Radiosondes: it's what's overhead that counts

by

Paul Ciesielski
Senior Research Associate
Colorado State University

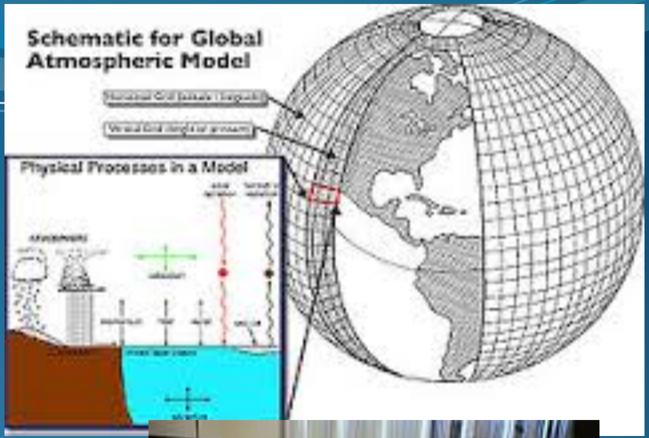
Many of the slides herein were graciously provided by Junhong Wang, an assistant professor at SUNY Albany.


40%
60%


7 DAY FORECAST
MON TUE WED THU FRI SAT SUN
84 84 85 84 83 83 84
61 62 63 62 62 61 61


Tue 2:00AM EDT
70 mph
Mon 2:00AM EDT
90 mph
Sun 2:00AM EDT
110 mph
Sat 2:00AM EDT
125 mph
Fri 2:00PM EDT
140 mph
Charleston
Miami
BAHAMAS
Wind: 120 mph

Weather at earth's surface, where we live, is largely determined by the atmospheric conditions above the surface
- in short, it's what's overhead that counts.

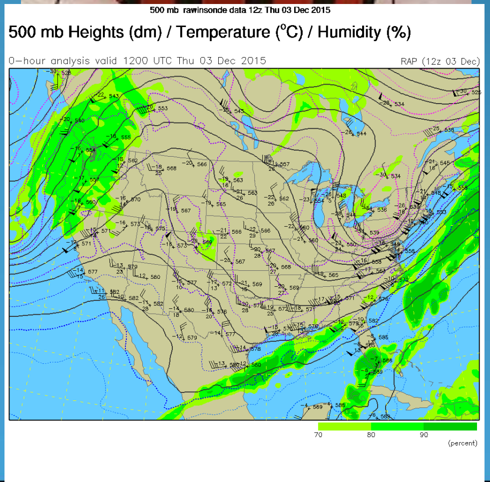


How are weather forecasts made?

1) We need a sophisticated computer model which precisely describes how the atmosphere works.

2) a fast super computer to run the model in timely fashion.

3) accurate initial conditions to start the model (description of present state of the atmosphere at the surface but more importantly at upper-levels).

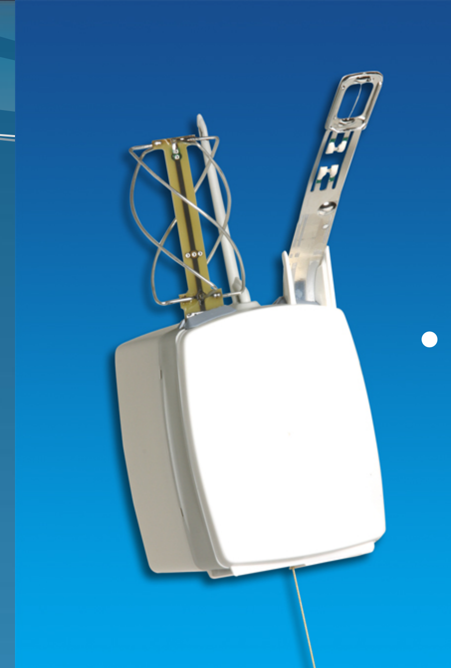


How do we get this accurate description of the upper-level air? – radiosondes!

Outline:

- **What is a radiosonde?**
- **Brief history of radiosondes**
- **Where radiosonde measurement are taken**
- **How we use the radiosonde data**
- **Different types of sondes**

What is a radiosonde?

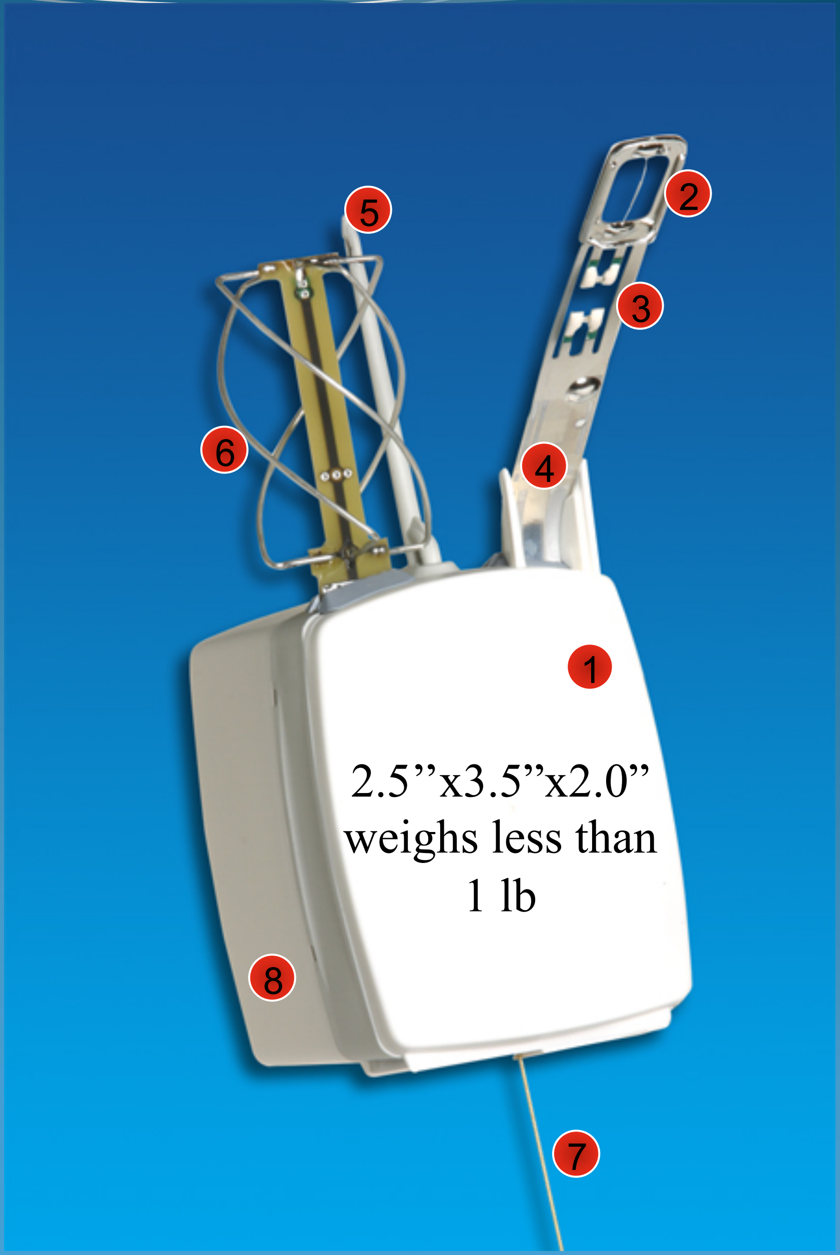


- radiosonde manufactured by Vaisala

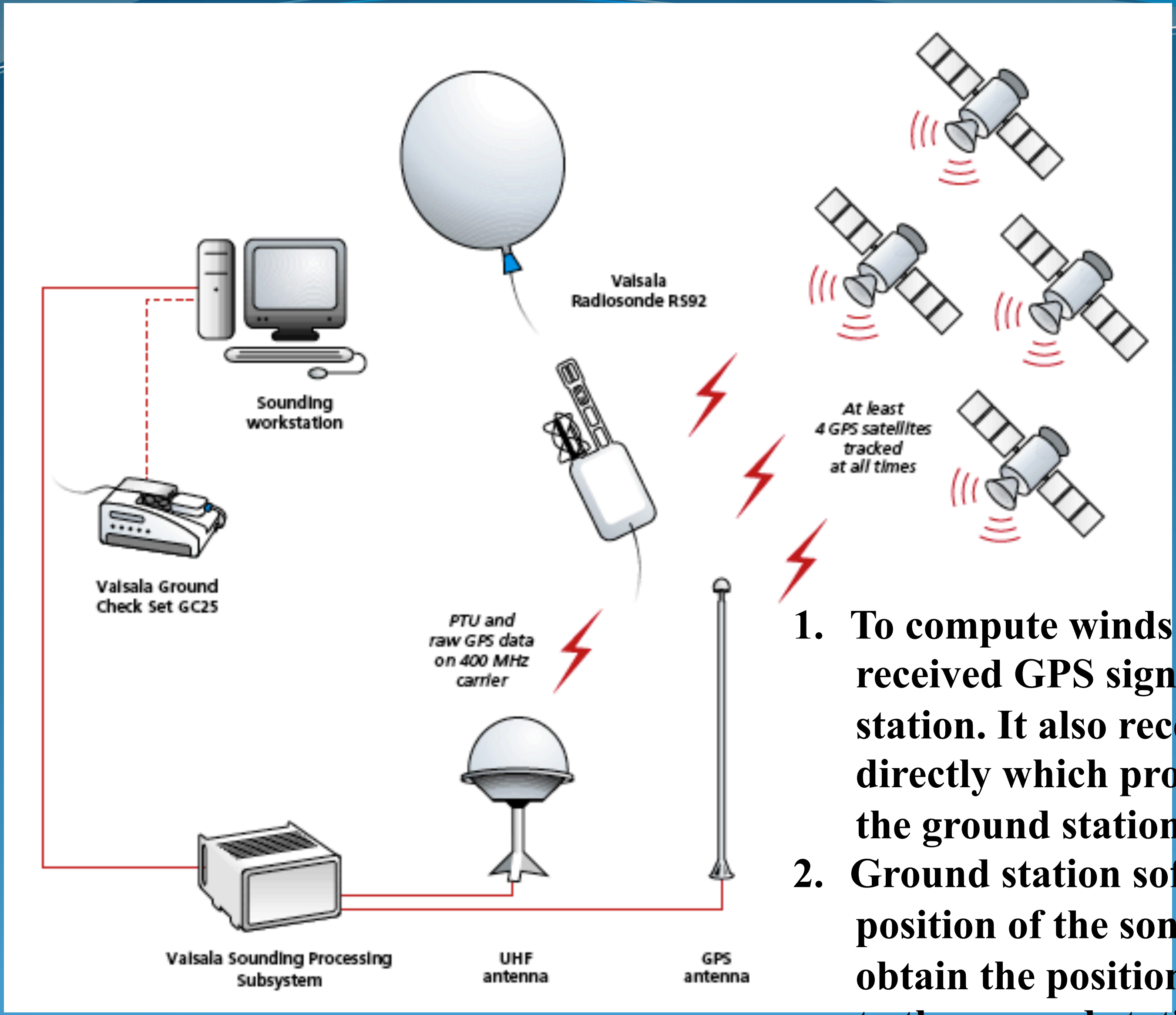
- A *radiosonde* is an expendable instrument platform (usually launched with a balloon) which has radio transmitting capabilities.
  - "radio" because it has an onboard UHF radio transmitter
  - "sonde" comes from French, meaning probe
- A radiosonde carries sensors capable of making in-situ measurements of air temperature, humidity, and pressure as a function of height up to about 32 km (20 miles or 105,000 ft).
- Sometimes this instrument is referred to as a *rawinsonde* which means that it is also capable of measuring wind speed and direction.

