Satellite Upper Air Network (SUAN) and the Climate Retrieval Problem

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What is the Mission of the Radiosondes ?

(*Past vs Present vs Future*)

Is There an Optimal Sampling Strategy ?

(*Synoptic vs Satellite Coincident vs ???*)

Satellite Upper Air Network (SUAN)

- Global network of radiosonde sites providing ***"standard"*** measurements coincident with NOAA polar satellite overpass

- SUAN Report (Reale and Thorne)
  - "http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes/suan"

History

- **UKMO Workshop on Vertical Temperature Trends (September, 2004)**
- **WMO/AOPC (Geneva, April, 2004)**
  - *Subset of GUAN … "supersites"*
- **International ATOVS Study Conference (November, 2003)**
  - *Recommendation to pursue deployment through WMO Document*
- **White Paper: Creating Climate Data Records from NOAA Operational Satellites (August, 2003). (Goldberg and Bates)**
  - *Section 4.2.1, Observing System Performance Monitoring (visit ITSC web page:* http://cimss.ssec.wisc.edu/itwg/)
- **Workshop to Improve Usefulness of Radiosondes (March, 2003)**
  - *formal "unveiling" of SUAN, underlying concepts and evolving compensatory roles of global radiosondes and polar satellites to serve as transfer standards …*
- **NOAA Council on Long-Term Climate Monitoring (Jan., 2003)**
  - *includes specific recommendations for "integrated global observing systems which include reference radiosonde and overflying satellite observations … **with goal of accurate, long term monirtoring of global temperature and moisture …***

CANDIDATE SITE SELECTION

- Subset of GUAN (150) … "*super-sites*"
  - Active and Reliable (Green, Blue, Red)
    (*UKMO, w/McCarthy; NESDIS, w/Tilley*)
  - Global/Robust
  - Low terrain (500m; 950mb)
  - Non-coastal

- *ARM Sites* (Black)

- ***SHIPS***

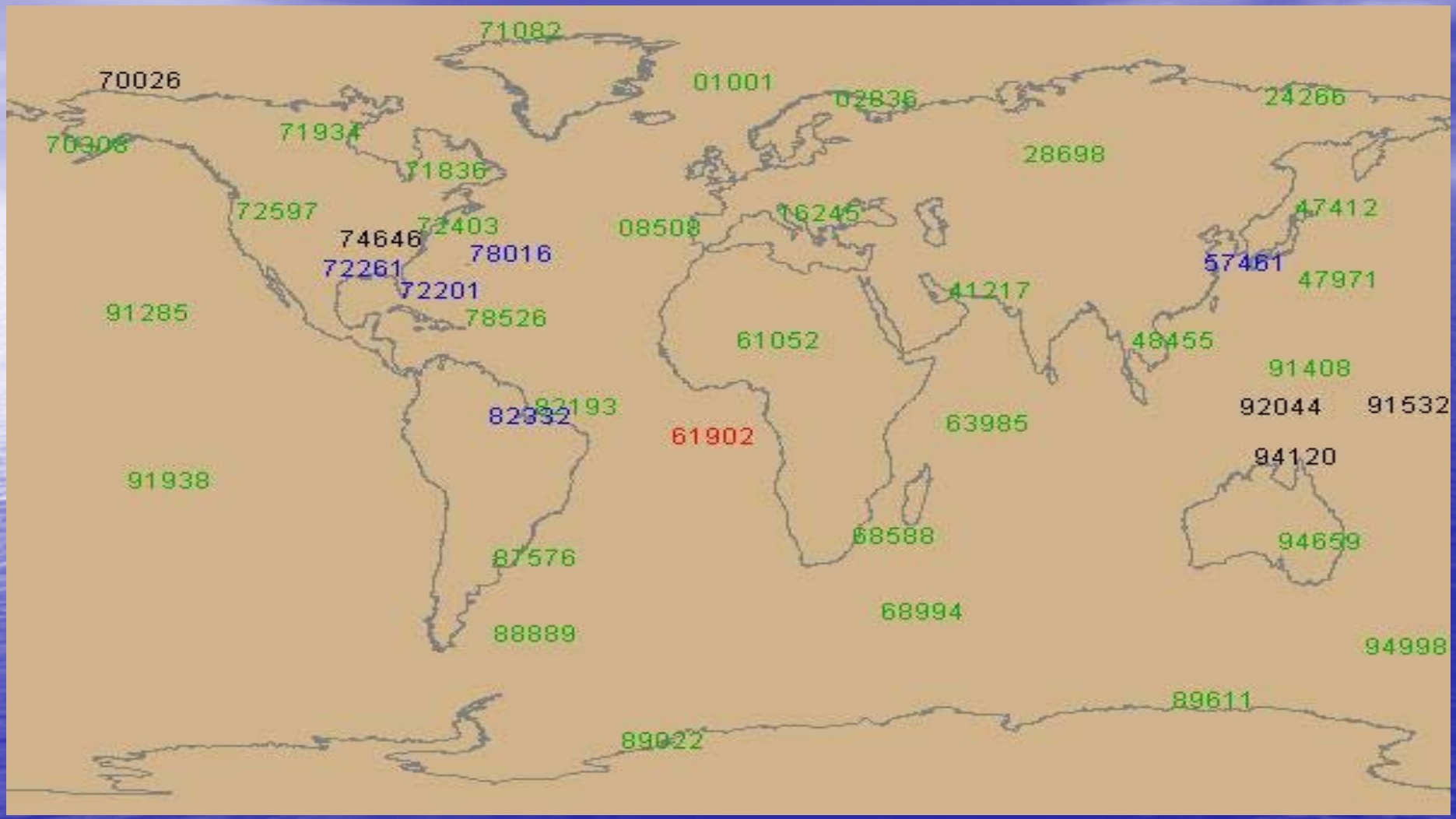
ID	T	Lat	Long	Z	UKMO		NES(D)	NES(A)		Alternates
01001	S	70.9	-8.7	10	100	G	14/14	11/13		03005
02836	L	67.4	26.6	179	92	G	14/14	12/13		22550
08508	S	38.7	-27.1	113	98	G	7/8	12/12		60018
16245	L	41.7	12.4	32	95	G	25/25	27/27		08495, 11035
24266	L	67.6	133.4	138	90	G	7/7	6/7		
28698	L	54.9	73.4	90	100	G	14/14	13/13		23472
41217	L	24.4	54.7	27	100	G	13/13	9/10		62414
47412	S	43.1	141.3	19	100	G	14/14	13/13		32540
47971	S	27.1	142.2	8	97	B	14/15	13/13		47936, 47991
48455	L	13.7	100.6	20	93	G	6/6	7/7		45004
57461	L	30.7	111.3	134	45	P	12/14	13/14	*	50527
61052	L	13.5	2.2	227	78	P	11/13	13/13		61641, 64910*
61902	S	-8.0	-14.4	75	0	R	3/4	3/3	**	68906, 61901**
63985	S	-4.9	54.5	4	72	P	13/13	11/11		96996
68588	L	-30.0	31.0	0	92	B	14/14	13/13		68816
68994	S	-46.9	37.9	0	93	B	14/15	12/12		61998, 61996
70026##	I	71.3	-156.8	4	63	P	9/10	13/13	*	
71082	I	82.5	-62.3	66	90	G	14/14	13/13		
70308 #	S	57.1	-170.2	9	100	G	14/14	13/13		
71836	L	51.2	-80.7	10	88	P	14/14	12/13		71816
71934	L	60.0	-111.9	205	88	P	14/14	13/13		72764 #
72201 #	S	24.6	-81.1	6	63	P	14/14	13/13	*	
72261 #	L	29.4	-100.9	313	63	P	14/14	13/13	*	
72403 #	L	39.0	-77.5	98	93	G	13/14	13/13		
72597 #	L	42.4	-122.9	405	100	G	14/14	13/13		
74646 #	L	36.4	-97.3							
78016	S	32.4	-64.7	6	0	R	14/14	17/17	*	
78526#	S	18.4	-66.0	19	98	G	14/14	12/13		78583*, 78954*
82193	S	-1.4	-48.5	16	87	P	4/8	9//9		81405*, 82397*
82332	L	-3.2	-60.0	84	87	R	4/4	5/5	*	85442
87576	L	-34.8	-58.5	20	93	G	6/7	4/4		85586, 85799
88889	S	-51.8	-58.5	73	73	P	13/14	13/13		85934
89022	I	-75.5	-26.7	30	95	G	6/7	6/6		89002
89611	I	-66.3	110.5	42	98	G	10/10	13/13		89592
91285 #	S	19.7	-155.1	11	100	G	14/14	13/13		
91408 #	S	7.3	134.5	33	98	G	14/15	13/13		91334#
91532 #	S	-0.5	166.9							
91938	S	-17.6	-149.6	2	100	G	12/12	12/13		91592, 91958
92044 #	S	-2.1	147.4							
94120 #	S	-12.4	130.9	30	98	G	14/14	13/13		
94659	L	-31.1	136.8	167	98	G	13/14	12/12		
94998	S	-54.5	159.0	8	98	G	12/14	13/13		

# indicates current NWS sites (11)

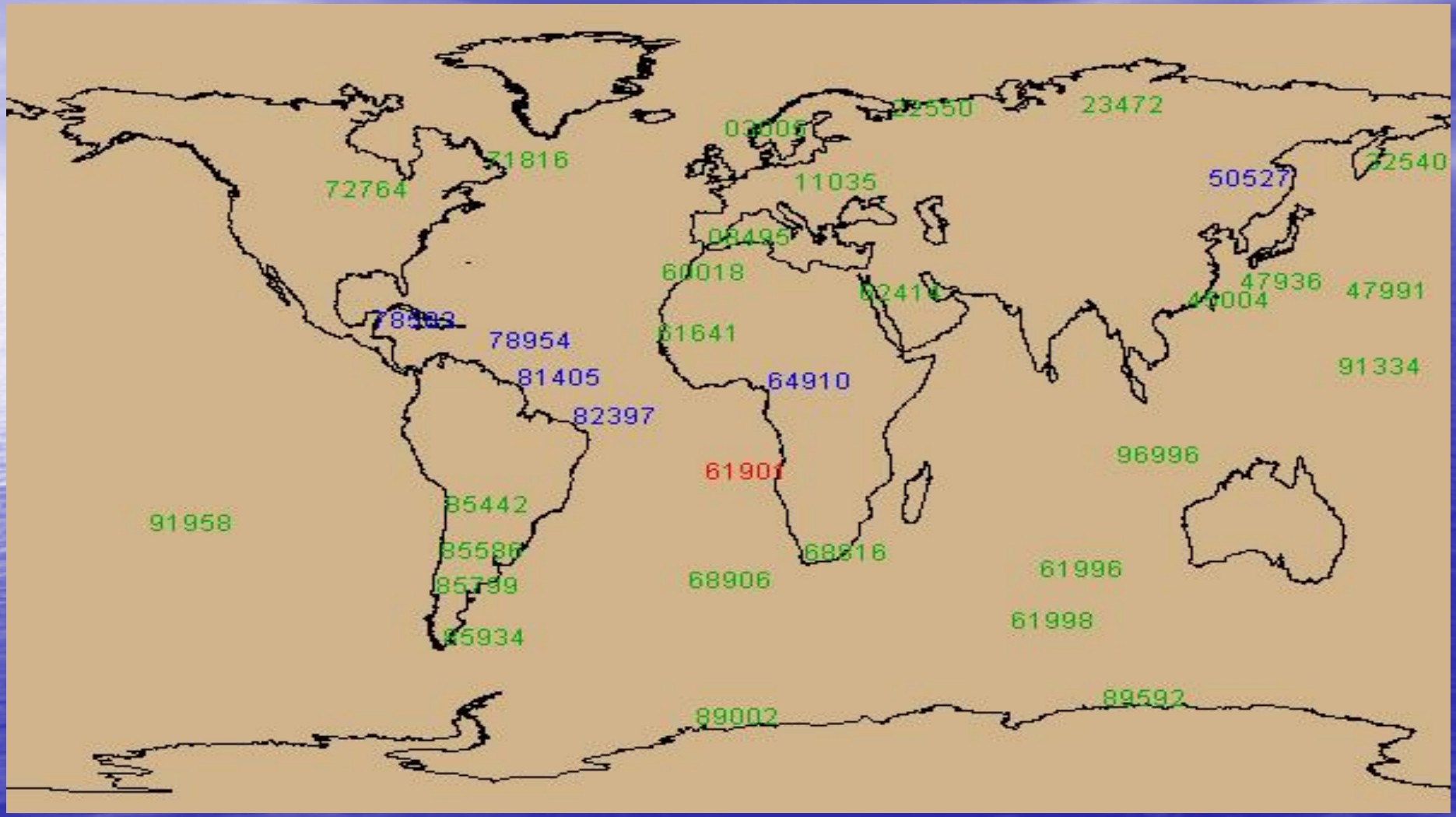
ARM sites (5)

20 Sea
18 Land
4 Sea-Ice

Primary SUAN Candidates



Alternate SUAN Sites



Super-Sites

WMO/AOPC in April 2004 :

- Standard Reference Sondes
  - Temperature, *moisture, w*ind, surface …
  - 5 mb
- Ground Measurements
  - Lidars, GPS, clouds, surface …
- R & D
  - dual launches …

Program To Include:

- Generation and Distribution of Launch Schedules (...45 minutes before overpass)
  - Fixed sites
  - Ships
- Metadata Records ... corrections, site protocols ...
- Network Performance Monitoring/Feedback
- International Coordination ... WMO

Program (continued):

- Integration into NESDIS Operational Sounding Product Systems (ATOVS, METOP, NPP, NPOESS ...)
- Relational Collocation File Structure (Raobs, raw satellite, level 1 ...)
- Open to Expansion, i.e., other satellites (i.e., GPS ...) and data (i.e., Ground, ACARS, Dropsondes ...)
- Accessible Archive (Data, Software readers) ... Web-based ?
- ***R & D Impact ...***

How Many Observations

- 40 sites (not including Alternates and Ships)
- ***One launch per day! ...*** *(minimal requirement)*
- 2 (or 3) operational (NOAA and METOP ...) satellites
  - 15 (or 10) observations per satellite, per site, per month
  - ***over 600 (or 400)*** observations globally, per satellite, per month
  - ***over 6000 (or 4000)*** observations globally, per satellite, per year
- ***COST:***
  - **$ 5 million** (... @ $300 per sonde)

