Atmospheric Sounding:
Basics, Research and Development
Radiosonde, Dropsonde and Driftsonde

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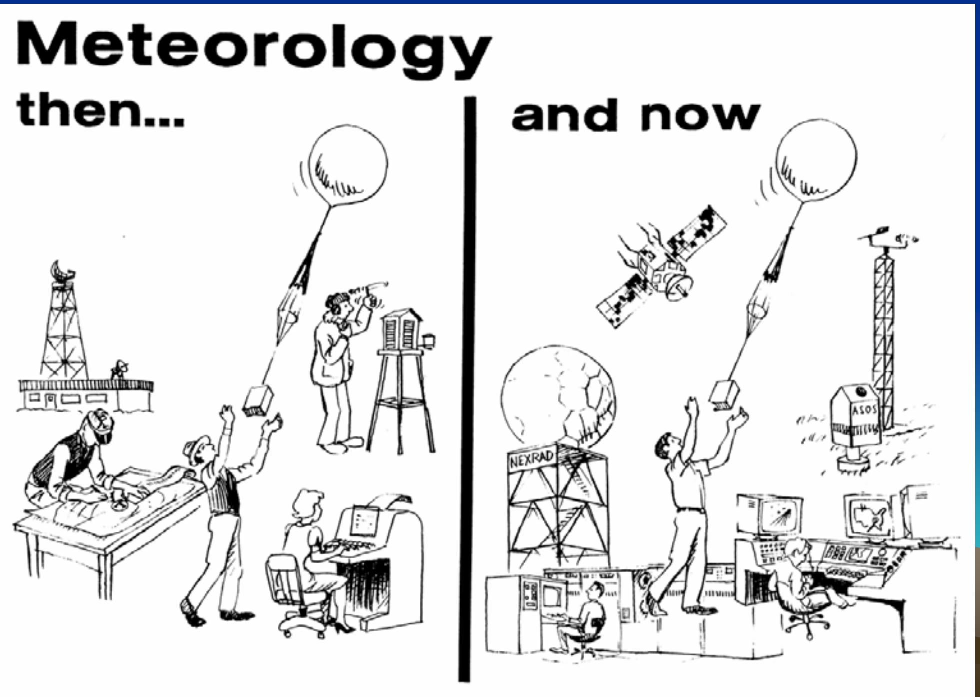
NCAR Earth Observing Laboratory



Courtesy of EOL sounding group: Terry Hock, Hal Cole, Kate Young, Dean Lauritsen, Scot Loehrer and others

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Outline:

1. **Radiosonde**
   - **Overview**
   - **History**
   - **Sensors**
   - **Future** **(sensor, network, other applications)**

2. **Dropsonde**

3. **Driftsonde**

4. **Questions, comments and feedback**

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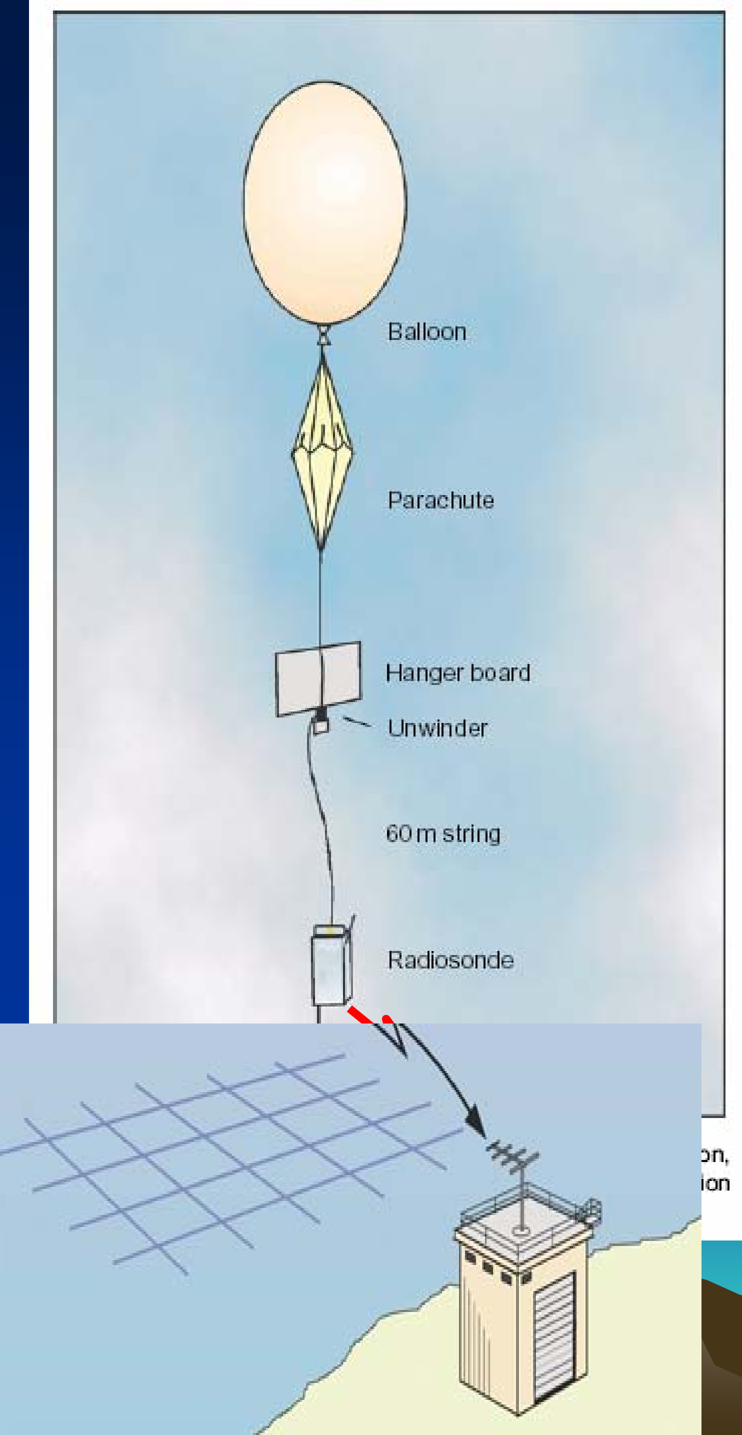
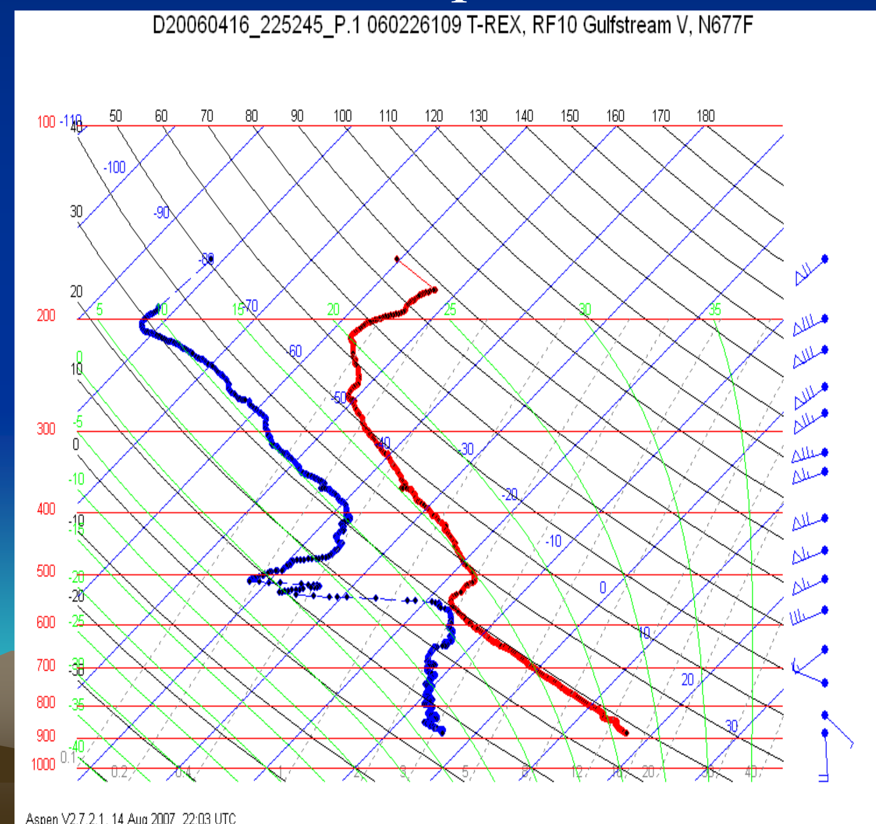


Radiosonde Overview

(1) To make accurate measurements of important atmospheric parameters (usually temperature, pressure, humidity and wind) above the surface

(2) To send this information back in as close to real-time as possible



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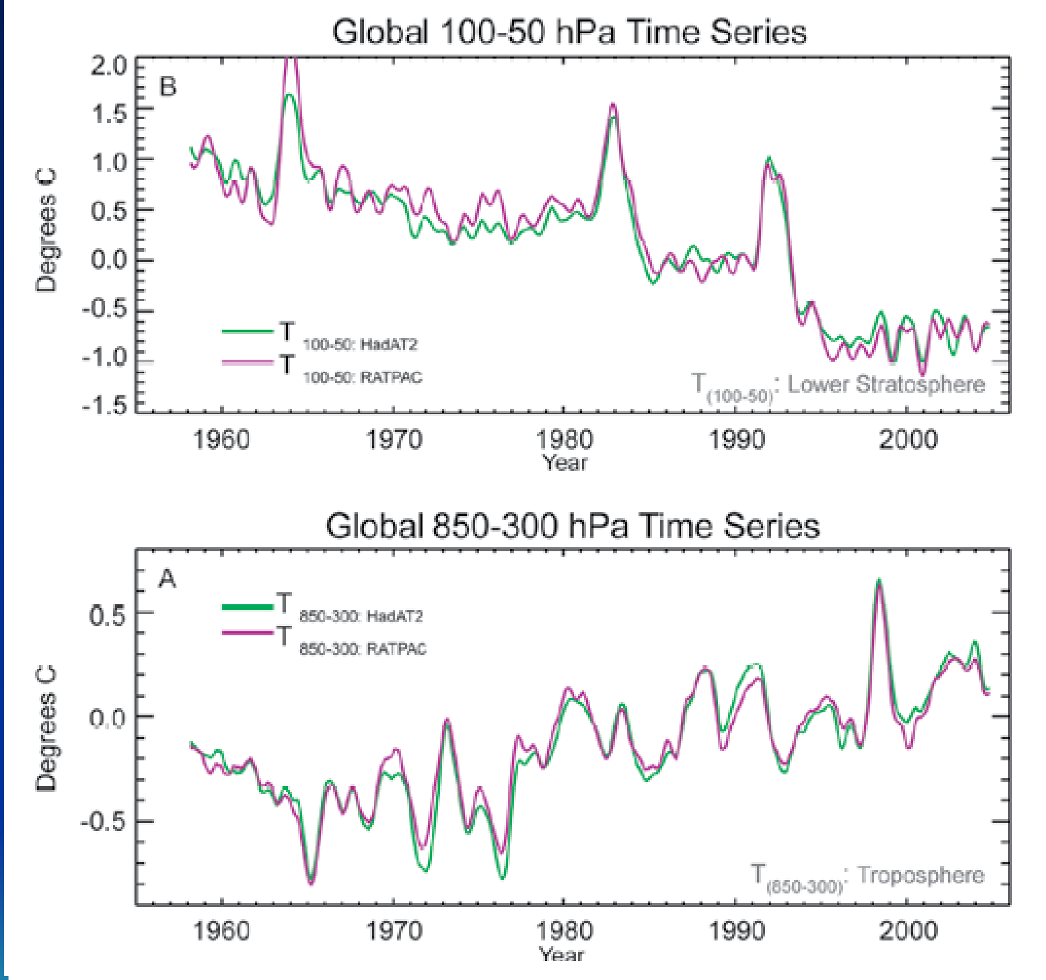
Radiosonde Applications: Operation and Field projects

- Input for weather prediction models;
- Local severe storm, aviation, and marine forecasts;
- Climate change research;
- Input for air pollution models;
- Ground truth for satellite data;
- Characterization of thermo-dynamical and wind profiles



CCSP (2006)

http://www.eol.ucar.edu/homes/junhong/Ency-radiosonde.pdf

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Other special radiosondes

Needs:

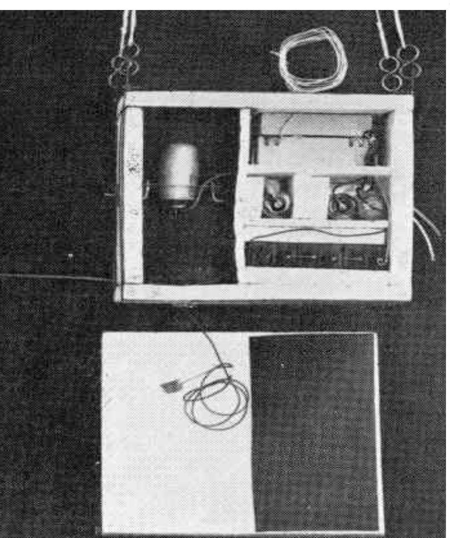
1. Trace gases
2. Vertical velocity
3. Turbulence
4. Radiation profiles

Ozonesonde:
ozone profiles

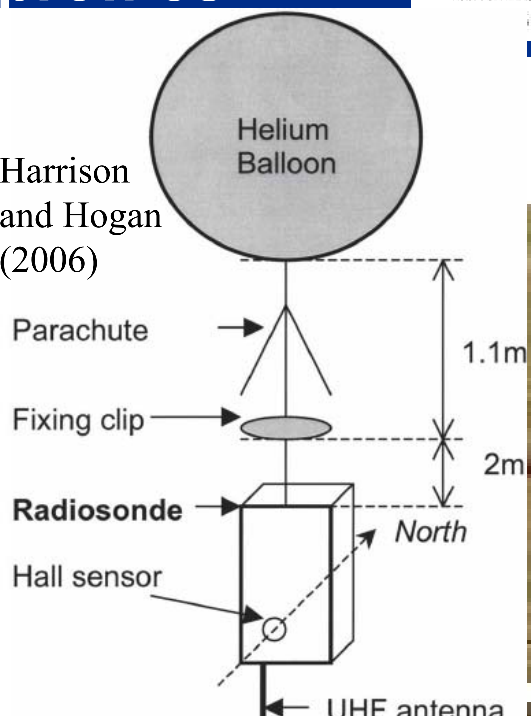
An RS80 radiosonde with ozone ...r.