Components of a Vaisala radiosonde:

1. Housing for Pressure Sensor and Transducer Electronics
2. Temperature Sensor
3. Humidity Sensors
4. Sensor Boom
5. Balloon Tether Mast
6. GPS Receiver
7. UHF Transmitter
8. Battery Pack (contains 6 AA batteries)

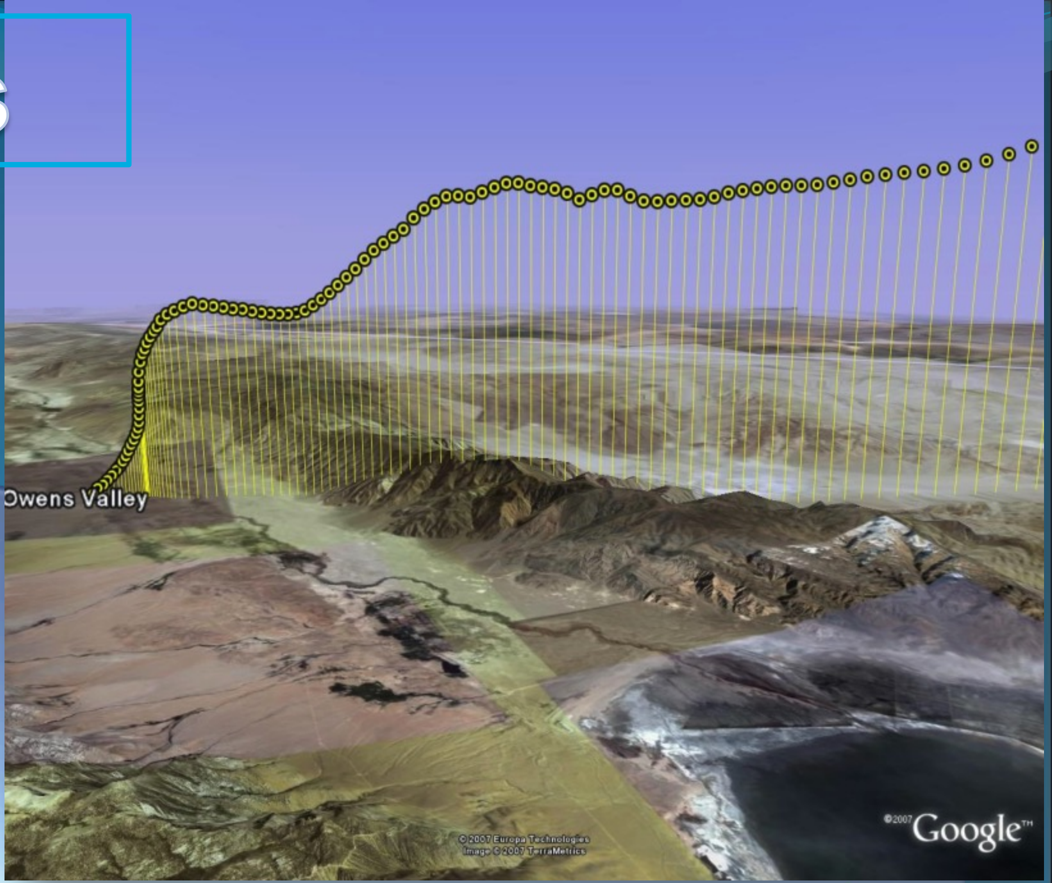


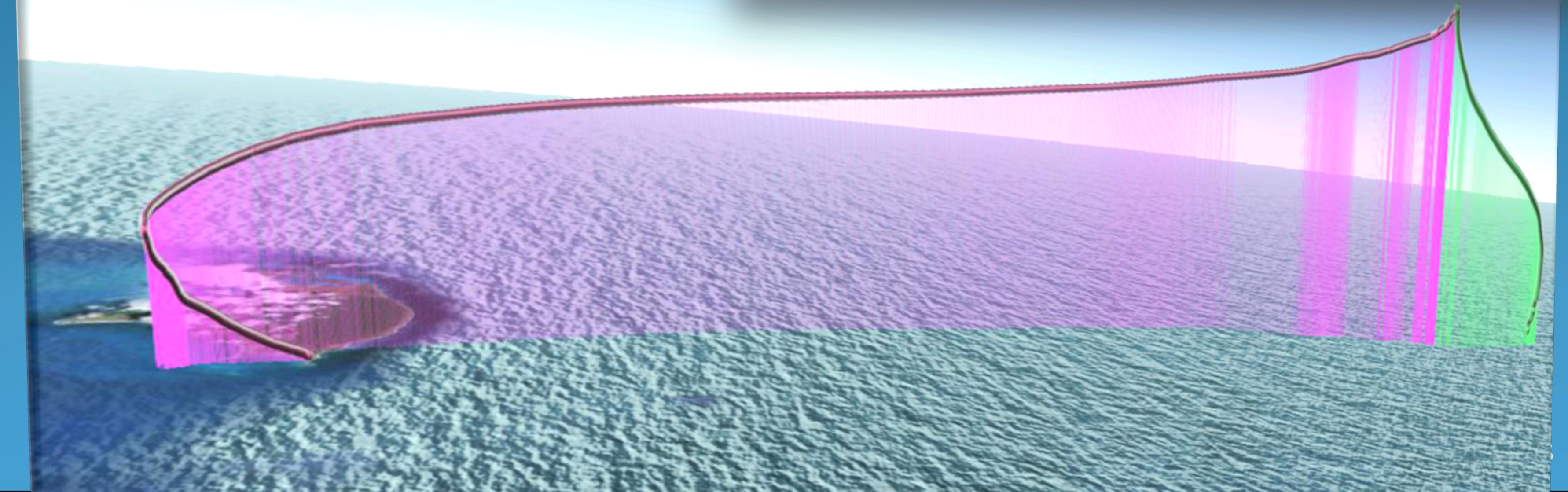
Components of a modern radiosonde system



1. To compute winds the sonde transmits the received GPS signals to the ground station. It also receives the GPS signal directly which provides the location of the ground station.
2. Ground station software computes the position of the sonde and of itself to obtain the position of the sonde relative to the ground station.
3. Change in position of sonde with time determines wind speed and direction.

Balloon Tracks





Video a radiosonde launch produced by a TV station (courtesy of WKRG) in Mobile, AL

https://www.youtube.com/watch?v=AoUxq4mTv5M

The Weather Balloon

- Weather balloons are usually white in color and come in sizes from 10-3000 grams. Smaller sizes often are red in color.
- The balloon, usually made of latex, is filled with helium (or hydrogen) so that it will achieve a certain rate of ascent. (~4-5 m/s)
- It is attached to the radiosonde via a plastic hook and unwinder with a 60 m (200 ft) cord.
- The 200-gr balloon is about 4 feet in diameter at the time of launch but expands to 15-20 feet before it burst.
- Time from launch to balloon burst can last from 1-2 hours.

Having fun with a weather balloon

https://www.youtube.com/watch?v=fja3qfm7rwU

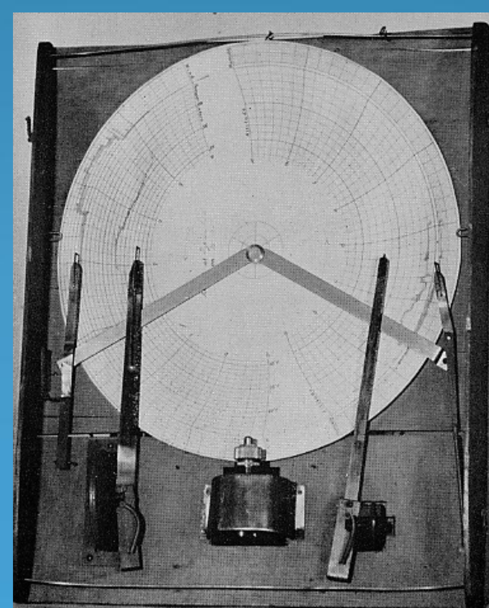
Are radiosondes launched in all weather conditions?

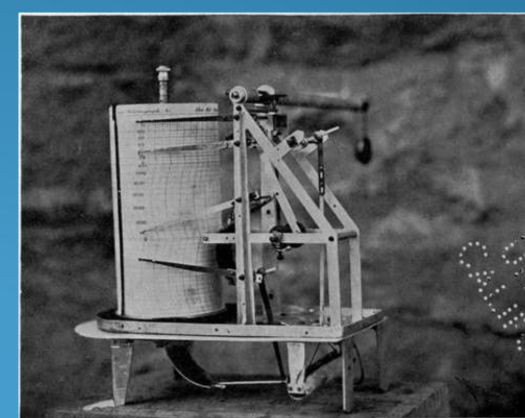
https://www.youtube.com/watch?v=pQuCXT40o6M

History of radiosondes

- **18th and 19th centuries:**
  1. A kite with a thermometer in 1749 in Glasgow, Sco by Alexander Wilson
  2. First untethered balloon in 1783 in Paris
  3. Manned hot air and hydrogen balloons in 1800's
  4. Kite observation network in U.S. by the end of the 1800's
- **Early 1900's:**
  1. Meteorograph carried by free, unmanned balloons
  2. Aircraft sounding in 1925-1940s
  3. Pilot balloon tracked by optical theodolite

- 3-5 km
- data loss
- good weather





Meteorographs

- Pilot balloon (**pibal**) sondes use optical theodolites. Usually one observer tracks the balloon through a scope and reads the range and angles (azimuth, elevation), while another records the time and data.

- Pibals are especially popular in second and third world countries in Central and South America and Africa.

Advantage: balloon carries no instrument package
- very inexpensive (10 pibal sites can be operated for the cost of one radiosonde site)

Disadvantages:
- human errors
- limitations due to cloudiness, daylight (in tropics, generally only can get wind data in lowest 5-6 km)
- no pressure, temperature and humidity data

History of radiosondes (continued)

- **1930's-1950's:**
  1. The first radio-meteorographs ("radiosondes") in the early 1930's
  2. 1937: the U.S. NWS radiosonde network
  3. Automated radio-theodolites ("rawinsonde") by the 1950s

Phased-array radiotheodolite which tracks the radiosonde by searching for the strongest radio signal being transmitted by the sonde.

