# Climate considerations for Upper Air Reference Network Operating Strategies

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In the WOAP-1 meeting (June 2004), we took action to draft a letter on need to exploit satellite data we already have and continue observational streams on behalf WCRP; it went to **CEOS members** and **GEO co-chairs**. It pointed out and endorsed GCOS IP, and emphasized WCRP needs, GEOSS links. Main points:

1) **ensure the continuity of established capabilities;**
2) **need for continuity and homogeneity of observations for climate purposes;**
3) **need for more attention to data synthesis, reprocessing, analysis and re-analysis of existing data sets; and**
4) **recognition of the need for a complementary in situ observation strategy.**

Done 30 June

Response received 15 August (not satisfactory)

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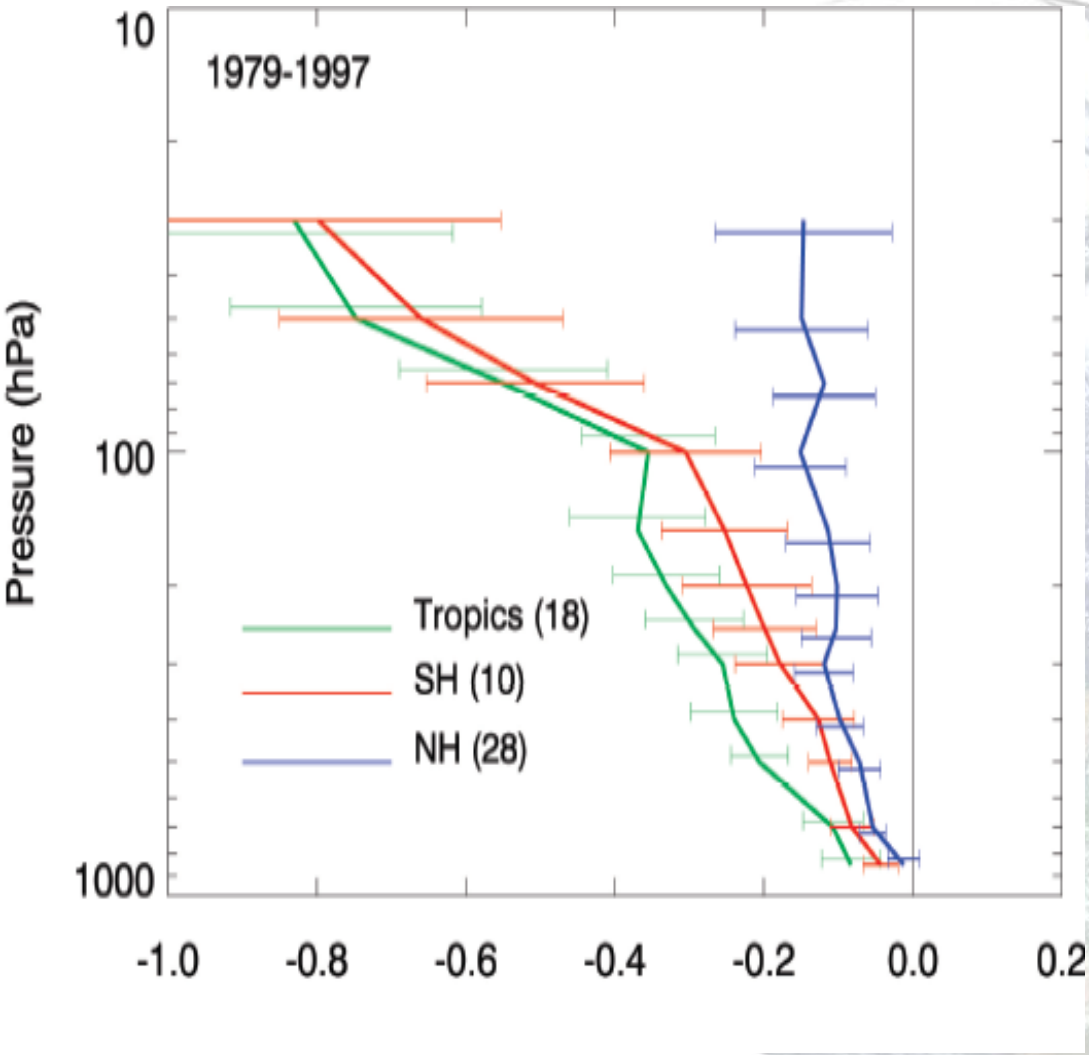
# Radiosondes




**Spurious cooling trends in sondes from reduced daytime heating:**
Trend in $\Delta T$ *(00Z-12Z)* during 1979-1997 at LKS stations.
Tropics (30N-30S),
SH (90S-30S),
NH (30N-90N).
Error bars are 1 sigma sampling uncertainty. Figures in parentheses are number of stations used.

Sherwood et al (2005)

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# Premise: Radiosondes

The main issues with radiosondes are that:

1) They are not sufficiently accurate.
2) They keep changing. At a given station they change type and/or manufacturer. But even the same brand continually changes and evolves.
3) Records of metadata and how the changes have occurred over time are inadequate.
4) Calibration is grossly inadequate.

5) The result has been a fragmented and unreliable record that is of limited value for climate trends.