Radioactivity sonde:
B and γ radioactivity

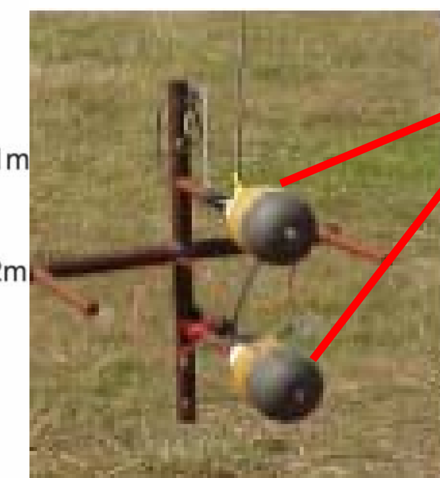
Electricity:
ectric field probe



Harrison and Hogan (2006)



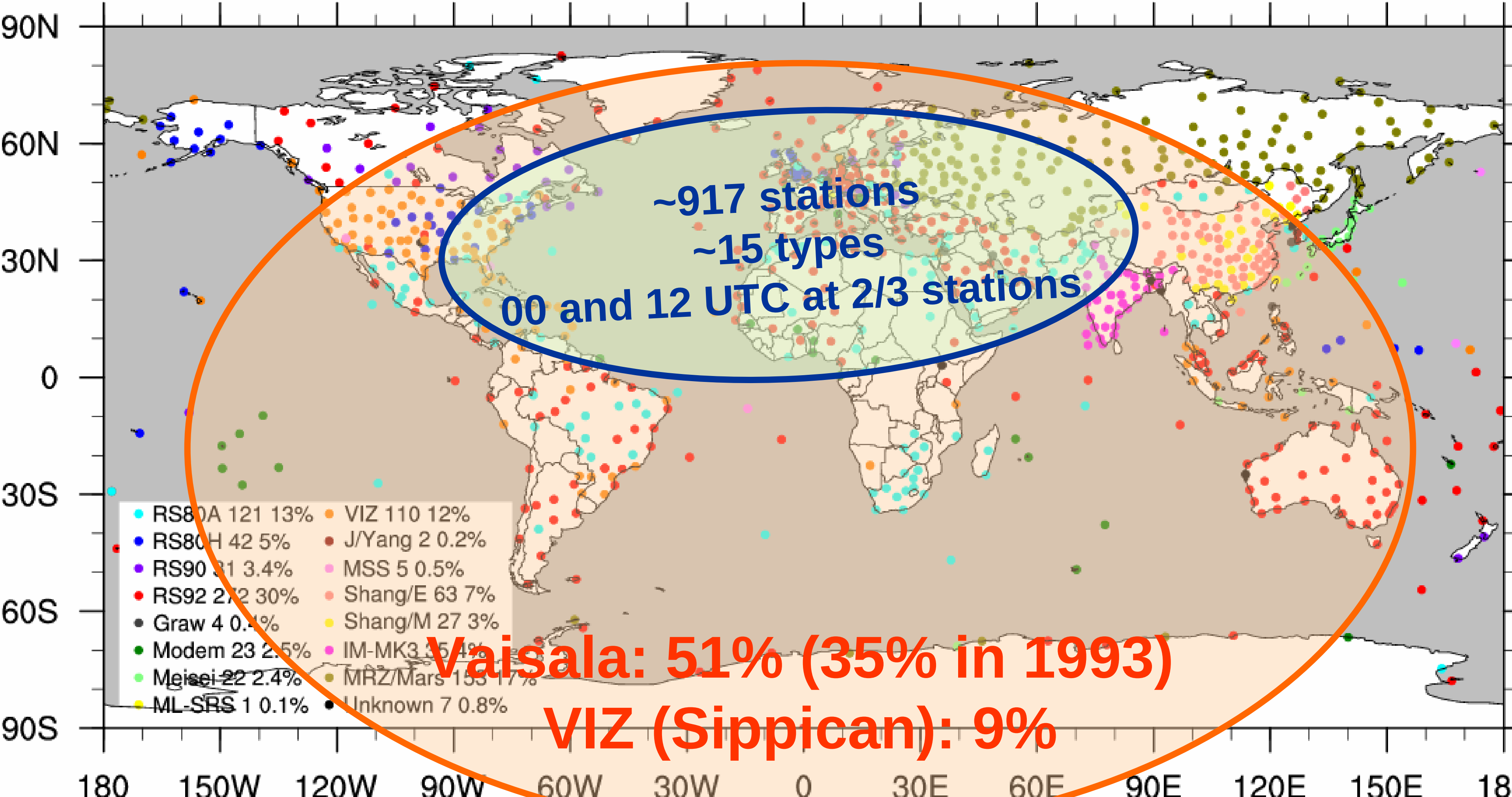
In-cloud measurements:
changes in charge, aerosols



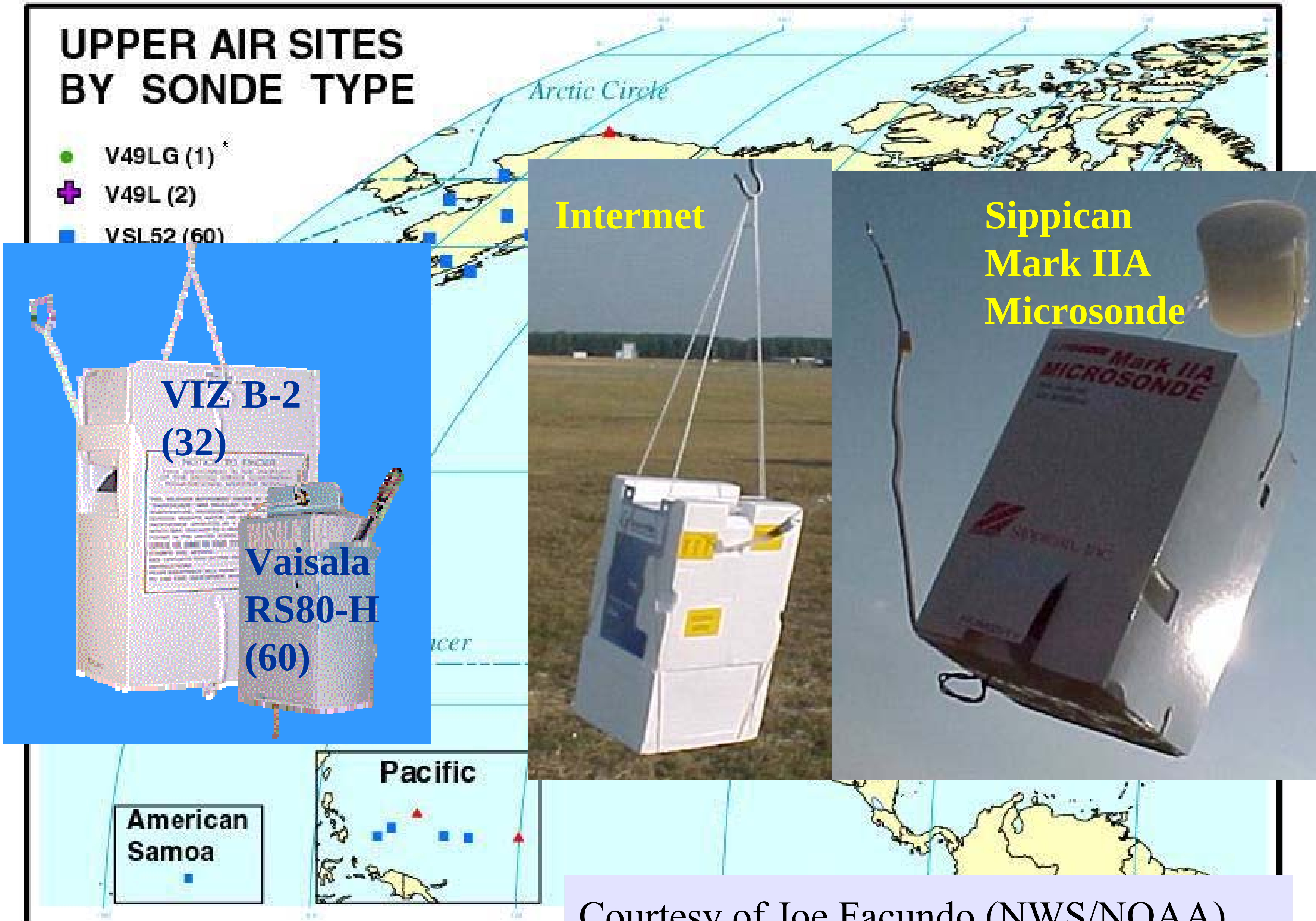
"The housing is that originally supplied to house the small plastic toy contained within a children's confectionery KinderEgg. The outer chocolate enclosure and foil coating must first be removed."

http://www.eol.ucar.edu/homes/junhong/MT11B_radiosondes.pdf

Global radiosonde network (WMO report, July 2007)



Current and future radiosondes in U.S.A.



Courtesy of Joe Facundo (NWS/NOAA)

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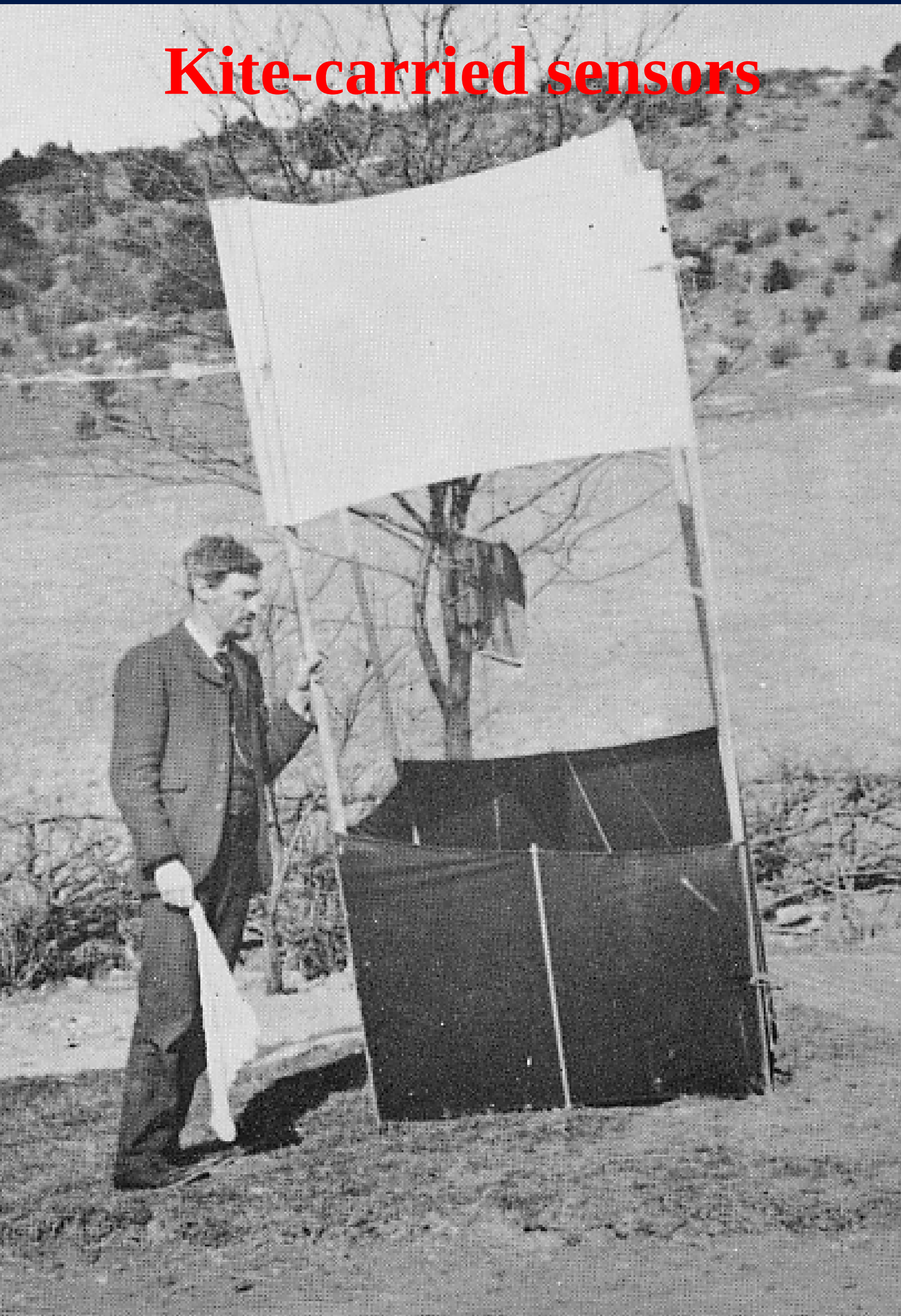
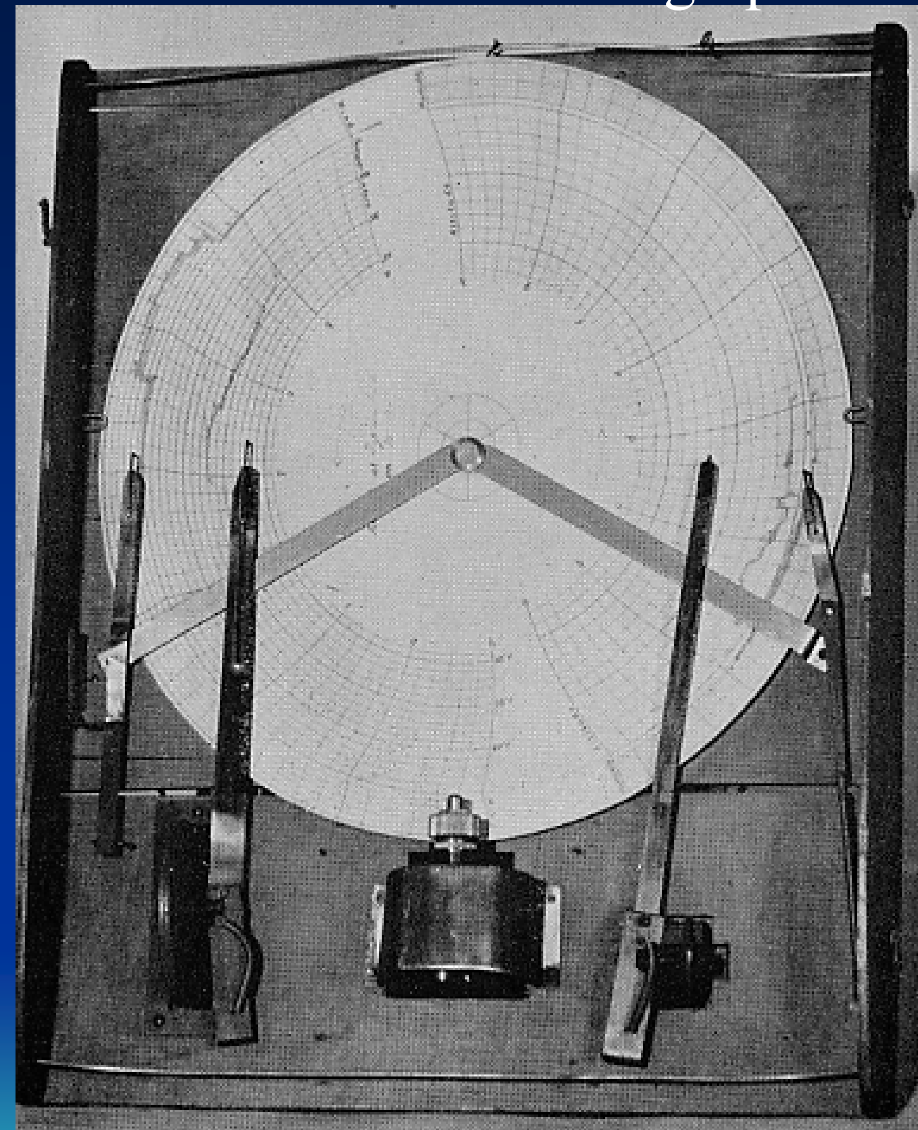
History of radiosondes

- **18th and 19th centuries:**
  1. A kite with a thermometer in 1749 in Glasgow, Sco
  2. Manned hot air and hydrogen balloons in 1800's
  3. 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
- **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
- **1960's – 1980's:**
  1. Computerized reduction of rawinsonde data (automation)
  2. Radio-navigation aids (NAVAID): LORAN and Omega for wind
- **1990's:**
  1. Improved sensors, data processing and NAVAID system
  2. GPS for wind measurements