- **1960's – 1980's:**
  1. Computerized reduction of rawinsonde data (automation)
  2. Radio-navigation aids (NAVAID): LORAN and Omega for wind – basically these are global networks of low-frequencies transmitters which the sondes used to determine their position and thus computation of winds
- **1990's:**
  1. Improved sensors, data processing and NAVAID system
  2. Global Positioning Satellites (GPS) for wind measurements
- **2000's**: sensor improvements continue, particularly measurements of humidity

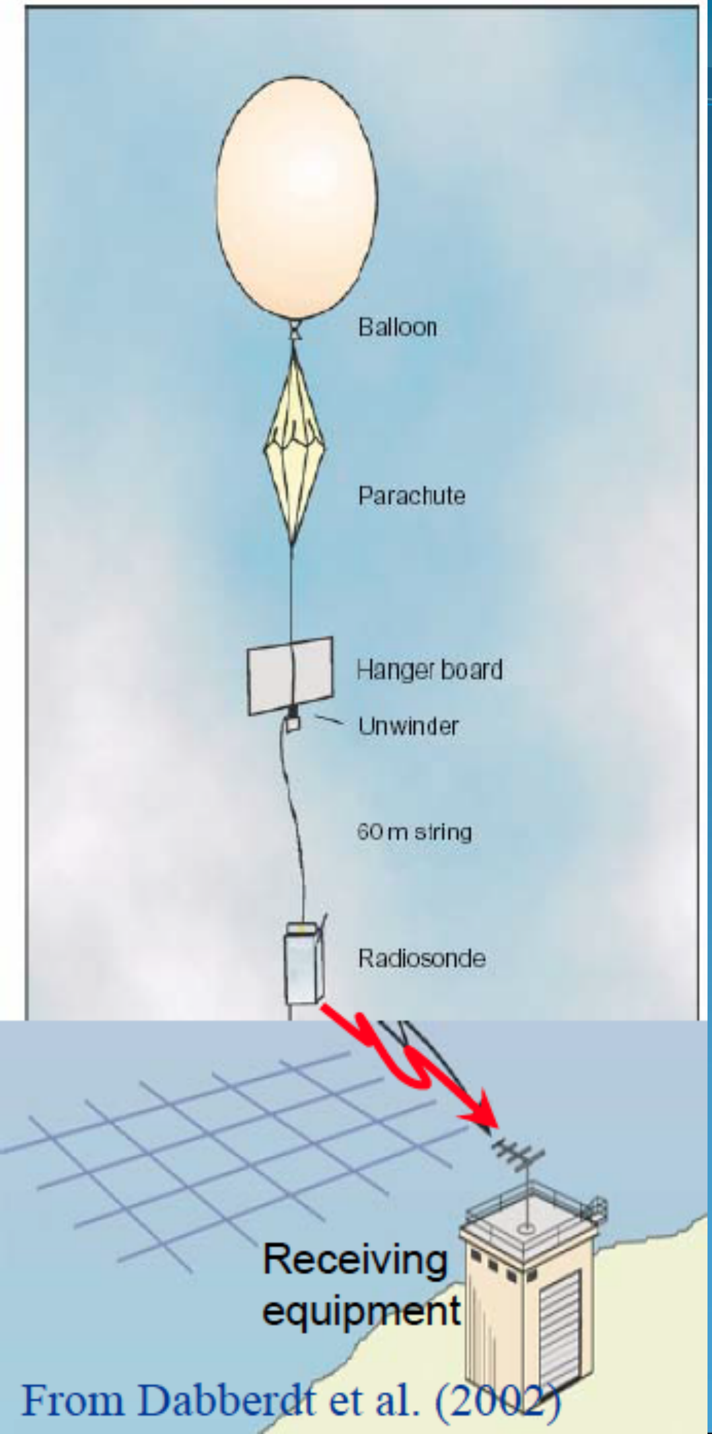
Accuracy of radiosonde measurements

Wind speed and vertical position errors for various system

System	Years in use	Speed (m/s)	Vertical (m)
Theodolite	1950 - present	1.0 – 3.0	90-900*
Radar	1945 - present	0.1 – 0.3	30-90*
OMEGA	1980s-1997	1.5	300
Loran-C	1960s-1990s	0.7	150
GPS	1998-present	0.1	30

* Theodolite and radar errors increase as a function of height and wind speed as errors at low elevation angles (< 10° above horizon) amplify wind errors.

- Use of GPS technology has greatly enhanced our ability to accurately measure upper-level winds.
- Accuracy for pressure (0.1-0.5 mb), temperature (0.1°C), humidity (2%) for a modern day Vaisala sonde
- **In short, radiosondes over the years have become more accurate, smaller and cheaper.**



Radiosonde cost:

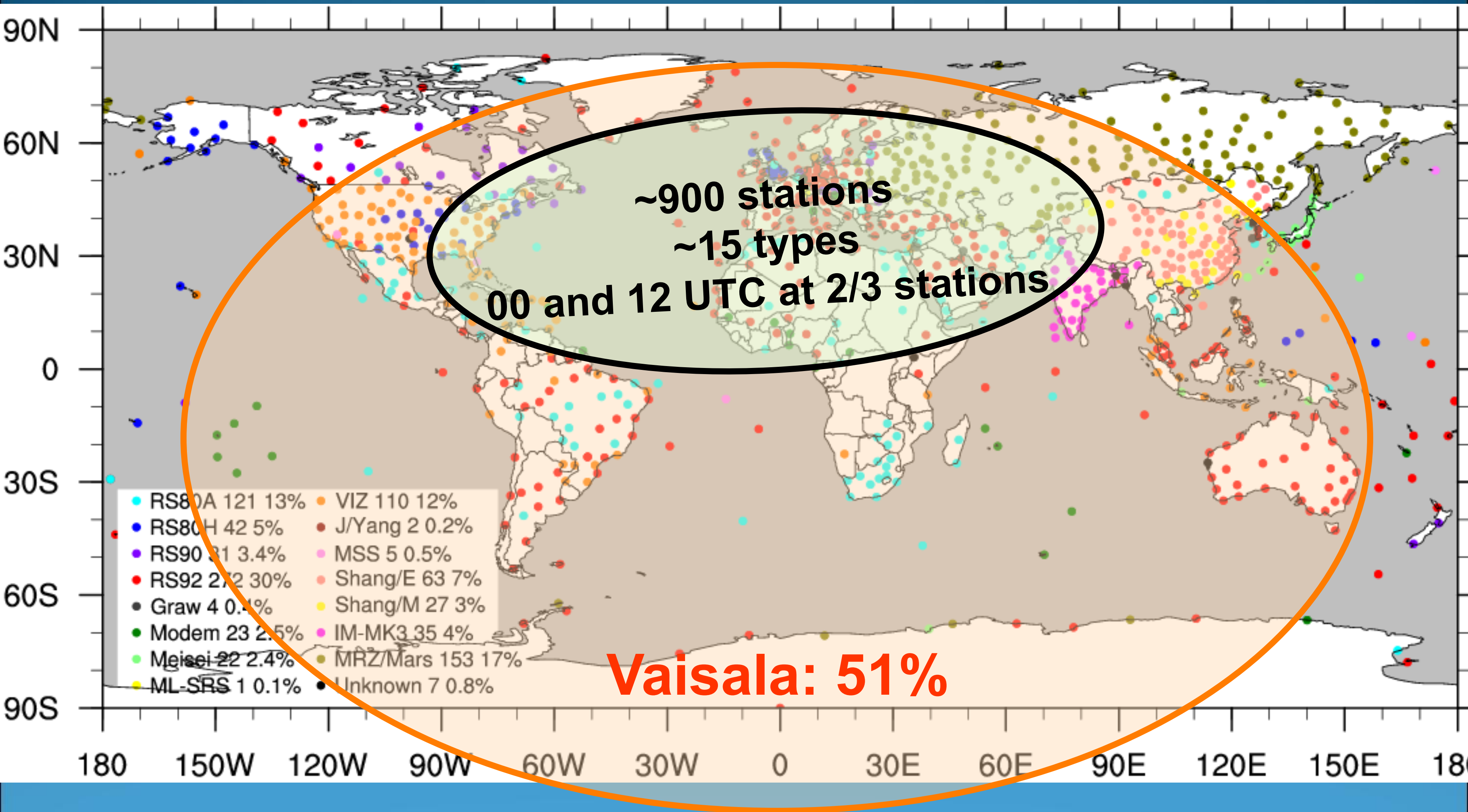
- Vaisala sonde: $240
- 200 gr balloon: $30
- Helium: ~$20--$30
- Total cost for expendables is ~$300
- Ground station hardware: $100,000

- We do not use a parachute for demonstration launches at our university.

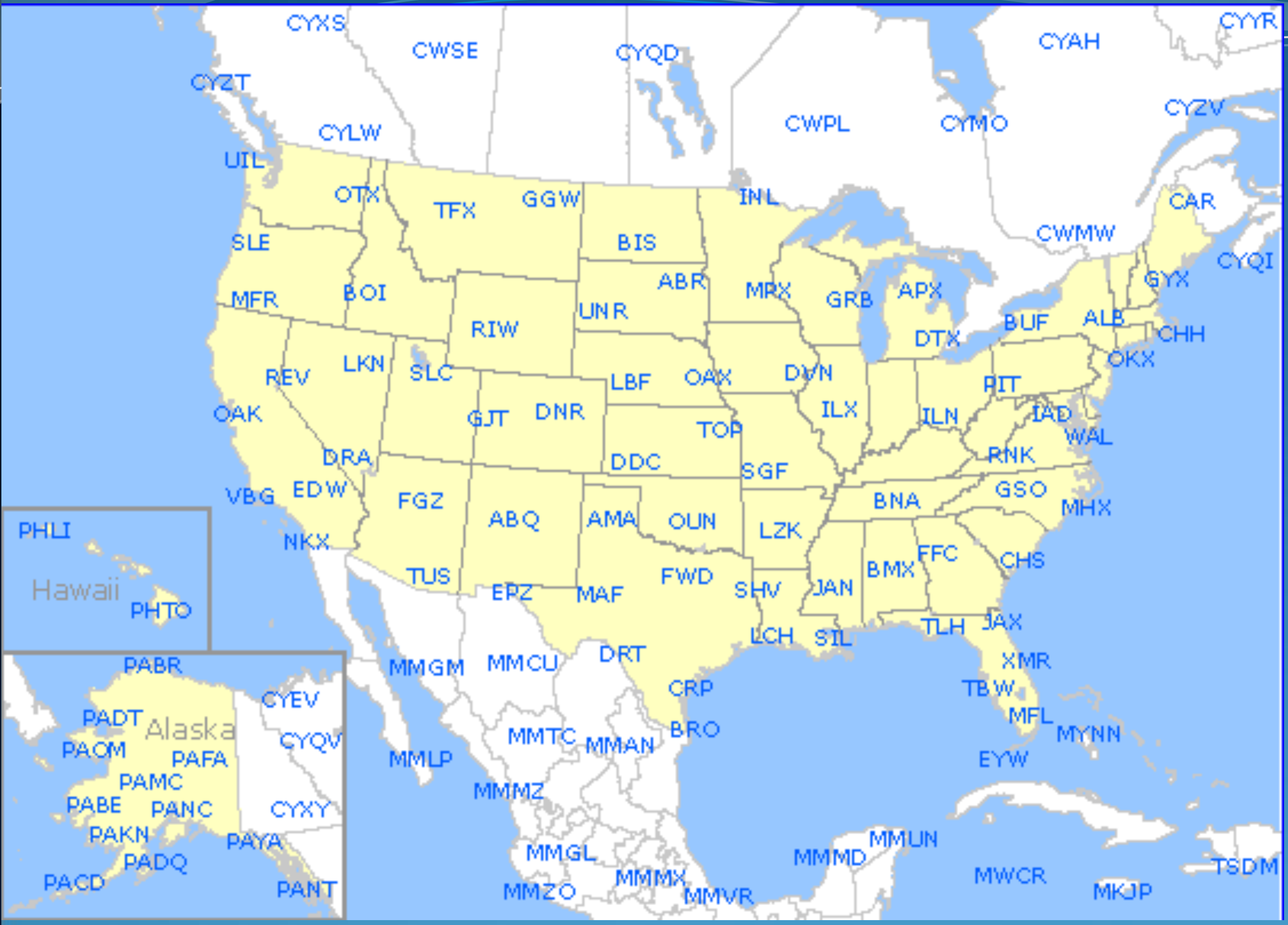
- US National weather sites do use parachutes and larger balloons (800-1200gr) and typically hydrogen gas.