SHIPS

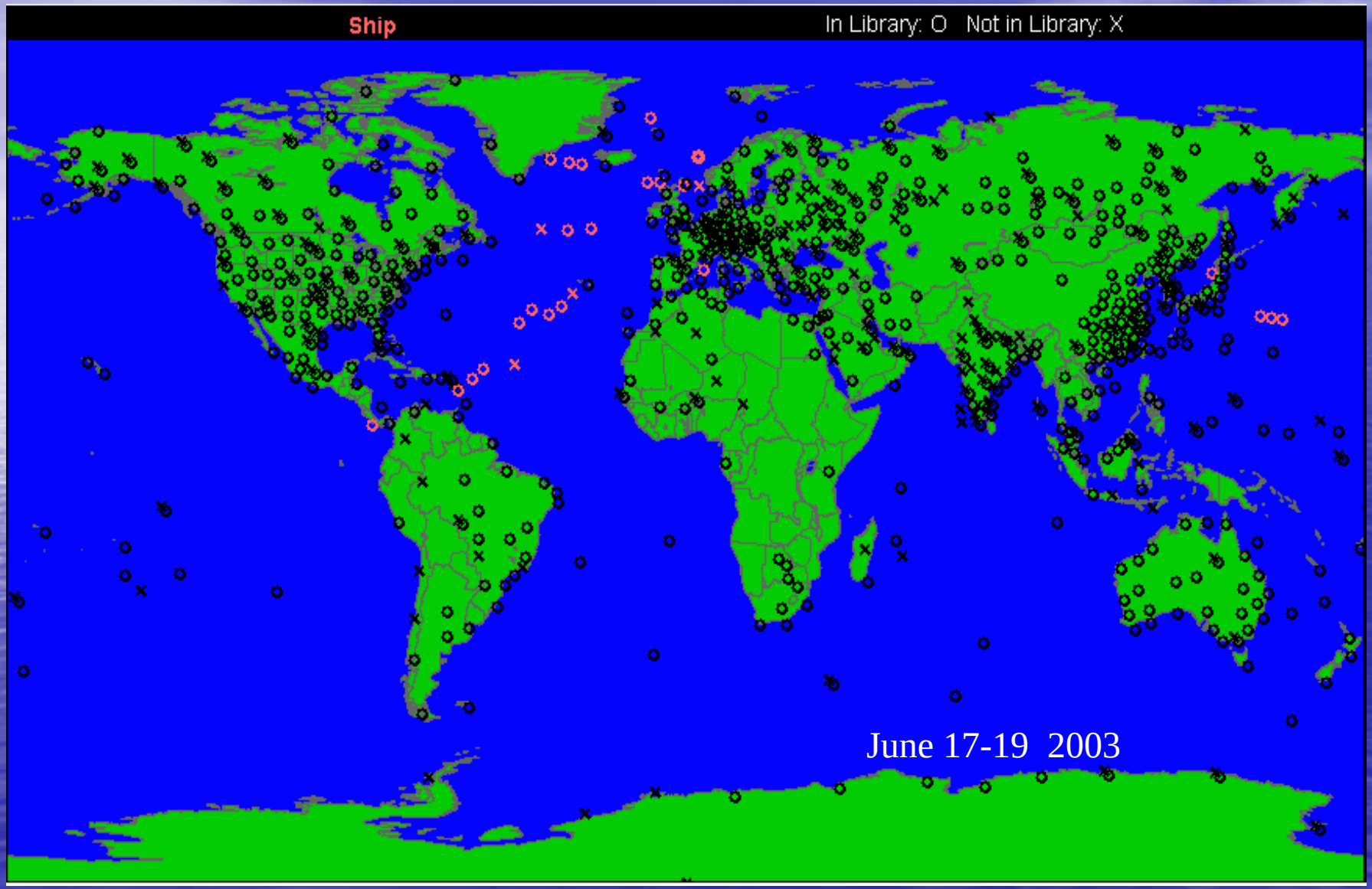
The NOAA science vessel RHB provides radiosonde launch, insitu measurement, cloud observation and polar satellite direct receipt capabilities … ***an optimal platform for SUAN demonstration / support !***

At about $250 per raob, twice per day, 250 days per year, estimated SUAN support is $125K yearly; ***very cost effective*** at fraction of RHB and NOAA polar program budget …

WHY SUAN ?

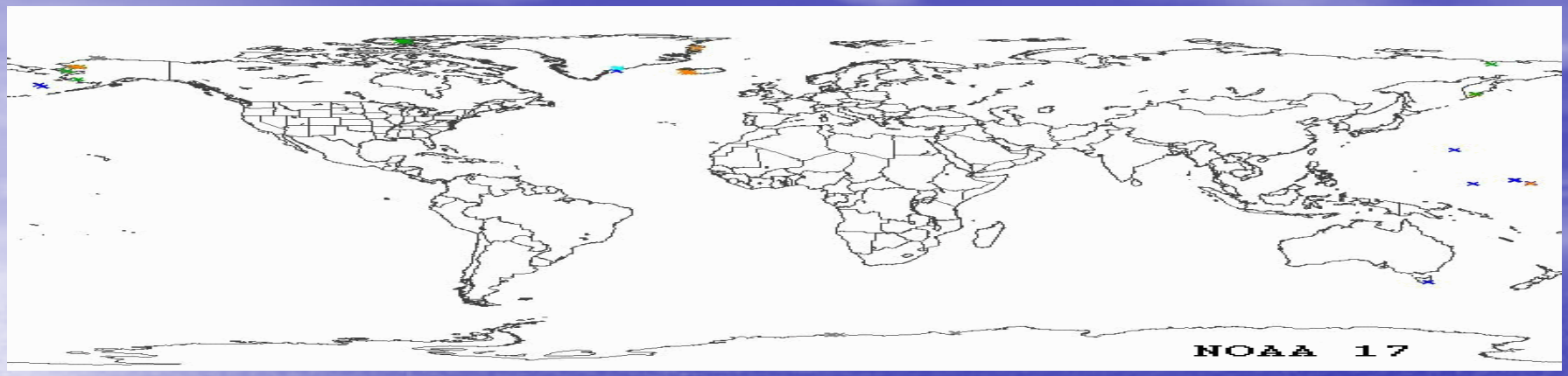
- ***Operational polar satellite***
  - Measurements/Products require (*long-term*) "scientific" Monitoring/Tuning ... *using collocated radiosonde and satellite observations*
- ***Radiative Transfer (RT) models***
  - require coincident T, H20 and Radiometric profiles
  - *"key to absolute accuracy" !?*
- ***Global Radiosondes***
  - "can" provide necessary ground truth data, but have problems ...
- ***Standard Baseline Dataset Needed (since 1979 ...)***
  - currently available collocated radiosonde and satellite observations are ***Not Adequate***

Global Radiosondes



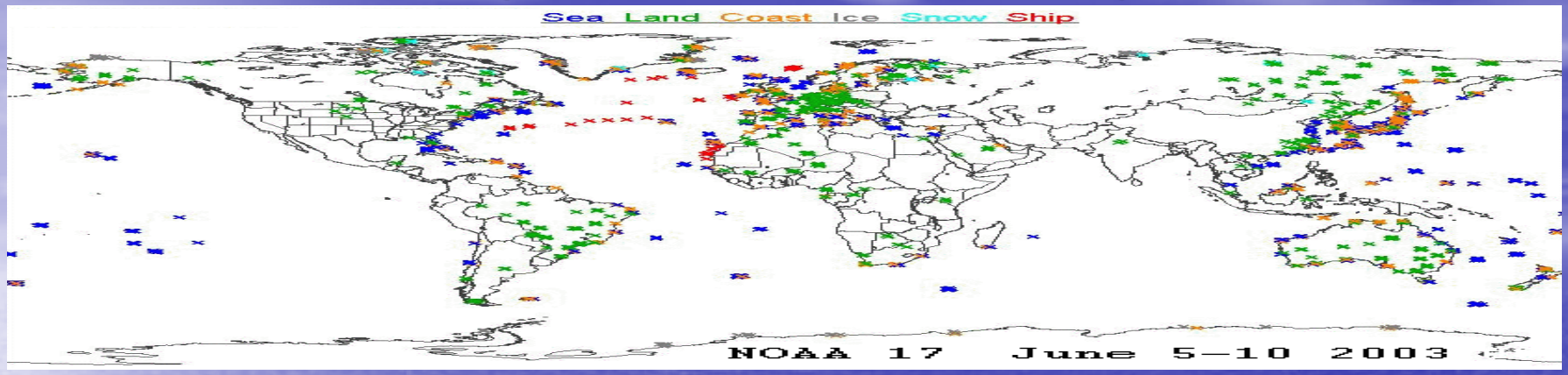
Satellite and Radiosonde Collocations

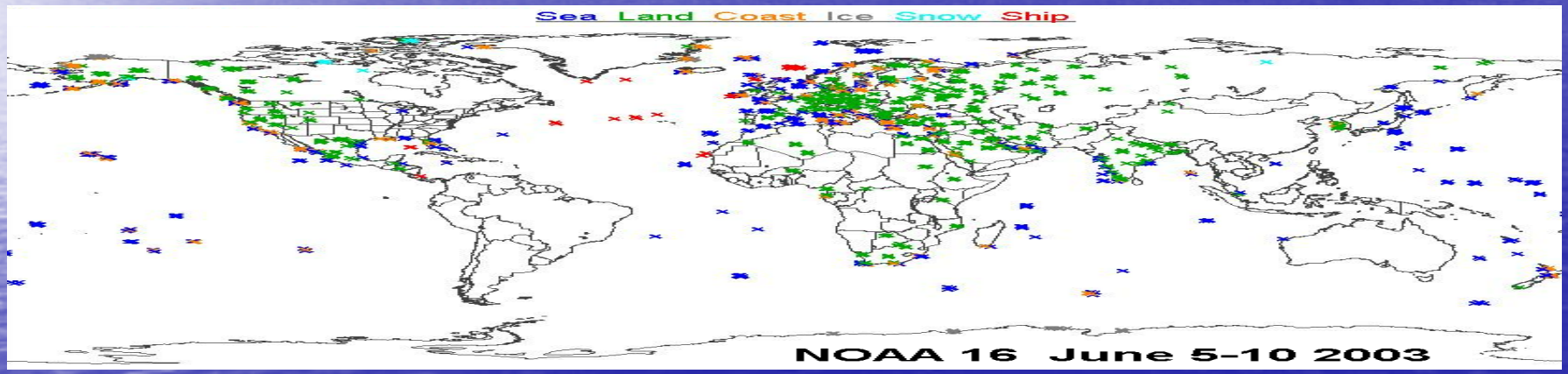
(Radiosondes launched within 1 hour "prior" to satellite overpass)

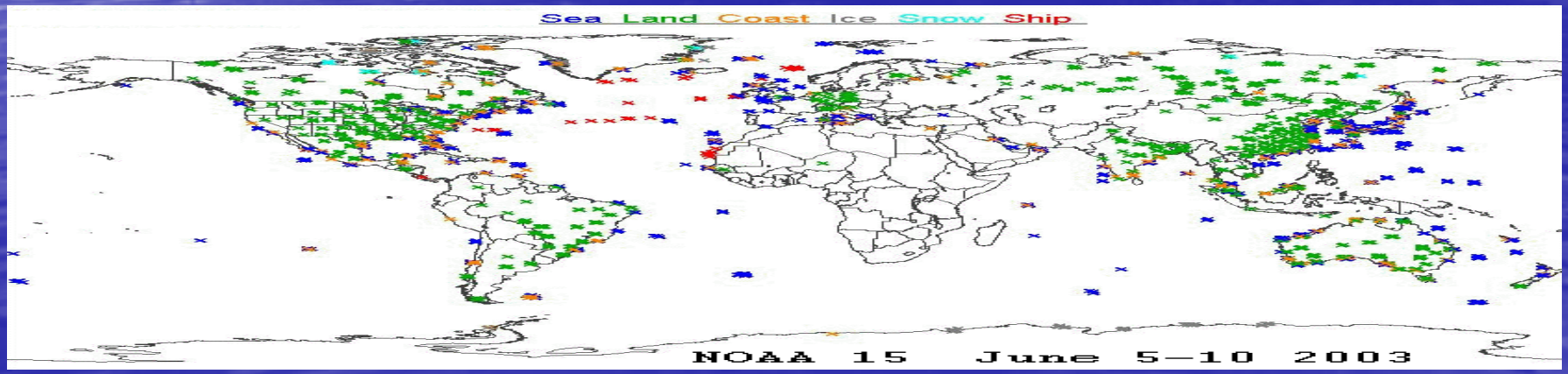


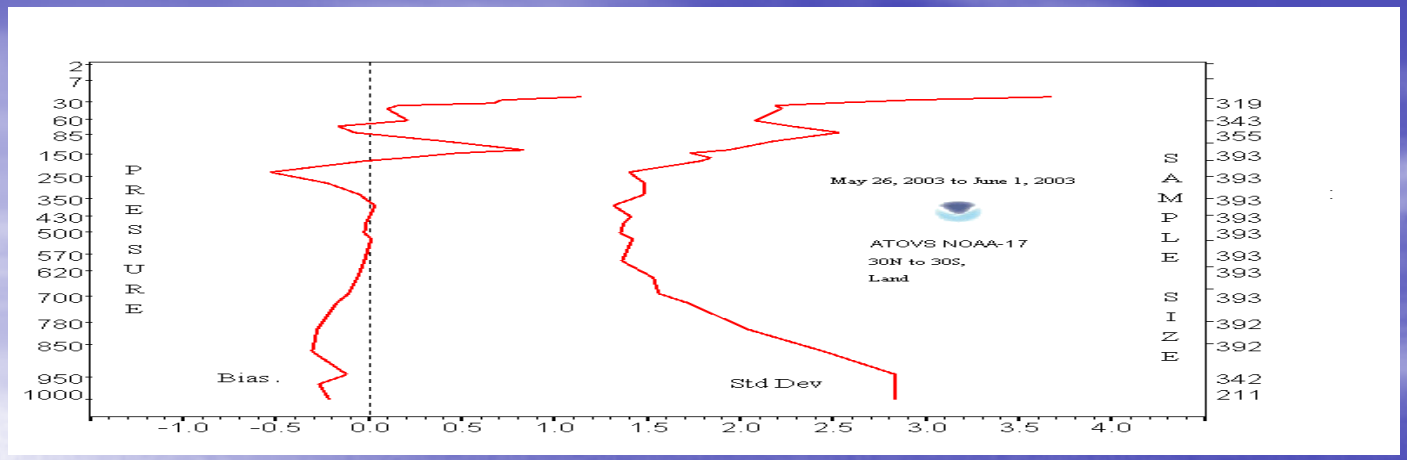
Operational Satellite and Radiosonde Collocations

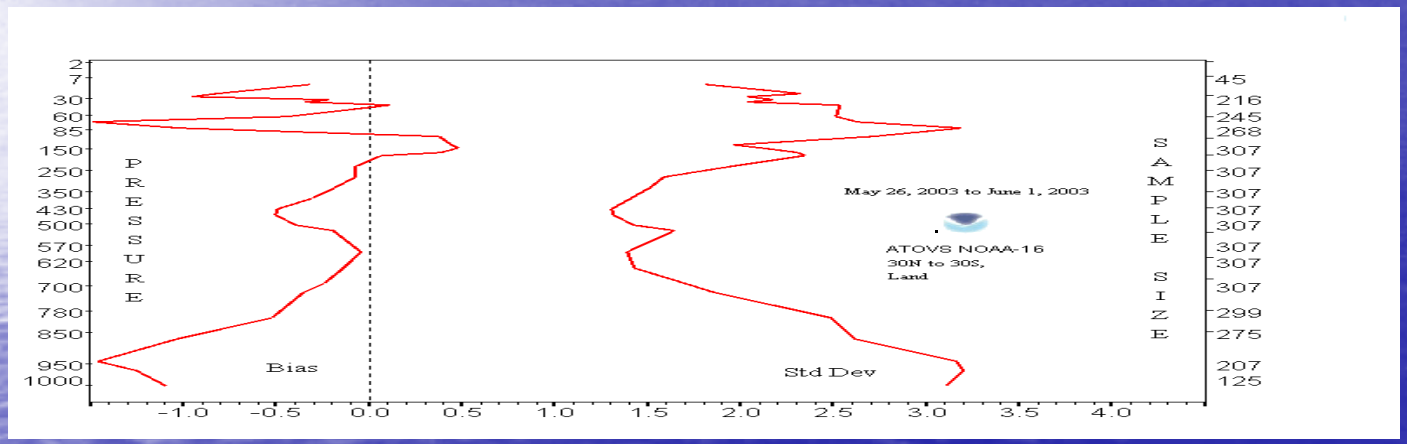
(+/- 5hrs sea, +/- 3hrs land; 100km)