- 3-5 km
- data loss
- good weather



Dines’ Kite Meteorograph



Handbook of Meteorological Instruments, HMSO, 1961

Measurements 1905-1932 at Aeronautical Observatory Lindenberg

Am Aeronautischen Observatorium Lindenberg (1914—1931) mit Fesselaufstiegen erreichte Höhen in m

Jahr	mit Drachen: Anzahl	mit Drachen: max. Höhe	mit Drachen: mittl. tägl. Höhe	mit Fesselballonen: Anzahl	mit Fesselballonen: max. Höhe	mit Fesselballonen: mittl. tägl. Höhe
1914	778	6200	3340	454	8000	3668
1915	701	5610	3517	439	5500	3089
1916	755	7500	3998	400	9200**	4332
1917	720	8240	4025	360	[illegible]	4160
1918	703	[illegible]	3661	[illegible]	3990	2869
1919	601	9750*	3811	182	5334	2484
1920	697	6700	3306	91	3950	2427
1921	711	5710	2968	30	2560	1867
1922	697	5860	2880	—	—	—
1923	630	4720	2560	55	4080	1677
1924	410	4660	2800	203	3260	2089
1925	456	4470	2488	166	4270	2462
1926	431	5403	2551	203	4788	2384
1927	461	4708	2535	222	4219	2182
1928	508	4260	2321	320	4070	2309
1929	703	5705	2308	220	4175	2567
1930	640	5865	2553	233	4421	2594
1931	609	5772	3030	142	4131	2385
1914—1931	11211			4032		

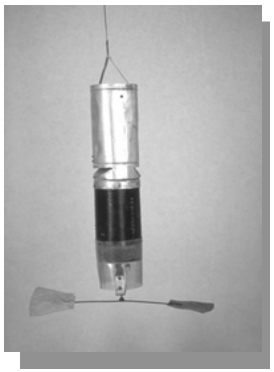
*) 1. 8. 1919 9750 m [illegible] **) 26. 9. [illegible]

World Record

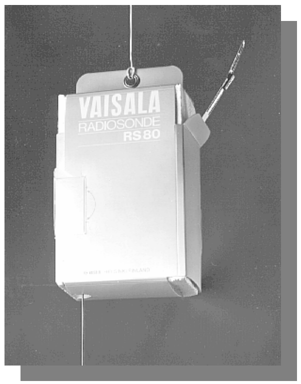
kites & balloons

Continuous Evolution of Vaisala Radiosondes

1931
RS11



1983
RS80



1997
RS90

Vaisala RS92
- Code-correlating GPS
- Digital transmission
- Twin Humicaps
- New ground check set
- Smaller/faster T sensor

CLASS-LORAN based, 10 second data, species extinct in ‘98

GLASS–1st generation GPS winds, used RS-80 Radiosonde, extinct in ‘05

GAUS- RS92SGP radiosonde compatible, all digital radiosonde

Courtesy of Tim Lim

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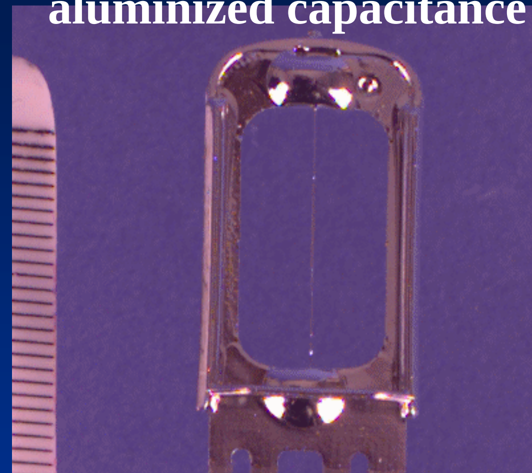
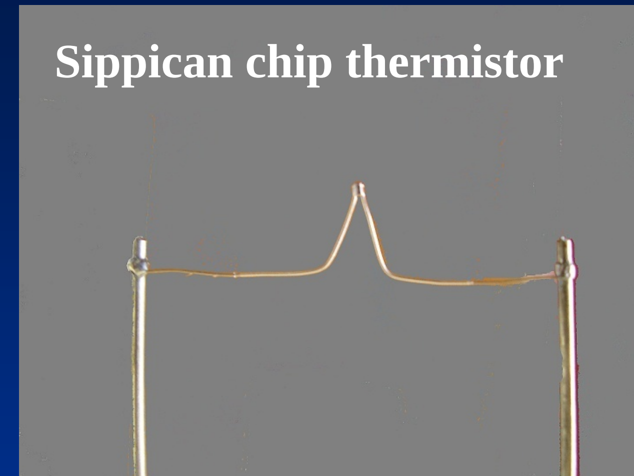
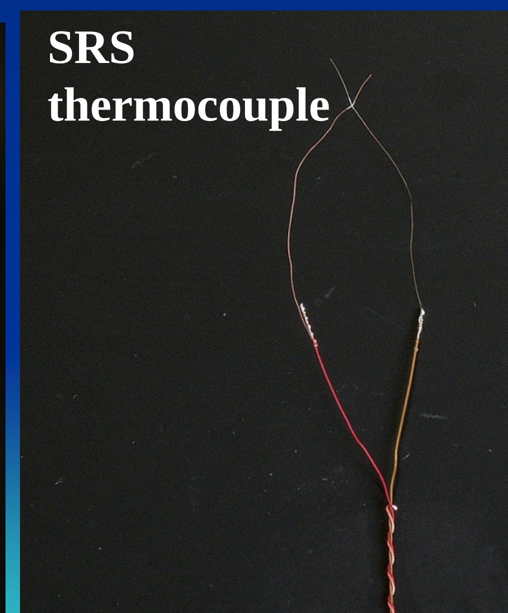
Temperature sensors:

1. Thermistor
2. Thermocapacitor
3. Wire resistor
4. Thermocouple
5. Bimetallic







Nash et al. (2006)

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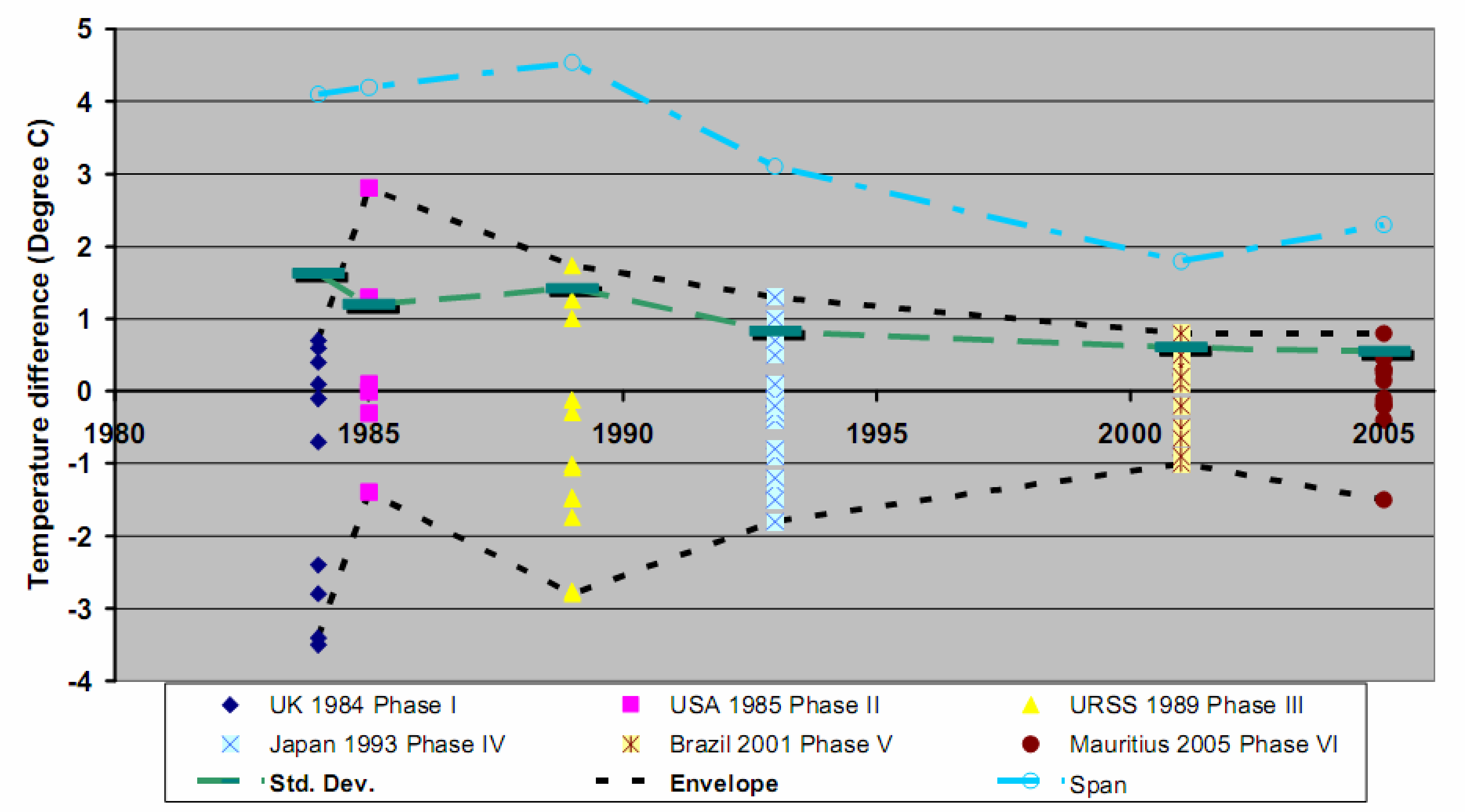
Temperature bias at 10 hPa for six WMO radiosonde intercomparisons



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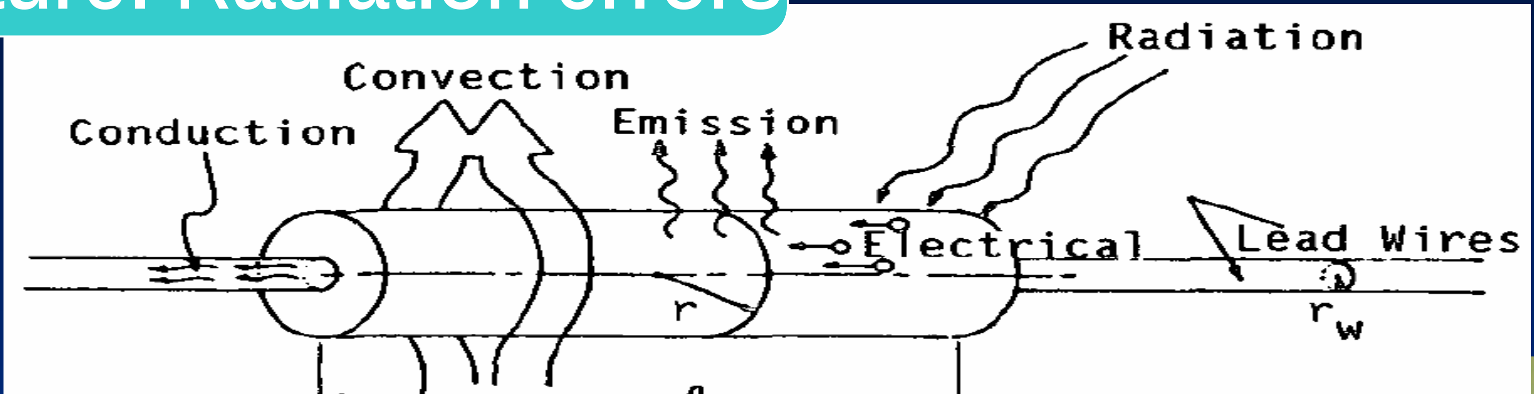
Future: Radiation errors



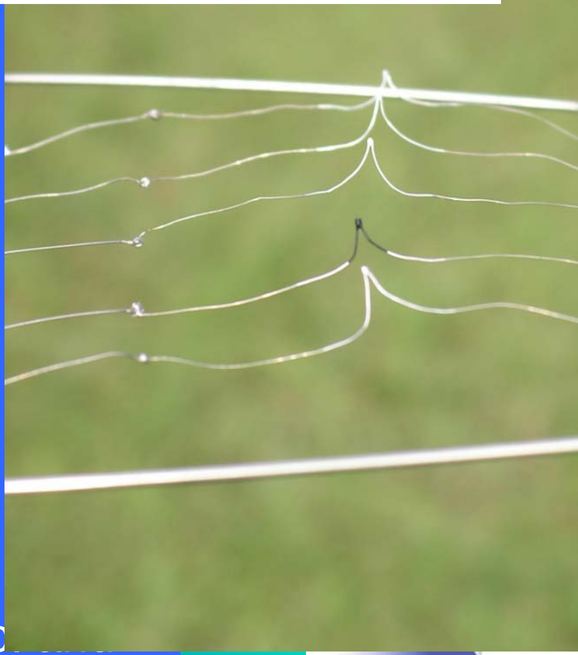
Luers (1990)

FIG. 1. Thermistor geometry and heat transfer processes.

$$mC(dT/dt) = q_{abs} - q_{emit} + q_{conv} + q_{elec} + q_{cond}$$

Option #1: Multi-thermistor Technology

- Simultaneously solving multiple heat balance equations;
- Each with different emissivity and absorptivity values;
- Conduction and thermal lag error correction are included;
- Knowledge of the environmental radiative background is not necessary.



