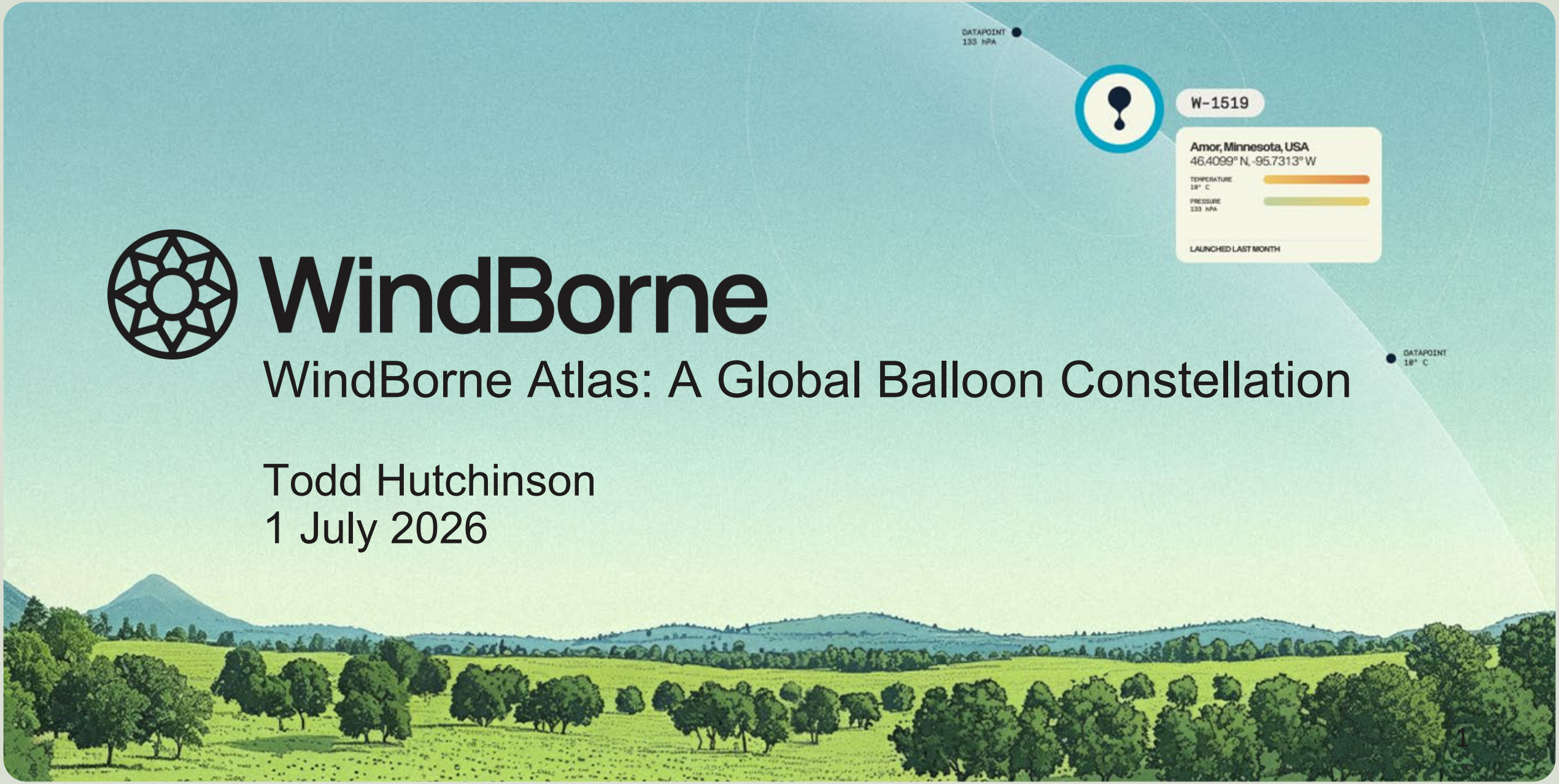


WindBorne

WindBorne Atlas: A Global Balloon Constellation

Todd Hutchinson

1 July 2026

Global Sounding Balloon

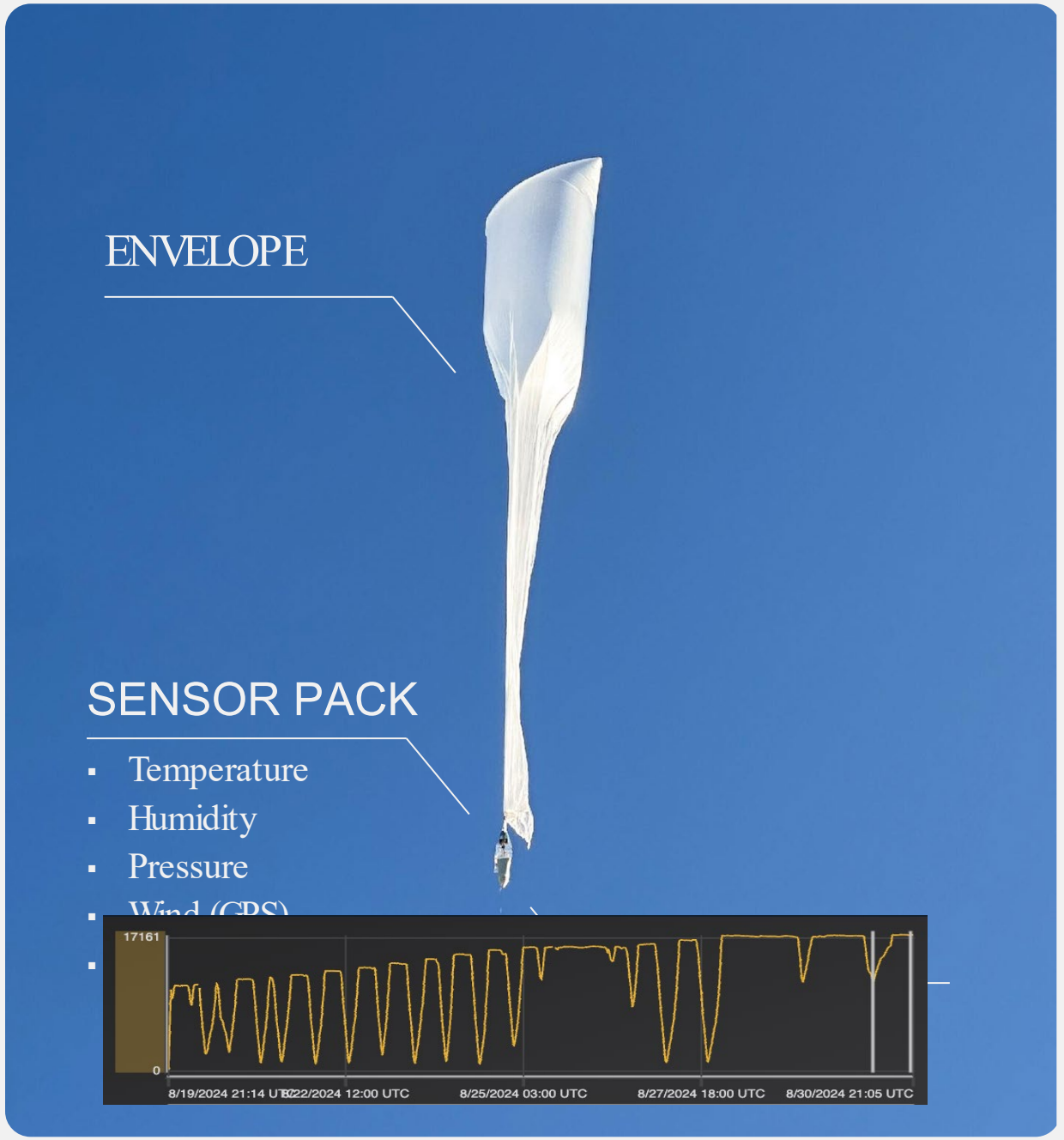
Controllable, long -duration weather balloon

- In-situ observations from surface to stratosphere
- Weeks-long flight duration
- Long-range across continents and over oceans
- Real-time, full-range altitude control
- Targeting capability to areas of interest using winds
- Low latency two-way communications
- Simple and low-cost hardware, automated flight control
- Small & lightweight

Highly cost -effective platform can collect…

- More data per unit cost over land
- A lot more data per cost over ocean

…compared to traditional in -situ methods .