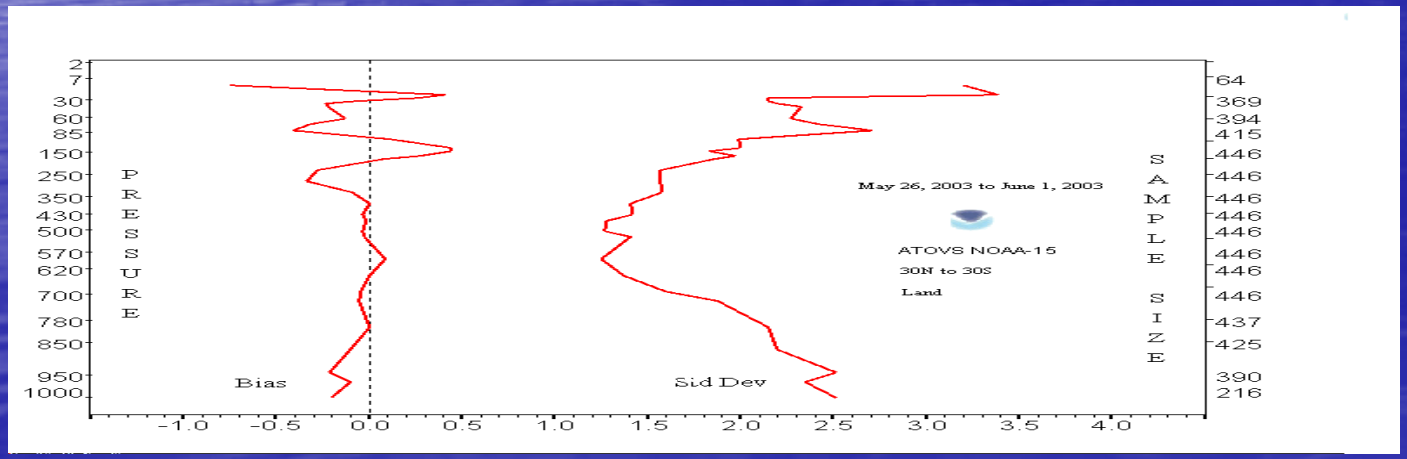










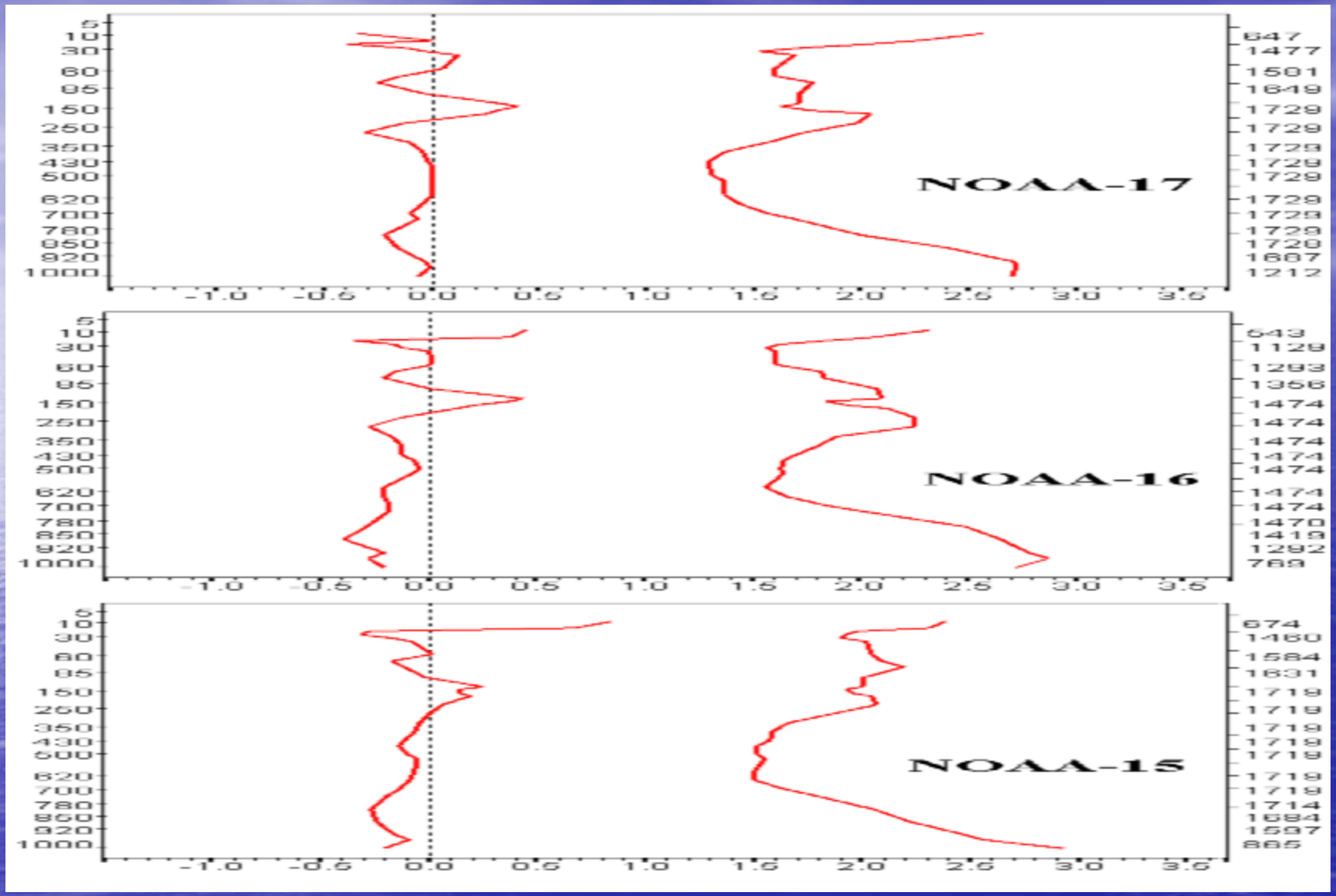


(Satellite – Radiosonde)
Temperature statistics

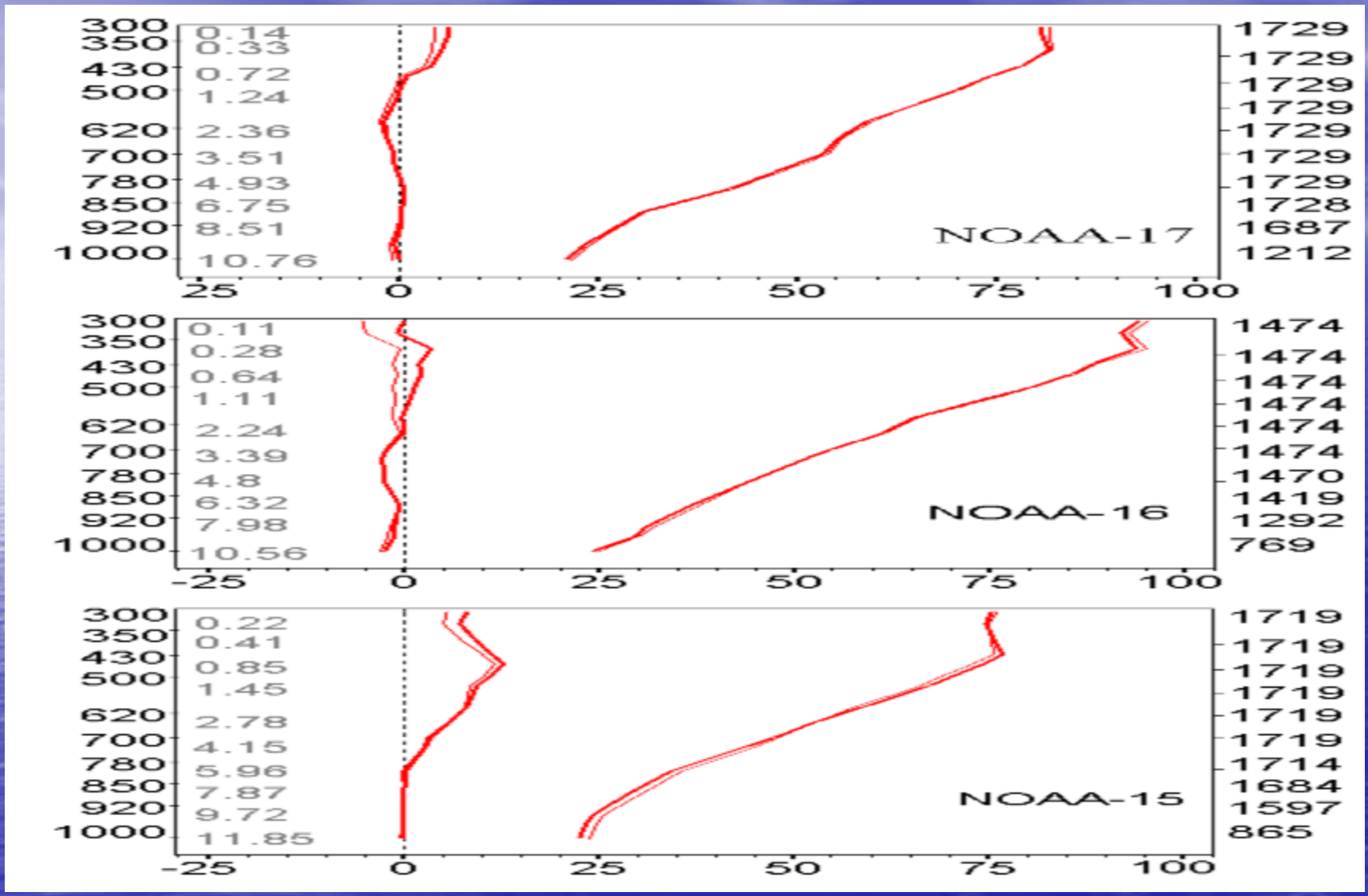
Tropical land
(30N to 30S)