Optional #2: Better radiation corrections

- Radiation sensors on the sonde
- Calculating radiation flux profiles with observed cloud, aerosol and other parameters

Humidity sensors:

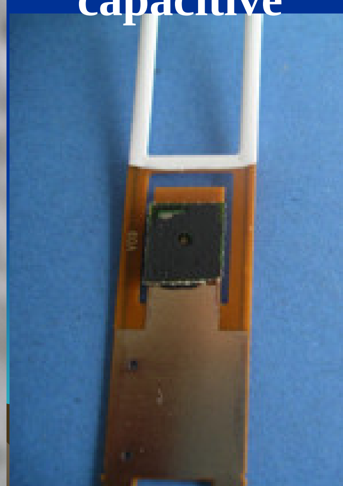
1. Thin-film capacitor
2. Carbon hygristor
3. Goldbeater's skin
4. Dew/frost-point hygrometer
5. Tunable diode laser (TDL)

Carbon hygristor

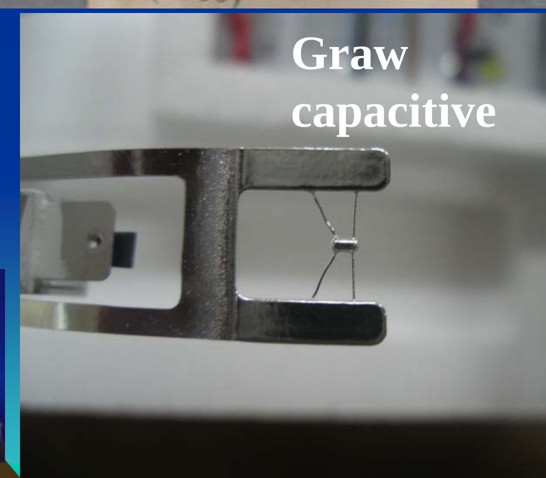
Goldbeater's skin

Vaisala Humicap

Modem capacitive

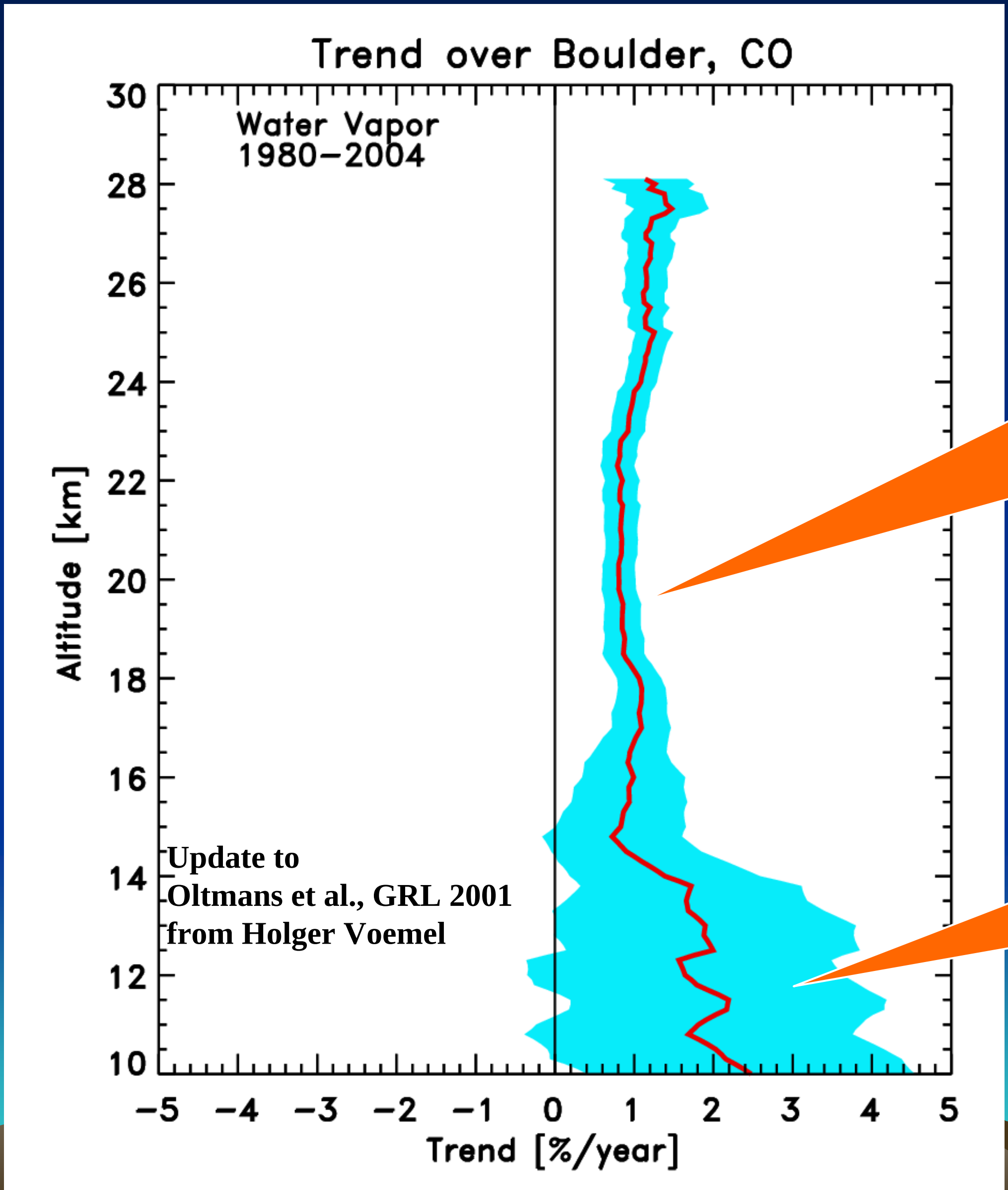


Meisei capacitive



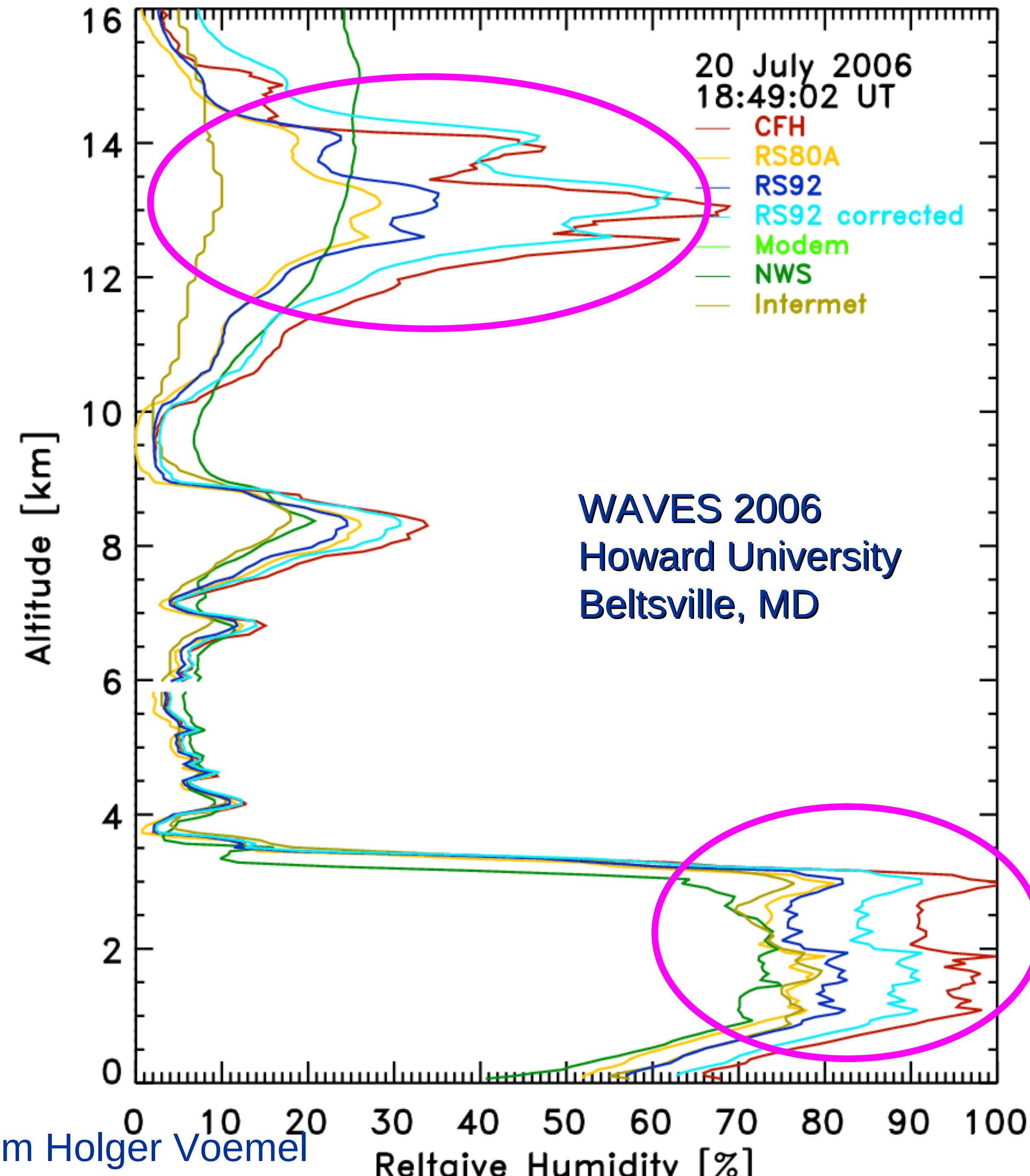
Graw capacitive

Current status on water vapor



Stratosphere:
- **No current operational radiosonde can provide humidity measurements in ST.**
- **Should we continue to ignore the ST?**

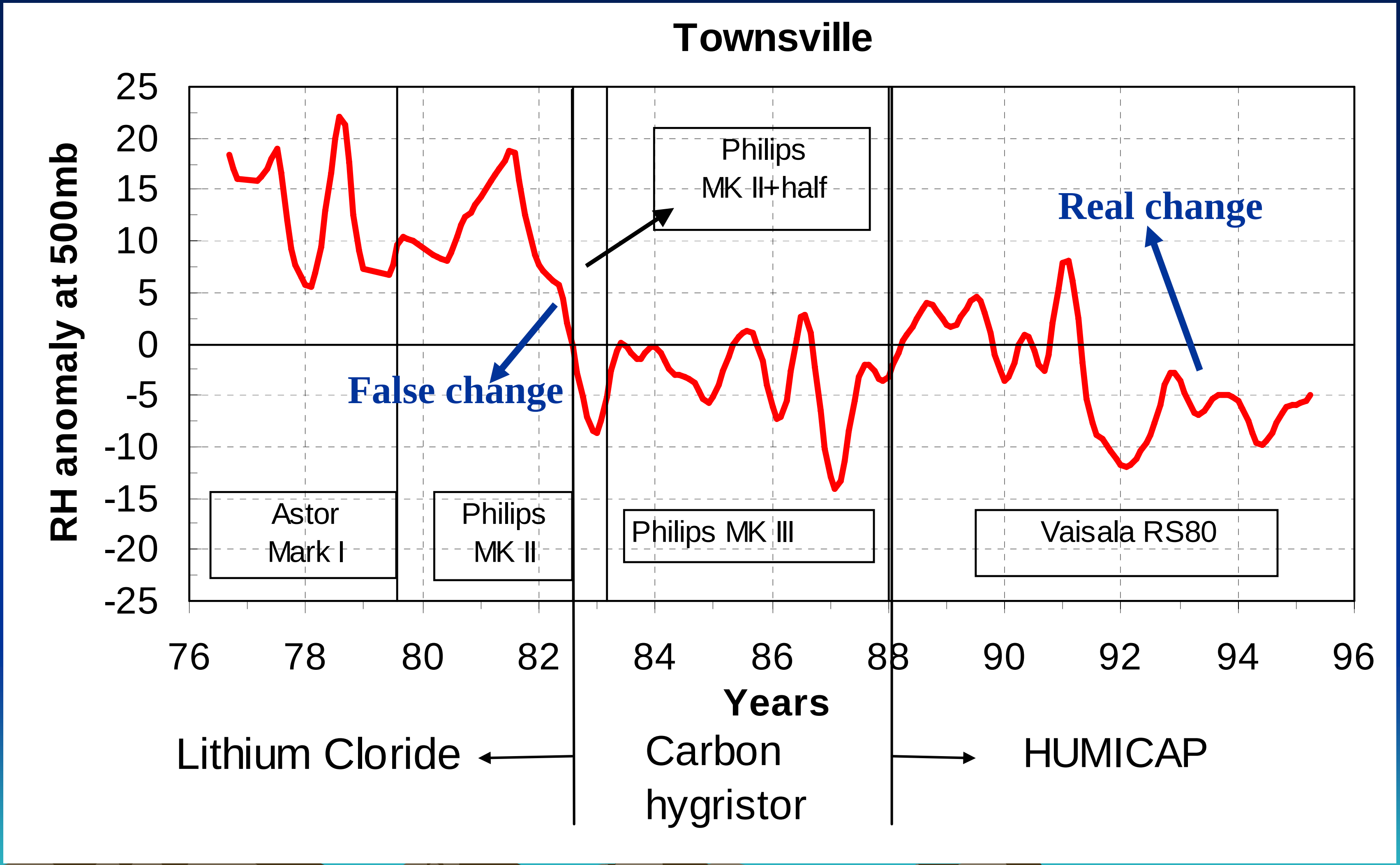
Troposphere:
- **Various problems still exist.**
- **Corrections are needed, but not effective in UT.**