- About 20% of the ~70,000 sondes launched by US annually are recovered, refurbished and then reused.

Global radiosonde network (WMO report, July 2007)



US sonde network



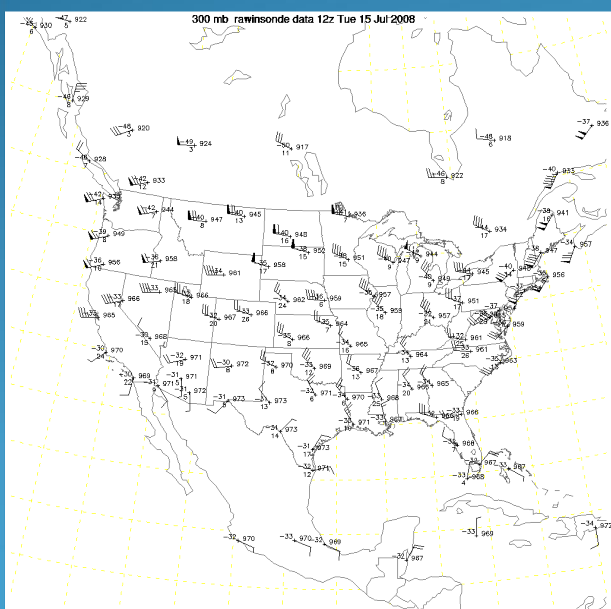
http://weather.rap.ucar.edu/upper/

- The US sonde network consist of 92 sites launching at 00 and 12 GMT each day.
- The National Weather Service (US Weather Bureau) began launching radiosondes in 1937
- US network currently uses primarily the Sippican Mark II sonde which is manufactured by Lockheed Martin in Mexico.

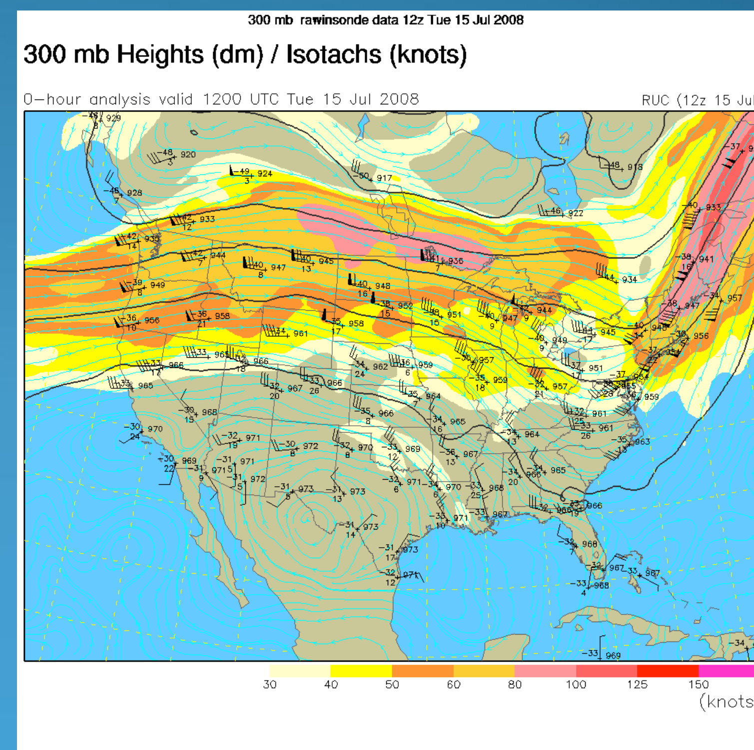
- Colorado has two upper-air sonde sites: one in Denver and a second in Grand Junction. Some states have none.

Radiosonde Applications: how the data are used

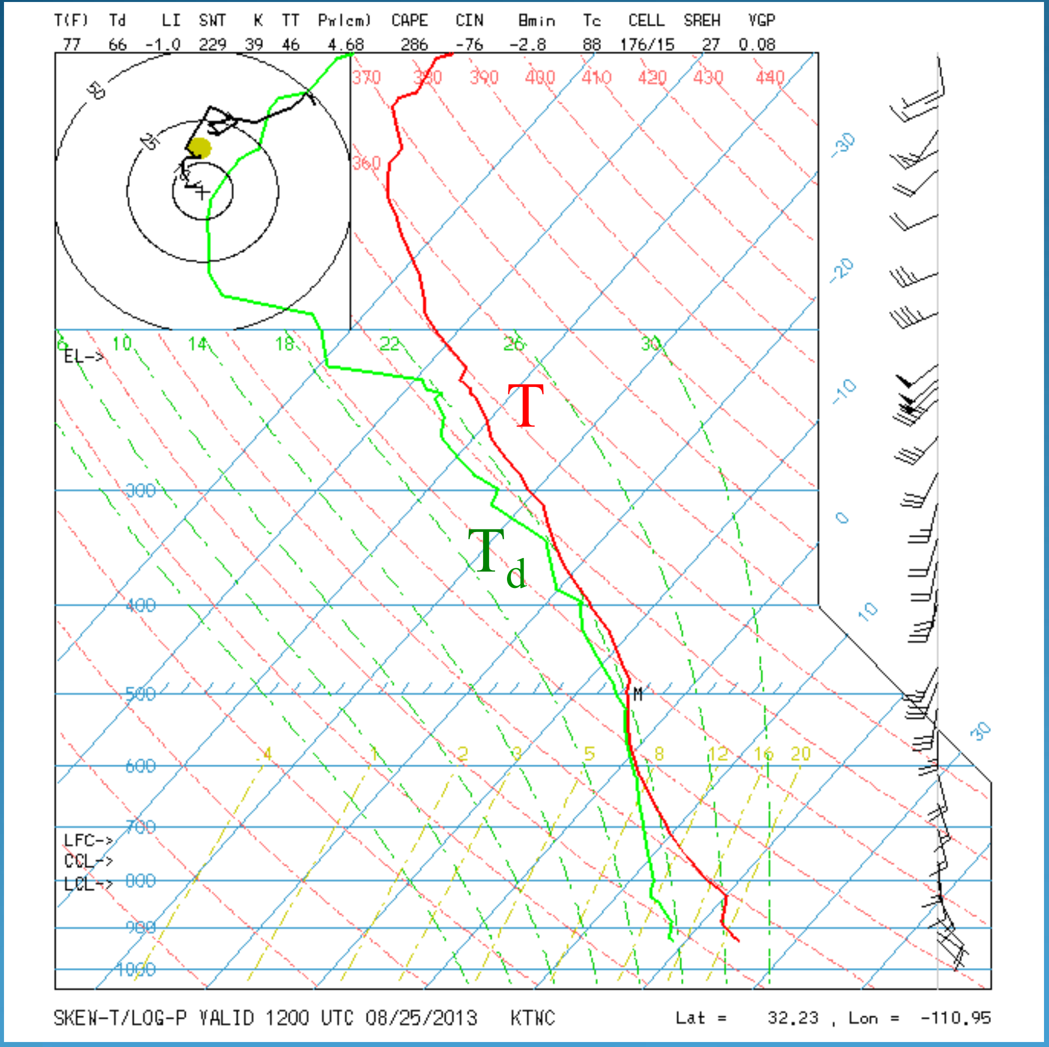
- Input for weather prediction models that predict future weather from a few hours to a few weeks.
- Local severe storm, aviation, and marine forecasts;
- Climate change research;
- Field programs to study specific atmospheric phenonema
- Input for air pollution models;
- Ground truth for satellite data;



Data are plotted and turned in useful maps for use by forecasters.