June 7-14, 2003

Results "skewed" by regional sampling differences

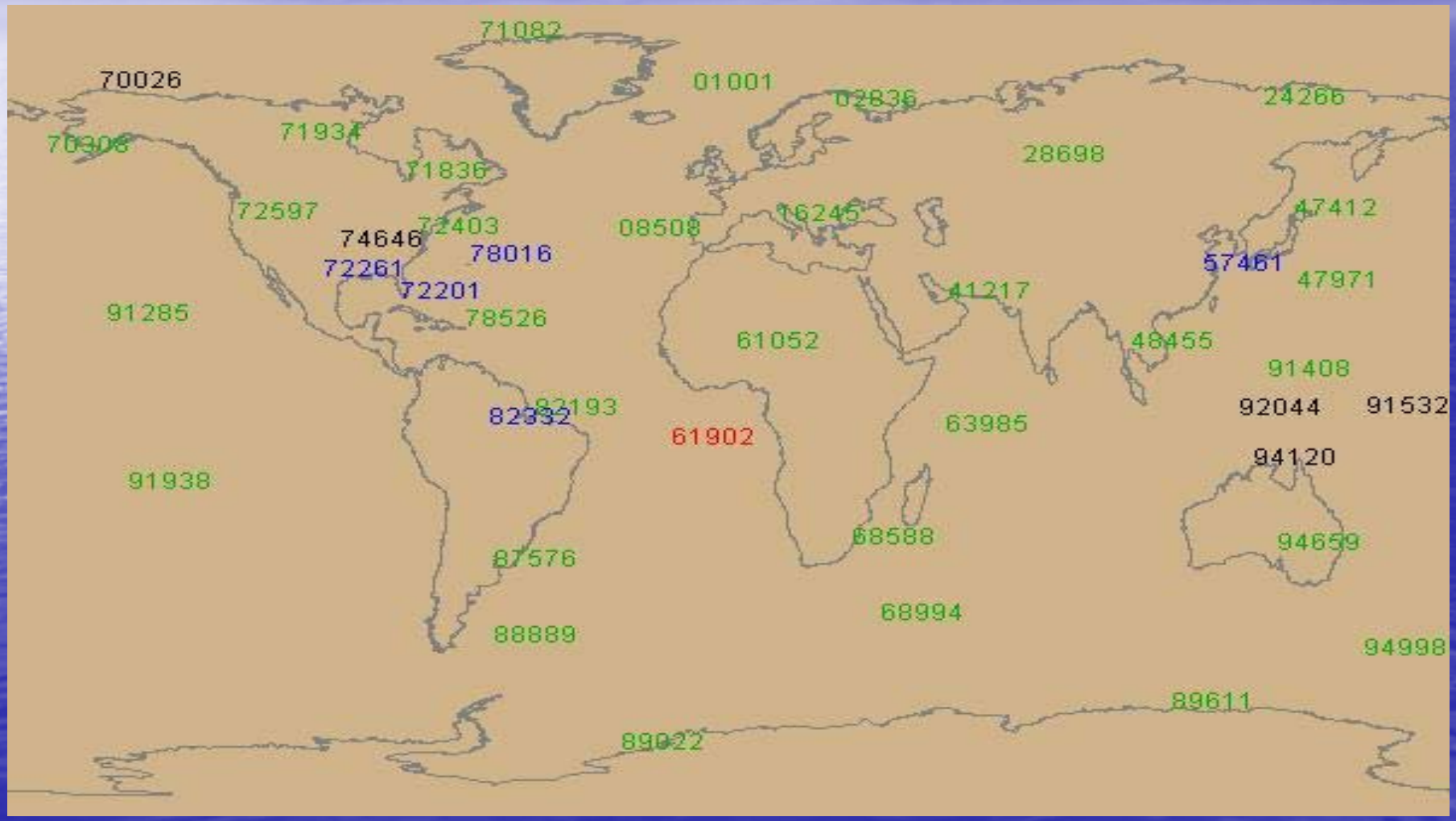


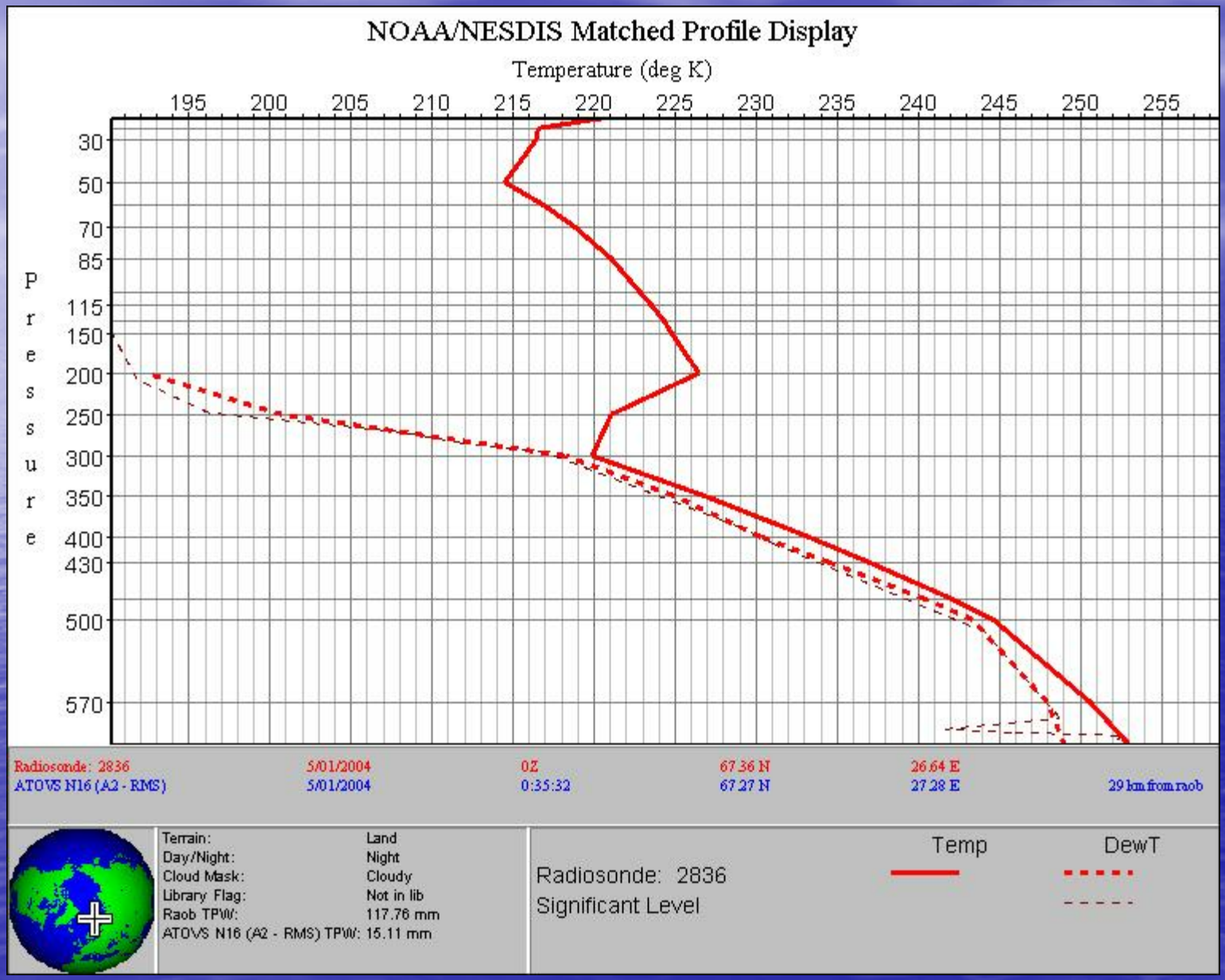
60N to 60S

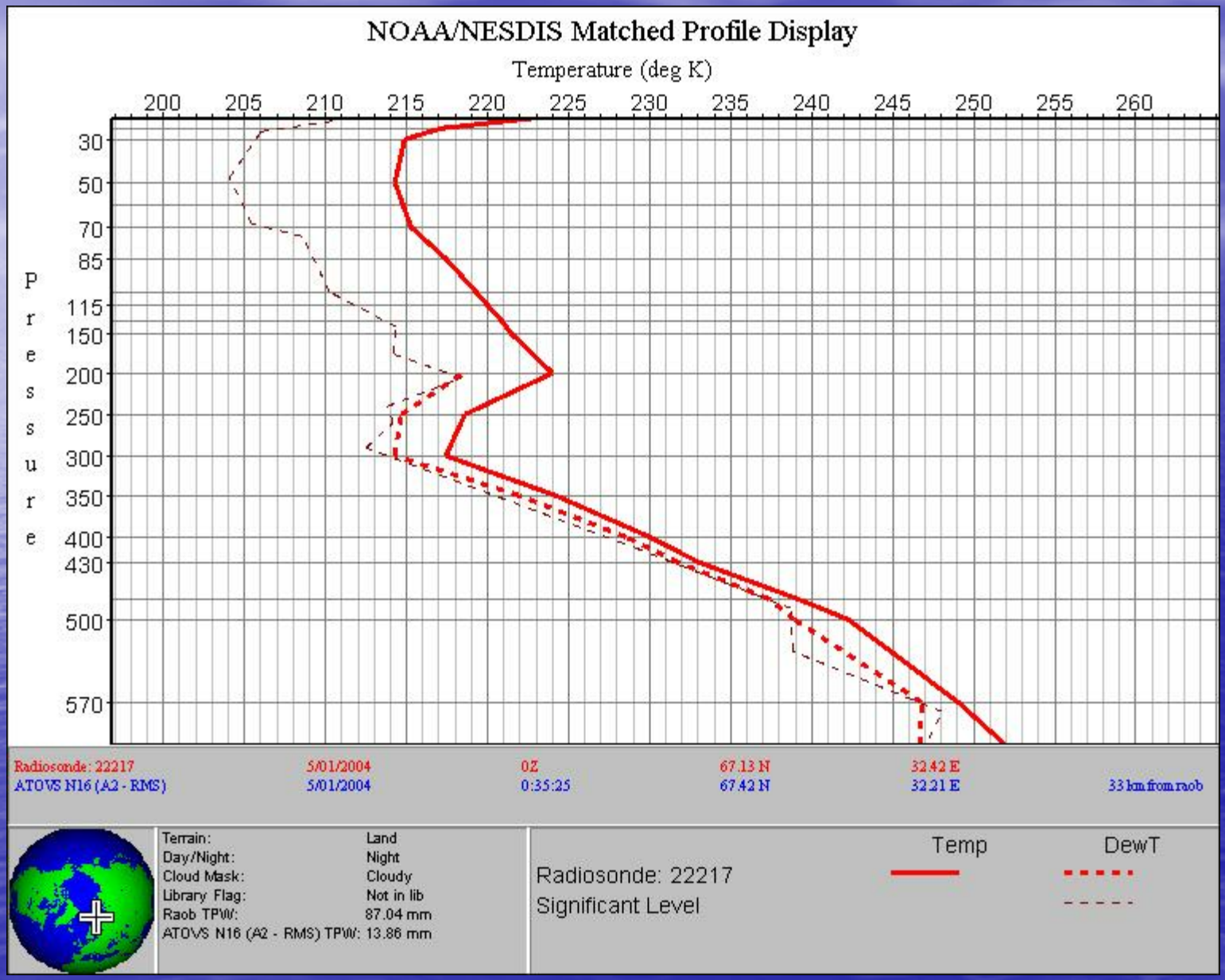


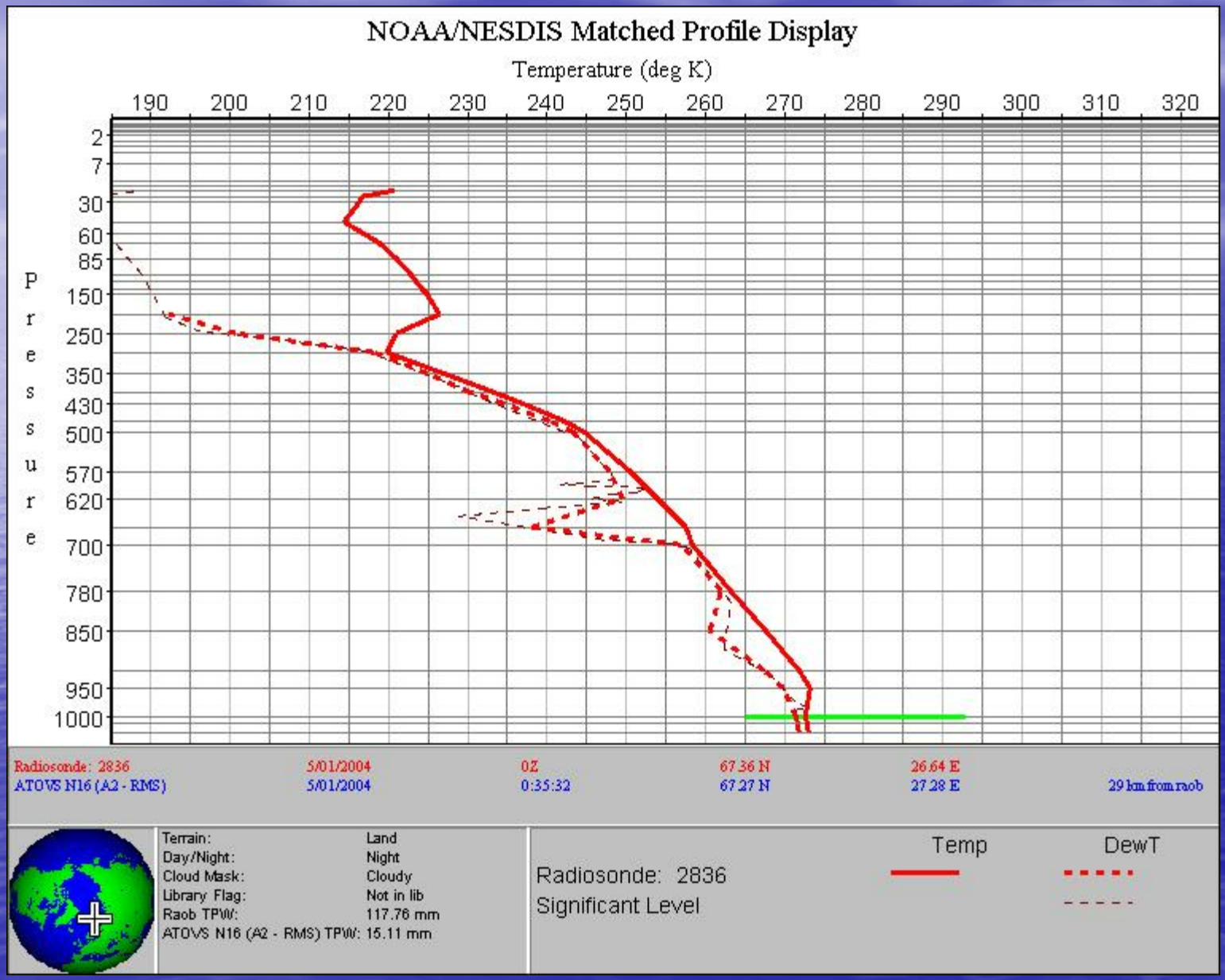
60N to 60S Moisture

SUAN Minimizes "***Artificial***" (not Same-Same) Sampling Related Errors to Better Monitor "***Real***" Sensor and Product Performance/Uncertainty




NOAA/NESDIS Matched Profile Display
Temperature (deg K)
195 200 205 210 215 220 225 230 235 240 245 250 255
Pressure
30 50 70 85 115 150 200 250 300 350 400 430 500 570
Radiosonde: 2836 5/01/2004 0Z 67.36 N 26.64 E
ATOVS N16 (A2 - RMS) 5/01/2004 0:35:32 67.27 N 27.28 E 29 km from raob
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 117.76 mm
ATOVS N16 (A2 - RMS) TPW: 15.11 mm
Radiosonde: 2836
Significant Level
Temp
DewT


NOAA/NESDIS Matched Profile Display
Temperature (deg K)
200 205 210 215 220 225 230 235 240 245 250 255 260
Pressure
30 50 70 85 115 150 200 250 300 350 400 430 500 570
Radiosonde: 22217 5/01/2004 0Z 67.13 N 32.42 E
ATOVS N16 (A2 - RMS) 5/01/2004 0:35:25 67.42 N 32.21 E 33 km from raob
Terrain: Land
Day/Night: Night
Cloud Mask: Cloudy
Library Flag: Not in lib
Raob TPW: 87.04 mm
ATOVS N16 (A2 - RMS) TPW: 13.86 mm
Radiosonde: 22217
Significant Level
Temp
DewT


NOAA/NESDIS Matched Profile Display
Temperature (deg K)
190 200 210 220 230 240 250 260 270 280 290 300 310 320
Pressure
2 7 30 60 85 150 250 350 430 500 570 620 700 780 850 950 1000
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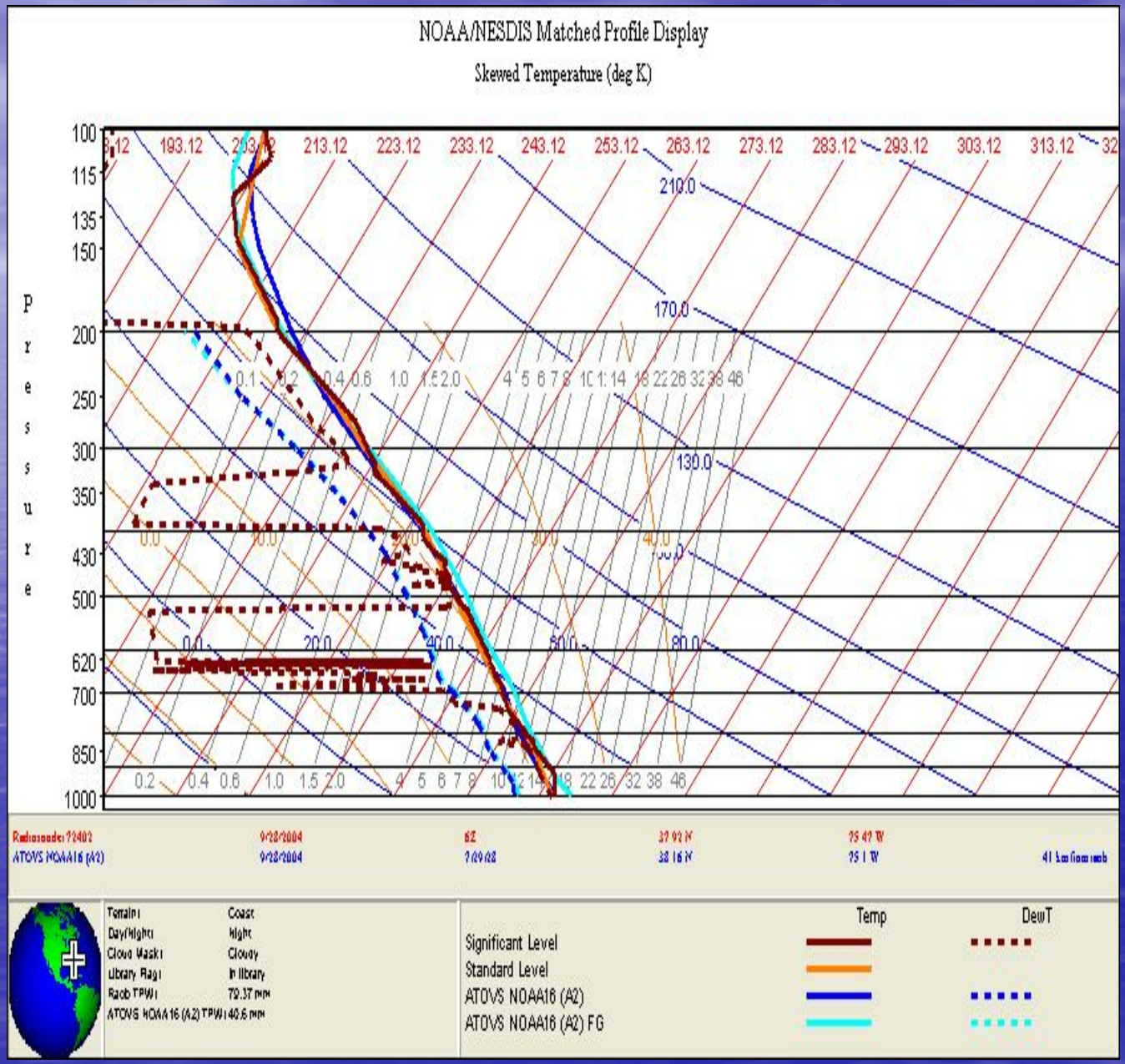
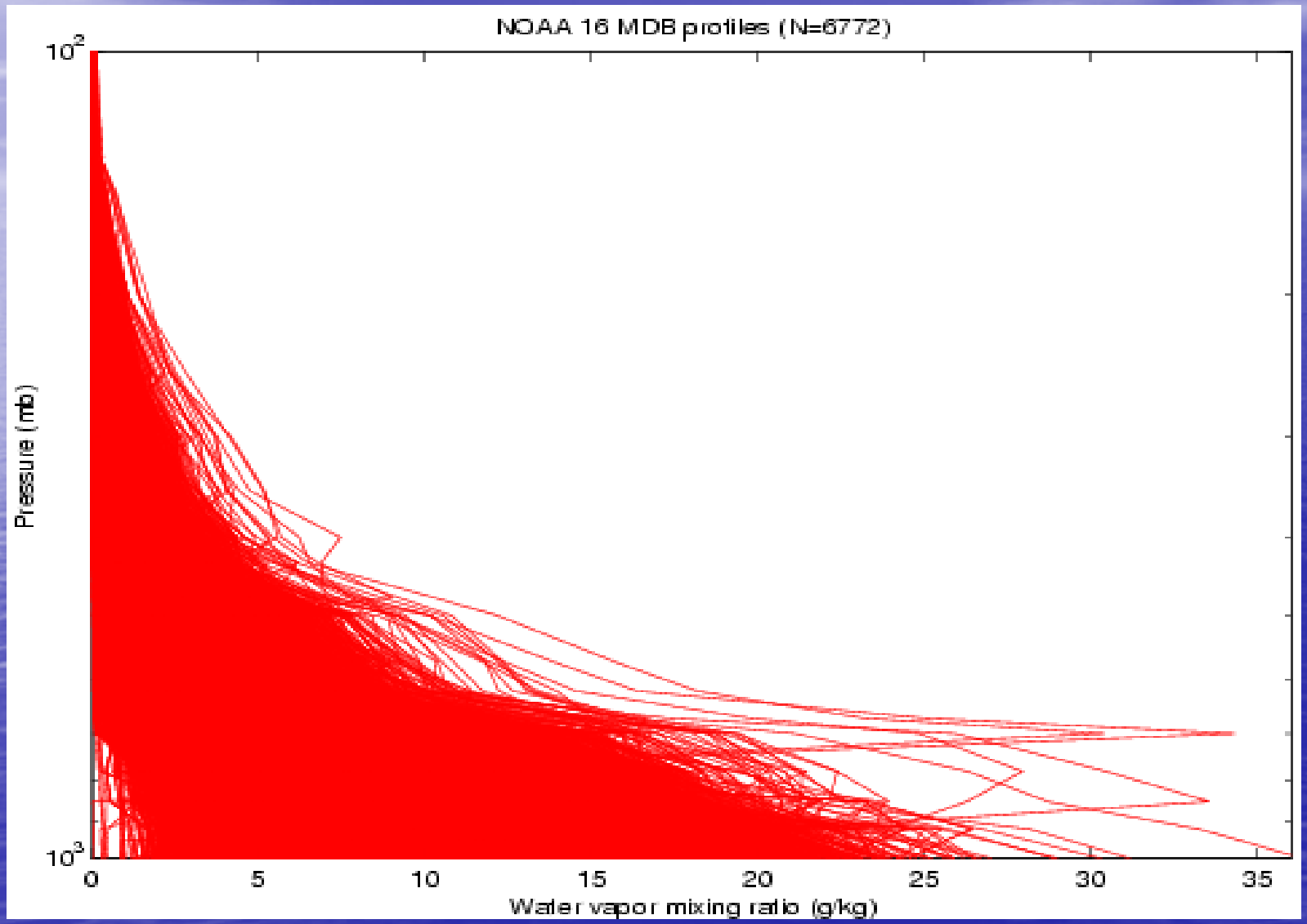
Temp
DewT
Radiosonde: 2836
Significant Level