WAVES 2006
Howard University
Beltsville, MD

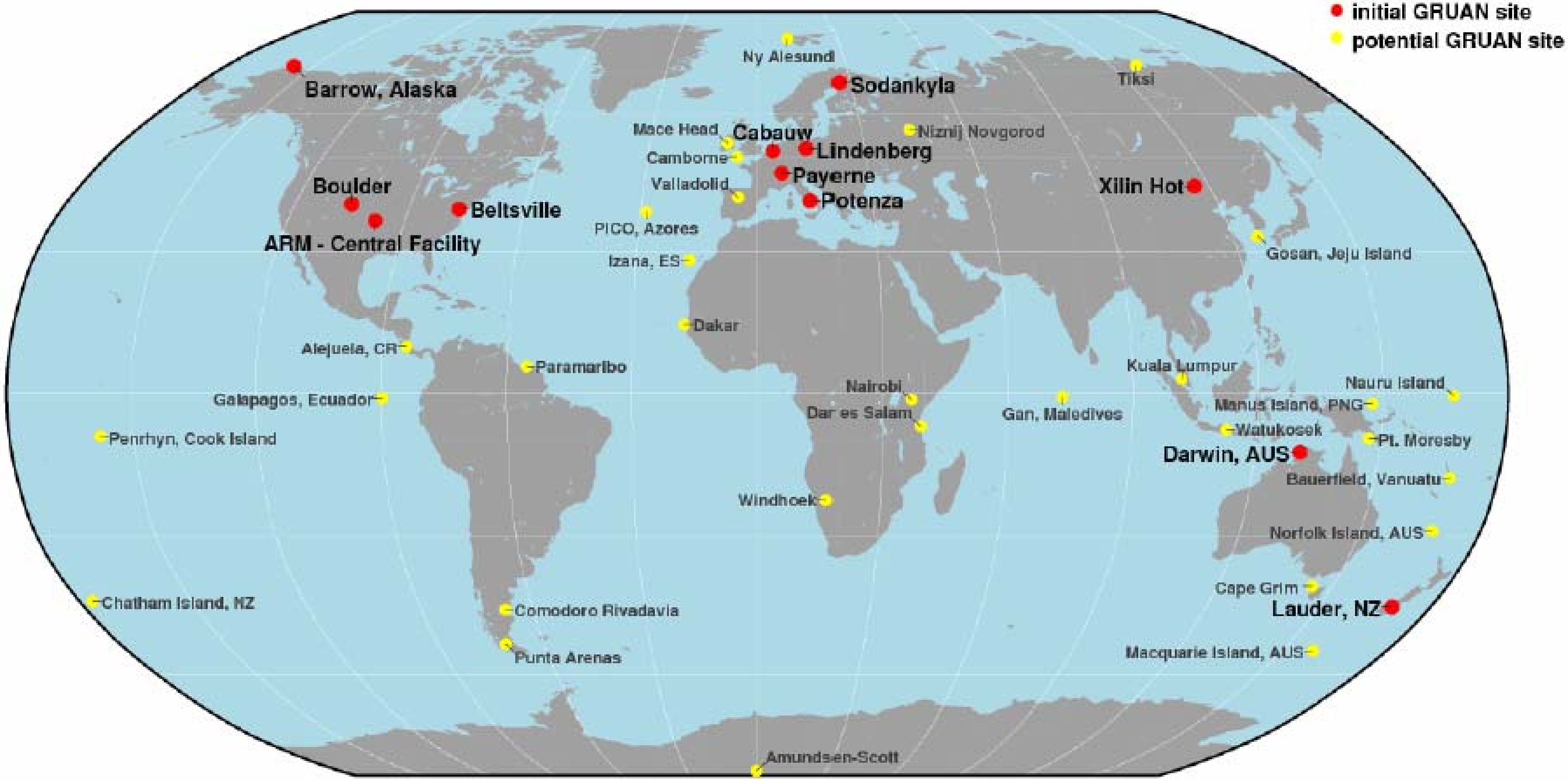
From Holger Voemel

Future: Homogenization global radiosonde humidity data



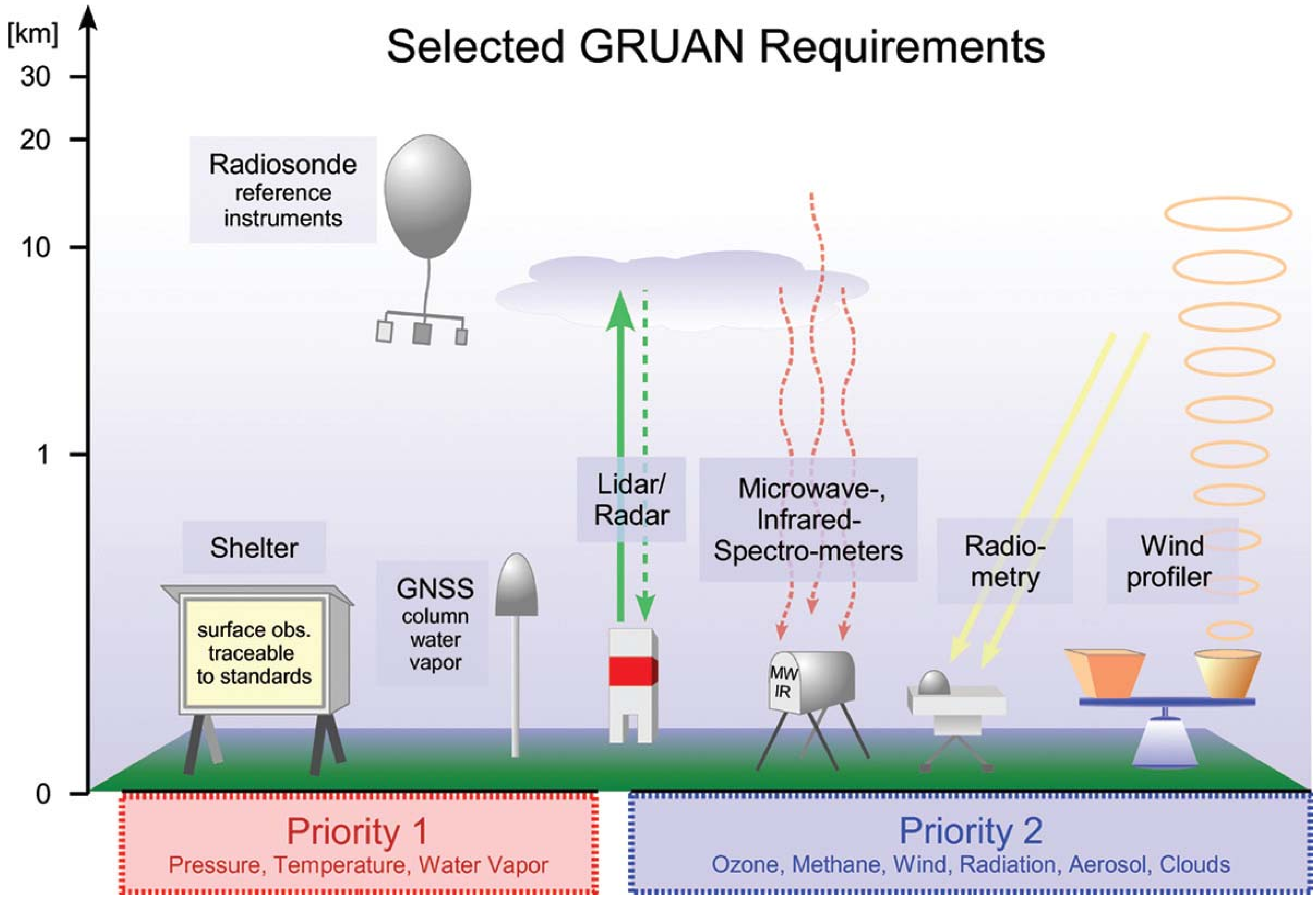
Wang et al. (2001)

Future: GCOS Reference Upper Network



Seidel et al. (2009, BAMS)

- **Provide long-term, high-quality climate records**
- **Constrain/calibrate data from more spatially-comprehensive global observing systems**
- **Measure large suite of co-related climate variables**


Selected GRUAN Requirements
[km]
30
20
10
1
0
Radiosonde reference instruments
Shelter
surface obs. traceable to standards
GNSS column water vapor
Lidar/ Radar
Microwave-, Infrared- Spectro-meters
MW IR
Radio- metry
Wind profiler
Priority 1
Pressure, Temperature, Water Vapor
Priority 2
Ozone, Methane, Wind, Radiation, Aerosol, Clouds

Future: Other parameters -- rise rate calculation

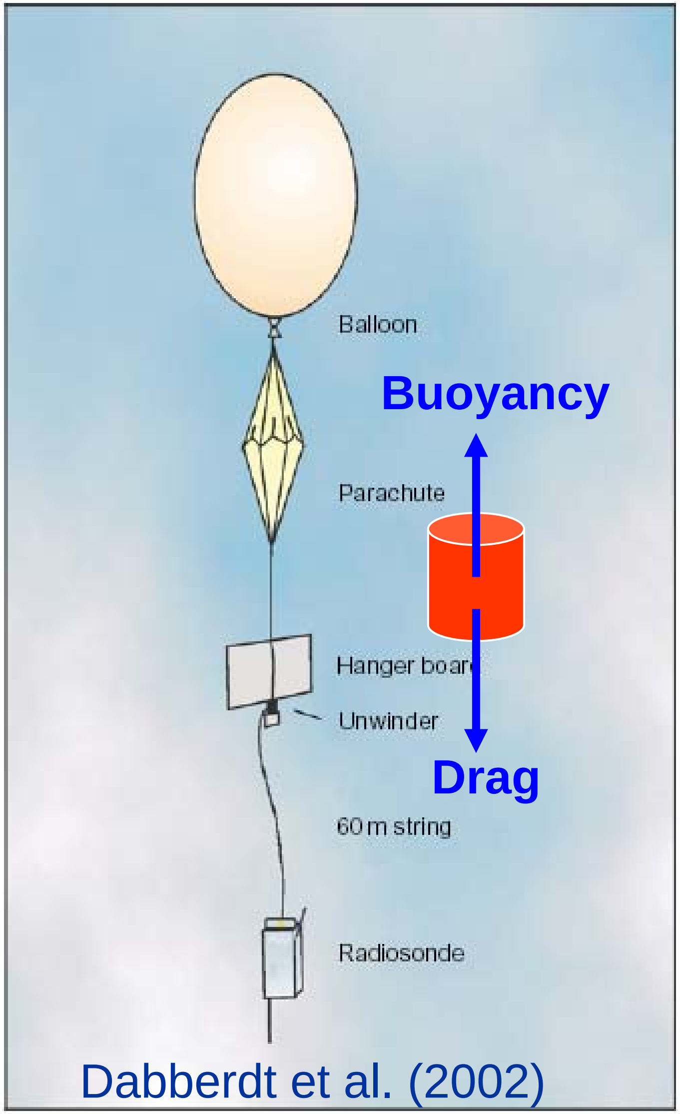


Figure 2 Typical radiosonde flight train, including balloon, parachute and hanger board, unwinder mechanism, line, and radiosonde.

Buoyancy force = Drag force

$$[BV*\rho_s - (m_s + m_b + m_h)]*g = C_D*A*\rho*V_f^2/2$$

$$m_h = BV * \rho *4.0026/28.9644$$

$$V_f = (2*BF/ C_D*A*\rho)^{1/2}$$

BV: ~20-40 ft^3 ?

m_s = 330g m_b=200g

C_D ~ 0.4 ?

$A = 4*\pi *[3*BV/(4*\pi)]^{2/3}$

ρ: density (kg m^{-3})

Vertical Wind = $V_{measured}$ - V_f

Wang et al. (2009)

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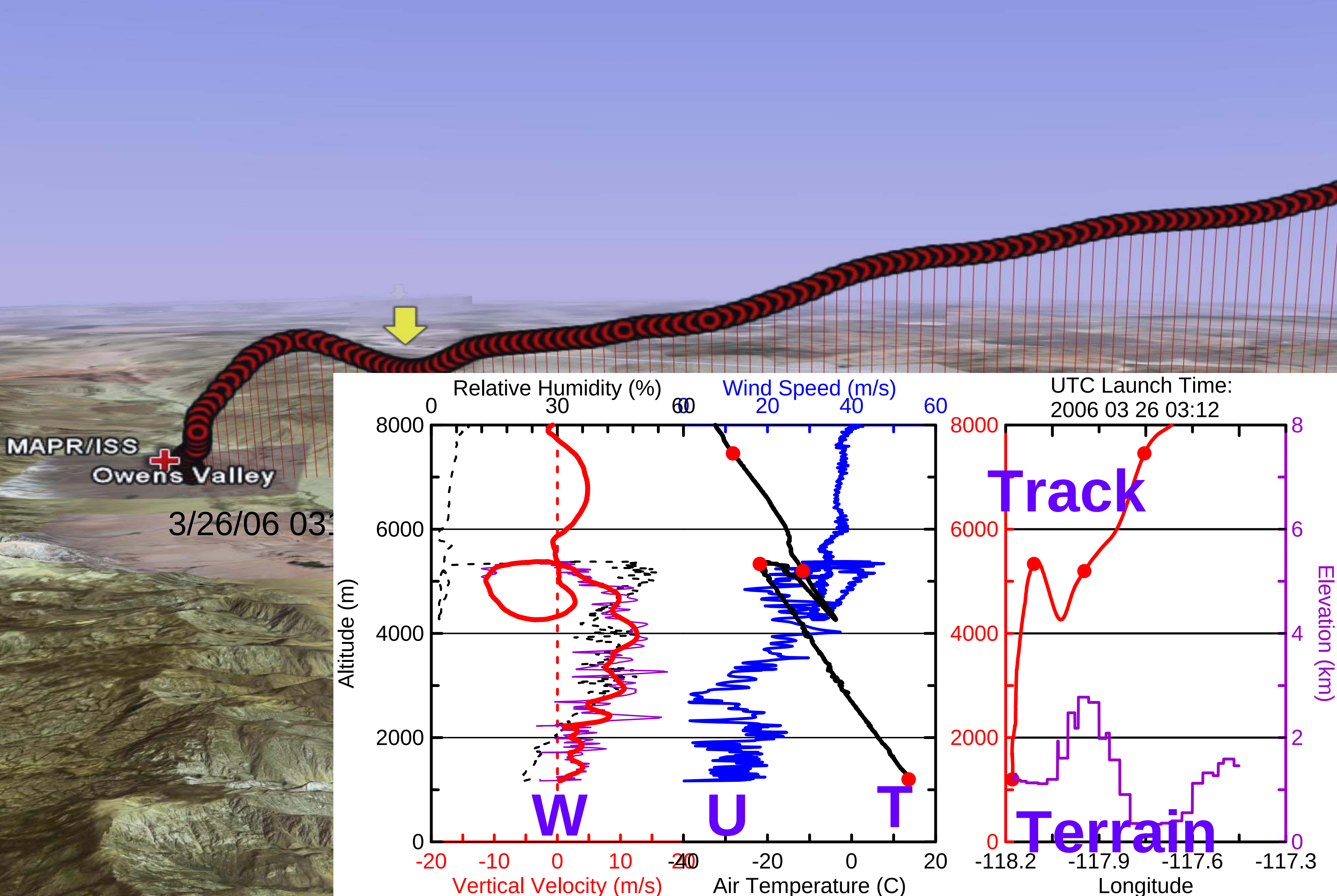
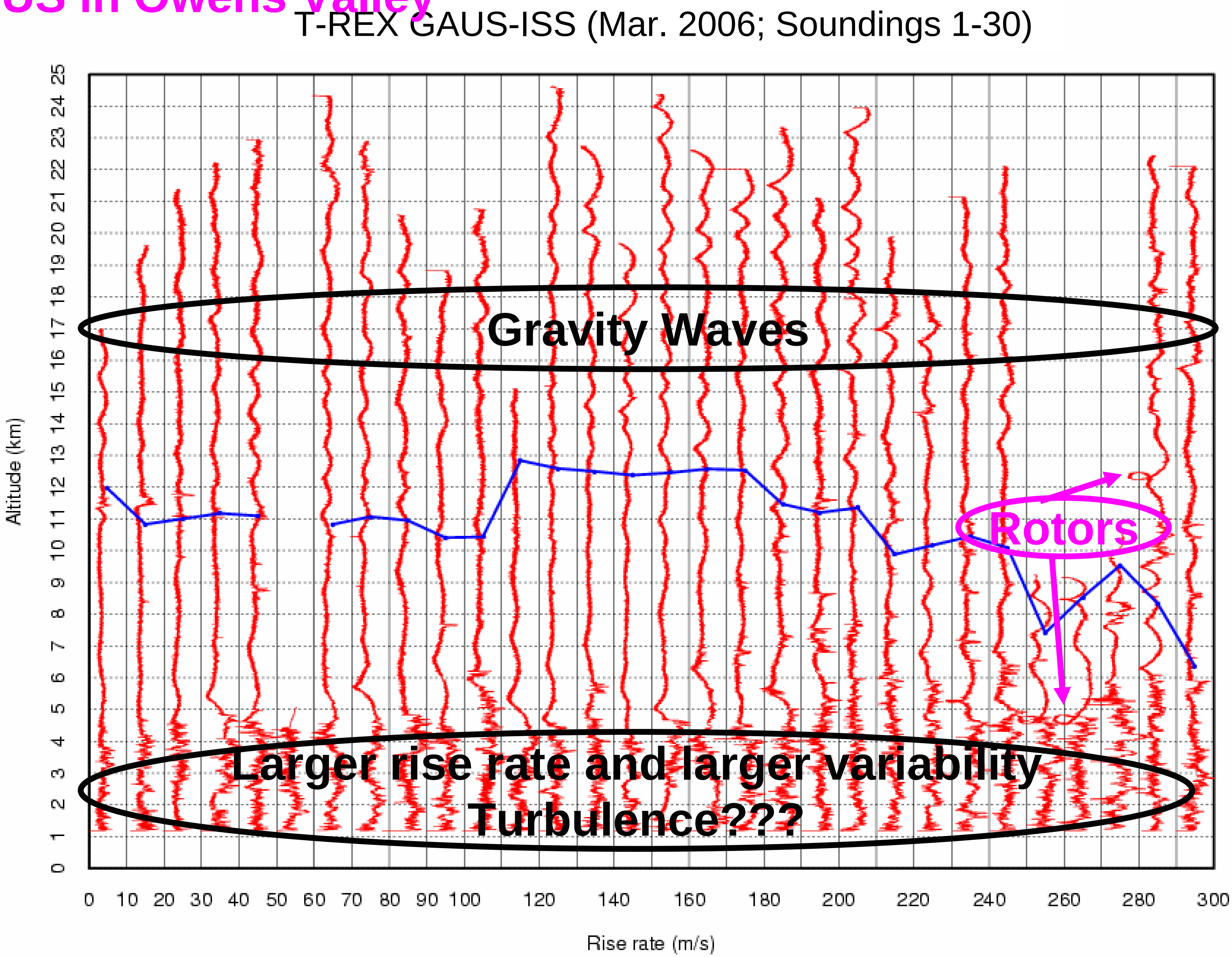
T-REX (Terrain-induced Rotors Experiment) in 2006: Radiosonde Detected Downdrafts