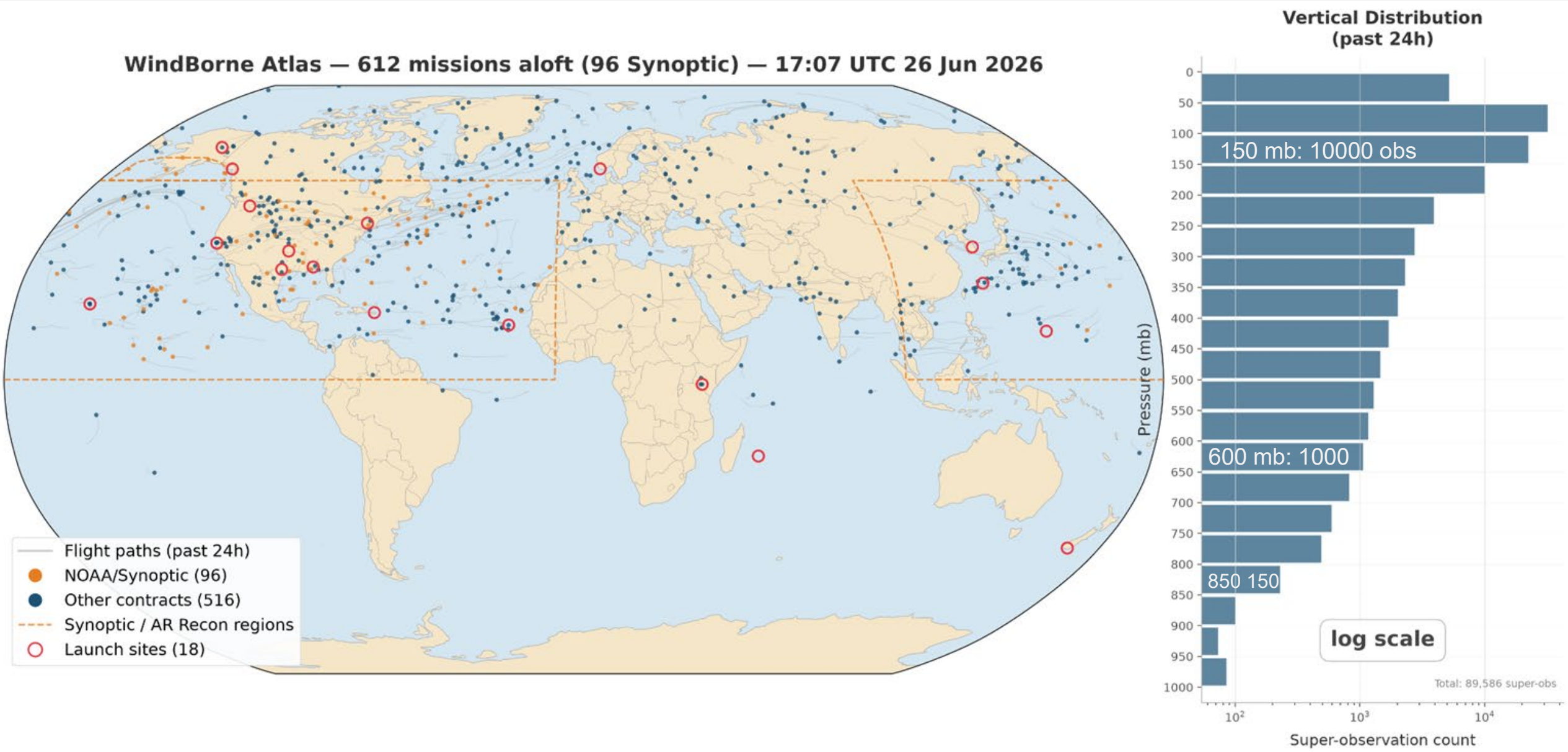
Launching daily from 21 sites across the world