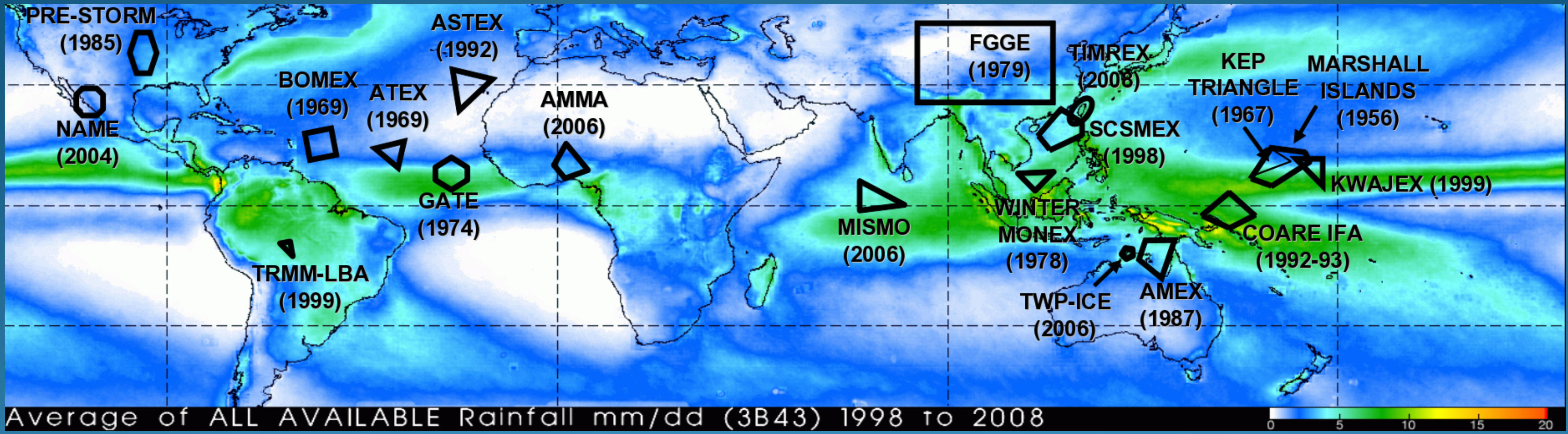


Skew-T plot for a sounding at Tuscon, AZ



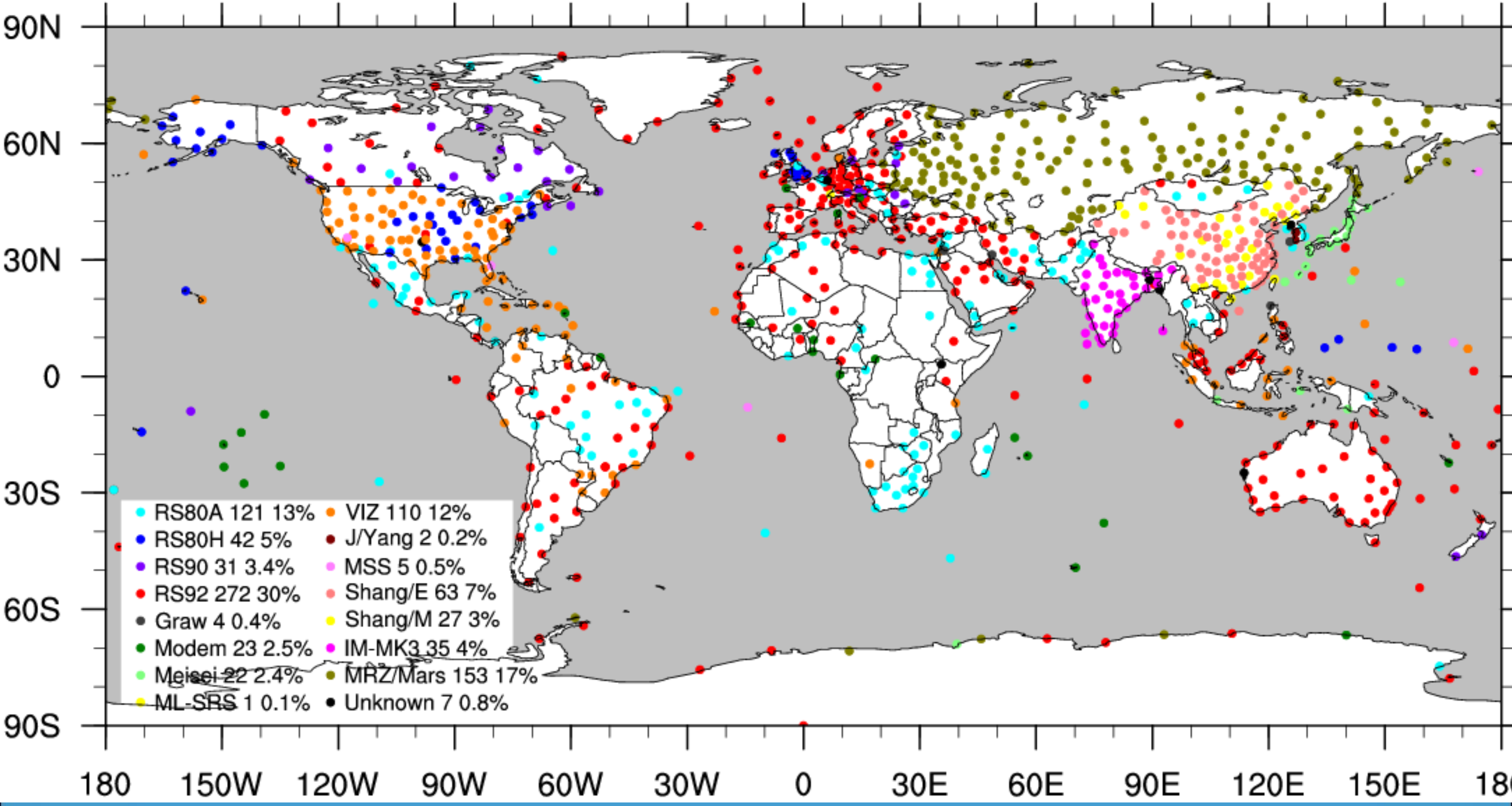
Data from individual soundings are plotted to aid forecaster in determining the potential for: heavy rain, thunderstorms, hail, damaging winds, whether the precipitation will fall as rain or snow, and many other useful aspects of the weather.

Sounding arrays for major tropical and midlatitude field campaigns during the last 4 decades superimposed on a satellite-derived rainfall map



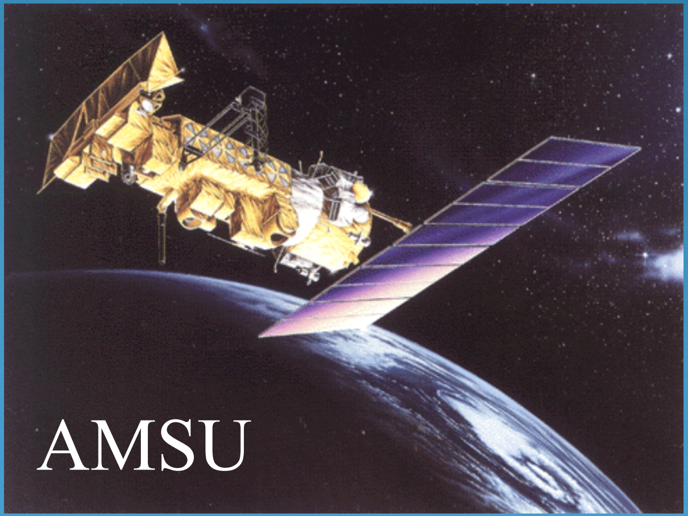
- Many of these field programs were designed to study the heavy-rain producing regimes around the globe.
- Some of these field programs launched 10,000's of radiosondes in period of only a few months.
- In addition to radiosonde observations, data are collected from many other instrument platforms including: aircrafts, ships, ground-based radars, satellites, rain gauges, etc.
- The component of these field program data sets that tends to have the greatest lasting value to the scientific community is the atmospheric vertical profiles represented by the upper-air sounding data.

Where are the holes in the global radiosonde network?

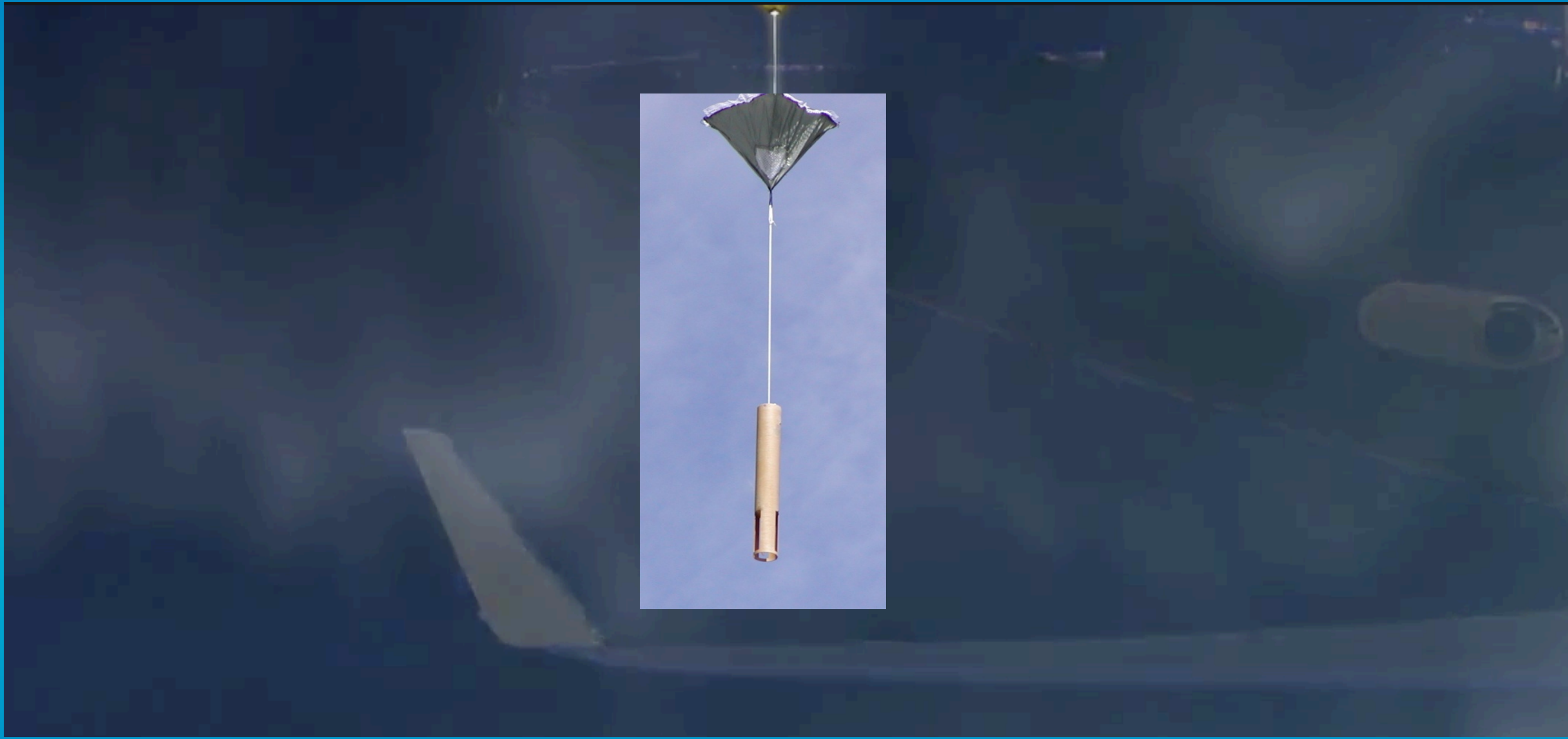


How do we fill in these holes over the oceans and data sparse land regions?

- Remote sensing from satellites
  - advantage: great spatial and temporal coverage
  - disadvantage: expensive, coarse vertical resolution
- Whereas radiosondes provide 5-m vertical resolution, satellite-data resolution is generally on order of few kilometers (~2000-m).



