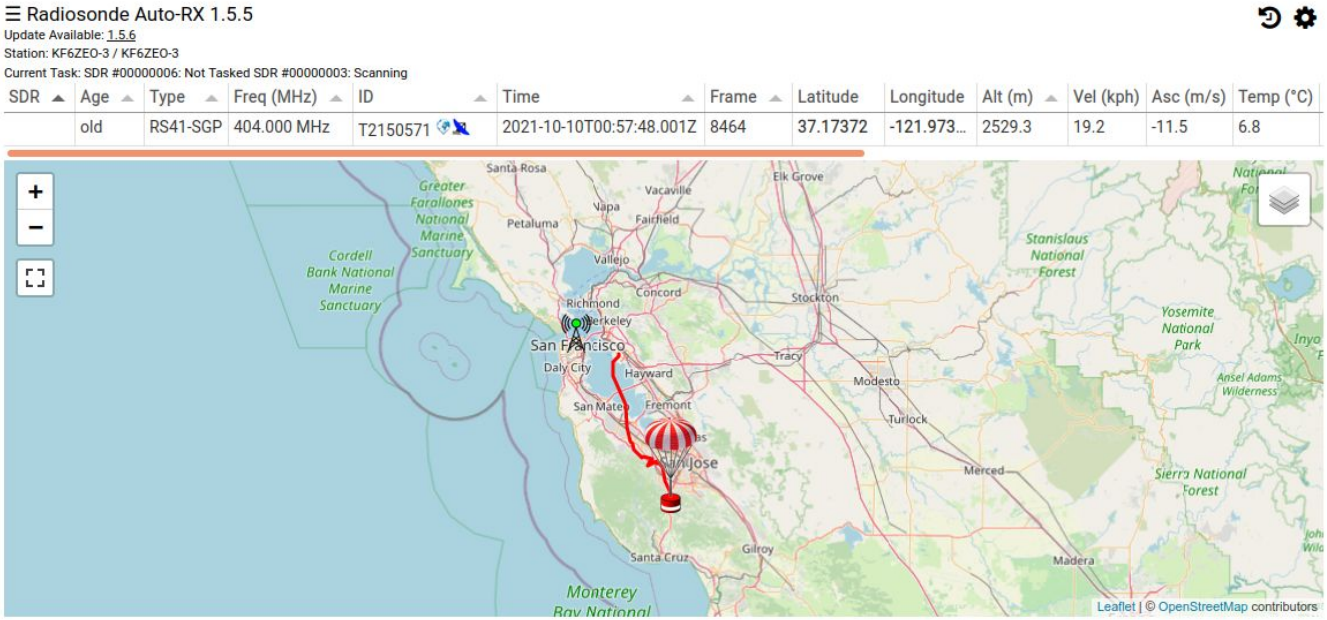
- Radiosondes are launched at 1100 and 2300 UTC every day
  - 3am and 3pm Pacific time (until DST starts)
- Balloon ascends at ~5 m/s for 90 minutes, up to ~30k meters (~100k feet)
- Balloon bursts, and free falls for 30 minutes until it hits the ground