New York

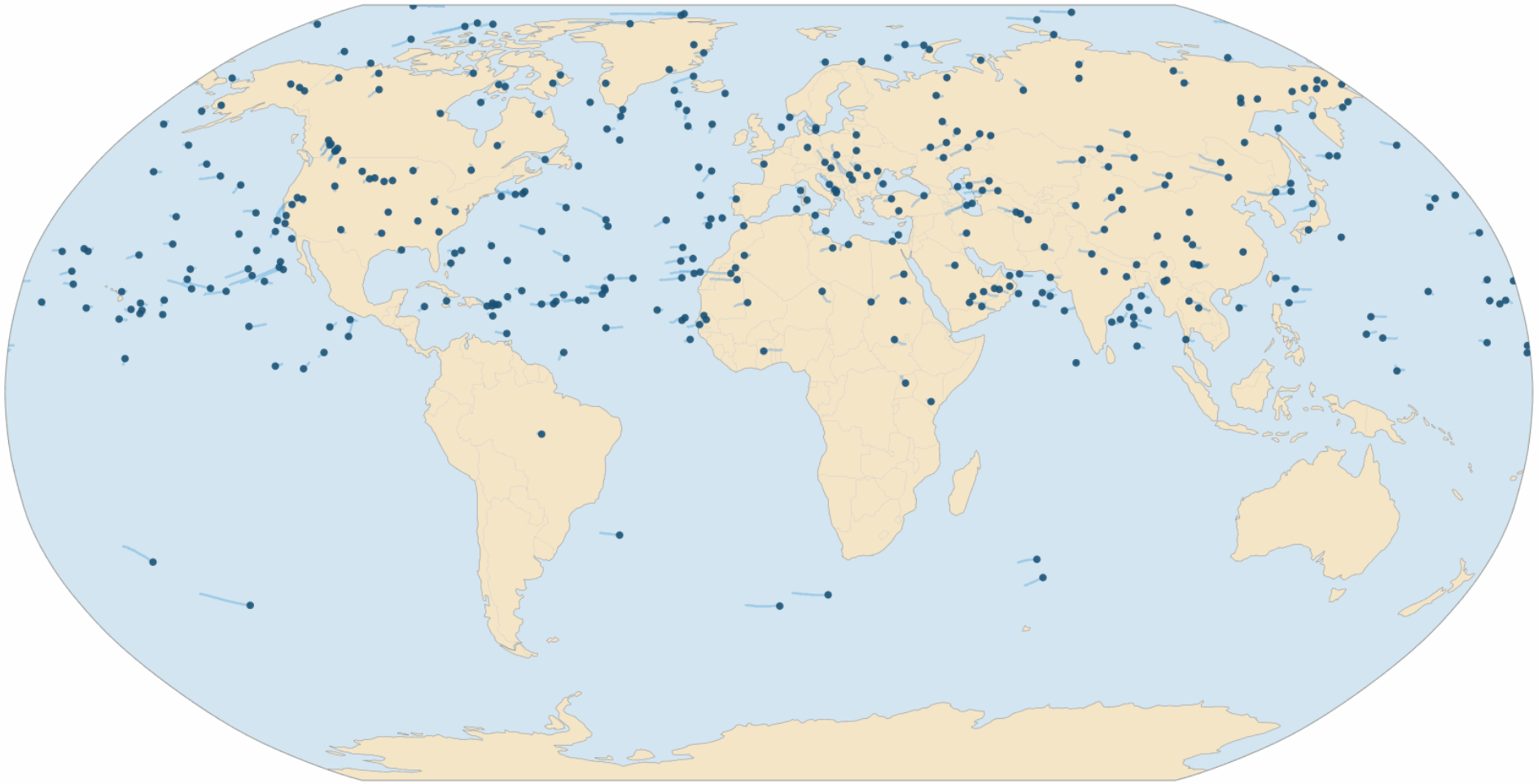
South Korea

Bodega Bay

WindBorne Atlas Constellation: 18 UTC 26 June 2026



WindBorne Atlas Constellation: June 2026



← 6 h distance travelled (tails)

29 May 2026 00:00z
378 balloons in view

1,062

WindBorne Flights

379,300 km

Total Vertical Distance Travelled

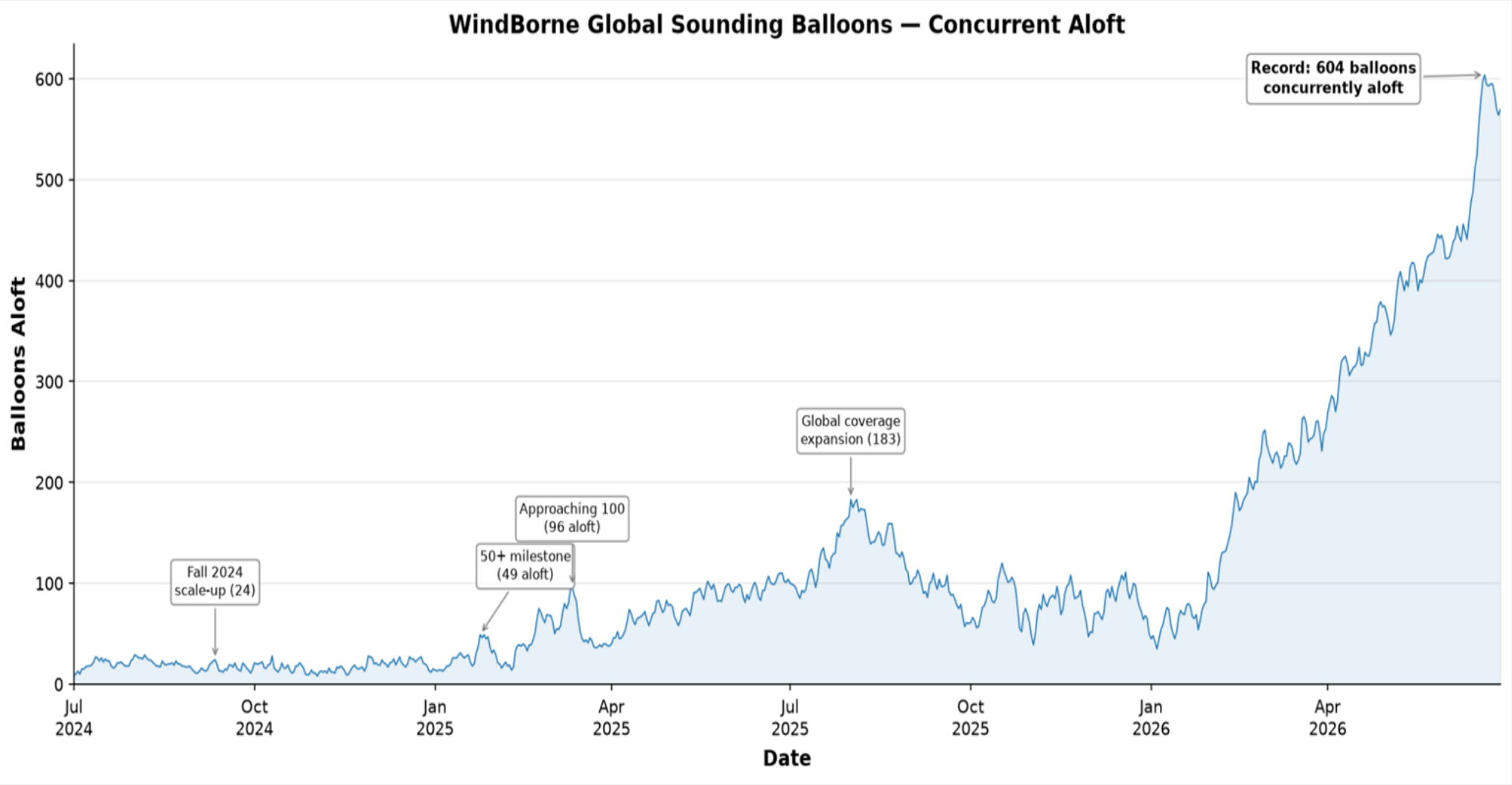
¼ size of global radiosonde network

2,558,243

Super-Observations

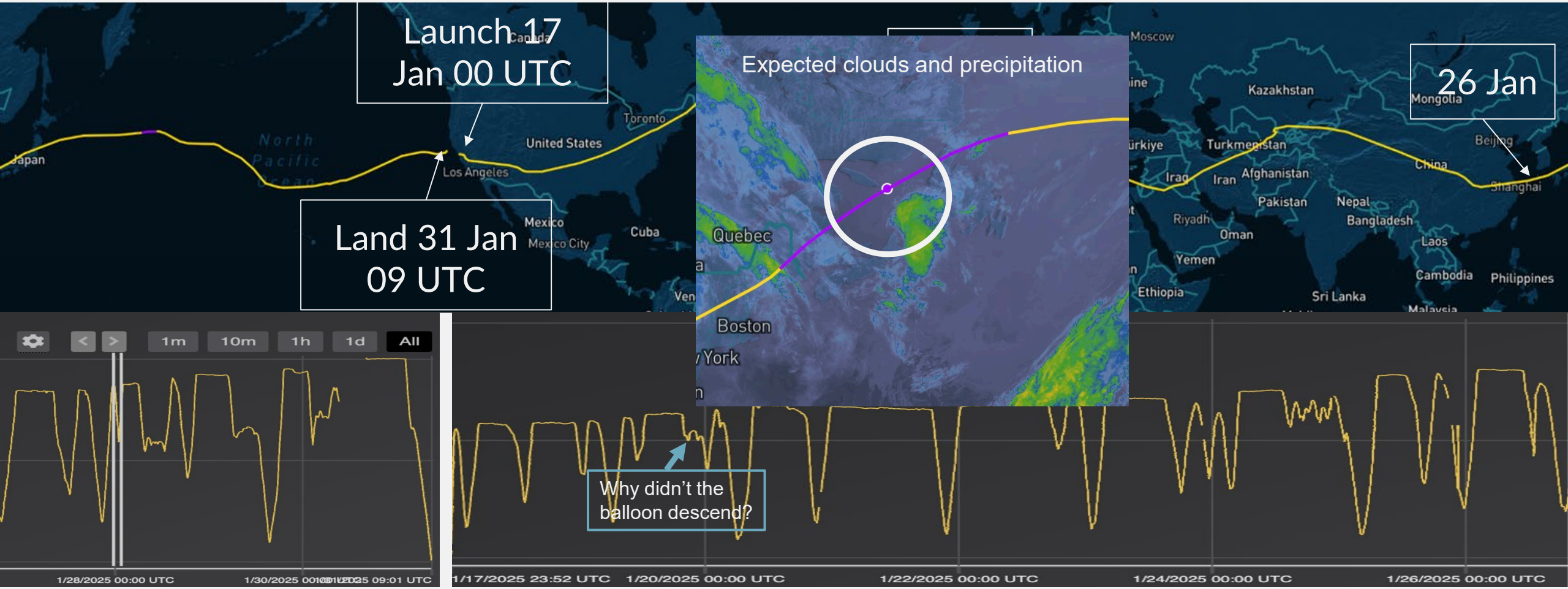
(averaged over 100 m vertical or 30 min time)