**Water vapor** is the most important greenhouse gas. Its changes in the upper troposphere are especially important for climate change. Yet such changes are extremely poorly known. Trends in the Boulder record and HALOE disagree.

**There is an urgent need for a true reference sonde network with better temporal sampling than the Boulder record. GUAN has not been working well. Regular radiosondes have not been good enough for climate monitoring.**

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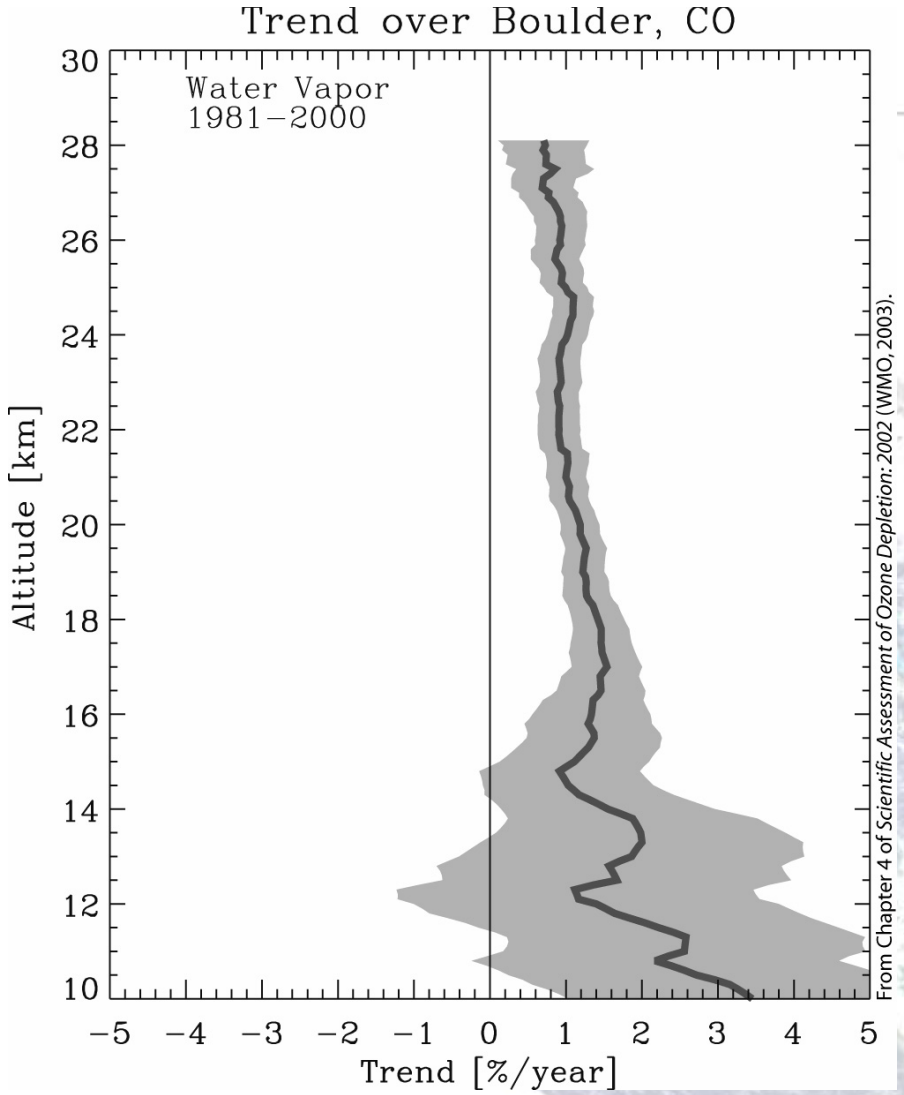


**Water vapor trends** over Boulder CO 1981-2000
% long-term mean
Shaded region is 95% confidence region

Based on balloon-borne frost-point hygrometer flown about 1/month.

**HALOE** satellite occultations for 1991-2000 also show positive trends above 25 km but **not** below. Causes of differences not well understood.