What is a dropsonde?



https://www.youtube.com/watch?v=iMvydih9rlM

OAA-14 AVHRR HRPT RGB=CH1,CH2,CH4 09/28/2000 19:39 UTC

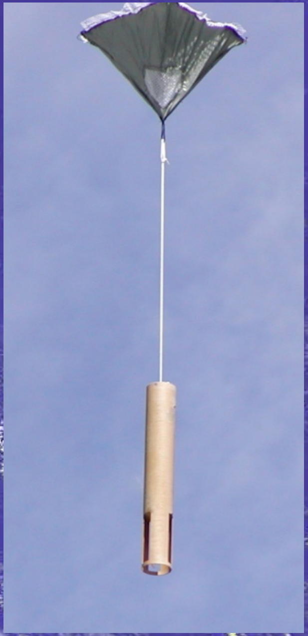
Hurricane and Dropsonde

Hurricane Observations:

- Satellites
- Ships and Buoys
- Land-based Observations
- Aircraft Reconnaissance

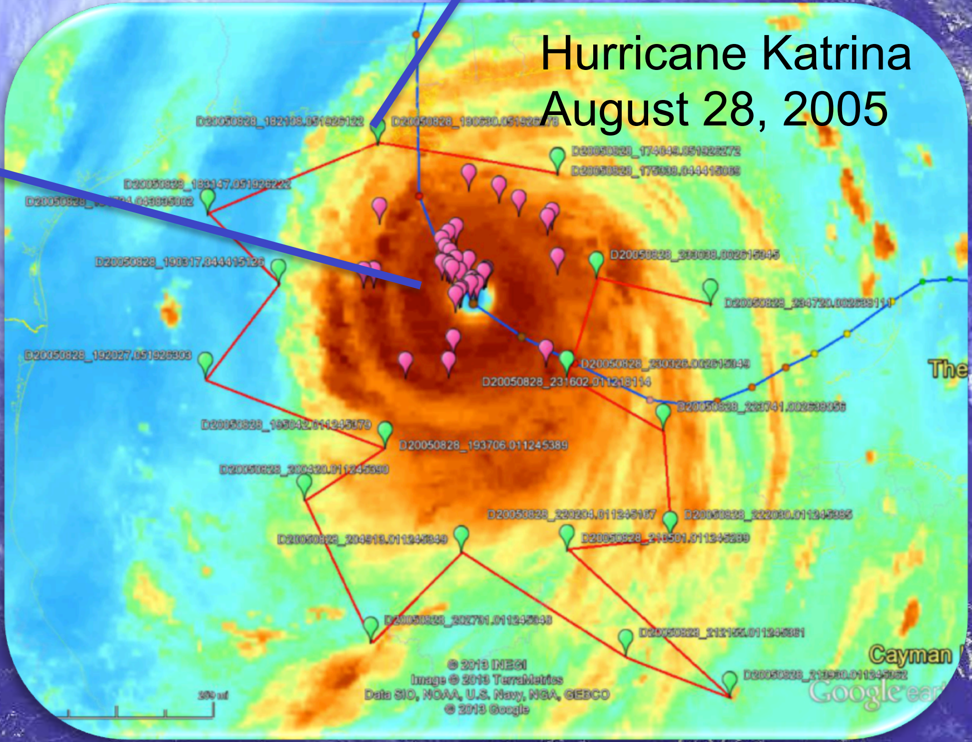
Synoptic Surveillance

G-IV: 45,000 feet



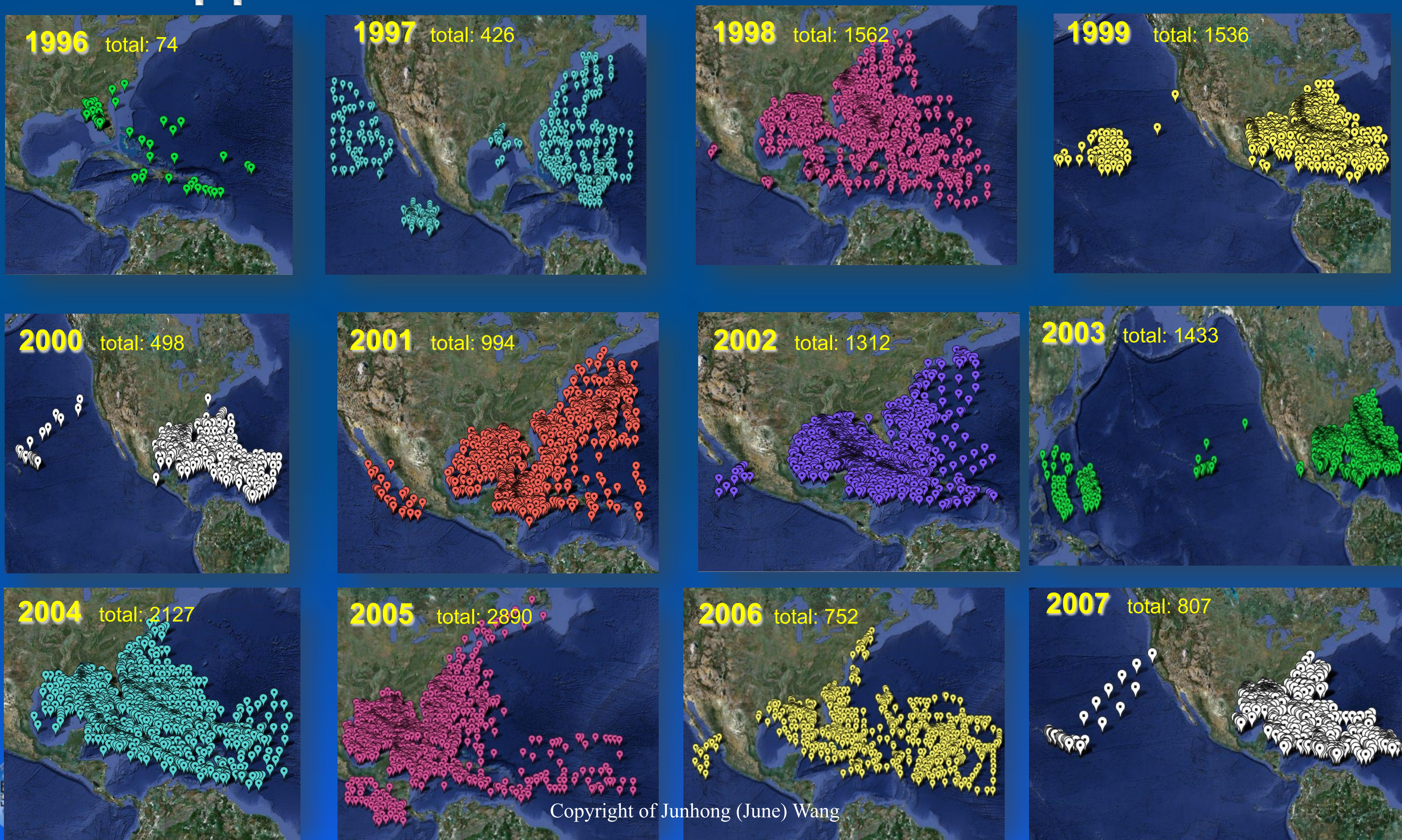
Eyewall drops

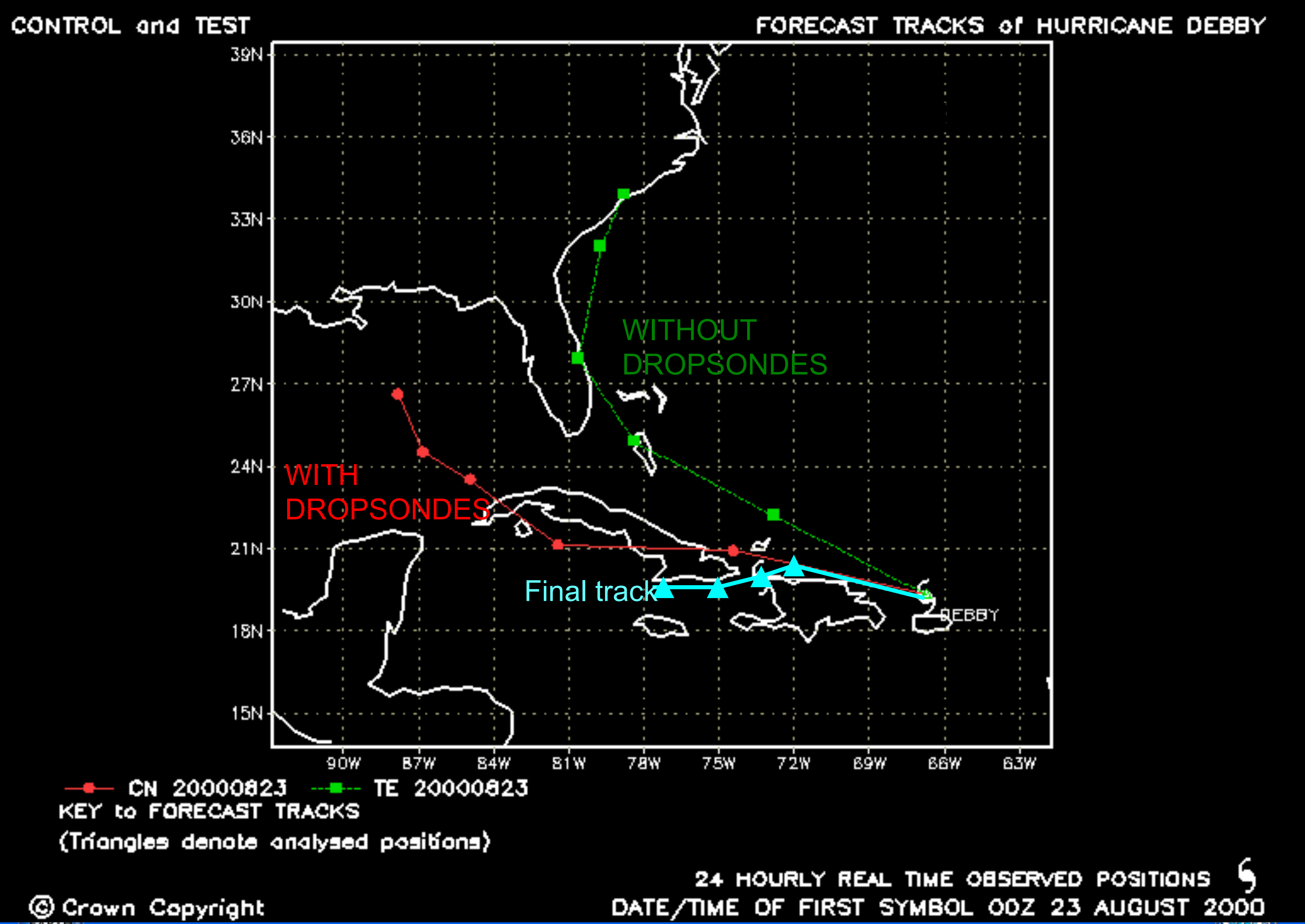
WC-130/WP-3D
10,000 feet



Hurricane Reconnaissance Dropsondes

From 1996-2012, > 22,000 dropsondes dropped into hurricanes for 125 storms.





James Franklin

Courtesy Julian Heming, UKMO

Global Hawk Dropsonde System Overview

The Global Hawk aircraft is a unmanned, high-altitude, long-endurance, remotely piloted aircraft (116-ft wingspan). It’s range is 8,500 mile range with a28 hr endurance.