Atlas Constellation has grown rapidly: 1 July 2024 – 1 July 2026



Steady for rest of 2026

Anatomy of Flight W-2162 (24 Jan 2025)



Sensor Performance

Sensor Suite (Spisak et al. 2026)

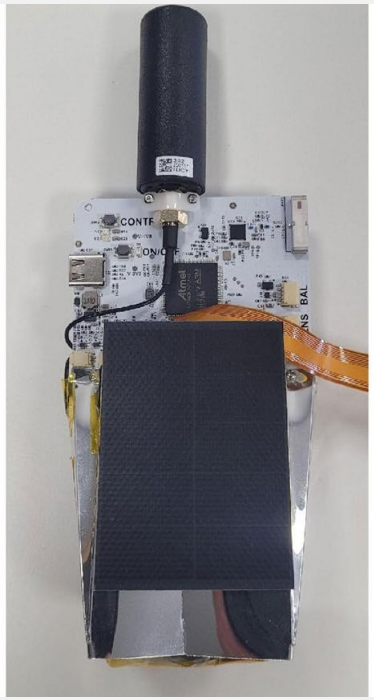
- MEMS pressure (x4): ±0.2 hPa cal. (2σ), 0.25 hPa repro.
- Thermistor: ±0.1°C cal. (2σ), 0.25°C repro.
  - 9 m wire; solar bias correction 0.5-3 K subtracted
- E+E Elektronik heated RH: 0.5% resolution, 2% uncertainty
  - Dual sensors averaged; time lag corrected
- Multi-GNSS: wind 0.4 m/s, altitude 8 m resolution

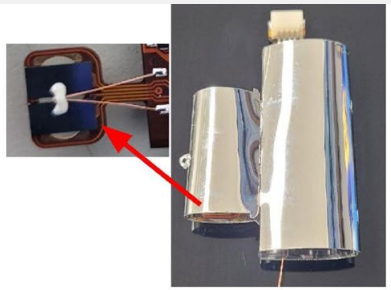
WMO Compliance

- Meets/exceeds WMO OSCAR 2.1 requirements for NWP
- 10 s sampling; Iridium downlink; <15 min latency

Documentation

Technical article available on arxiv.org now; under peer review





0.5m wire

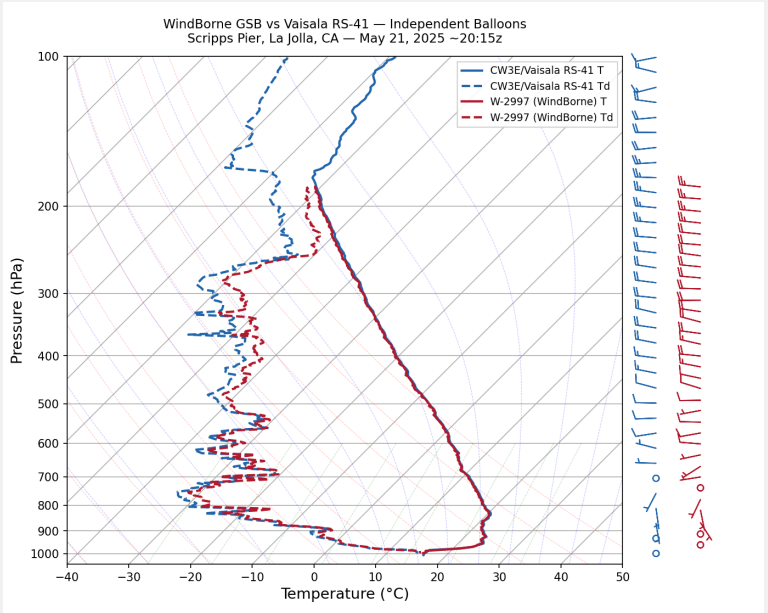
The Design and Performance of Meteorological Sensors for WindBorne Global Sounding Balloons

Jake Spisak,[a] Christopher P. Riedel,[a] Andrey Sushko,[a] Michal Adamkiewicz,[a] Joan Creus-Costa,[a] John Dean,[a] Jacob Radford,[a] F. Martin Ralph,[b] Larissa Reames,[a] Anna M. Wilson,[b] Subin Yoon,[b] Vijay Tallapragada,[c] Todd Hutchinson,[a]

[a] *WindBorne Systems, Palo Alto, CA 94303, USA*
[b] *Center for Western Weather and Water Extremes, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA*
[c] *NOAA/NCEP Environmental Modeling Center, College Park, Maryland*

Side-by-side testing on Scripps Pier

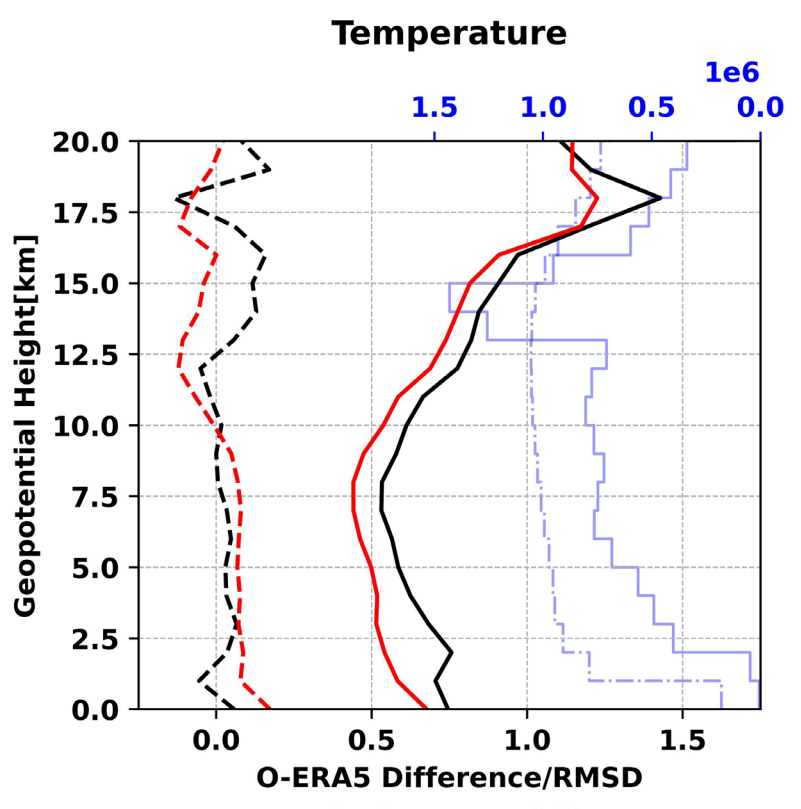
- CW3E and WindBorne staff performed side-by-side testing using Vaisala RS-41 and WindBorne instruments.
- Very similar temperature, moisture and wind results