From Scientific Assessment of Ozone Depletion: 2002

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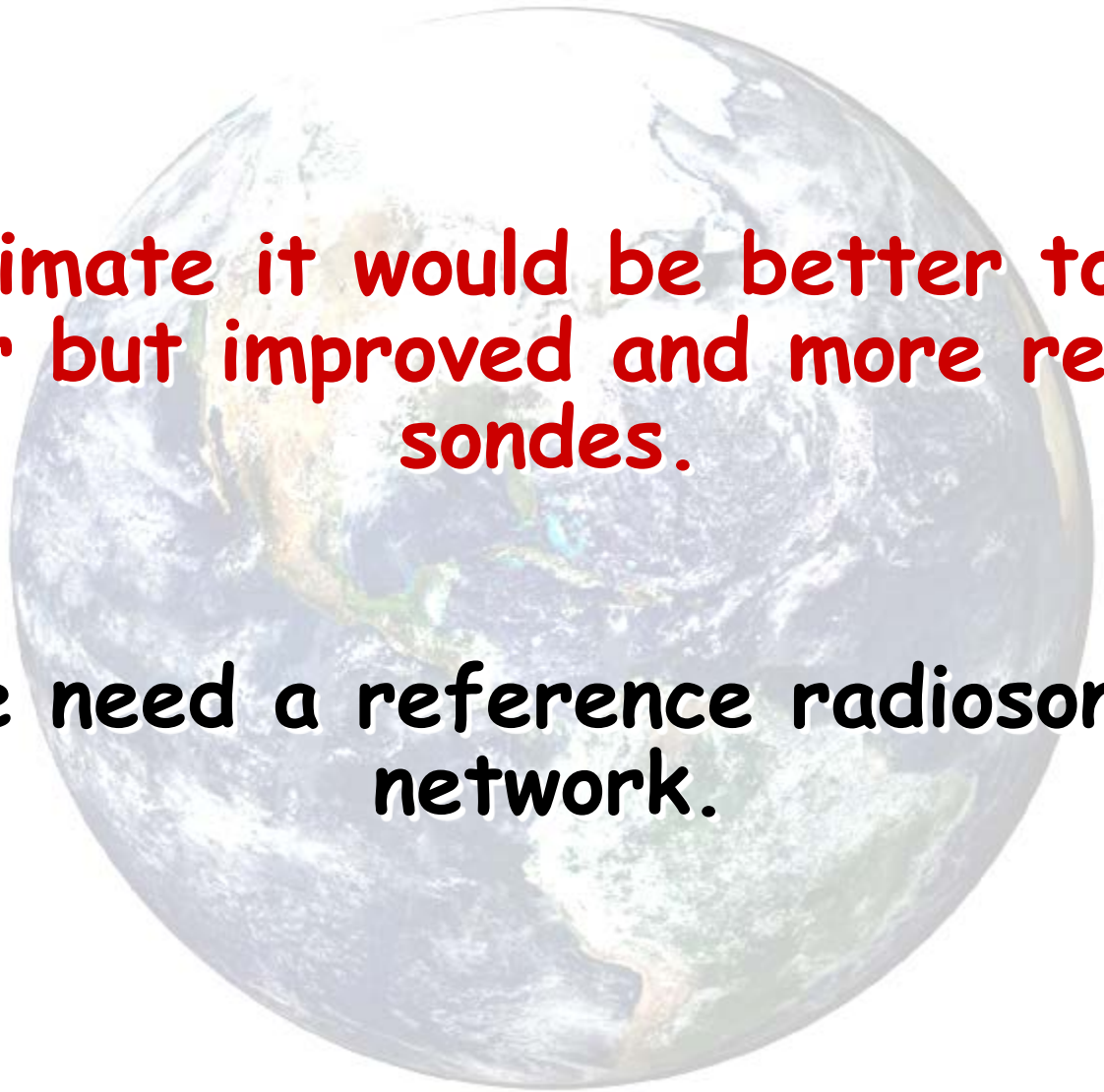

For climate it would be better to have fewer but improved and more reliable sondes.

We need a reference radiosonde network.

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1) Issue of diurnal cycle. Analyses of records should deal with systematic signals and random weather. The annual and diurnal cycles are systematic. The diurnal cycle is part of the issue for relationships of radiosonde soundings with satellite soundings. It may not require soundings co-located in time if the diurnal cycle is properly analyzed.

2) Soundings should be made with the reference sonde to correspond to the de-correlation time of temperature to ensure independent samples. e.g., every 3-4 days. In between, regular sondes can be used to fill in the record.