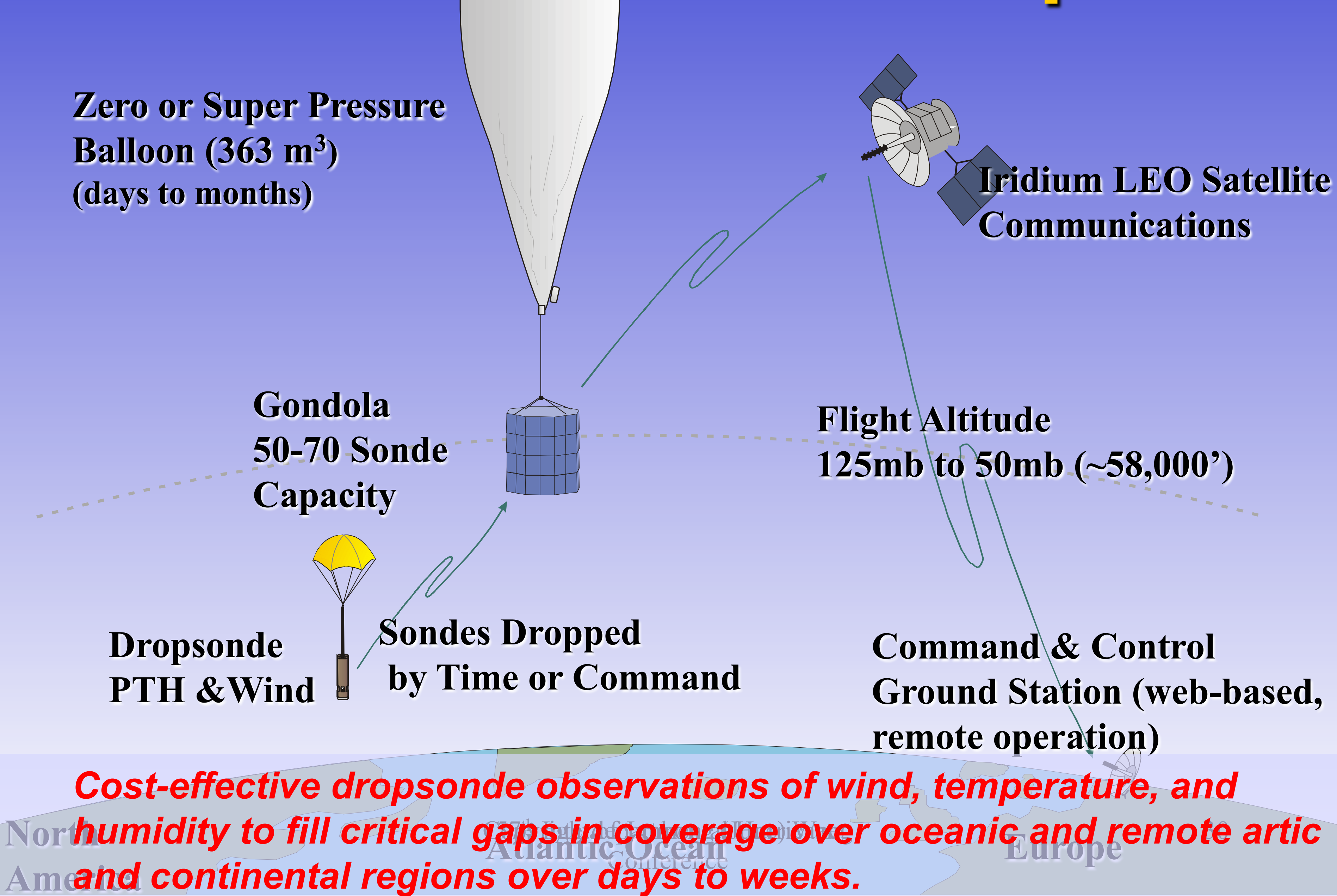
A ground control flight crew monitors and controls the aircrafts operations.

Instrument Description / Measurement Characteristics:

- The dropsonde unit can dispense up to 88 sondes per flight
- Remote operation from the Global Hawk Operations Center (GHOC)
- Multi-channel system, 8 sondes in descent at the same time
- **For additional information see:**

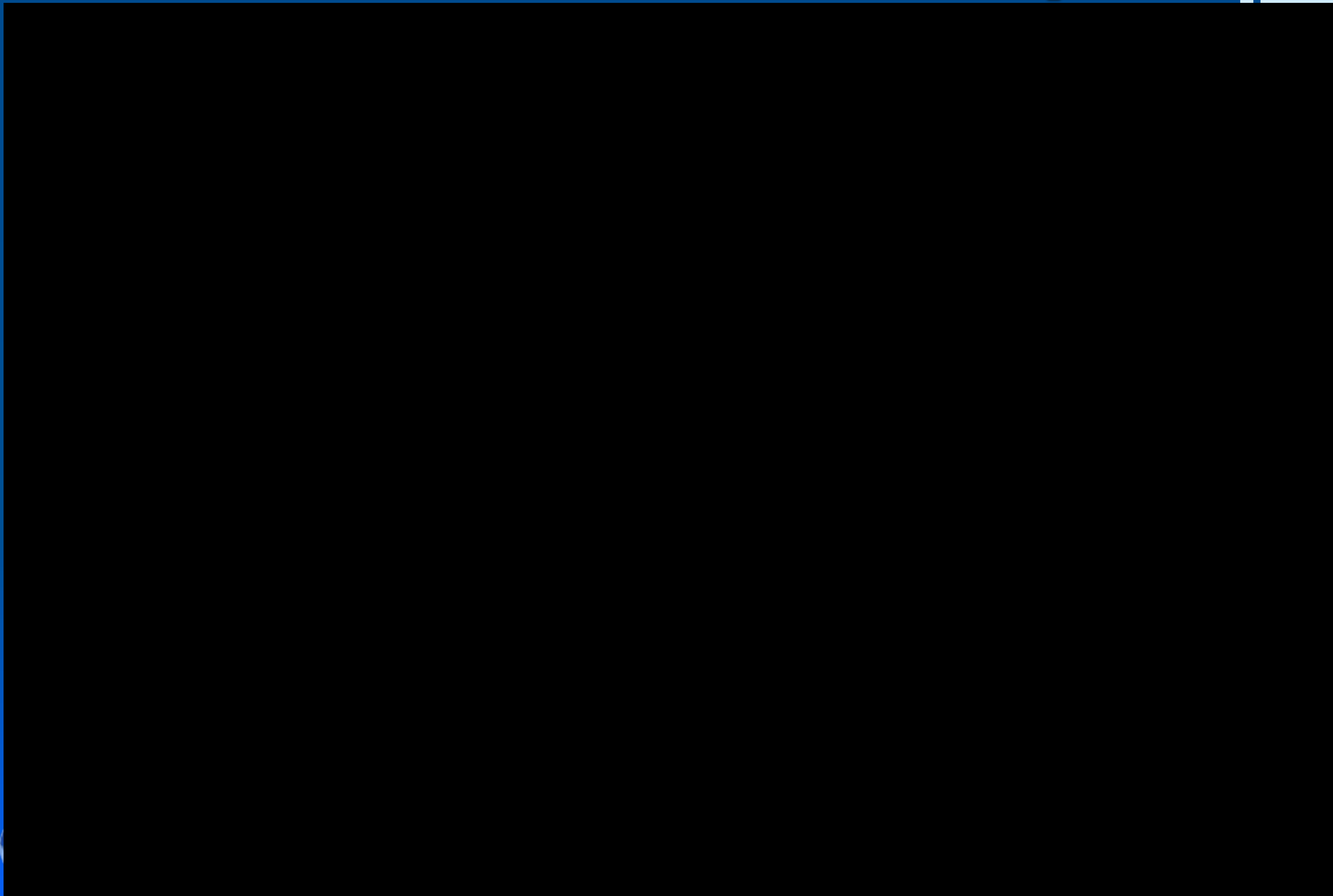
http://www.nasa.gov/centers/armstrong/news/FactSheets/FS-098-DFRC.html

DRIFTSONDE Concept

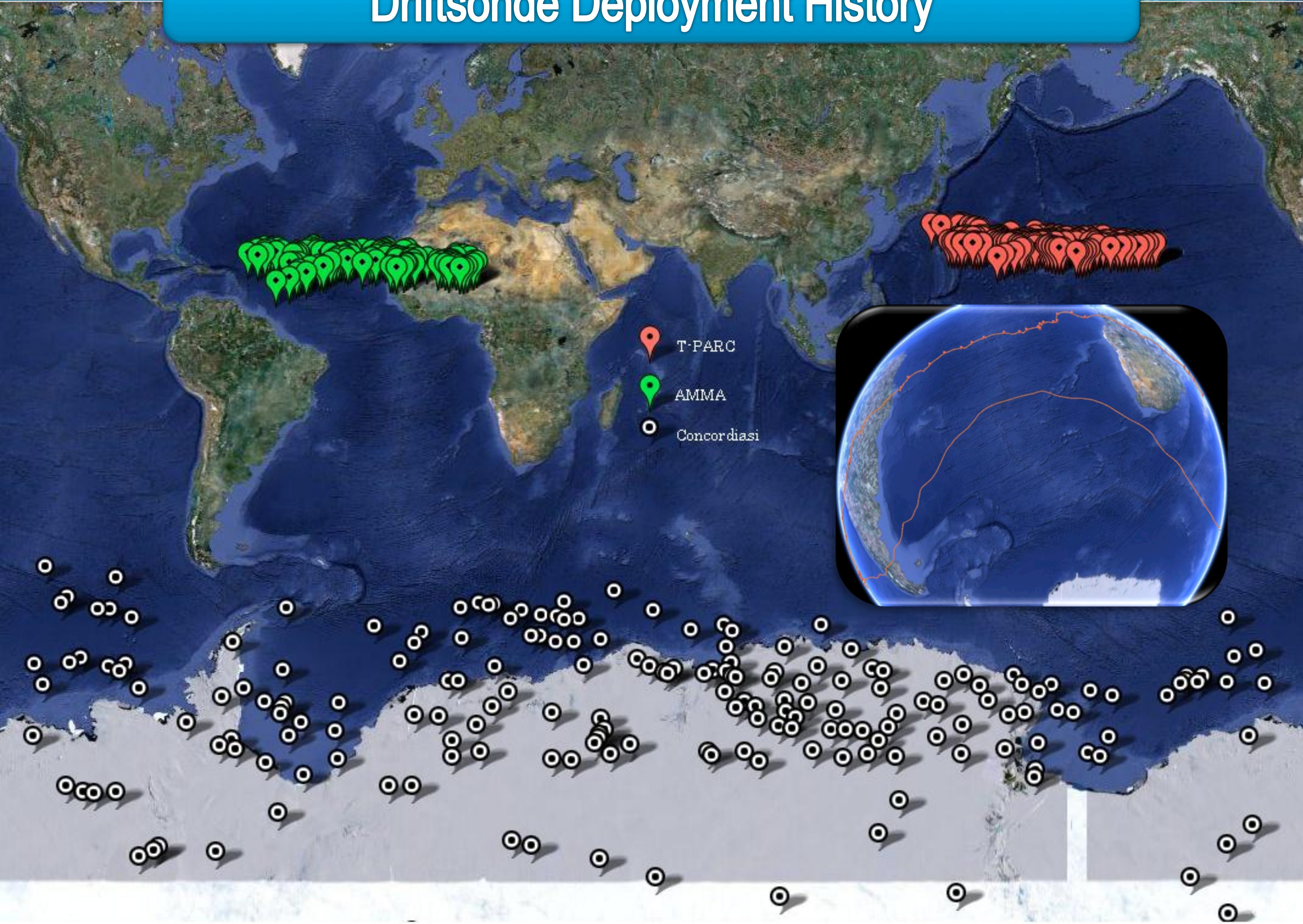


Cost-effective dropsonde observations of wind, temperature, and humidity to fill critical gaps in coverage over oceanic and remote artic and continental regions over days to weeks.