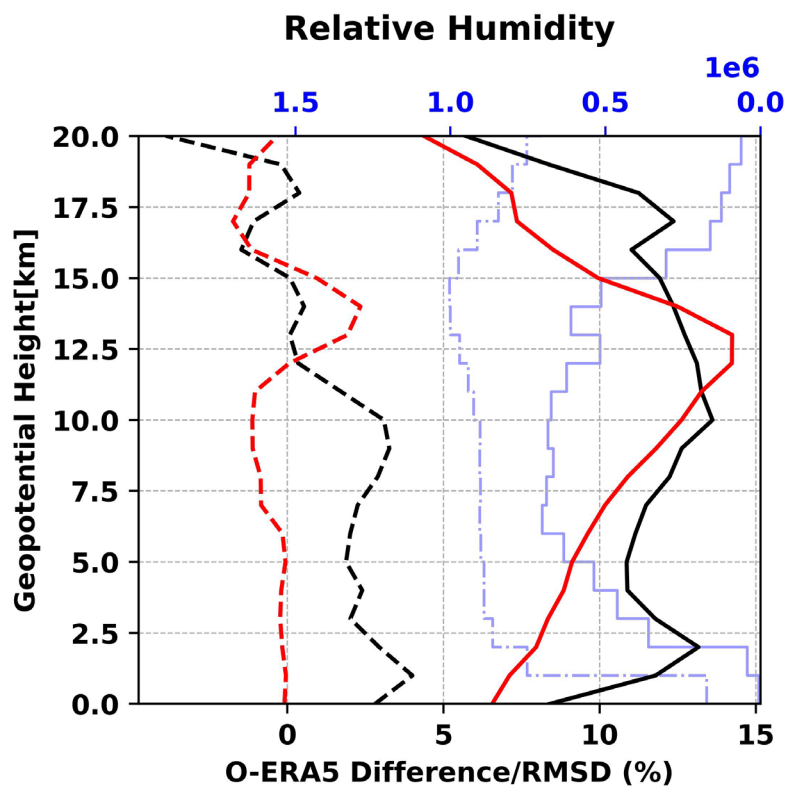


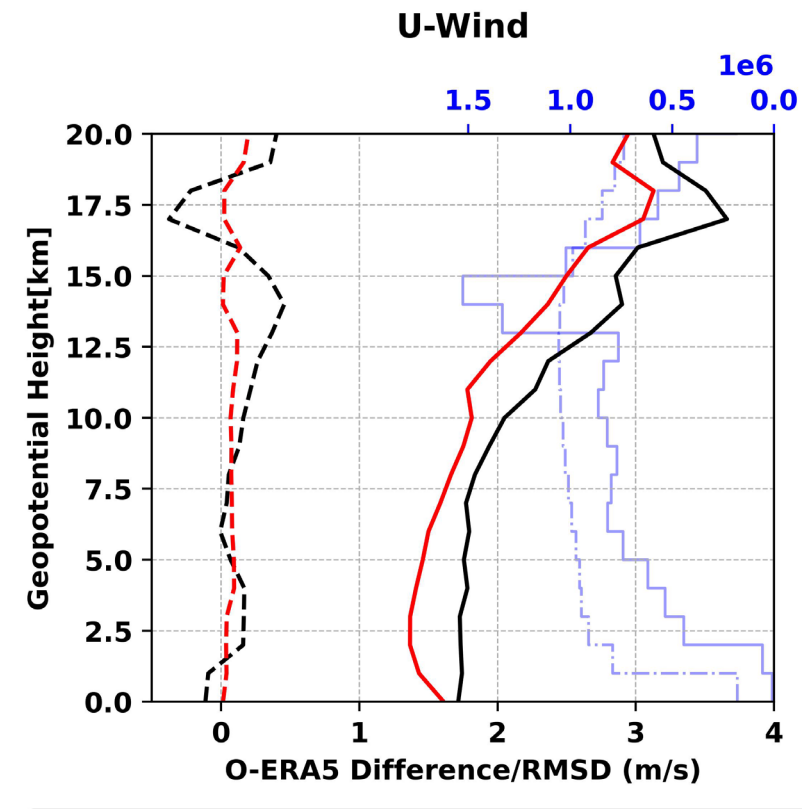
Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

GSB vs ERA5 (black); Radiosonde vs ERA5 (red)

- Temp, RH and Wind generally unbiased with similar RMS Differences to radiosondes
- 10^6 observations collected in November 2025 averaged at each level (blue)
- Additional information available in publication





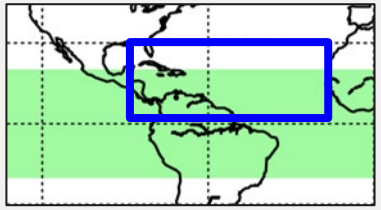


NOAA Path to Operations: Retrospective Studies

NOAA/EMC has run GFS retrospectively with and without WindBorne Observations

- Runs with obs yielded improved skill:
  - 1-3% reduction in 500 mb GPH errors 96-168 hour forecasts
  - Statistically significant reduction in forecast track; up to 18% at 132h
  - Large forecast track improvement for Hurricane Fiona

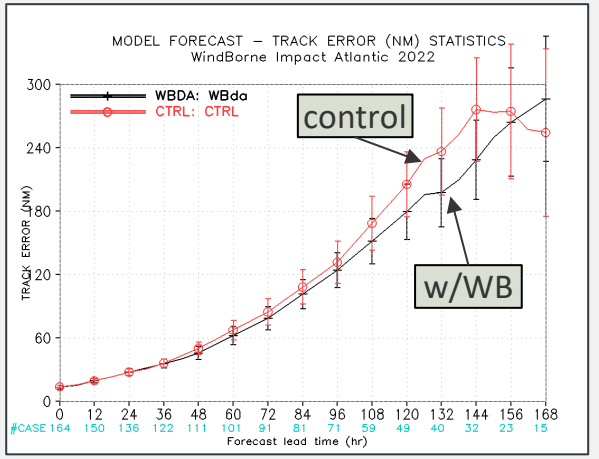
Bulk Statistics over tropical Atl.