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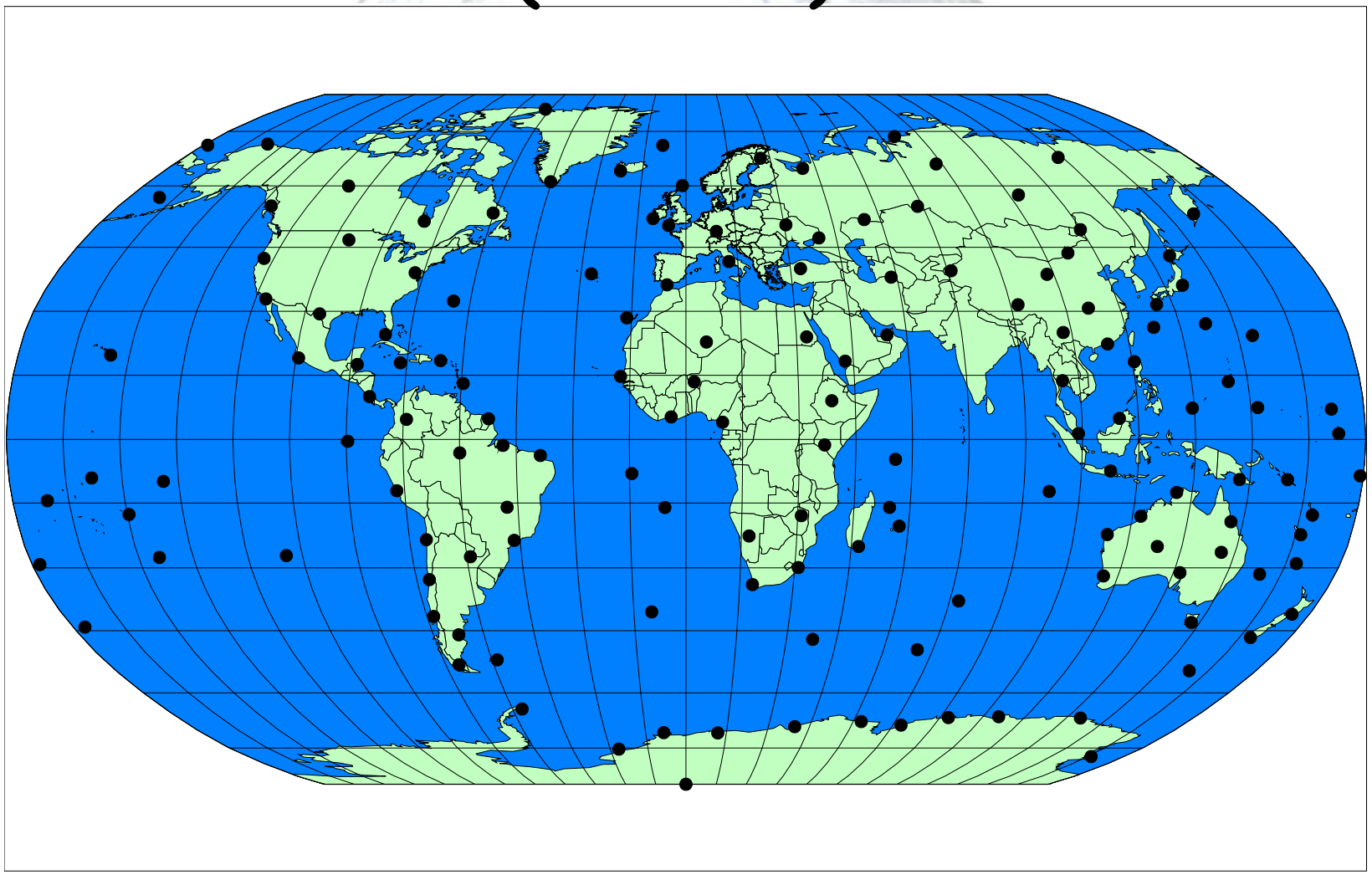
## Premises

1) There will be a network of high quality reference sondes
2) Such soundings are expensive (expendables, and requiring skilled staff).
3) Soundings must be sufficient in number to calibrate other records, but can be used with regular sondes in between times to help address spatial and temporal sampling issues and create a climate data record.
4) Stations must therefore be co-located with those for other purposes (sonde, ozone, GPS, baseline GAW, DOE ARM, BSRN, flux towers, etc)
    1) Is there an inventory of all these and the skill sets of personnel (technicians)?
    2) Is there a plan for consolidation or rationalization for these?

# Global Upper Air Network (GUAN)



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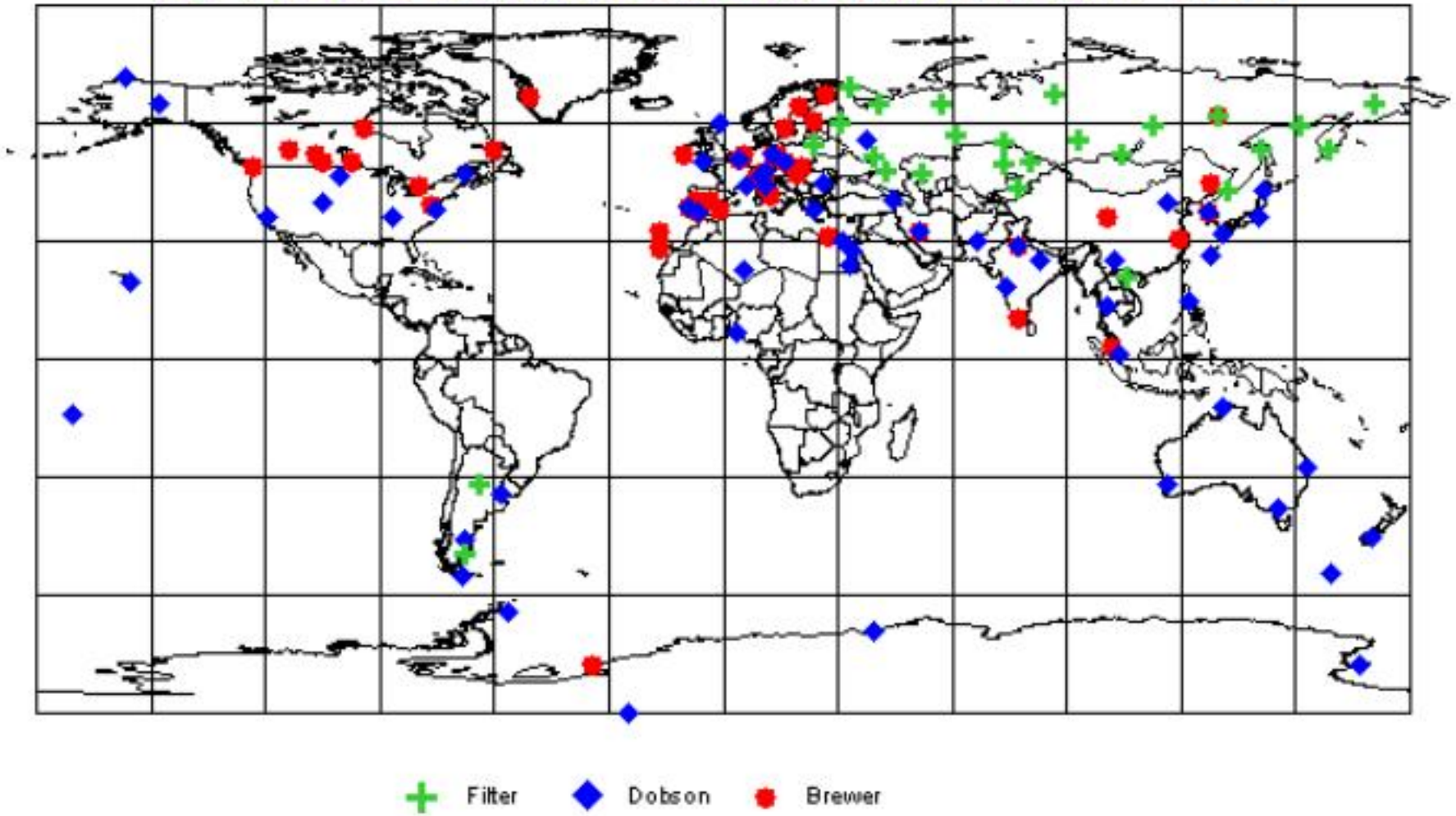
# COLUMN OZONE NETWORK
## IN 2003: Data since at least 1 Jan 1999