Launch Sites in North America
https://radiosonde.mah.priv.at/dev/

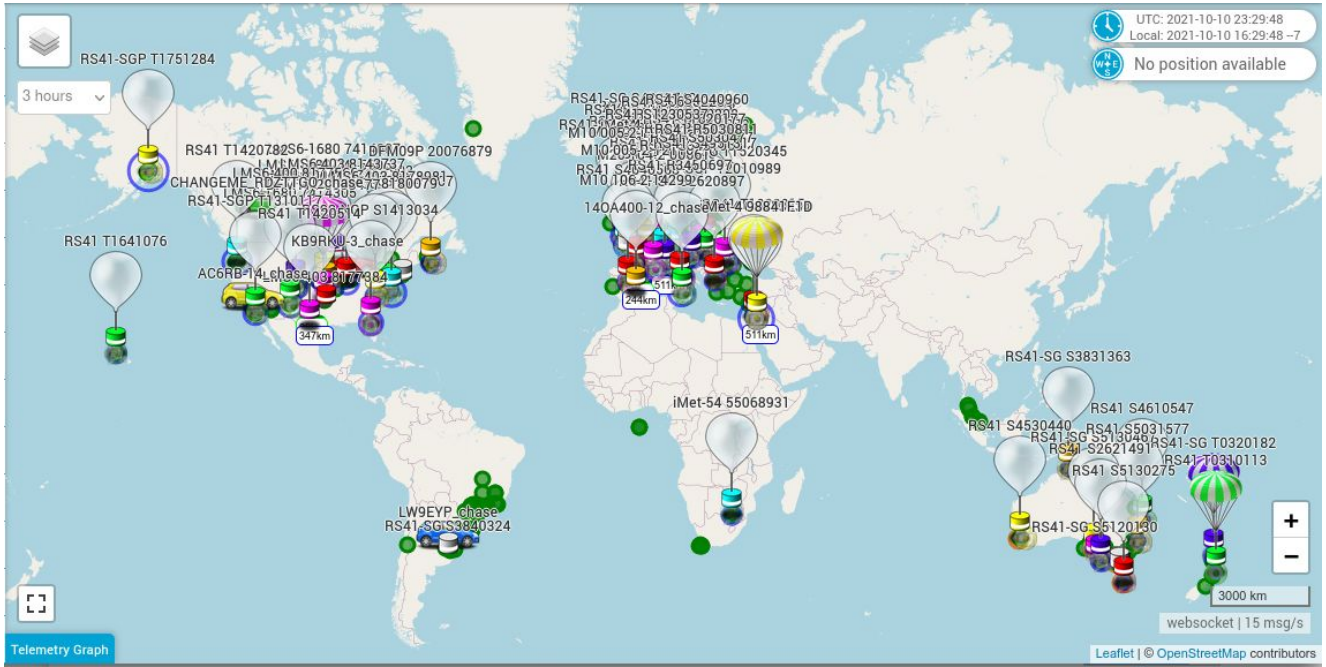
Radiosonde Receiving Software

- radiosonde_auto_rx runs on linux with a $25 RTL-SDR receiver
  - Runs in a docker container!
- rdzTTGOsonde runs on a TTGO LoRa ESP32 chipset

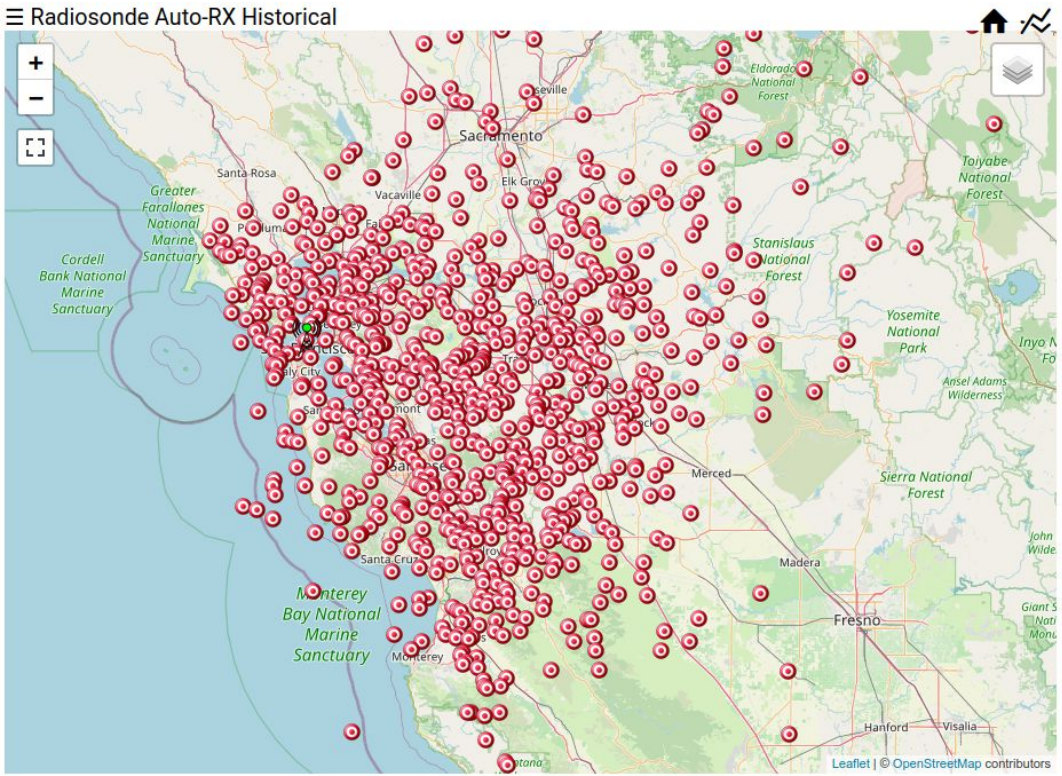


Worldwide Network of Radiosonde Receivers

- SondeHub collects all radiosonde_auto_rx telemetry
- Balloon tracking, real-time landing predictions, integration with Chasemapper



Where do Radiosondes Land?