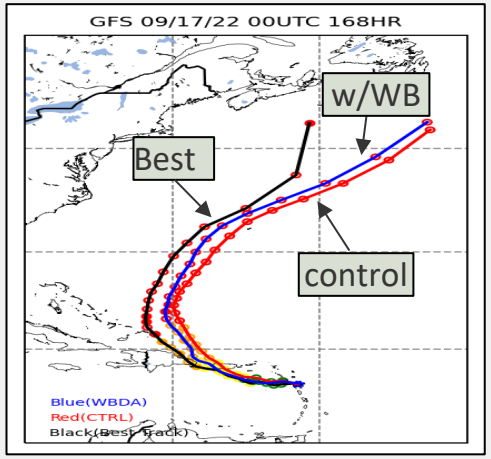
midatl_hr

		24 h	48 h	72 h	96 h	120 h	144 h	168 h
Height	All levels	-0.01 (-0.1%)	-0.10 (-1.4%)	-0.23 (-2.1%)	-0.09 (-0.4%)	-0.33 (-1.7%)	-0.57 (-2.9%)	-0.55 (-2.7%)
	50 - 250 mbar	-0.03 (-0.3%)	-0.13 (-1.2%)	-0.13 (-0.8%)	0.02 (0.4%)	-0.32 (-0.9%)	-0.85 (-3.2%)	-0.97 (-3.3%)
	300 - 500 mbar	-0.01 (-0.0%)	-0.01 (-0.2%)	-0.19 (-1.9%)	-0.05 (0.1%)	-0.21 (0.3%)	-0.40 (-0.9%)	-0.57 (-2.4%)
	550 - 750 mbar	0.01 (1.1%)	-0.08 (-0.4%)	-0.35 (-3.6%)	-0.20 (-1.5%)	-0.31 (-1.6%)	-0.38 (-1.9%)	-0.28 (-2.1%)
	800 - 1000 mbar	0.01 (0.7%)	-0.08 (-0.2%)	-0.29 (-1.9%)	-0.26 (-2.1%)	-0.33 (-1.8%)	-0.34 (-1.3%)	-0.21 (-1.2%)
Temperature	All levels	-0.00 (-0.2%)	-0.00 (-0.0%)	0.00 (0.4%)	-0.00 (-0.4%)	-0.01 (-0.7%)	-0.02 (-1.4%)	-0.02 (-1.4%)
	50 - 250 mbar	-0.00 (-0.4%)	-0.00 (-0.1%)	0.00 (0.5%)	-0.00 (-0.1%)	-0.01 (-0.7%)	-0.02 (-1.2%)	-0.02 (-1.2%)
	300 - 500 mbar	0.00 (0.5%)	0.00 (0.4%)	0.00 (0.2%)	-0.00 (-0.1%)	-0.01 (-0.8%)	-0.03 (-2.2%)	-0.05 (-2.9%)
	550 - 750 mbar	0.00 (0.1%)	0.00 (0.4%)	0.00 (0.1%)	-0.00 (-0.2%)	-0.00 (0.2%)	-0.02 (-1.2%)	-0.02 (-1.4%)
	800 - 1000 mbar	-0.00 (-0.4%)	-0.00 (-0.1%)	0.00 (0.6%)	-0.01 (-0.7%)	-0.01 (-0.8%)	-0.00 (0.0%)	0.00 (0.3%)
U wind	All levels	-0.01 (-0.5%)	-0.02 (-0.6%)	-0.02 (-0.6%)	-0.04 (-0.9%)	-0.09 (-1.7%)	-0.08 (-1.5%)	-0.08 (-1.4%)
	50 - 250 mbar	-0.01 (-0.3%)	-0.01 (-0.1%)	0.03 (0.6%)	-0.03 (-0.3%)	-0.10 (-1.1%)	-0.10 (-1.1%)	-0.14 (-1.7%)
	300 - 500 mbar	-0.00 (-0.1%)	-0.00 (-0.0%)	-0.02 (-0.4%)	-0.04 (-0.6%)	-0.09 (-1.5%)	-0.08 (-1.0%)	-0.10 (-1.5%)
	550 - 750 mbar	-0.02 (-1.0%)	-0.05 (-1.7%)	-0.08 (-2.3%)	-0.09 (-2.3%)	-0.10 (-2.2%)	-0.09 (-2.0%)	-0.04 (-0.5%)
	800 - 1000 mbar	-0.02 (-1.0%)	-0.03 (-0.9%)	-0.06 (-1.7%)	-0.03 (-0.7%)	-0.06 (-1.6%)	-0.05 (-1.2%)	-0.01 (-0.3%)
V wind	All levels	-0.02 (-0.6%)	-0.01 (-0.1%)	-0.01 (-0.3%)	-0.03 (-0.8%)	-0.04 (-0.7%)	-0.07 (-1.2%)	-0.10 (-1.8%)
	50 - 250 mbar	-0.02 (-0.6%)	-0.01 (-0.3%)	0.00 (0.1%)	-0.04 (-0.6%)	-0.02 (0.1%)	-0.07 (-0.7%)	-0.09 (-0.8%)
	300 - 500 mbar	-0.01 (-0.3%)	0.01 (0.5%)	-0.01 (-0.2%)	-0.01 (-0.3%)	-0.01 (-0.0%)	-0.03 (-0.3%)	-0.14 (-2.3%)
	550 - 750 mbar	-0.02 (-0.9%)	-0.02 (-0.4%)	-0.04 (-0.9%)	-0.04 (-0.9%)	-0.05 (-1.0%)	-0.08 (-1.6%)	-0.08 (-1.5%)
	800 - 1000 mbar	-0.01 (-0.6%)	-0.01 (0.1%)	-0.02 (-0.5%)	-0.03 (-0.8%)	-0.09 (-2.0%)	-0.09 (-2.0%)	-0.04 (-0.4%)
Relative humidity	All levels	-0.04 (-0.3%)	-0.04 (-0.2%)	-0.03 (-0.1%)	-0.02 (-0.0%)	0.04 (0.2%)	-0.03 (-0.1%)	-0.14 (-0.5%)
	50 - 250 mbar	-0.04 (-0.2%)	-0.07 (-0.3%)	-0.00 (0.0%)	0.02 (0.1%)	-0.02 (0.0%)	-0.11 (-0.3%)	-0.09 (-0.3%)
	300 - 500 mbar	-0.07 (-0.3%)	0.01 (0.1%)	-0.08 (-0.3%)	0.01 (0.1%)	0.20 (0.7%)	0.11 (0.5%)	-0.21 (-0.5%)
	550 - 750 mbar	-0.04 (-0.3%)	-0.06 (-0.3%)	-0.01 (-0.0%)	-0.07 (-0.3%)	-0.03 (-0.0%)	-0.09 (-0.3%)	-0.09 (-0.2%)
	800 - 1000 mbar	-0.03 (-0.2%)	-0.06 (-0.4%)	0.00 (0.0%)	-0.04 (-0.3%)	-0.07 (-0.4%)	-0.08 (-0.3%)	-0.14 (-0.7%)