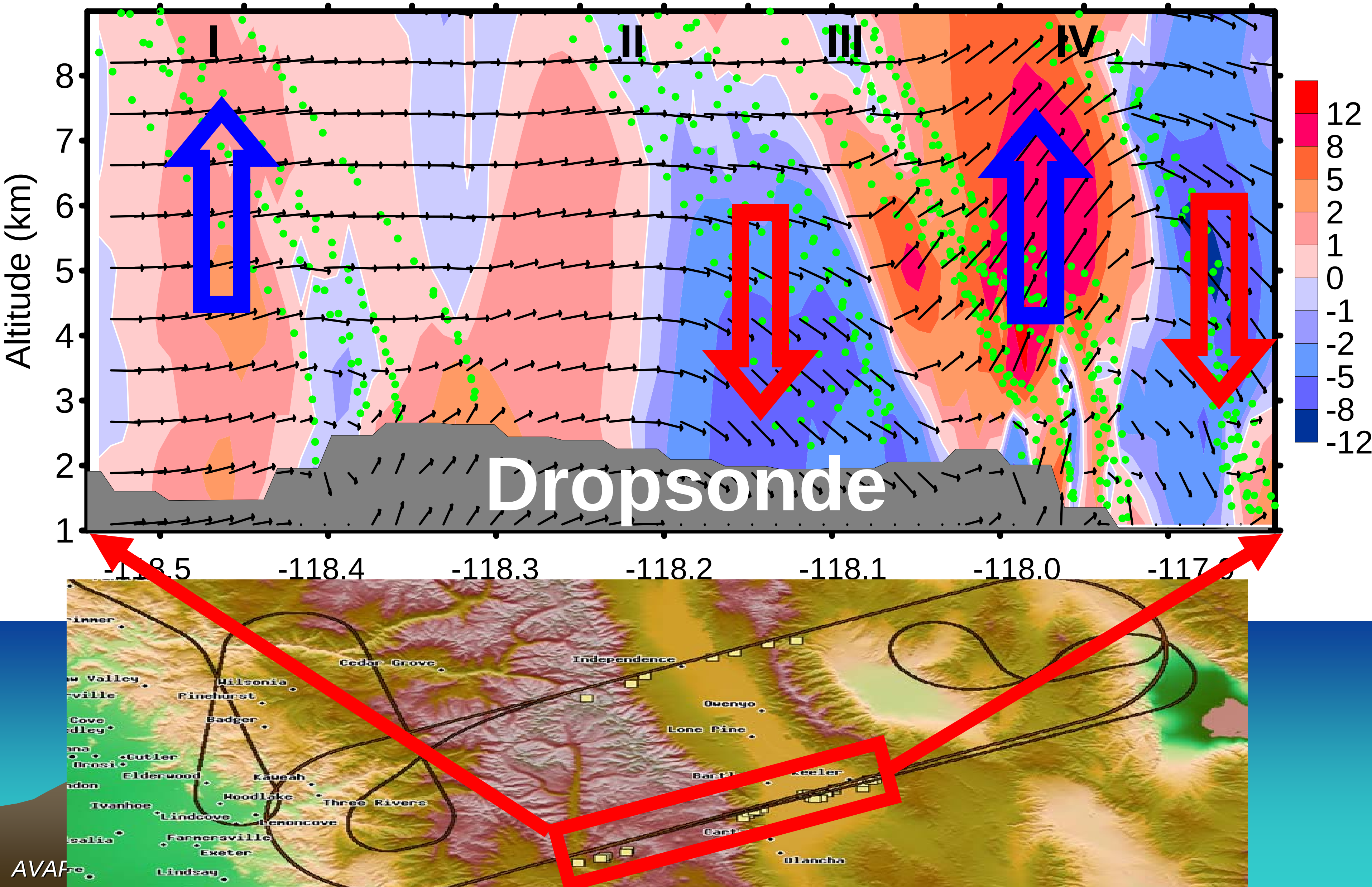
GAUS in Owens Valley



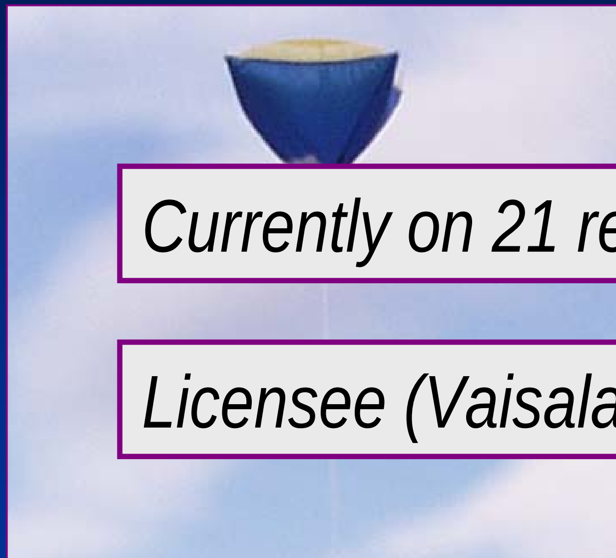
Mountain waves

● : track

Dropsonde 20060416 22:24:37 to 20060417 02:13:34 (36.23N-36.48N)

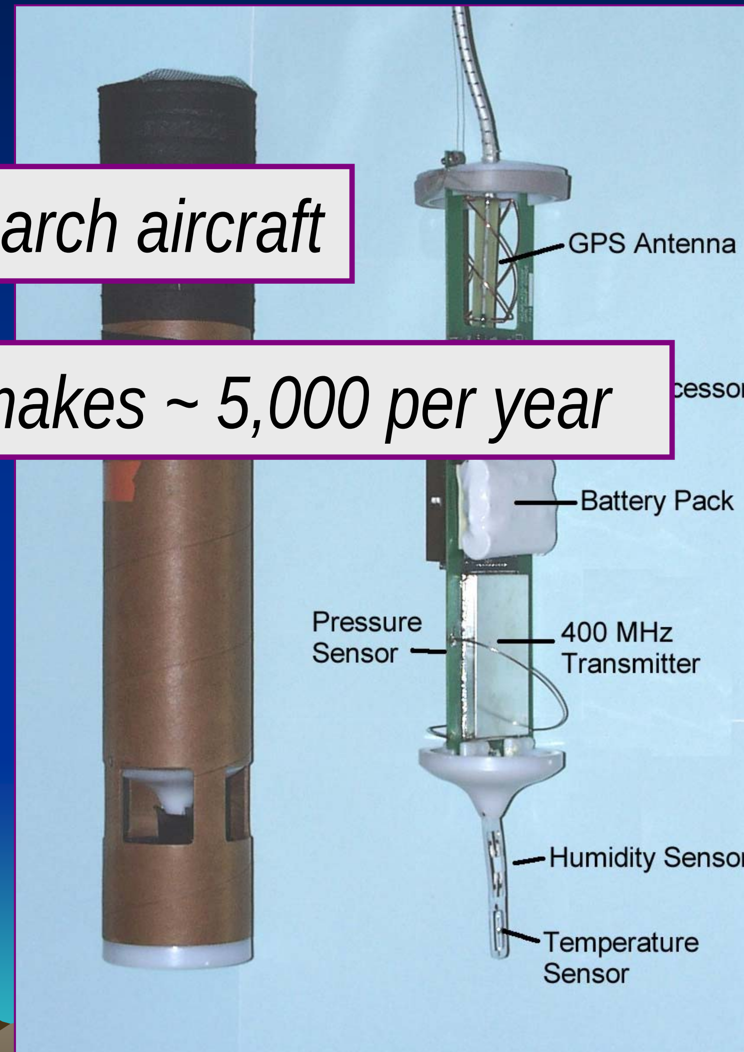


NCAR GPS Dropsonde



Currently on 21 research aircraft

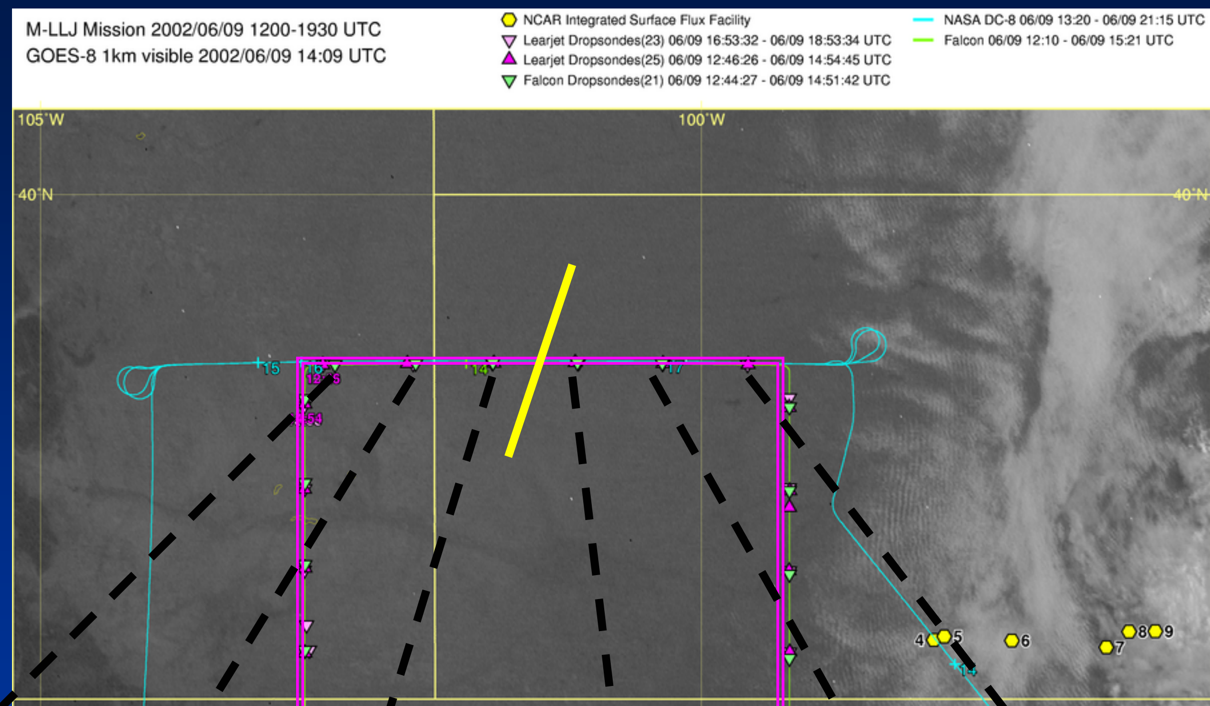
Licensee (Vaisala) makes ~ 5,000 per year

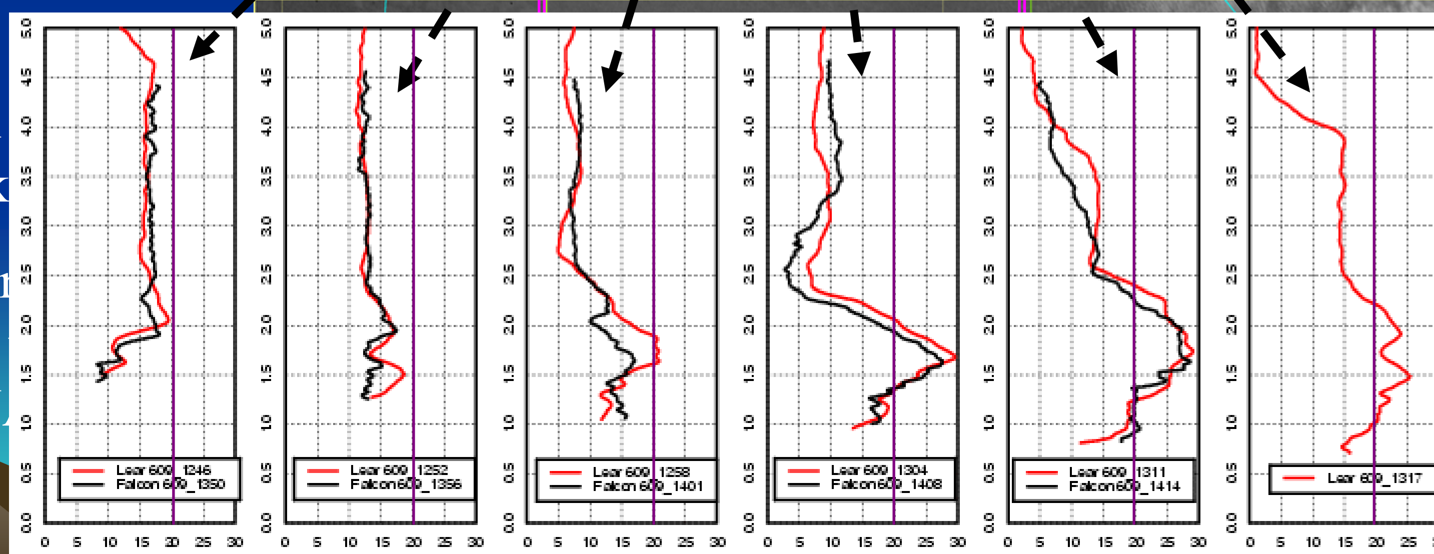


MLLJ on June 9 during IHOP

International H_2O Project
IHOP_2002

1. Box flight path (clockwise)
2. Clear sky in the domain
3. LLJ on the northern leg
4. Lear: 48 (took off from NW corner, ~50 km, two box flights)
5. Falcon: 21 (took SE corner, ~50 k
6. Mapping moistur intercomparison DIAL, LASE, N