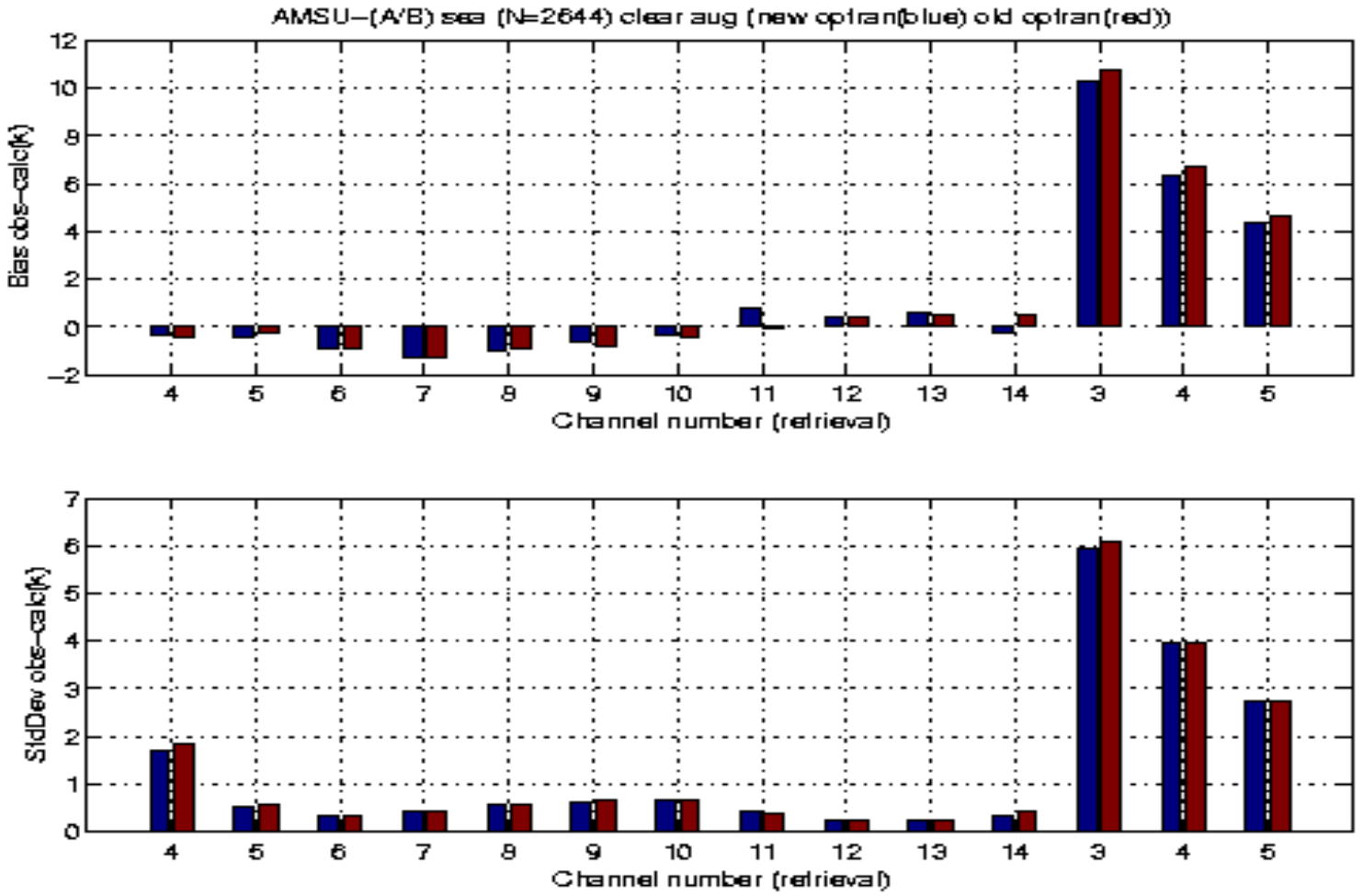

NOAA/NESDIS Matched Profile Display
Skewed Temperature (deg K)
Pressure
100
115
135
150
200
250
300
350
430
500
620
700
850
1000
193.12
213.12
223.12
233.12
243.12
253.12
263.12
273.12
283.12
293.12
303.12
313.12
210.0
170.0
130.0
Terrain Coast
Day/Night Night
Cloud Mask Cloudy
Library Flag In library
Raob TPW 79.37 mm
ATOVS NOAA16 (A2) TPW 40.6 mm
Temp
DewT
Significant Level
Standard Level
ATOVS NOAA16 (A2)
ATOVS NOAA16 (A2) FG


NOAA 16 MDB profiles (N=6772)
10^2
10^3
Pressure (mb)
0
5
10
15
20
25
30
35
Water vapor mixing ratio (g/kg)

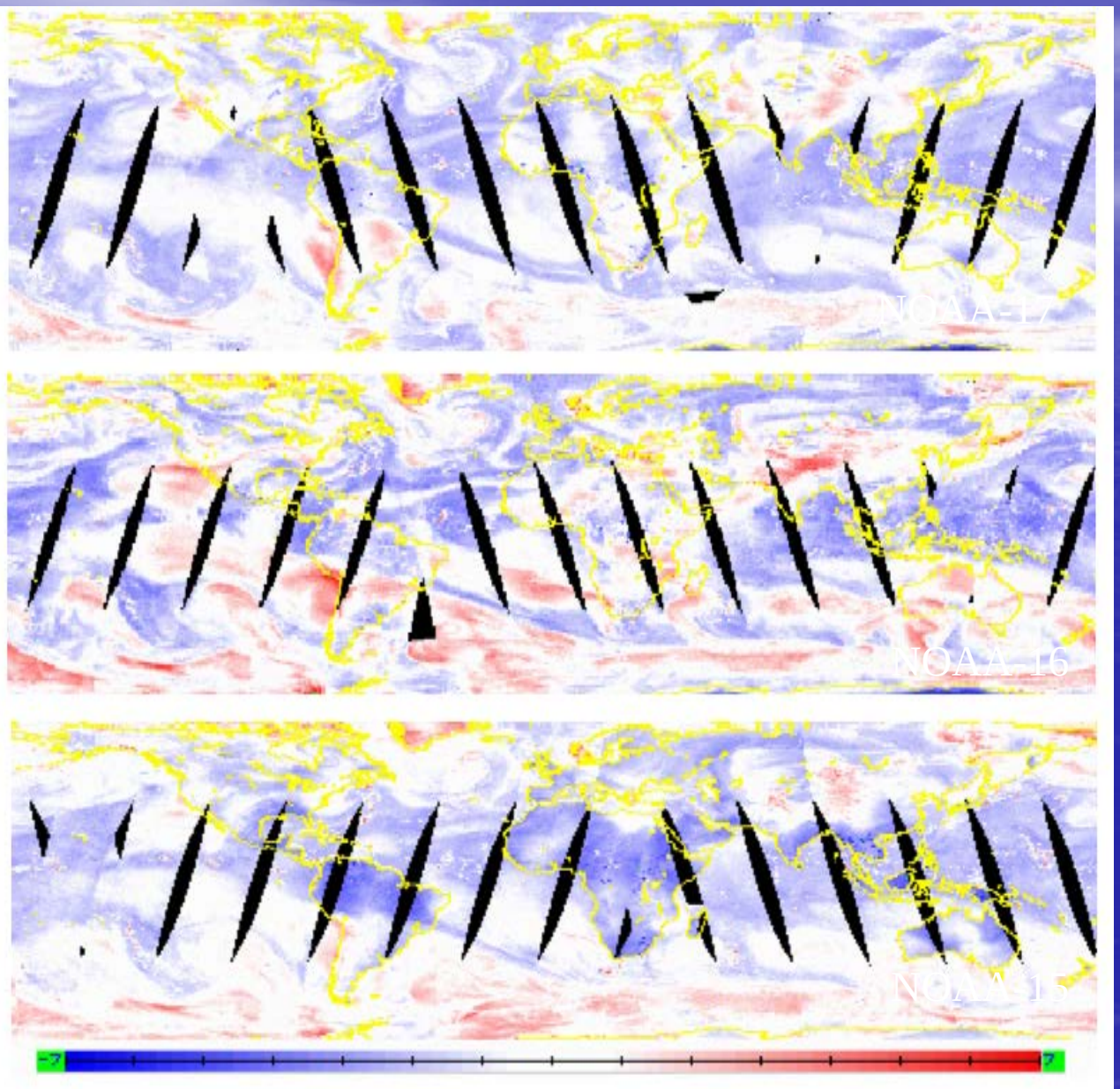
RT Models

- Critical for Cross-validation of Satellite, Radiosonde, Climate and NWP Data
- Require consistent, reliable and robust collocations in support of R & D, validation
- Are "***Key***" to ascertaining absolute accuracy ... resolve calculated (from Raob) vs observed (from satellite) radiance ... (*and climate retrieval problem)*
- ***SUAN sites optimal in support of long-term RT model validation and development ...***

AMSU Sounding Channels



RT Bias Adjustments



AMSU-B at 183 +/- 1 gHz
(upper troposhere moisture)

12-hour time composites

Adjustments are ***regressed from collocated satellite and radiosonde data***

Magnitude and inter-satellite variability "skewed" by systematic radiosonde sampling differences,

Radiosondes

- Satellite radiometers can serve as transfer standard for radiosonde monitoring via RT (McMillin et.al. 1988)

- ***SUAN sites would provide:***
  - ***validating radiosondes*** *(intersonde experiments, non-SUAN, ...)*
  - ***deriving radiation and inter-sonde "corrections"***
  - ***demonstration of new technologies (ie, upper tropospheric moisture, drop-sondes ...)***
  - ***balloon drift and local weather impacts***
  - ***other***

Climate Applications

Problems Include:

- Radiometer Sensor Bias
  - Systematic per satellite
  - Sensor response changes
  - Satellite drift
- Science Bias
  - RT model
  - Processing Approach
    - Measurement vs Derived Product
    - Tuning

End Result:

Uncertainty Outweighs the Signal (Seidel et al., 2004, Christy …)

Climate Applications Formula

"Real-time" Database Compilation Effort

...satellite data, ground truth collocations ...

(during satellite operational lifetime)

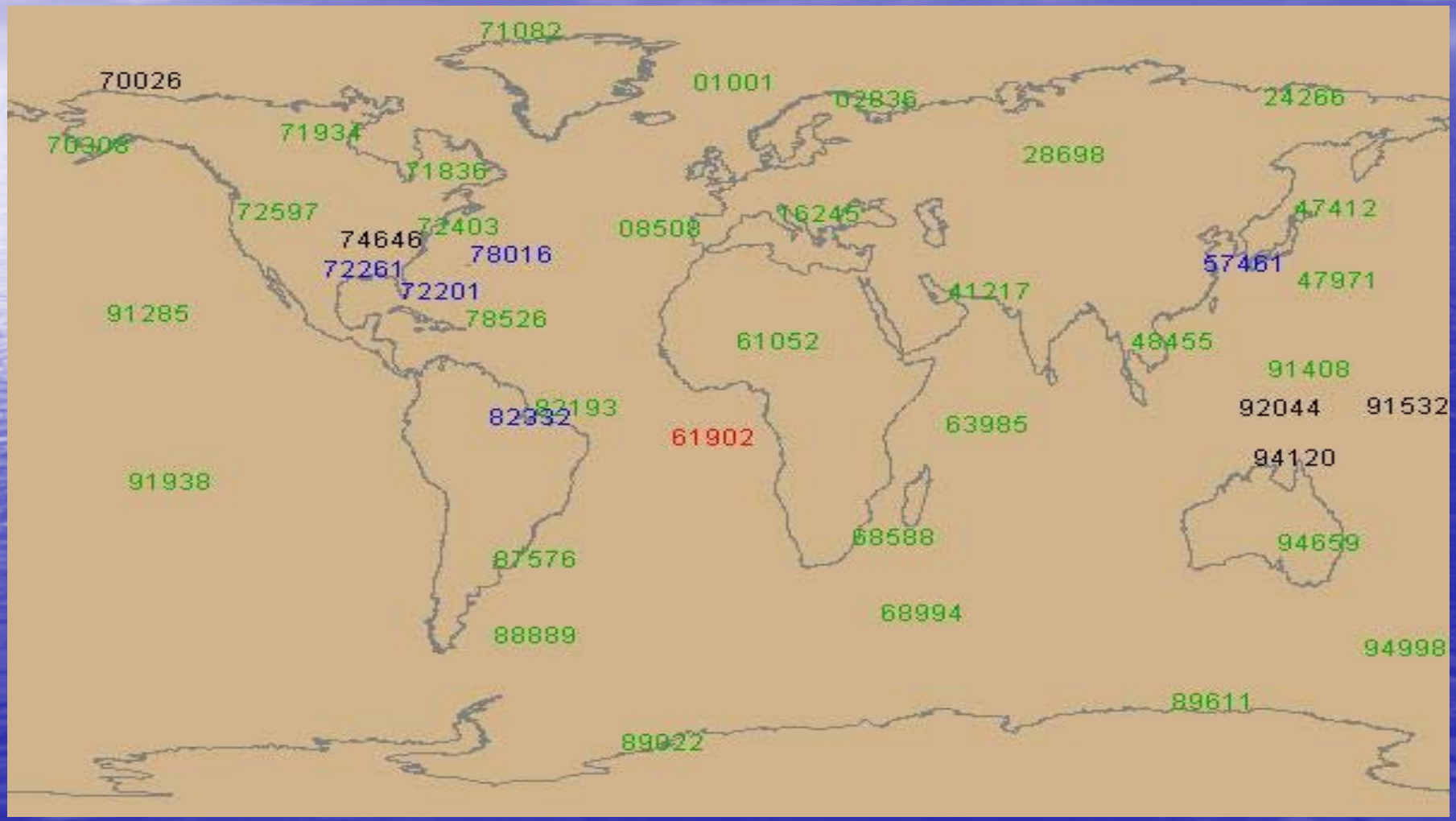
to serve as input for

"Retrospective" Processing Effort

...T, H2O, Clouds, Measurements ...