Last radiosonde RX location, as received from my San Francisco station, Jan 2021 to Feb 2022

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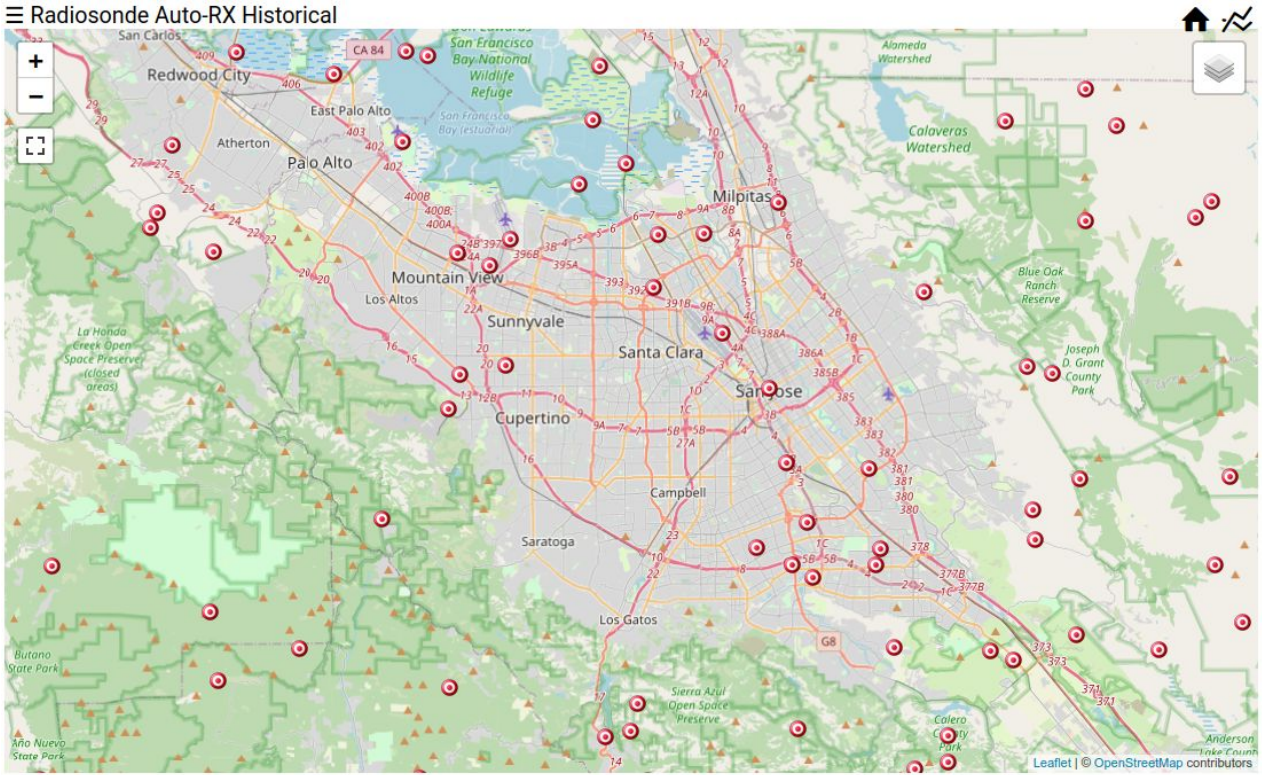
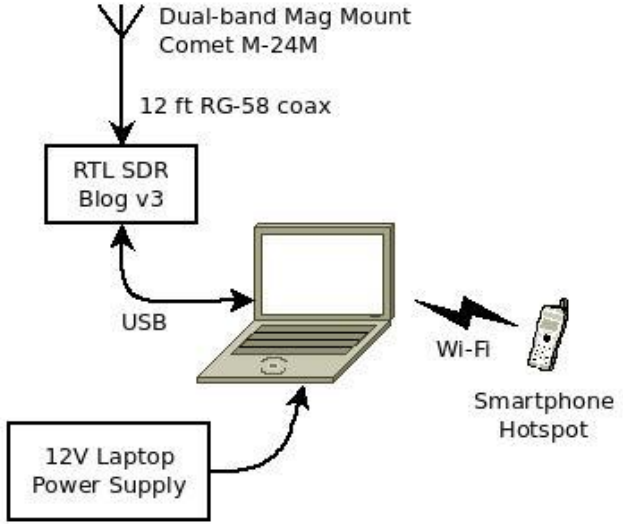