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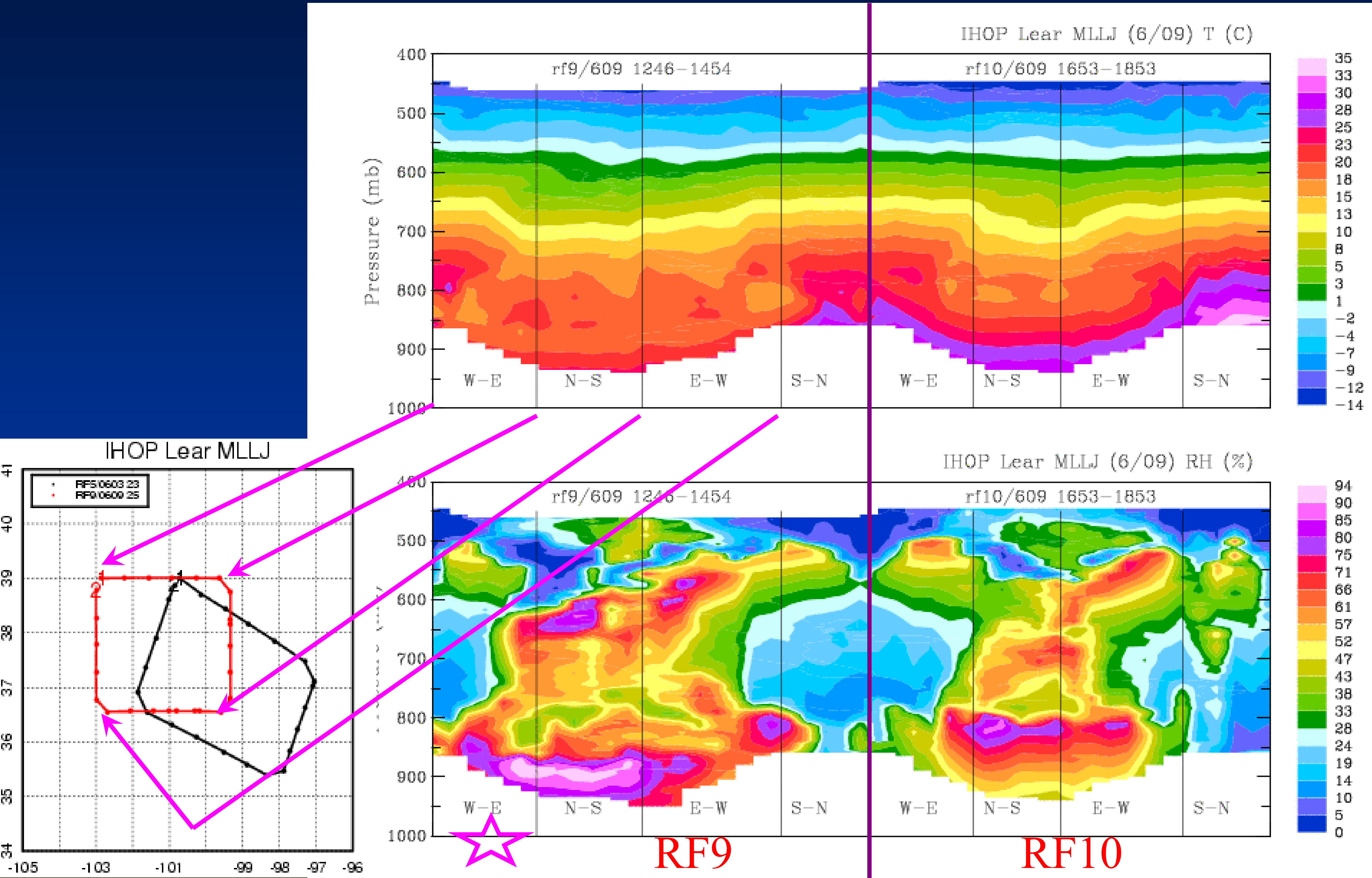
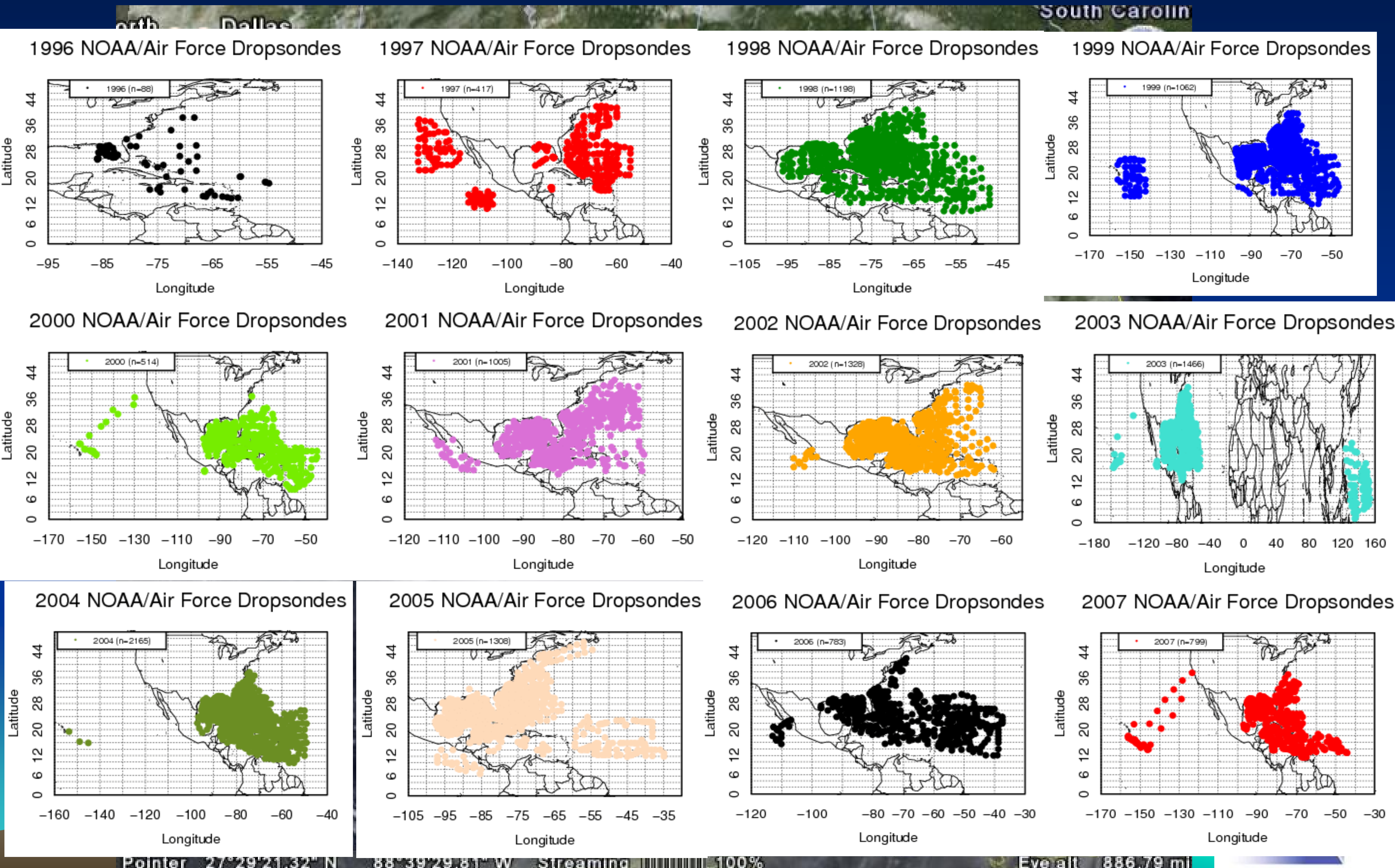
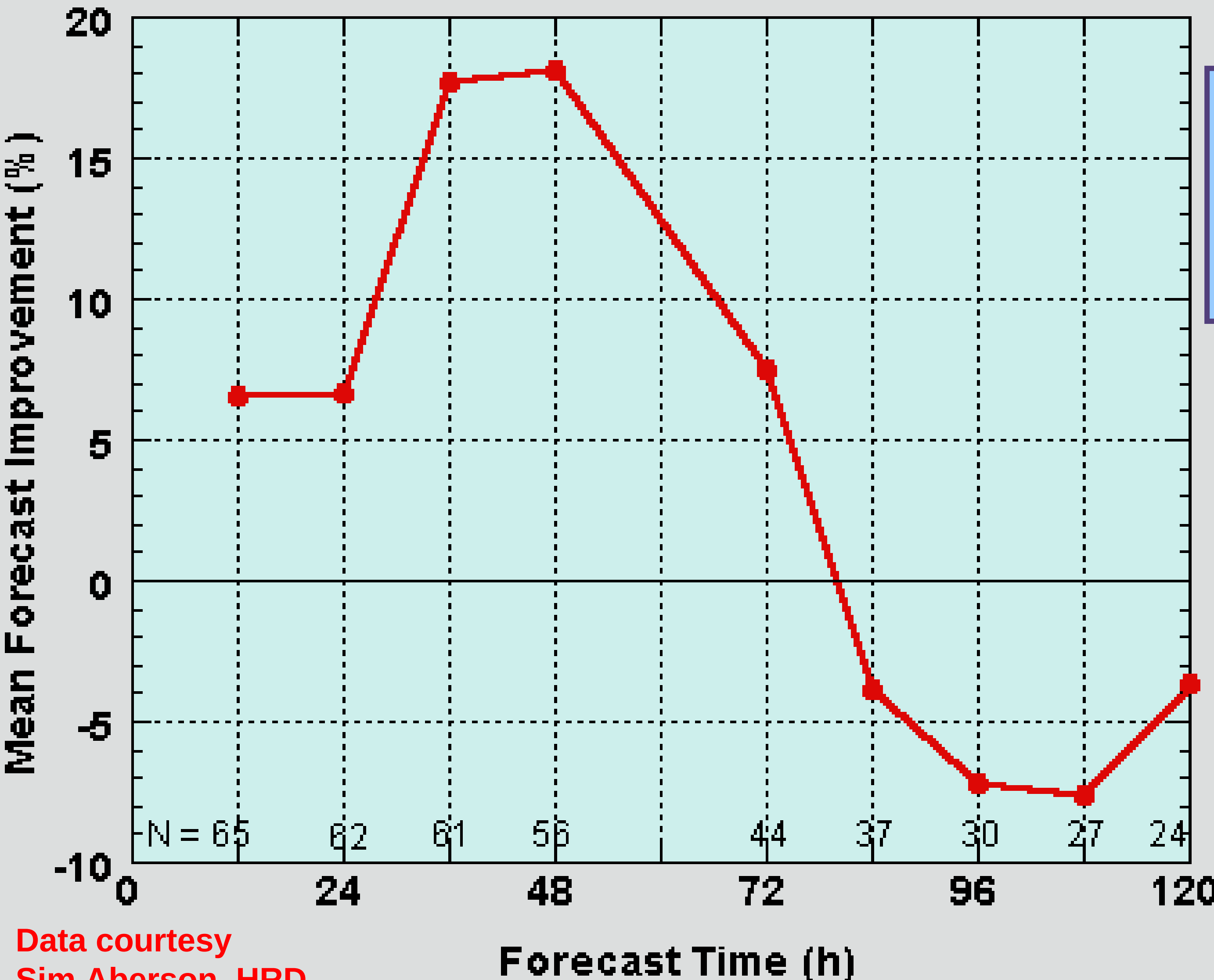
T/RH variations for two Lear box flights June 9



Dropsonde into Hurricanes



Forecast Improvements Due to GPS Dropwindsonde Observations Synoptic Surveillance Missions 1999-2002

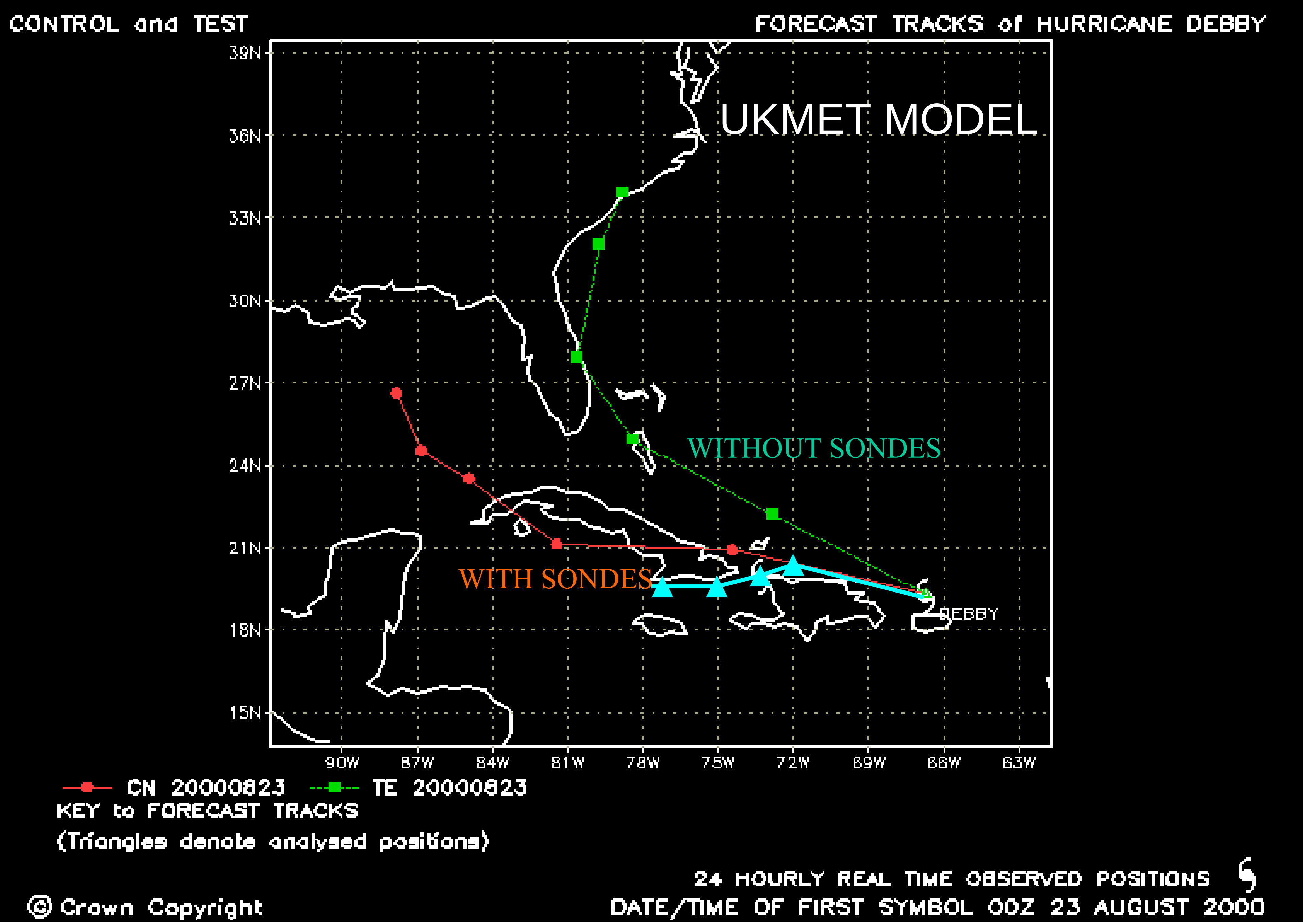


Data courtesy
Sim Aberson, HRD

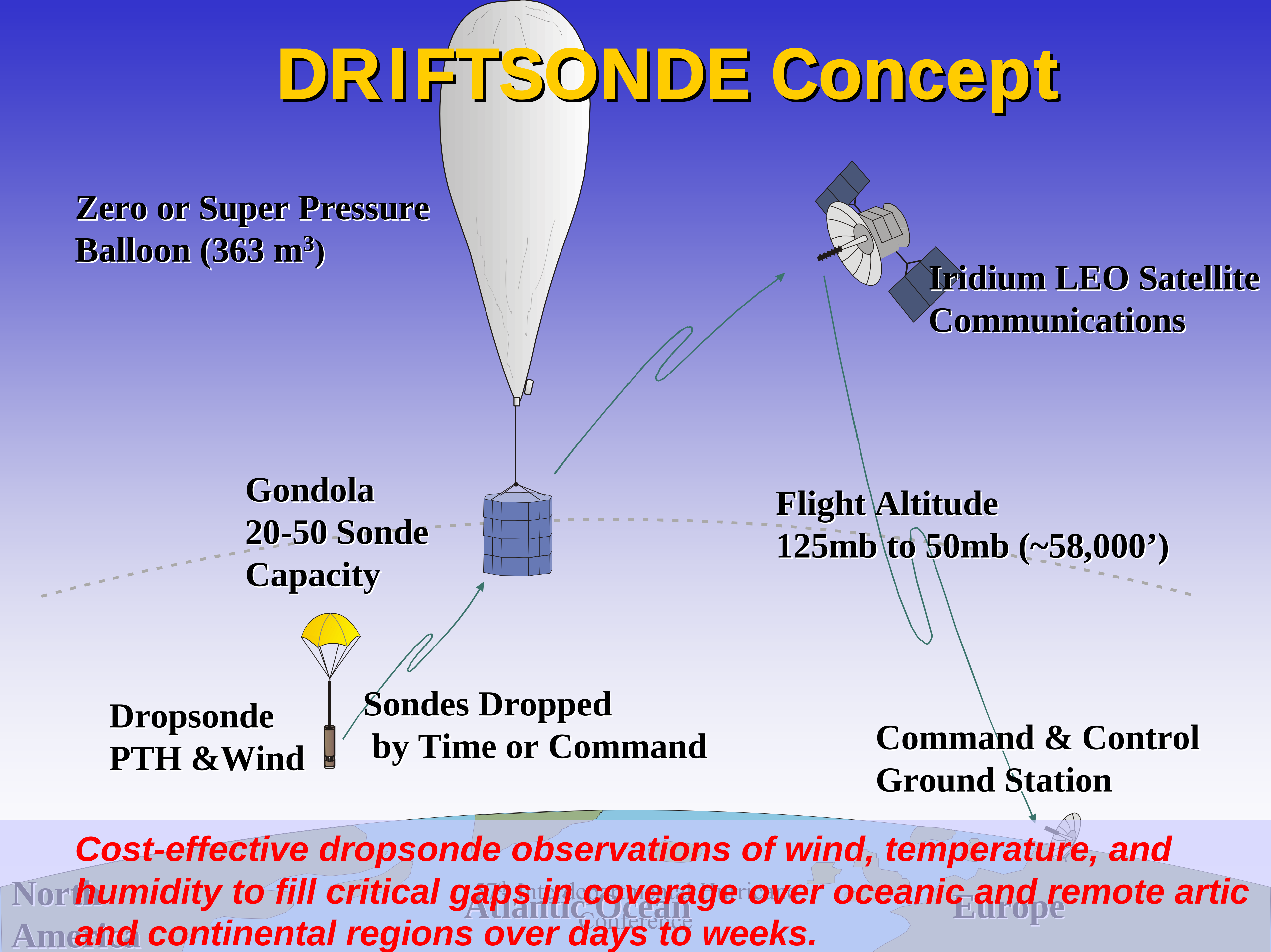
Thanks to

James Franklin,

NOAA/AOML/NHC



James Franklin



DRIFTSONDE Concept
Zero or Super Pressure Balloon (363 m³)
Iridium LEO Satellite Communications
Gondola
20-50 Sonde Capacity
Flight Altitude
125mb to 50mb (~58,000')
Dropsonde
PTH &Wind
Sondes Dropped
by Time or Command
Command & Control
Ground Station
North America
Atlantic Ocean
Europe
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.