(at conclusion of satellite operational lifetime)

SUAN can provide "long-term" records which "anchor" satellite and radiosonde performance (over time) for more effective utilization in retrospective climate applications …



Radiosonde and TOVS-1b History from 1979 …
(*correcting the past …*)

- GTS Radiosondes … (***NCEP, ERA-40, IGRA***…)
- Special Field Experiment Radiosondes:
  - ARM
  - JOSS (NCAR)
  - *SHIPS*
  - *Other ?*
- TOVS Historical 1b-level data
- **Goals:**
  - Relational Data Base of Collocations, Directories, Metadata …
  - TOVS , ATOVS … make operational
  - ***Reprocess TOVS for Climate !!!***
- *Costly and time consuming process*
  - ***Ongoing "Arctic" NOAA-SEARCH (w/ Francis)***
    http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes/polarsearch
  - ***looking for funding***

BENEFITS

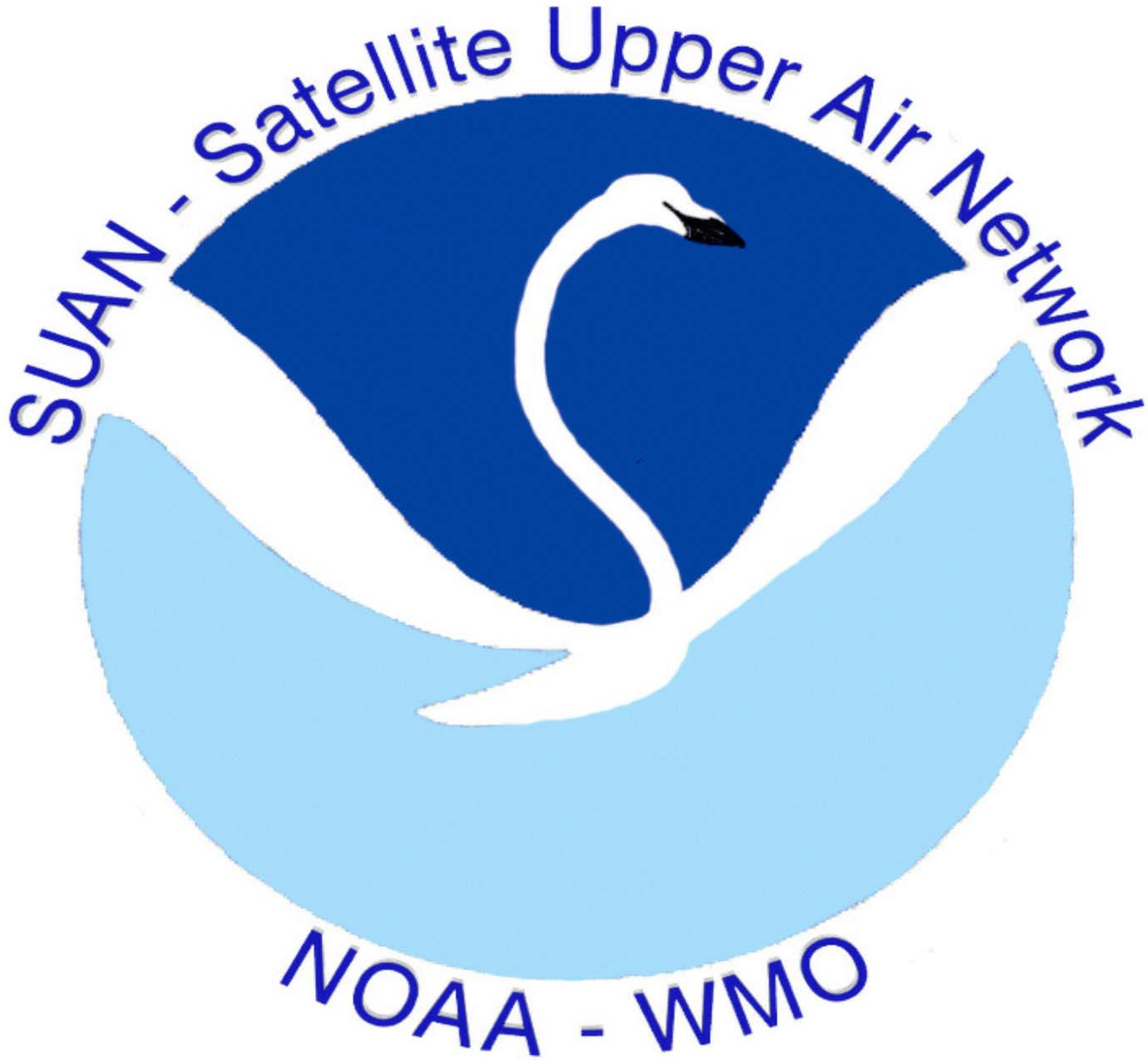
- Monitor/Quantify ***Satellite Measurement and Derived Product*** Error/Accuracy/Uncertainty (*ATOVS … NPP … METOP … NPOESS …)*

- Monitor/Quantify ***RT Model*** Error/Accuracy/Uncertainty

- Monitor/Quantify ***Radiosonde (and in-situ)*** Error/Accuracy/Uncertainty

- "Long-term" ***Performance*** Record

- ***Positive Impacts on Climate and NWP***

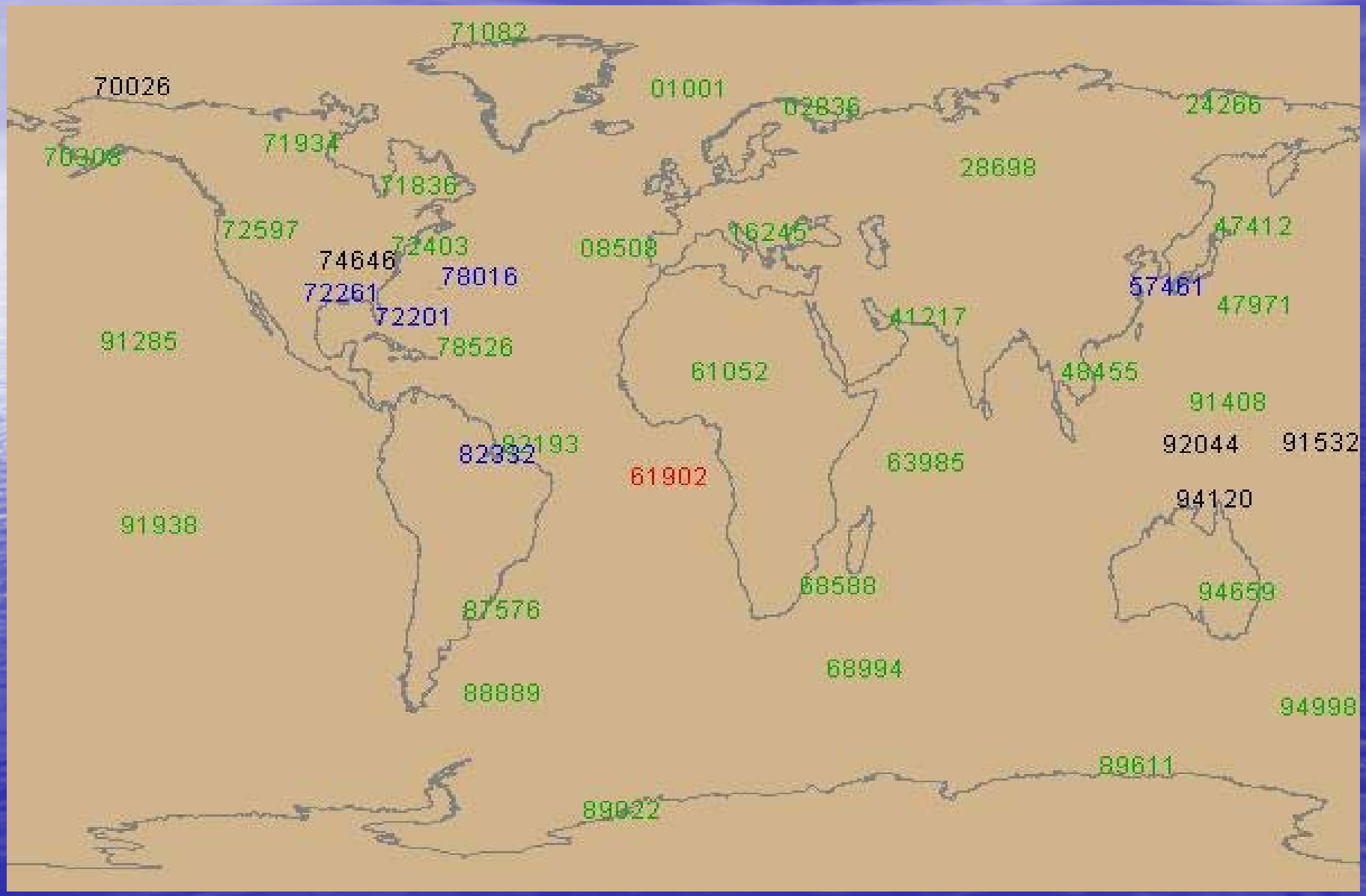

SUAN - Satellite Upper Air Network
NOAA - WMO

EXTRAS

Ongoing Activities

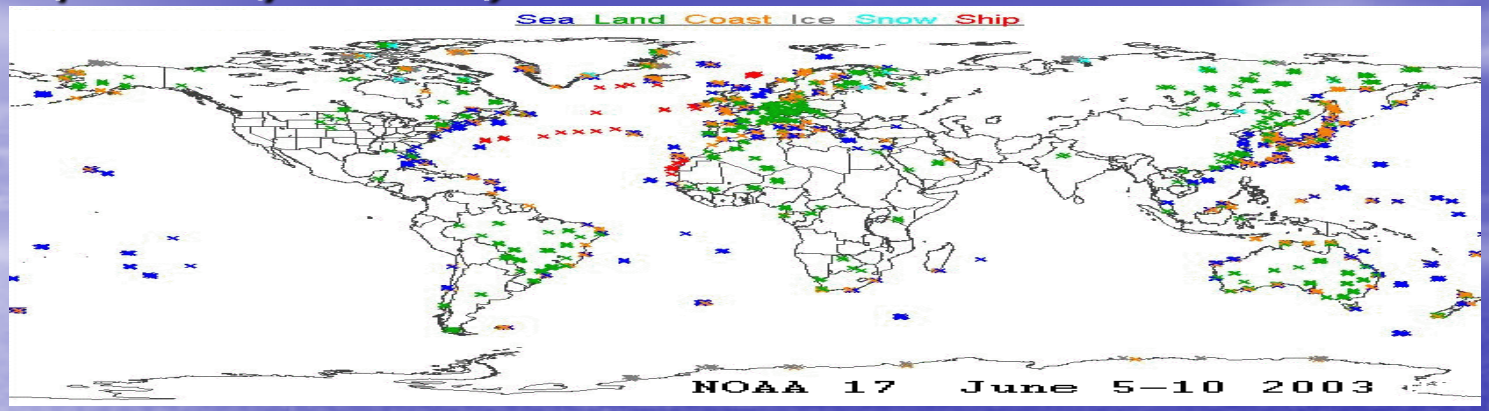
- **New WMO Working Group under AOPC to address GUAN future and network design …. Peter Thorne chair**
- **NOAA Workshop … improve quality of future upper air observations for climate (Seidel/Murray) :**
  - ***Phase-1 :*** **Winter 2005 to define requirements**
  - ***Phase-2 :*** **Spring 2005, potential networks and deployments to meet requirements**
  - ***Phase-3 :*** **Summer 2005, definition of integrated observing system**
- **TOVS 1b-level and radiosonde collocations since 1979**