DRIFTSONDE Concept

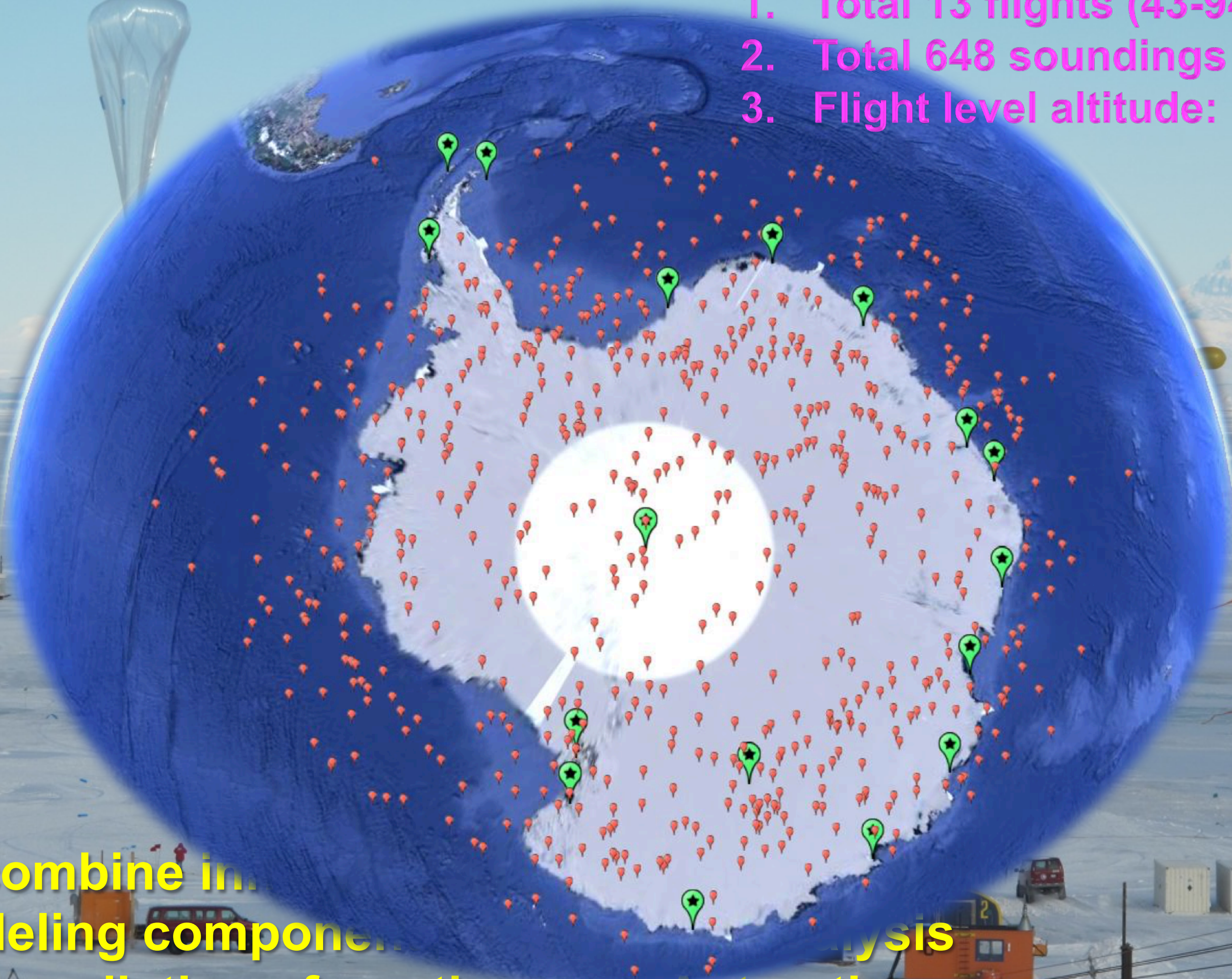


Driftsonde Deployment History



Concordiasi (Antarctica, Sept.-Dec. 2010)

1. Total 13 flights (43-94 days)
2. Total 648 soundings
3. Flight level altitude: 14-18 km



To combine in... modeling compone... ...lysis and prediction of weather over Antarctica.

Radiosondes observations are the backbone of the atmosphere's observational network and the workhorse of accurate weather forecasts.

Thank You

Picture taken from a dropsonde flight on 30 May 2008, thunderstorm cloud penetrating through low-level stratus deck is off the southwest coast of Taiwan.

Resources

1. "Encyclopedia of radiosondes" on http://www.atmos.albany.edu/daes/atmclasses/env327/ENV327syllabus_S2015_files/Ency-radiosonde.pdf

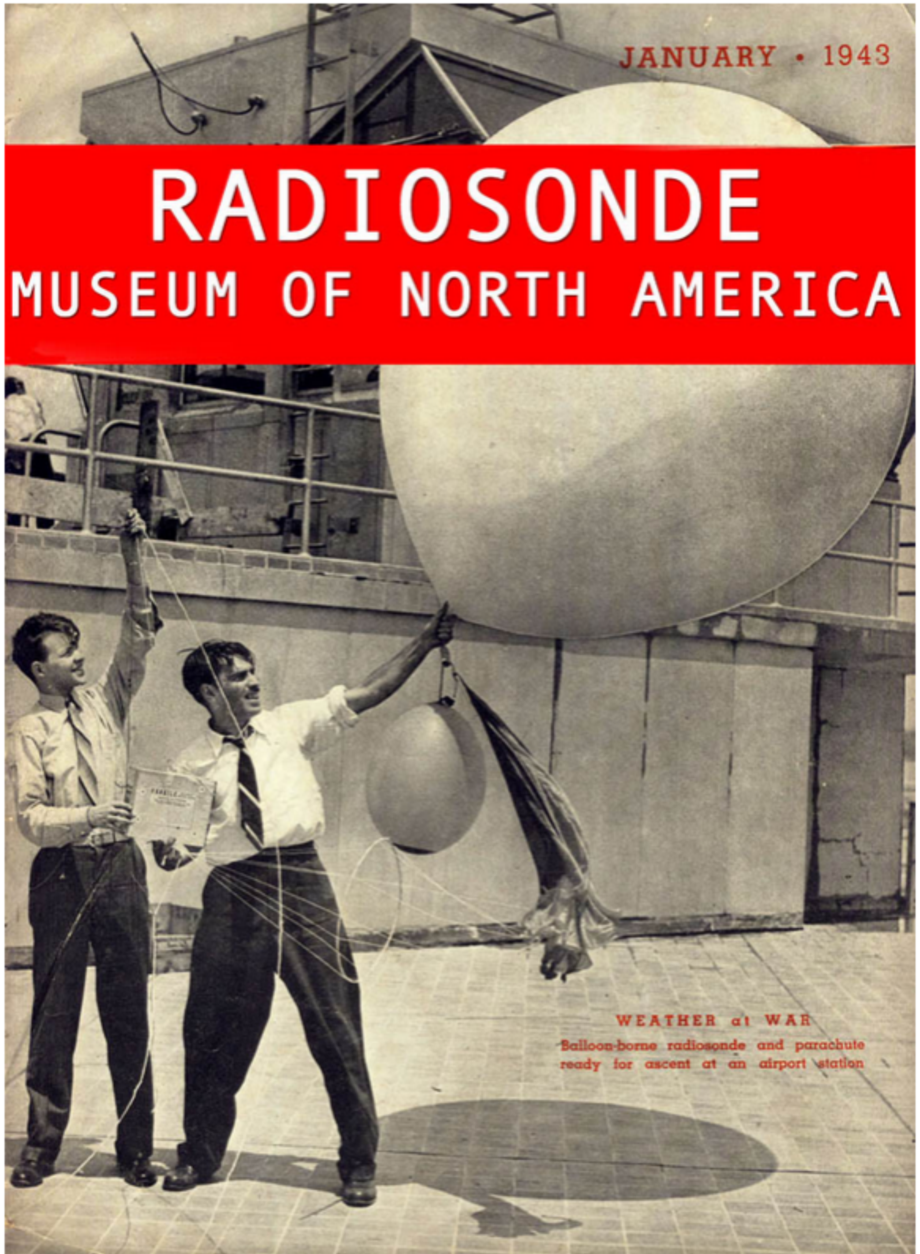
2. Radiosonde history: http://www.atmos.albany.edu/daes/atmclasses/env327/ENV327syllabus_S2015_files/UpperAirMeasurement-Weather-484_ftp.pdf

3. Radiosonde presentation from U.K. Met office on http://www.atmos.albany.edu/daes/atmclasses/env327/ENV327syllabus_S2015_files/MT11B_radiosondes.pdf

4. "WMO GUIDE TO METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION" on (Ch#12 and #13) http://www.wmo.int/pages/prog/www/IMOP/CIMO-Guide.html

5. http://radiosondemuseum.org/

Radiosonde Museum of North America



Radiosonde Museum of North America is all about radiosondes. The site is an educational resource—every item that you see on these pages is physically present in the collection, except for those on loan to museums and researchers. If you need additional information, photographs, measurements, etc., we will be delighted to provide that.

Most of the photographs on this site are high resolution. They will expand when clicked on, or you can drag them to your desktop and bump them up. Note that all material on this site is copyrighted; although we share freely, please let us know if there's anything you'd like to use. We genuinely welcome your questions, comments, corrections, and criticisms.

Enjoy your visit!

Cliff Lawson
Owner/Curator

Our Mission

To collect, preserve, and archive radiosondes and related artifacts, documents, and ephemera; to serve as a research collection for meteorologists, weather historians, and students; and to inform the public of the history of radiosondes, their role in meteorology, and their diverse designs.

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http://radiosondemuseum.org/

Contact information:

Paul Ciesielski
Department of Atmospheric Science
Fort Collins, CO 80523
Email: paulc@atmos.colostate.edu

Web links for cameras launched on weather balloons:

https://www.youtube.com/watch?v=veqJART9XBA

https://www.youtube.com/watch?v=y6ZMscMp8UM

https://www.youtube.com/watch?v=sEZk2U2t8D0