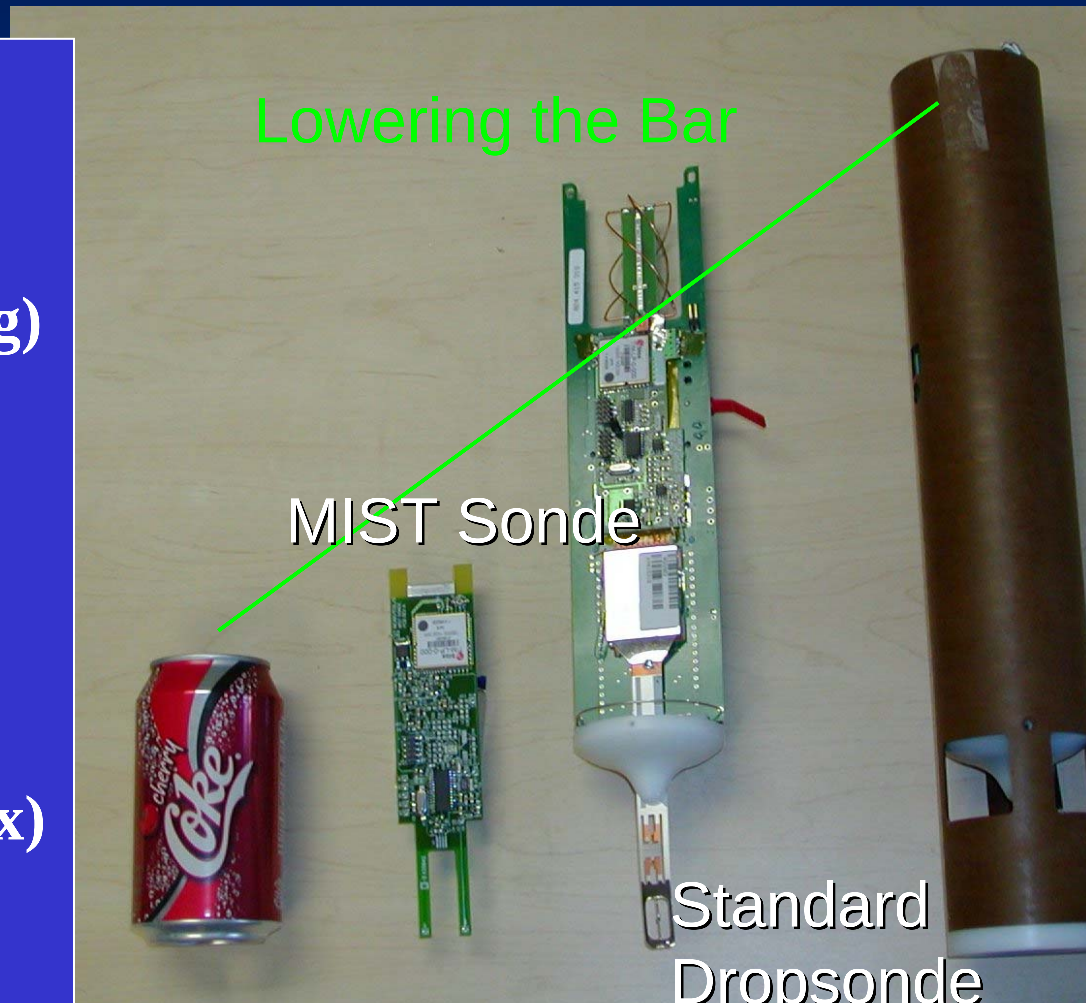
Miniature In-situ Sounding Technology (MIST Sonde)

MIST Sonde

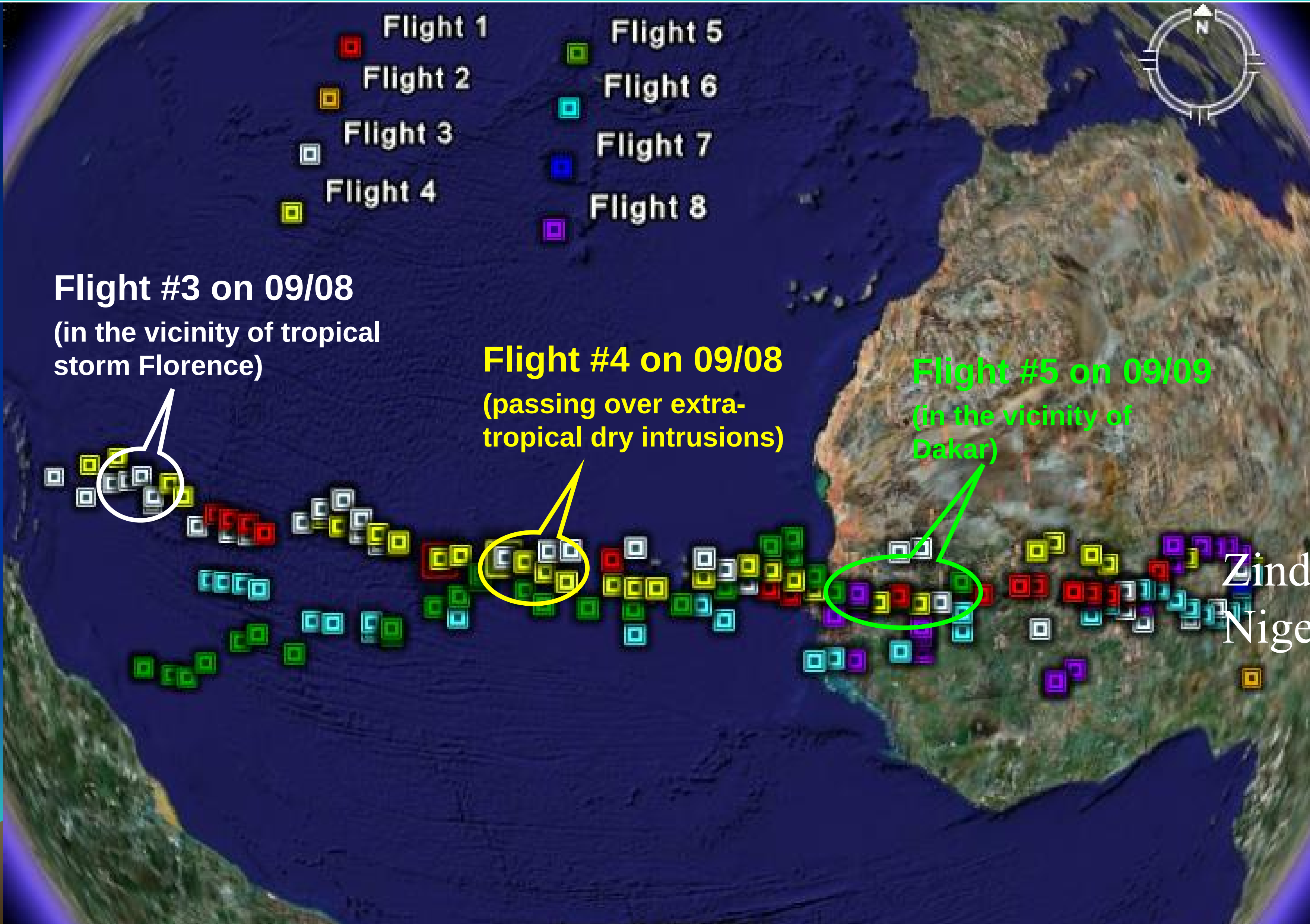
- Small size
- Lightweight (184 g)
- Low cost (compared to a Dropsonde)

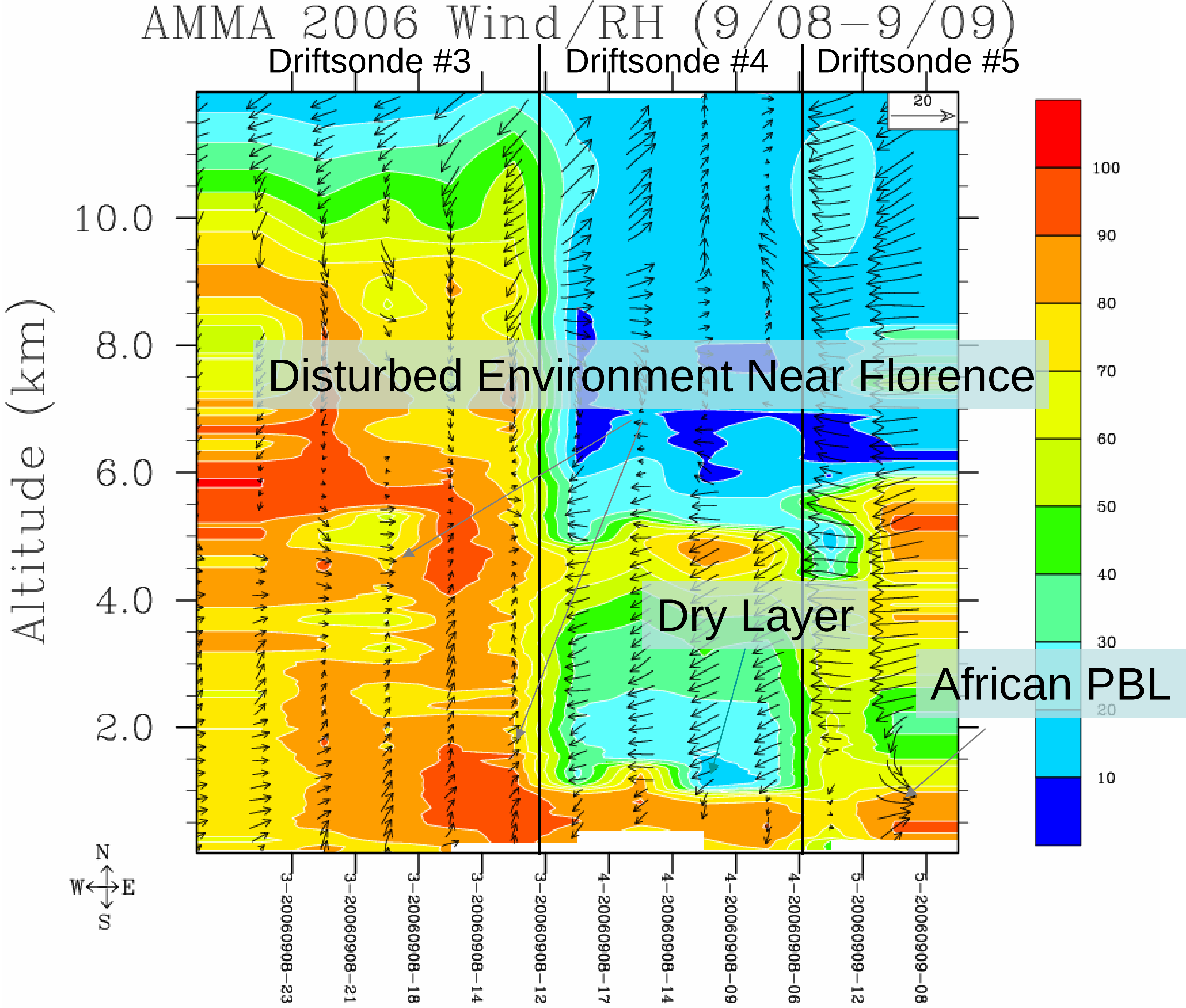
Sensors

- GPS Wind (U-blox)
- Vaisala PTU sensor module



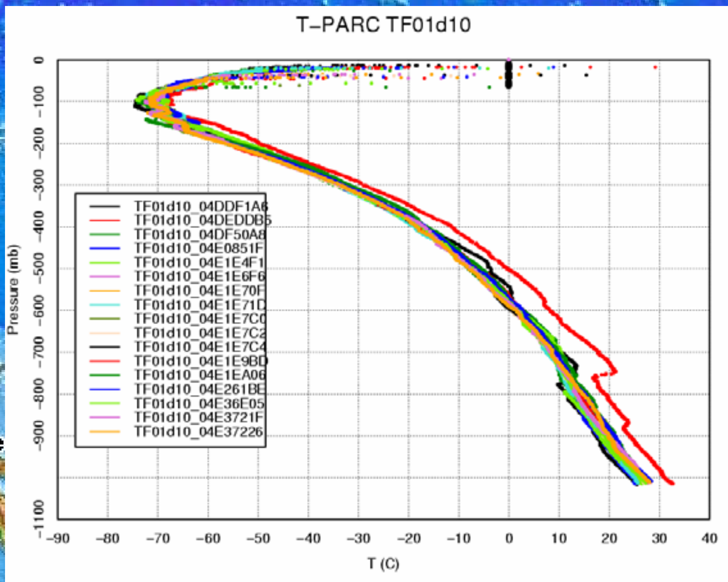
First deployment: African Monsoon Multidisciplinary Analysis (AMMA, Aug.-Oct. 2006)




AMMA 2006 Wind/RH (9/08-9/09)
Driftsonde #3
Driftsonde #4
Driftsonde #5
Altitude (km)
10.0
8.0
6.0
4.0
2.0
Disturbed Environment Near Florence
Dry Layer
African PBL
20
100
90
80
70
60
50
40
30
20
10
N
W
E
S
3-20060908-23
3-20060908-21
3-20060908-18
3-20060908-14
3-20060908-12
4-20060908-17
4-20060908-14
4-20060908-09
4-20060908-06
5-20060909-12
5-20060909-08

Second Development: The THORPEX Pacific Asian Regional Campaign (T-PARC, Aug.-Sept. 2008)

- 16 Balloons Launched (13 Good)
- 339 sounding files
- 268 Good (79%)
- 41 stuck in Gondola (12%)
- 30 terminated before 100 mb (9%)



Resources

1. "Encyclopedia of radiosondes" on http://www.eol.ucar.edu/homes/junhong/Ency-radiosonde.pdf
2. Radiosonde presentation from U.K. Met office on http://www.eol.ucar.edu/homes/junhong/MT11B_radiosondes.pdf
3. "WMO GUIDE TO METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION" on http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html (Chapters #12 and #13)

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