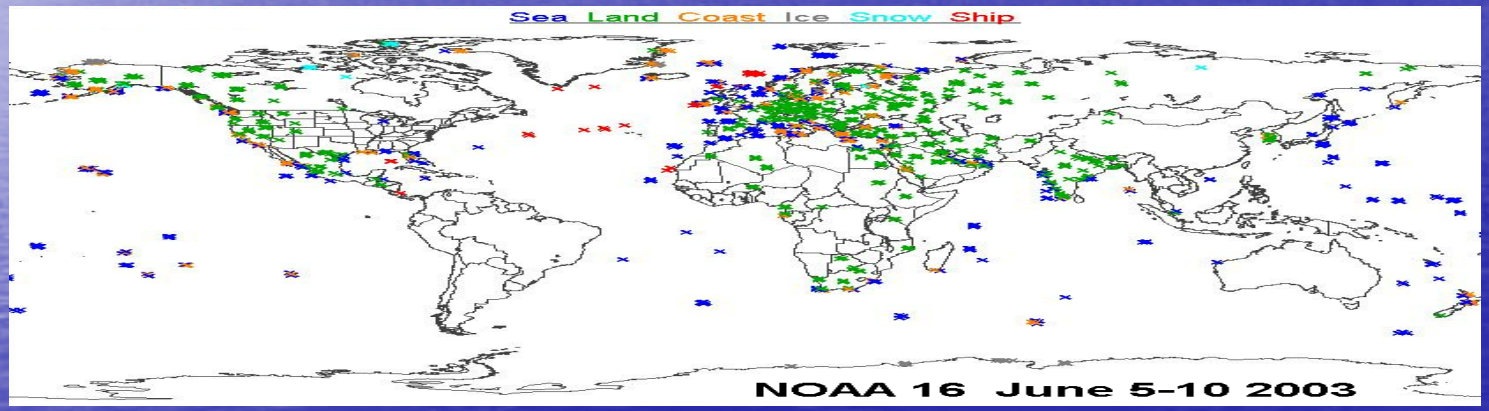
Primary SUAN Candidates

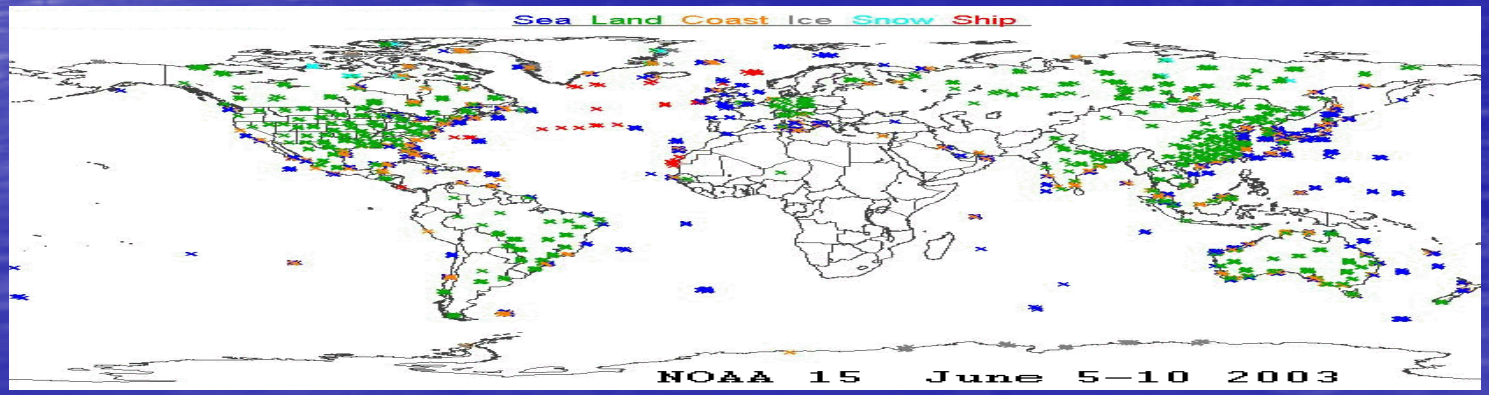


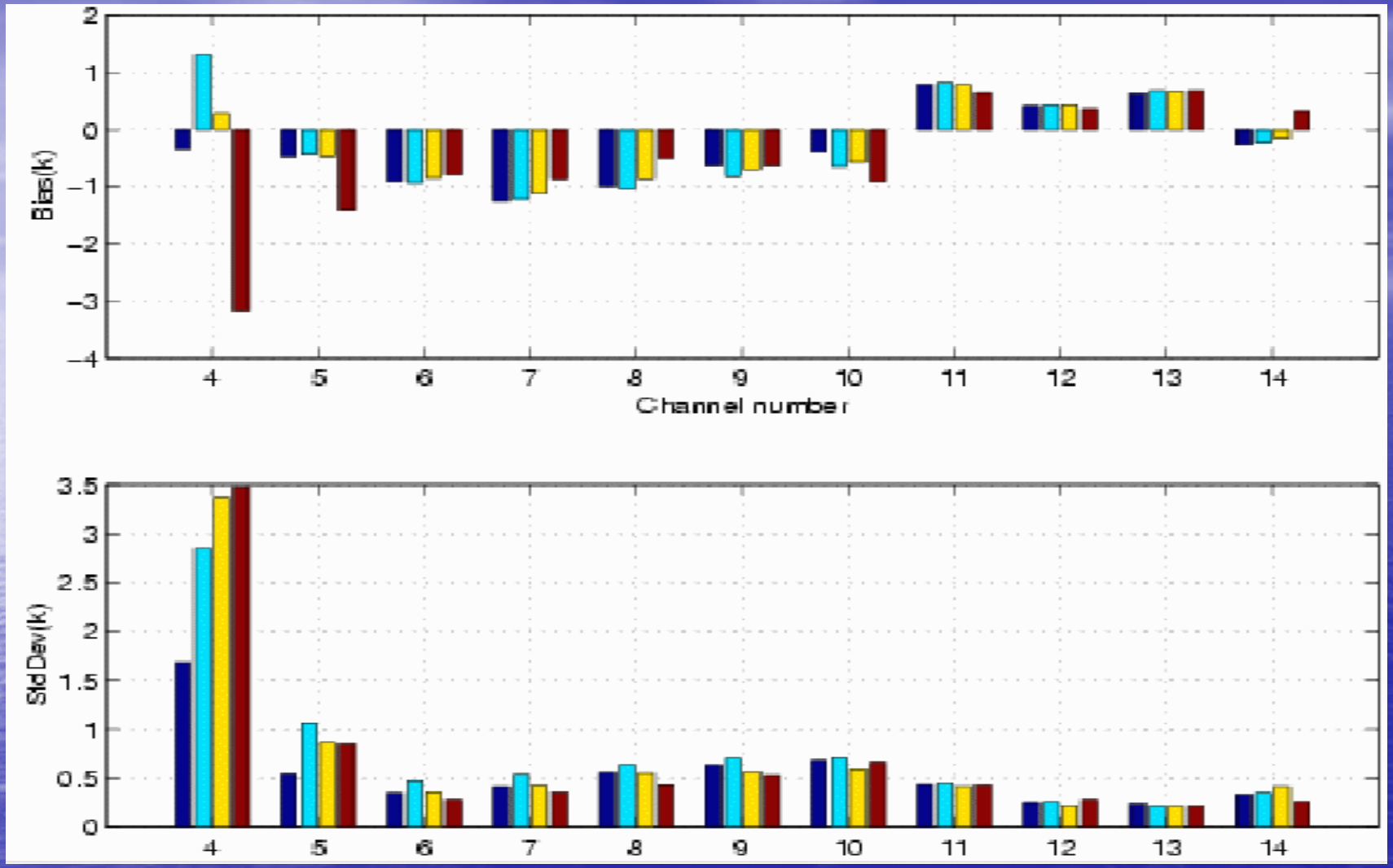
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

(used operationally at NESDIS)





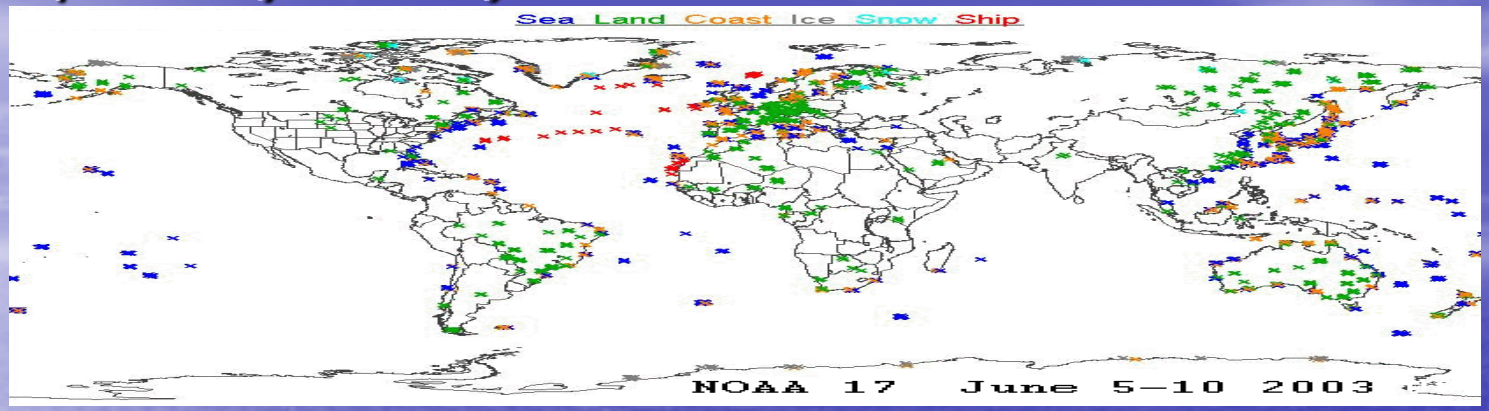


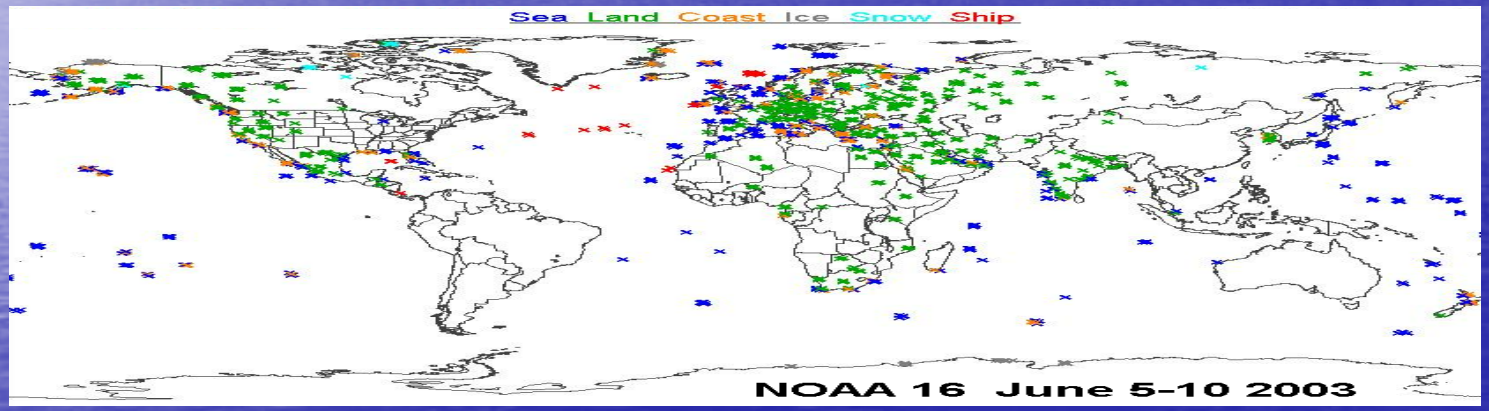


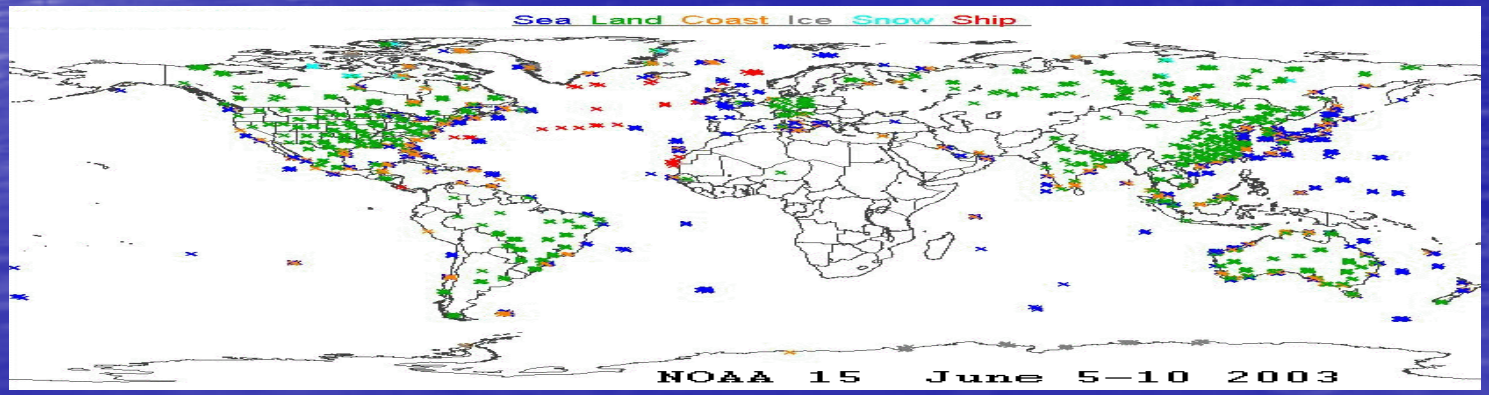
Calculated (from RT) minus Observed AMSU-A measurements for channels 4 through 14 (NOAA-16) over Land, Ice and Snow, Coastal, and Sea terrains

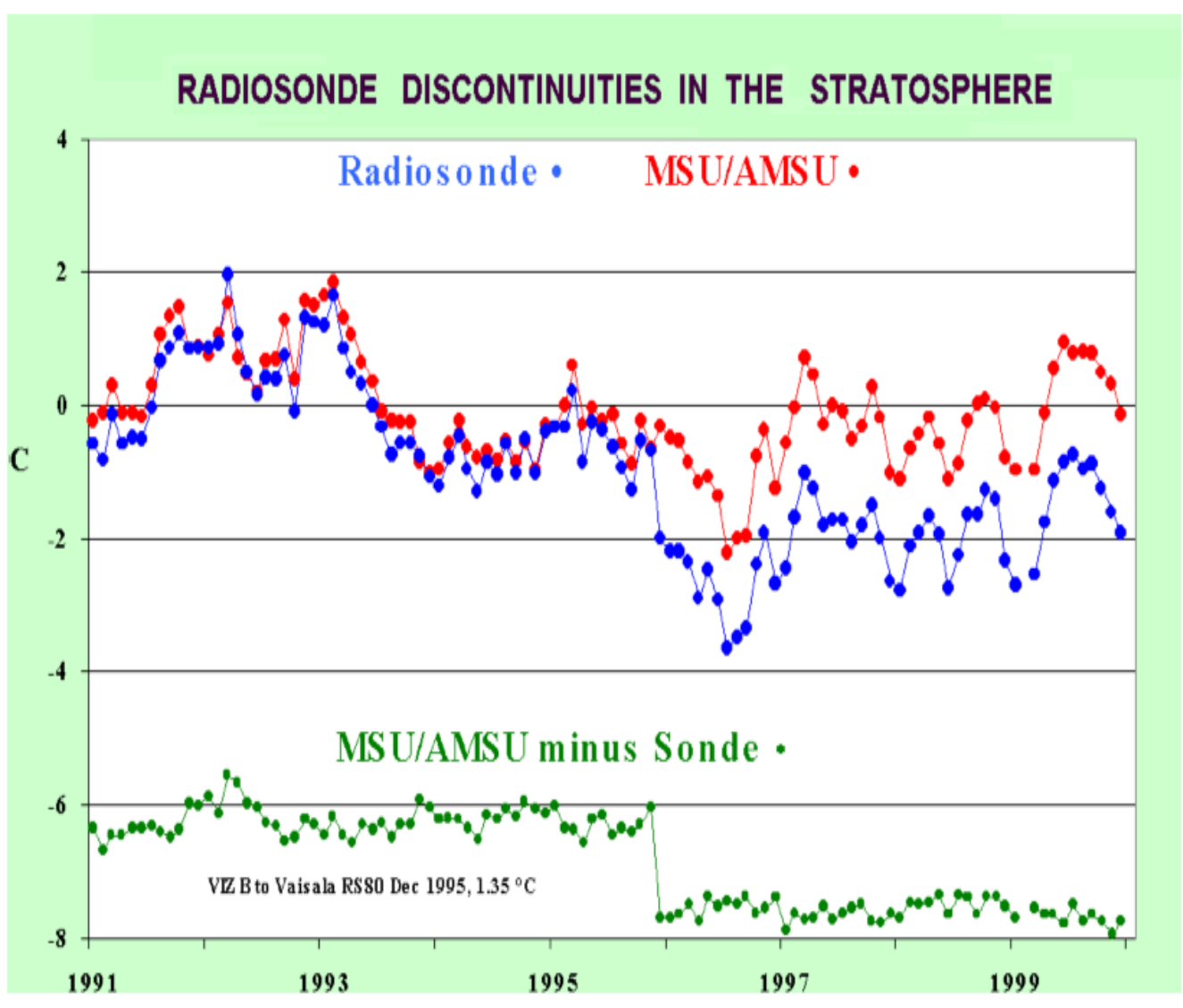
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

(used operationally at NESDIS)



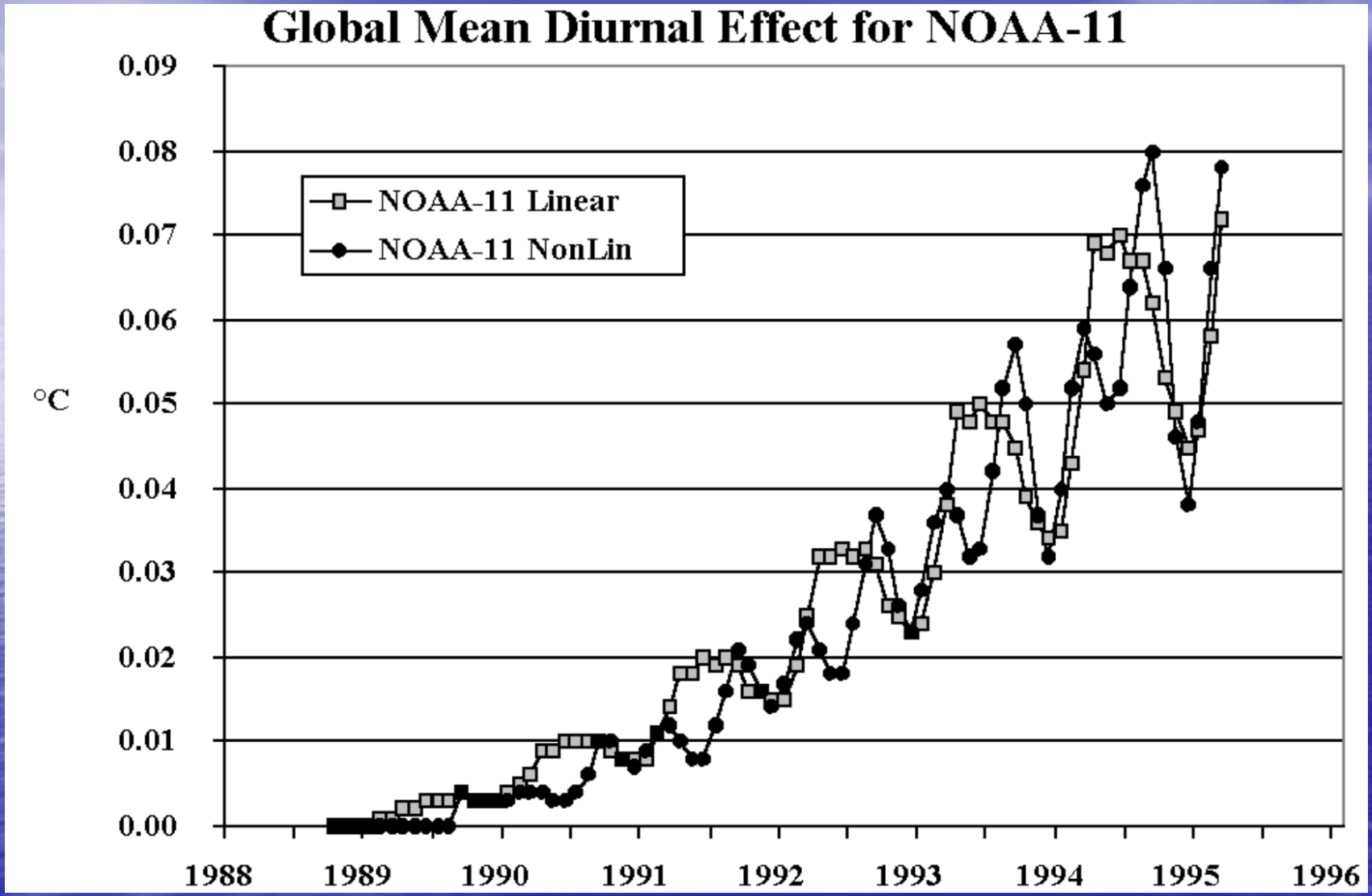






Satellites can serve as transfers standards to monitor radiosondes

VIZ B to Vaisala (RS80) at Chuuck Island


Global Mean Diurnal Effect for NOAA-11
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°C
NOAA-11 Linear
NOAA-11 NonLin
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1989
1990
1991
1992
1993
1994
1995
1996

Collocated Radiosonde and Satellite Observations provide basis for the

Monitoring
Validating and
Tuning

of ***Operational Satellite Data Systems***

(*… critical for climate retrieval problem)*

Radiosonde and TOVS-1b Collocation History from 1979 (... *correcting the past* ...)