Average tropical cyclone track error

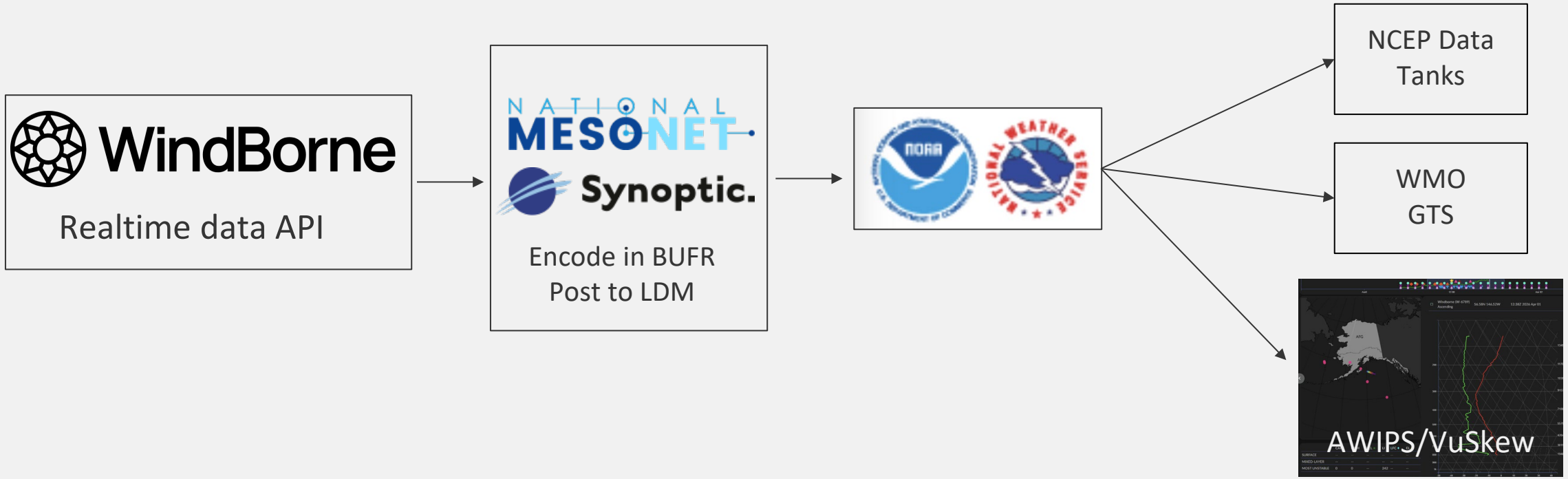


Fiona track comparison



NOAA Path to Operations

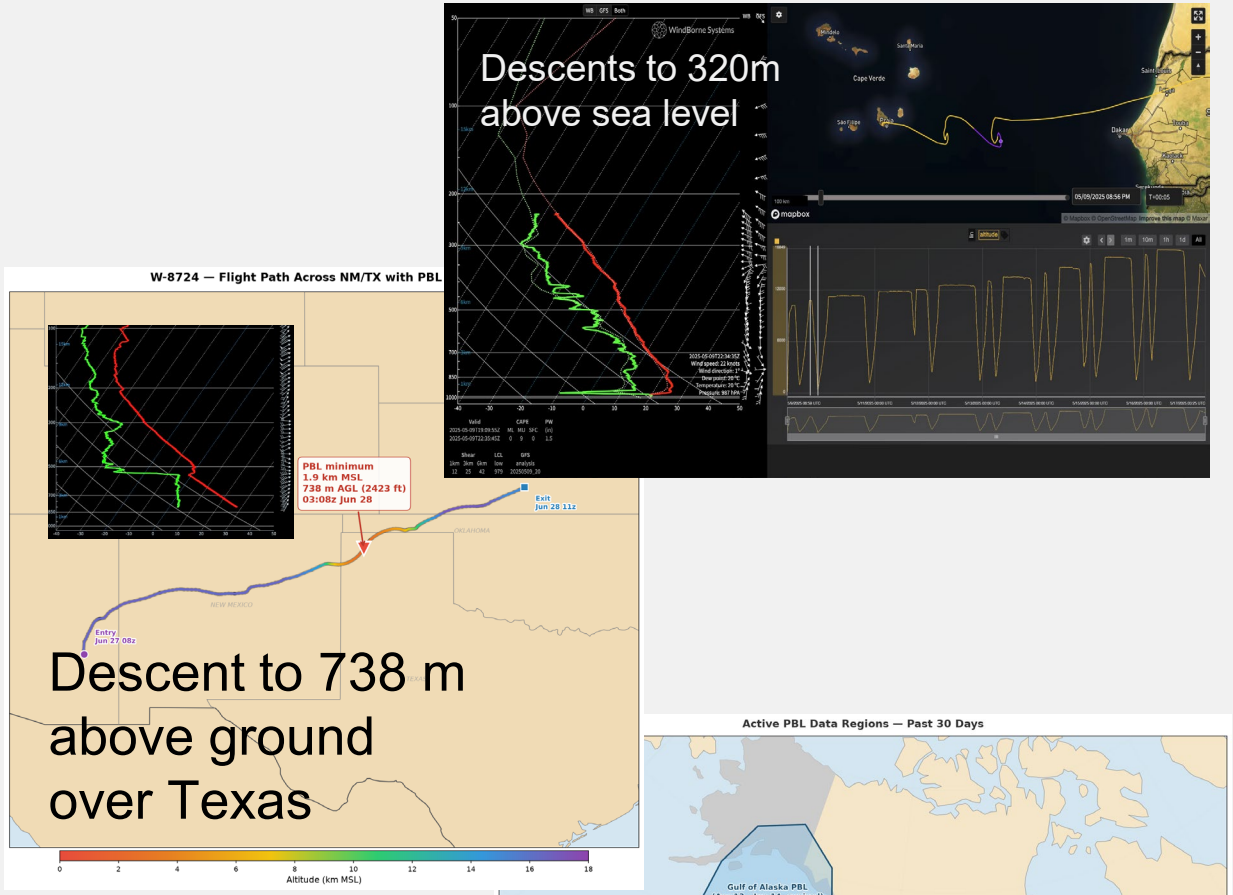
~3300 soundings/ mo (out of ~30000 / mo) available to NOAA in real-time