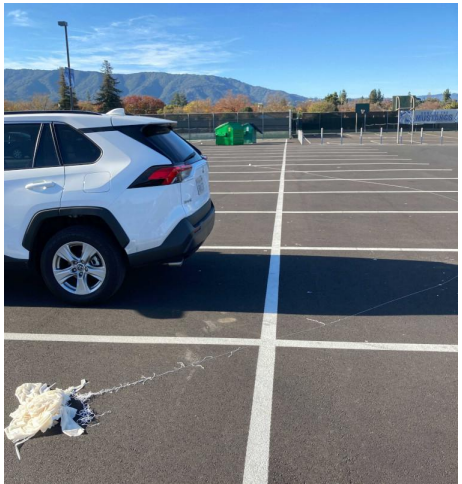
Last radiosonde RX location, as received from my San Francisco station, Jan 2021 to Feb 2022

Chasing and Recovering a Radiosonde

- Like amateur radio transmitter hunting
- Have someone else drive (so you can look at the screen and navigate)
- Ask for permission if it lands on private property
- Urban areas are more than 30% roadways and parking lots, so the odds are good
- Sondehub updates landing location during descent, you might be able to see it fall

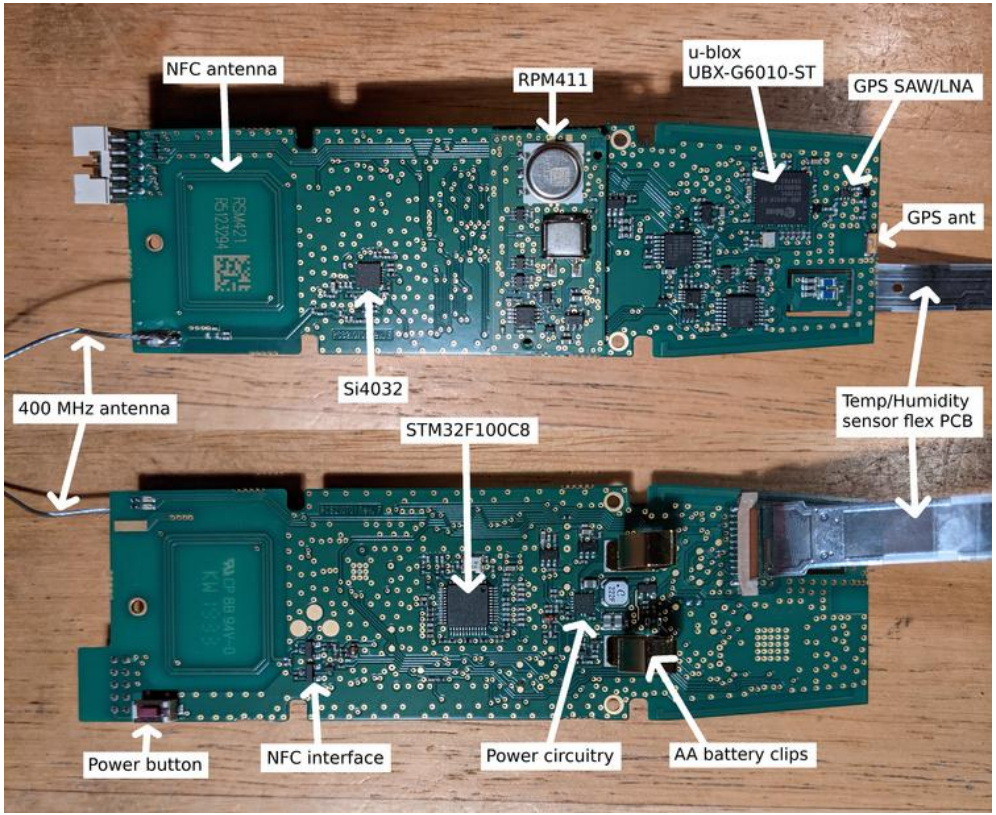


Radiosonde Recovery

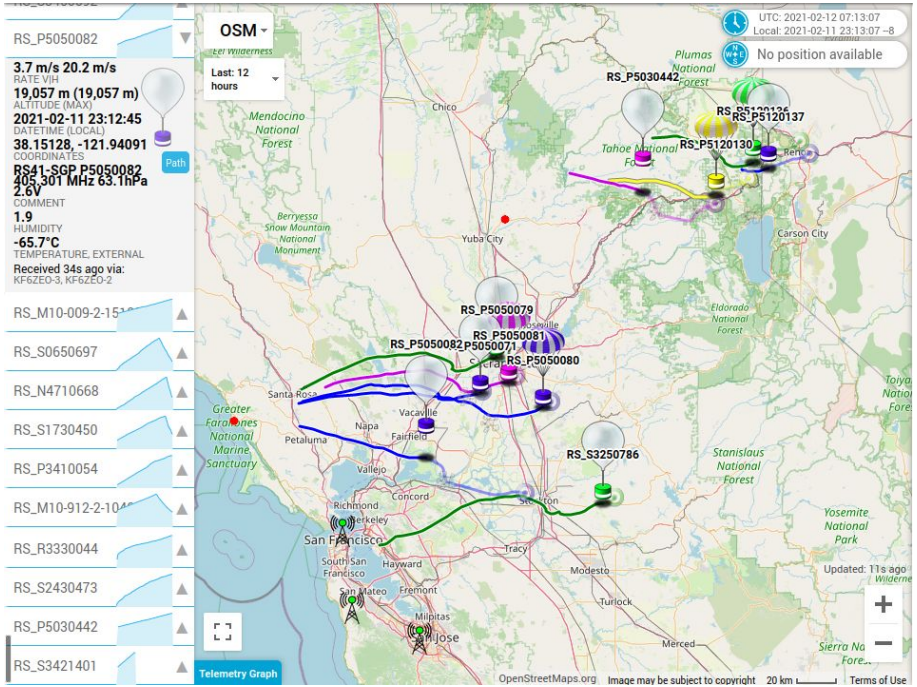


What Can You Do With a Radiosonde?

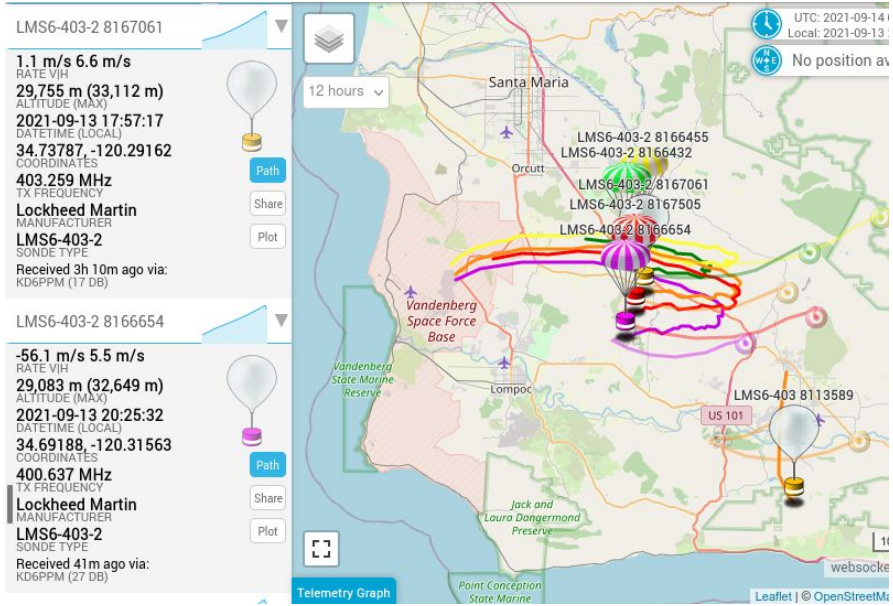
- Radiosondes are disposable, the NWS doesn't want them back
- Recycle/Reprogram:
  - Joseph OM3BC for 430 MHz APRS
  - DF8OE on github
- Scrap for parts:
  - Two AA lithium batteries
  - STMicroelectronics STM32F100C8
  - Silicon Labs Si4032
  - u-blox UBX-G6010-ST
  - Vaisala RPM411 pressure sensor