Compliments of GAW WOUDC, Toronto, Ed Hare, Manager

# The GAW Global Observatories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## Further Premises

1) GPS **radio occultation (RO)** will become operational. Currently a new 6 satellite array of small receivers has been launched: **COSMIC**
2) Such RO will provide a benchmark that can be used to help calibrate other observations: especially microwave and IR soundings.
3) Above about 6 km RO estimates temperature, but below the signal is mixed with water vapor.
4) RO itself needs to be calibrated initially to ensure contamination from the ionosphere effects, and other issues, including water vapor effects, are dealt with.
5) **Water vapor** will remain an issue, although the developing surface network of GPS used to get column water vapor will help enormously.
6) **A surface GPS receiver must be co-located and planned for with the reference sounding site.**

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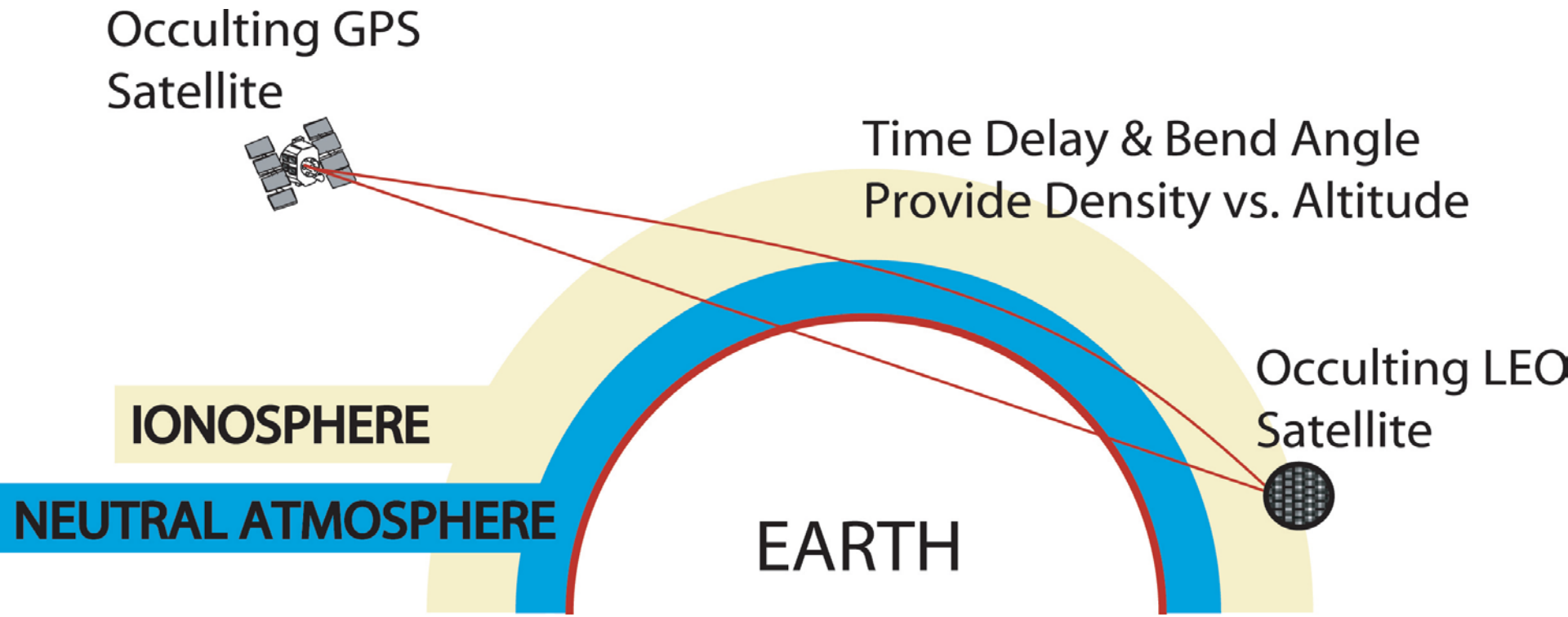
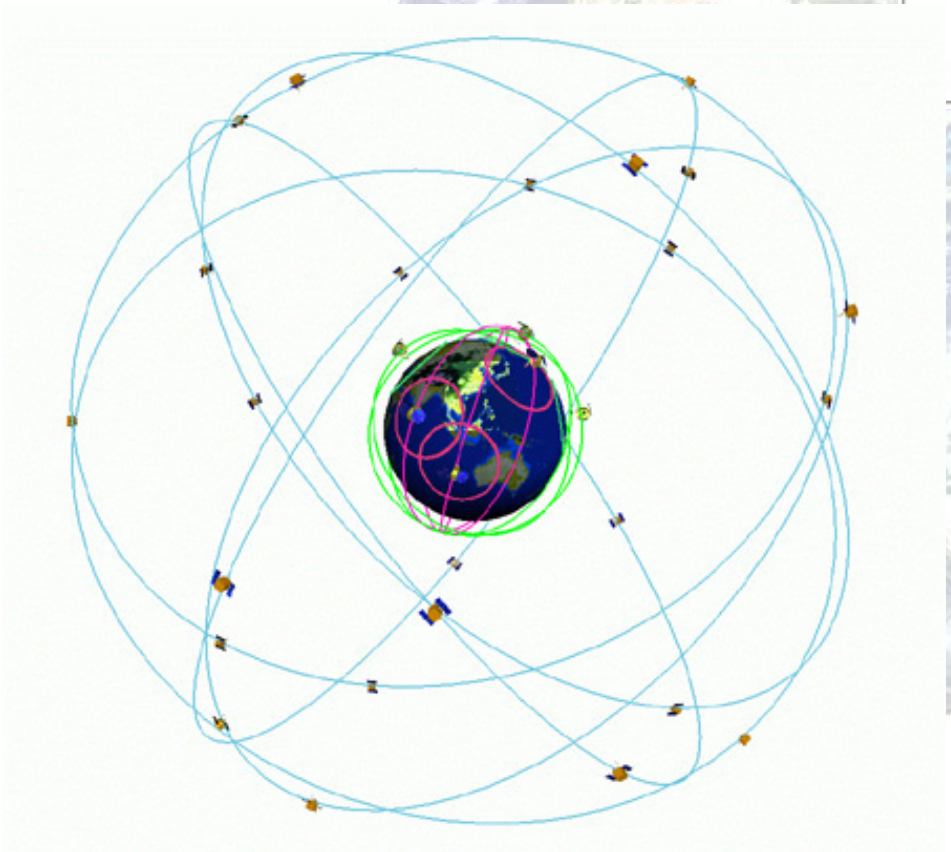
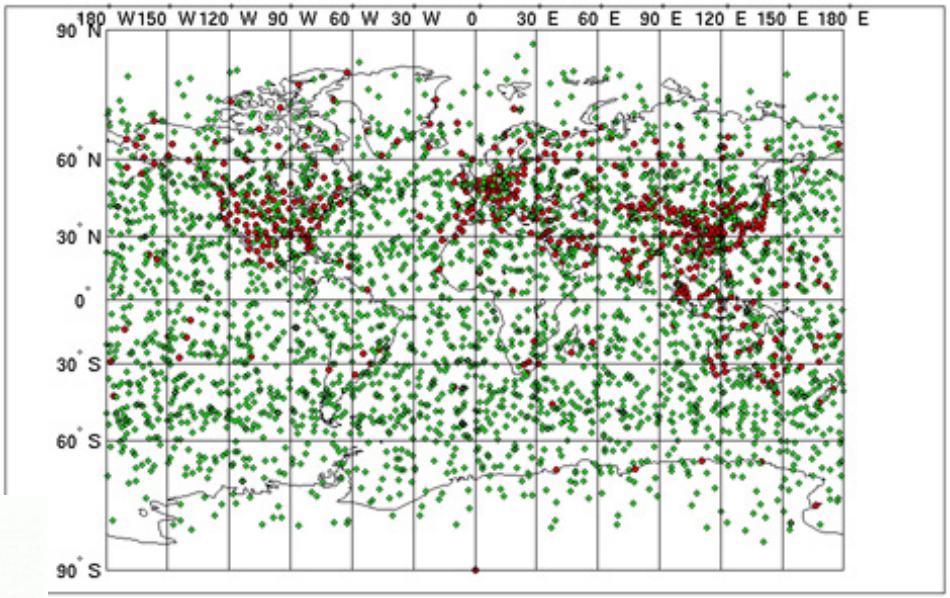



**A COSMIC microsatellite during testing**, with its solar panels open.

Constellation of GPS satellites (outer) and low earth orbiters which use occultation to make soundings as they rise and set.






Current global coverage of instruments launched via radiosondes each day (in red) with the expected coverage from the 6 satellite COSMIC network in a 24-hour period (in green).