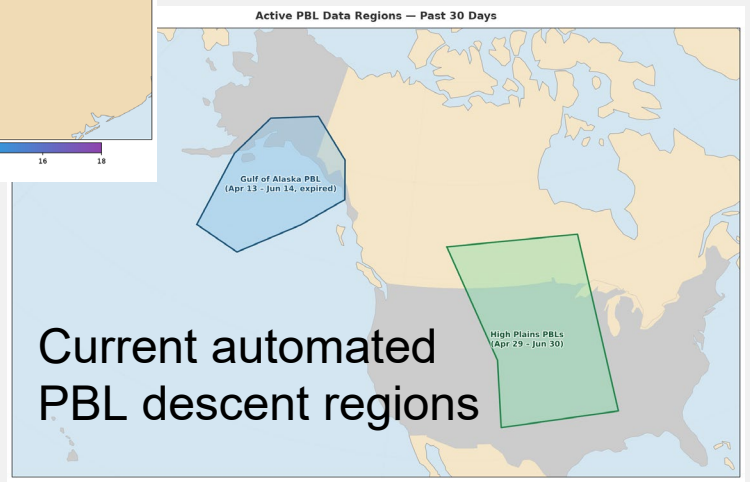


NOAA/NCEP incorporated WindBorne data into GFS in summer 2025

Descent into Boundary Layer

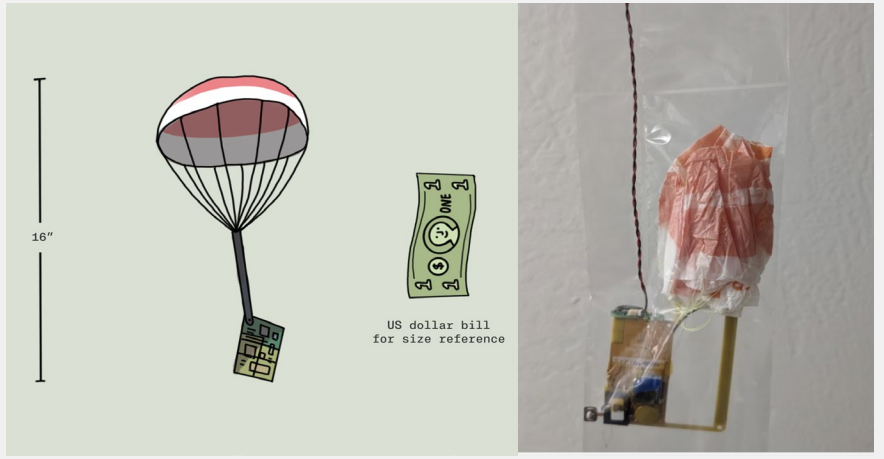
- Balloons currently descend to ~1500 -2000 above ground level in clear weather
- Manual efforts to descend lower are leading to automated descent refinement:
  - Examples include ~700m AGL over Texas
  - ~300m AGL over Ocean
- This has required on-board firmware updates, including an updated on -board terrain map
- Currently being rolled out for two test domains: Gulf of Alaska, High Plains of North America
- By next winter, expect to be rolled out globally to all tropospheric profiling flights
- Much more tolerant of nearby clouds/precipitation

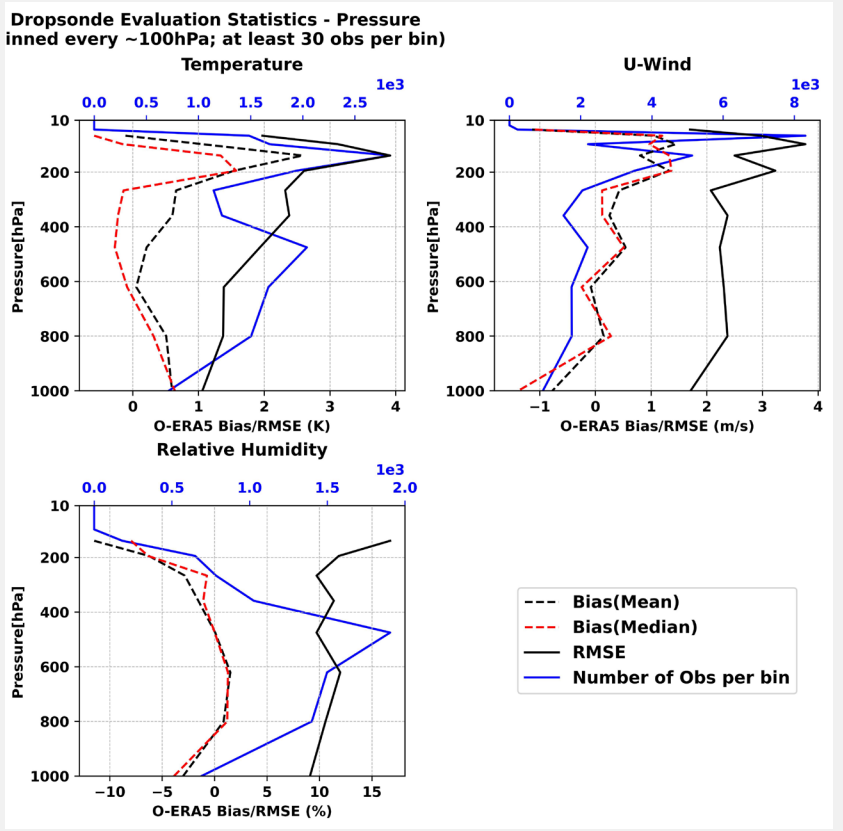




Development: Dropsondes

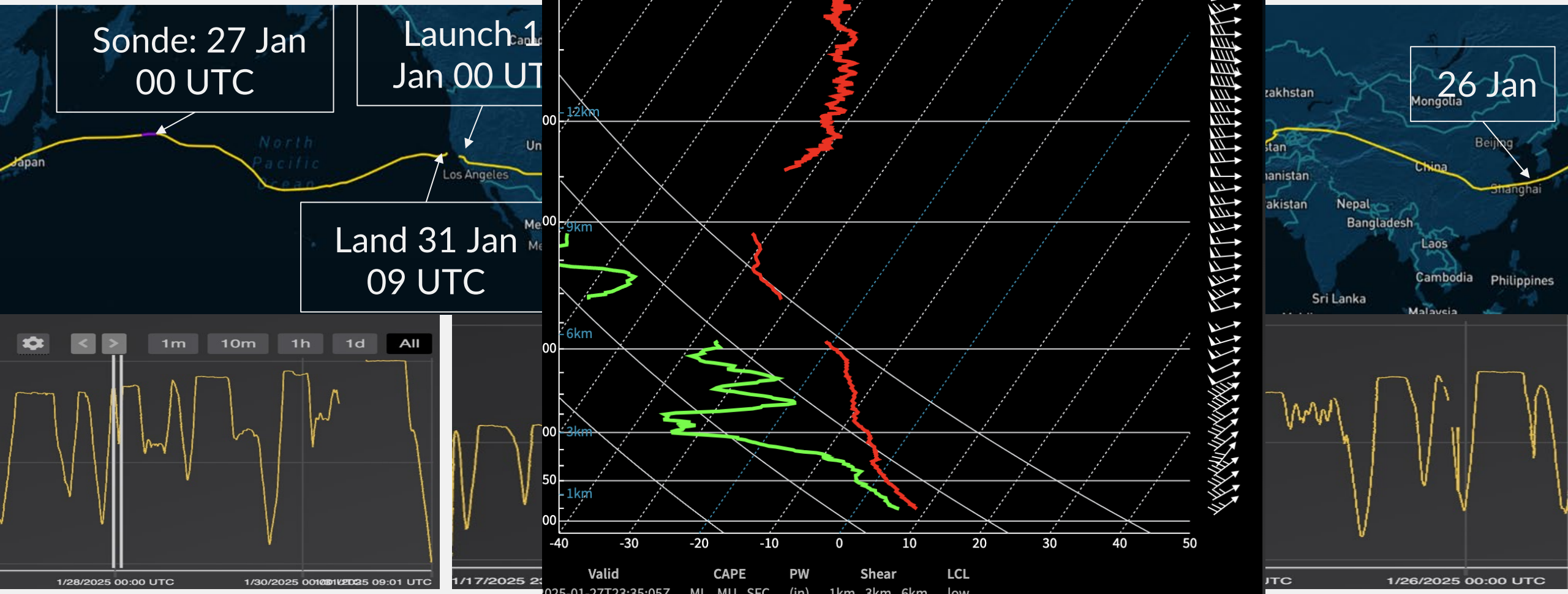
- Dropsonde capability developed and being tested
- This fall, some GSBs will carry 3 dropsondes
  - Flights from Guam and S Korea will be first to get dropsondes
  - Usually dropped from high -altitude flight
- Profiles from stratosphere to surface in (nearly) all weather
- Compact design: only 16 inches with parachute deployed
- 20 dropsondes have been deployed up to this point





NOAA WEATHER PROGRAM OFFICE

Flight W-2162 (24 J



Customer Site Visits and GSB Launch Demonstrations

We often visit partners and and demonstrate the system by launching a GSB


WindBorne