Special Radiosonde Launches



UCSD Atmospheric River Measurement



Falcon 9/Starlink launch from Vandenberg

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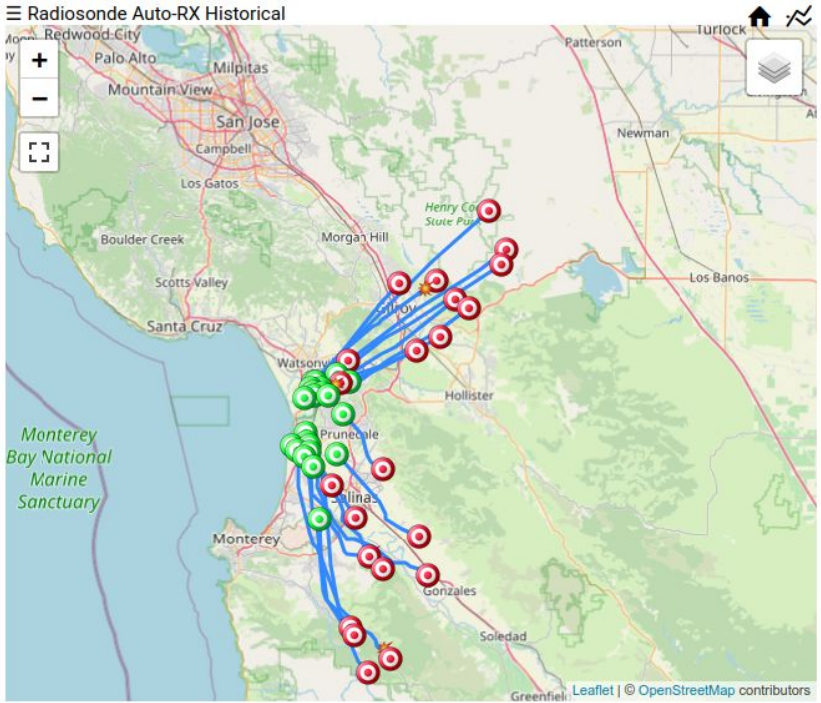
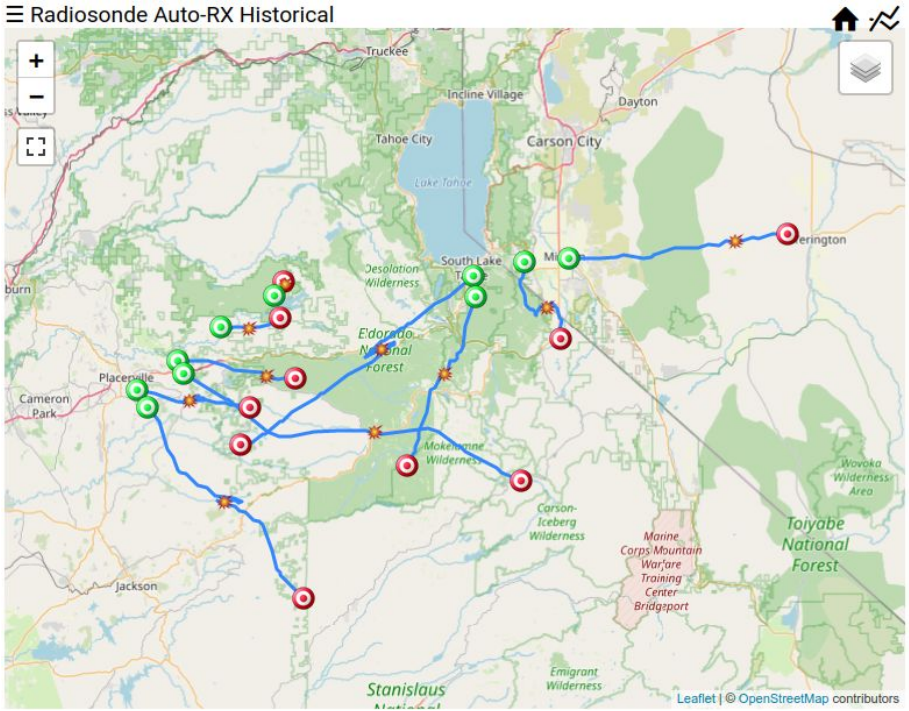


Monterey Bay Weather Measurements



Caldor Fire Winds

How can I get involved?

- Track radiosondes on Sondehub and recover them
  - Just a fun thing to do!
  - https://tracker.sondehub.org/
- Set up a radiosonde receiving station
  - Oakland radiosondes are on 403 MHz, 70cm ¼ wave whip will probably work fine
  - Handmade ¼ wave vertical antennas work really well
  - RTL-SDR dongles are cheap, linux computer required
  - Runs in a docker container, on Raspberry Pi or x86

Questions?

https://www.klofas.com/blog/

https://www.sf-hab.org