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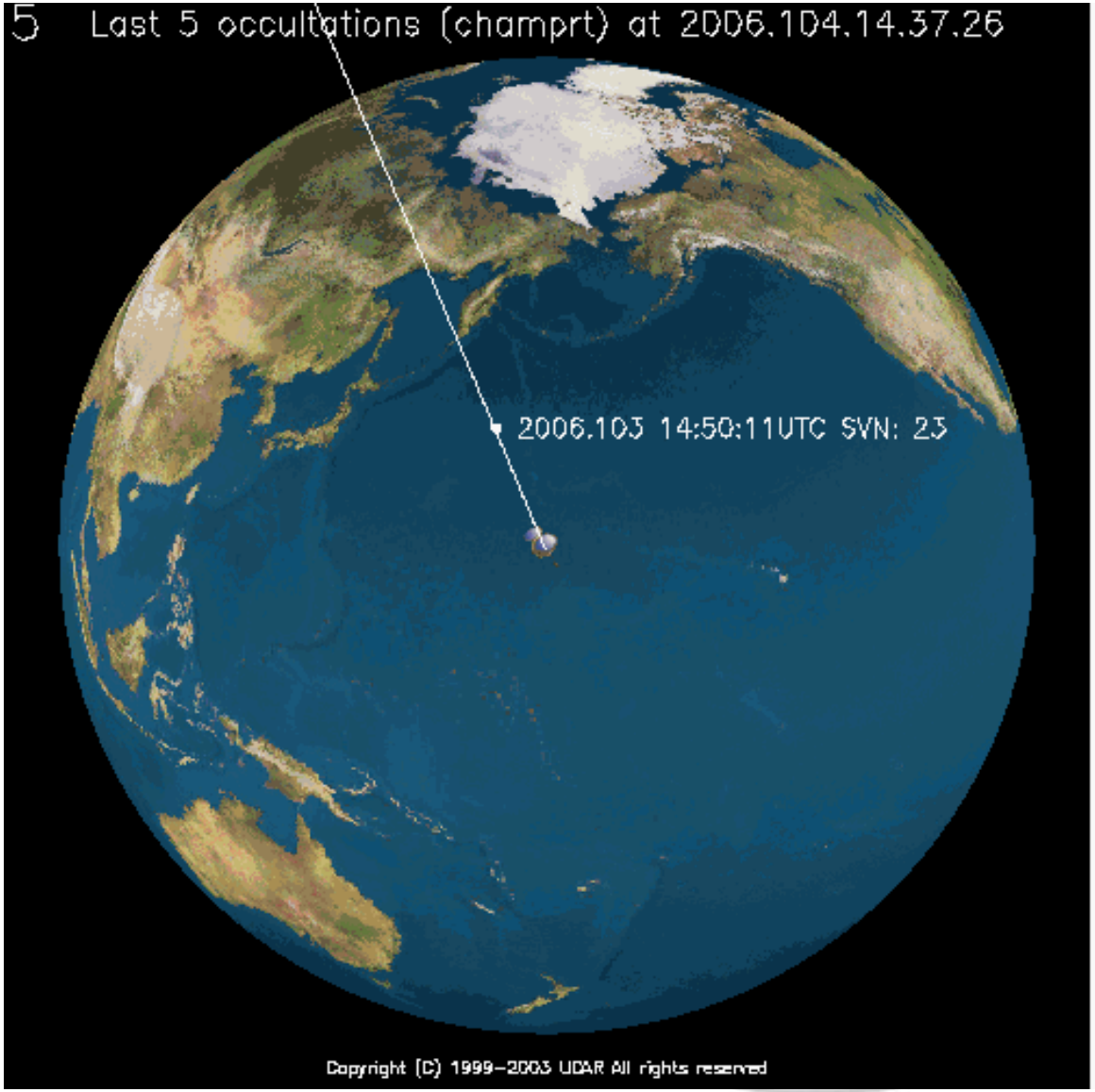
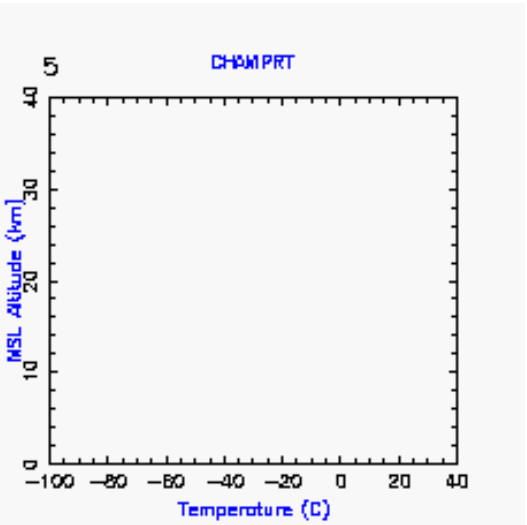
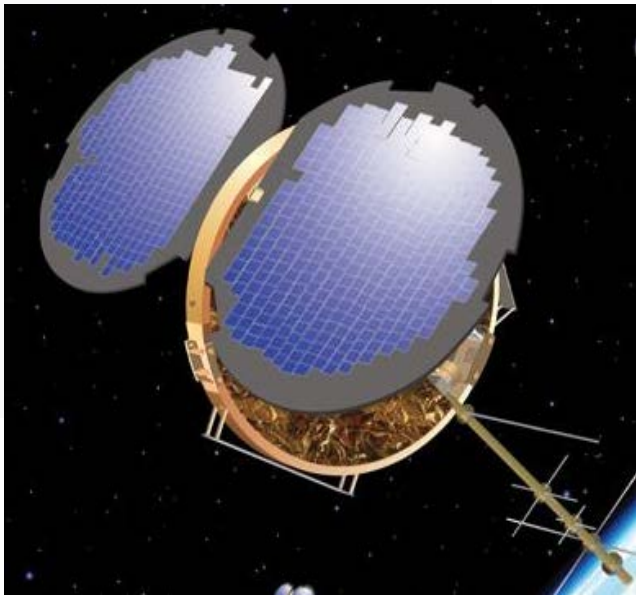