- ***Costly and time consuming process***
  - ***Pending FY-05 "GCC" proposal (w Goldberg, Thorne)***
  - ***Ongoing NOAA-SEARCH (w/ Francis)***

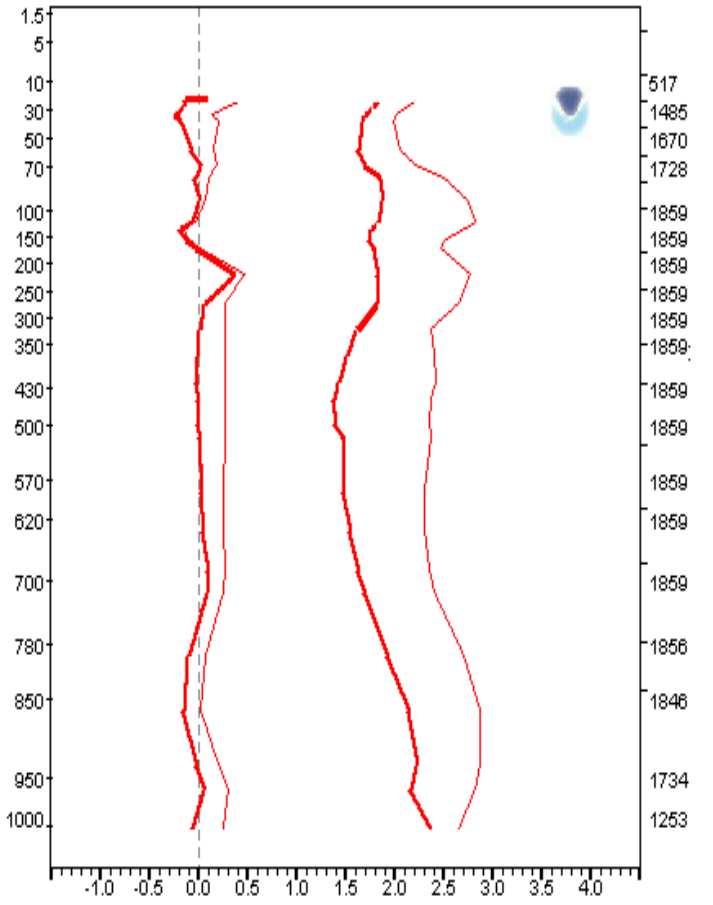
- GTS Radiosondes ... (NCEP, ERA-40, IGRA...)
- Special Field Experiment Radiosondes:
  - ARM
  - JOSS (NCAR)
  - *SHIPS*
  - *Other ?*

- TOVS historical 1b-level data

- **Goals:**
  - Relational Data Base of Collocations, Directories, Metadata ...
  - TOVS , ATOVS ... operational
  - *Useful for Climate*

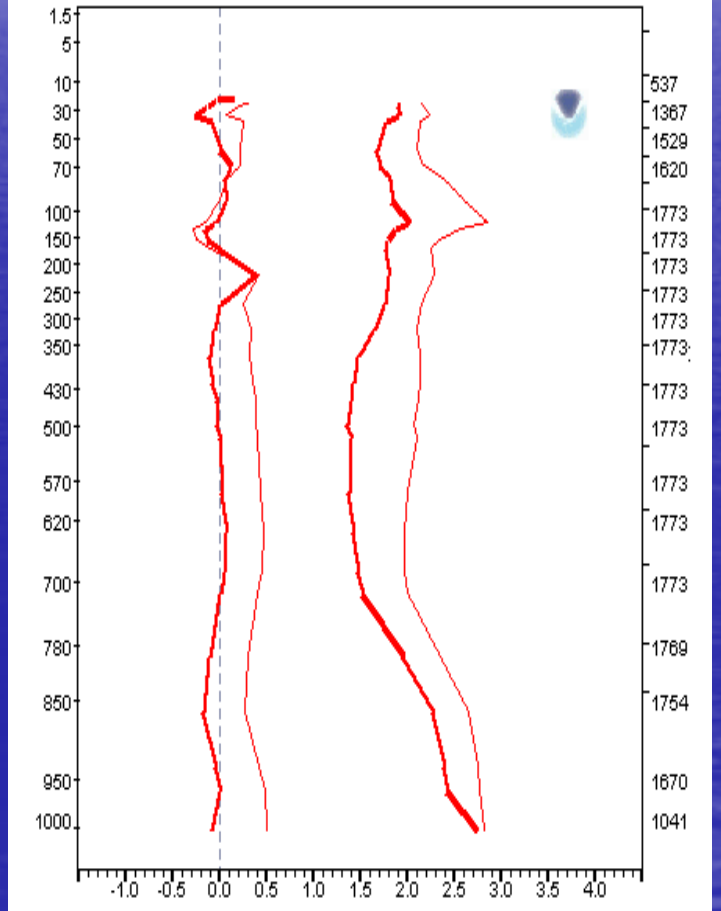
Accuracy Statistics vs Radiosondes
(*Guess (light)* vs *Retrieval (heavy)*)

Tuning to Errors



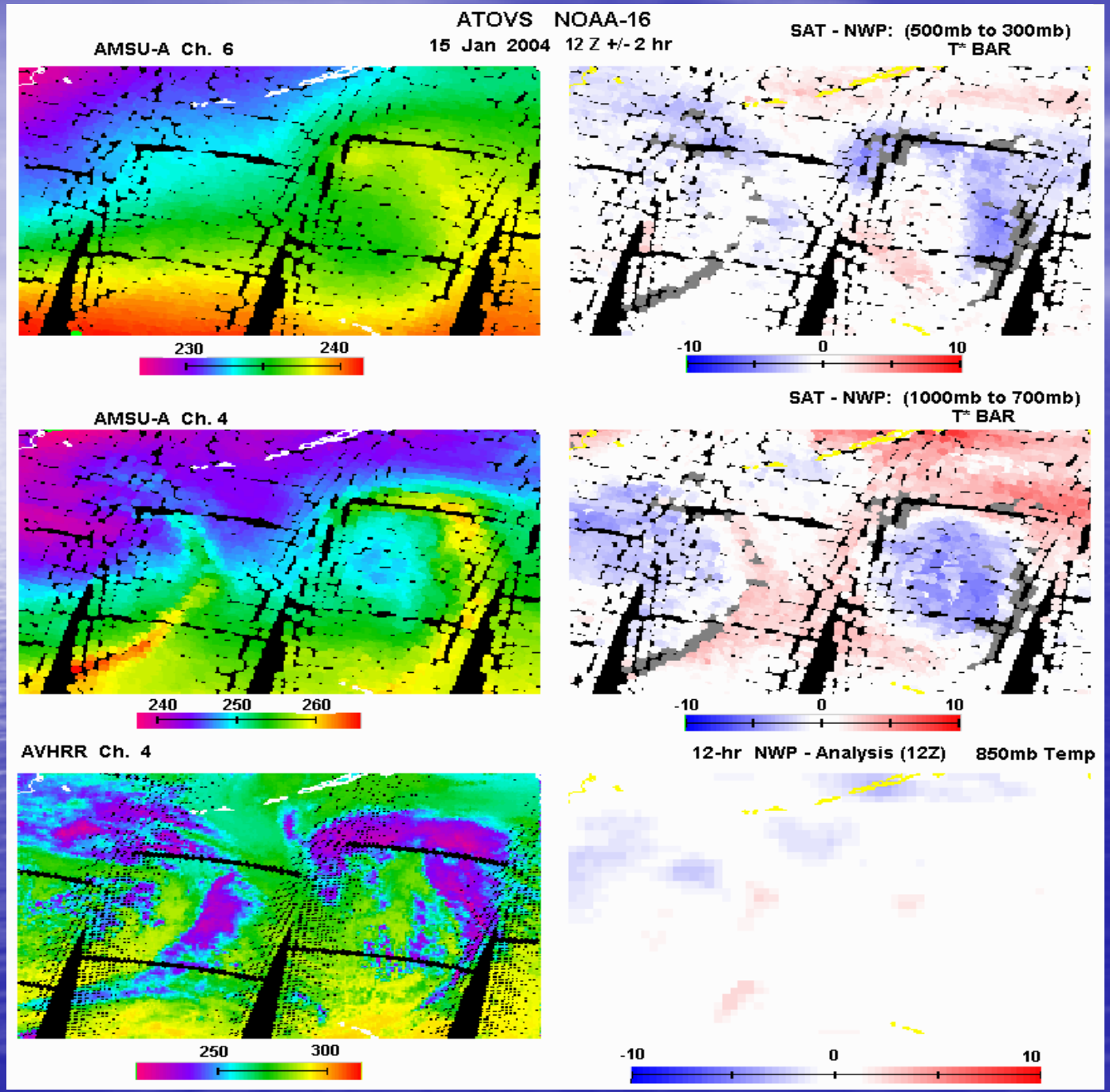
Collocations provide independent validation (heavy) and tuning (light) per satellite

NOAA-16
(60N to 60S)



NWP

- Significant positive impact of satellite data on NWP reported over last 5 years (McNally et.al. 2000, etc)
- Associated NWP-based adjustment of incoming satellite data ("cooking") may include systematic NWP error (Reale, 1995, 2001, 2002)
- ***SUAN can potentially segregate such errors ...***



SUAN can provide an NWP independent platform for "bias tuning"

leading to improved satellite data impact in frontal zones?

Climate

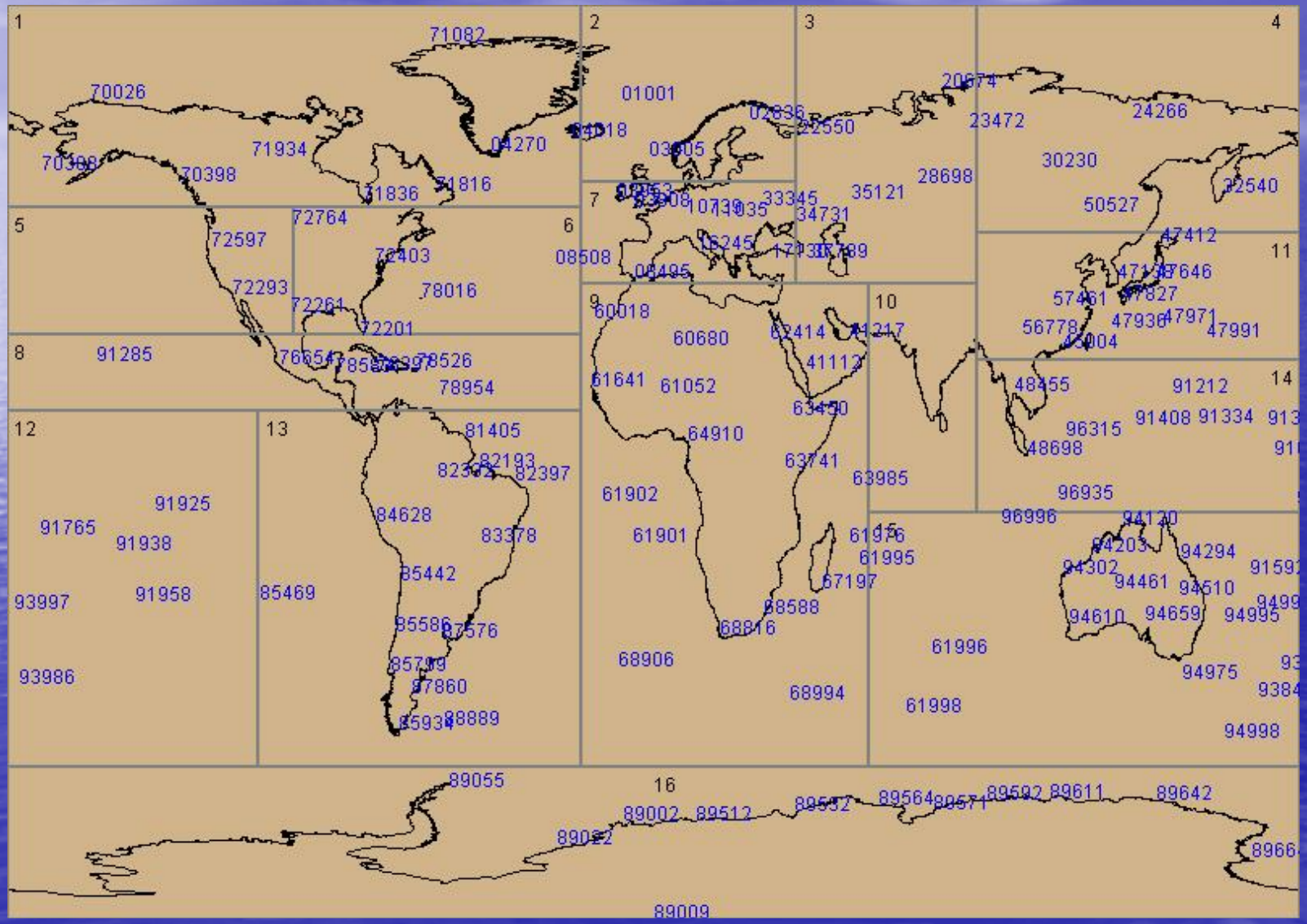
The Problem:

- Attempts to use 20+ years of TOVS (MSU) yield no meaningful overlap (Christy et.al, Mears et.al, Vinnikov and Grody; 2003)

- Conclude that "uncertainties" inherent in historical satellite and radiosonde data make them unsuitable for detecting long-term trends (Seidel et.al, 2004)

SUAN can provide optimal data sets for maintaining the "long-term" records of satellite and radiosonde performance necessary to effectively utilize them in climate applications.

GUAN Sites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