5 Last 5 occultations (champrt) at 2006.104.14.37.26
2006.103 14:50:11UTC SVN: 23
Copyright (C) 1999-2003 UCAR All rights reserved


CHAMPRT
MSL Altitude (km)
Temperature (C)
0
10
20
30
40
-100
-80
-60
-40
-20
0
20
40



Water vapor sampling can also be addressed by GPS **column** measurements and the diurnal cycle is an important issue. Constrains total. Gives full temporal sampling and thus is a nice complement to sondes.

Ware et al 2000

**Atmospheric and Geodetic Installation**

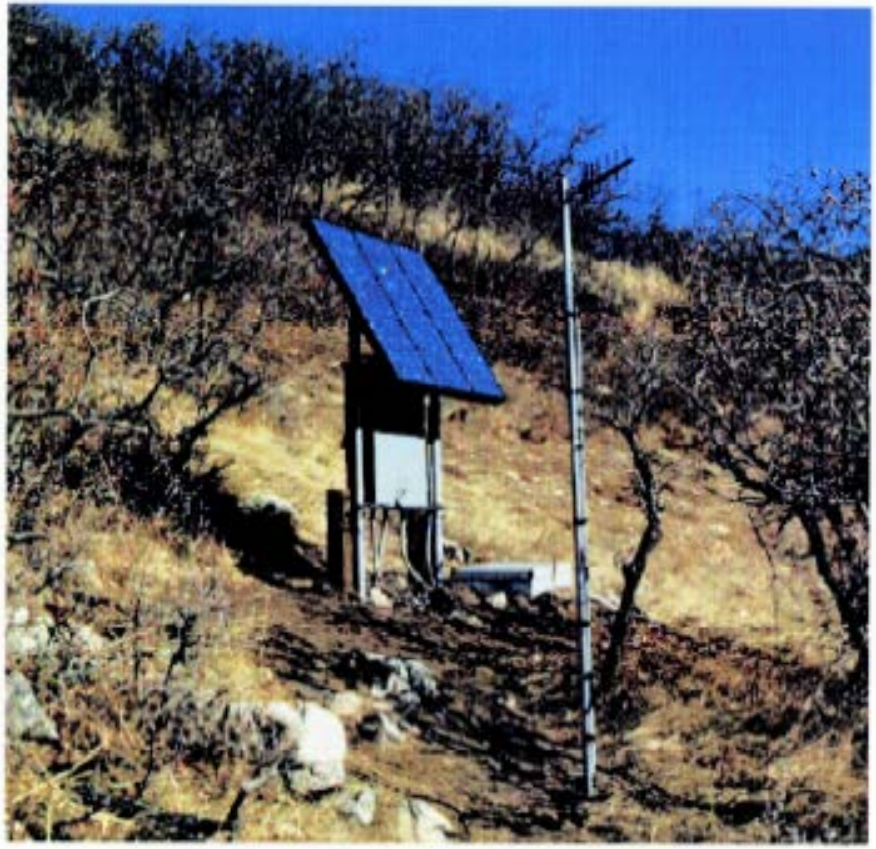


FIG. 12. GPS receiver, solar power, and telemetry equipment (University of Utah).

*Vol. 81, No. 4, April 2000*

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## Other issues:

- Day vs night (diurnal cycle)
- Maritime vs continental
- Tropics vs mid-latitude vs polar
- Need for skilled technicians
- Need real commitment from host nations (funding)

Based on GUAN experience, what countries are reliable? Should the network state with the developed countries only?

US: South Pole, McMurdo, Apia, Guam, Alaska, Hawaii, mainland US, etc)

Australia, New Zealand, Europe, Japan, Canada…

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# What about recovery of sondes?

Since these may cost >>$1000 each, should they be made so that they become floats on the ocean; continuing to broadcast SST and position to:

1) Give position for recovery

2) Give useful information on SST

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## A vision for the future:

- ✓ Few regular radiosonde stations
- ✓ GPS RO for temperatures above 500 mb
- ✓ IR and microwave soundings (T and water vapor)
- ✓ Winds from AMDAR, profilers
- ✓ Ground based GPS column water vapor network continuous in time
- ✓ Sparse network of "reference sondes" for satellite calibration and climate monitoring, and UT water vapor
- ✓ Co-locate new sondes with regular sonde sites to replace them at appropriate times
- ✓ Integrate with ozone sondes and/or GAW?

**Recommendation: Establish a new global baseline network of "reference" radiosondes**

From Trenberth 2002.

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