Reference Upper Air Network

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A question of Value ?

Large network of non-standard “synoptic” Radiosonde observations (NWP driven ?)

vs

Small network of multiple, independent, spatially and temporally coincident observations (Climate driven ?)

Reference Upper Air Network

- 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

- **NOAA/GCOS Workshop(s) to improve quality of upper air observations for Climate (February, 2005)**
  - *"Reference" network identified*
- **UKMO Workshop on Vertical Temperature Trends (September, 2004)**
- **WMO/AOPC (Geneva, April, 2004)**
  - *Subset of GUAN … "supersites"*
  - *WG to address future GUAN design … chaired by Peter Thorne*
- **International ATOVS Study Conference - 13 (November, 2003)**
  - *recommendation to pursue "SUAN" , including document targeted for WMO*
    http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes/suan
- **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)**
  - *initial candidate "SUAN" presented, major topics include **in-effectiveness** of existing radiosonde sampling strategies and need to address **complimentary roles** of global radiosondes and polar satellites 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 over-flying satellite observations … "**with goal of accurate, long term monitoring of global temperature and moisture …"***

ITSC-13 (and 14) Actions

… pursue SUAN ***funding*** and ***agreement*** through relevant bodies (NOAA, NASA, WMO, GCOS, etc.)

… this needs to be ***effectively targeted*** which will require research and further collaboration with interested parties before being presented

NOAA/GCOS Activities

- **NOAA/GCOS Workshop(s) … improve quality of future upper air observations for climate :**
  - ***Phase-1 :*** **Winter 2005 - to define requirements**
    - ***Reference Upper Air Network definition …***
  - ***Phase-2 :*** **Summer 2005 - potential networks and deployments to meet requirements**
  - ***Phase-3 :*** **Late 2005 - definition of integrated observing system**
    - **GEOSS "system of systems"**

A cascade of networks for future climate research

Peter Thorne
(UKMO)

NOAA/GCOS Workshop

Phase-1

Density of coverage

Degree to which climate is primary customer

Benchmark Network

- Traceable to international standards (SI units)
- Absolute accuracy

Reference Network

- Sites of Multi-instrument redundancy
- Coverage sufficient to act as anchor points for more globally complete networks
- provide continuity by monitoring effect of change (e.g. satellite, radiosonde)

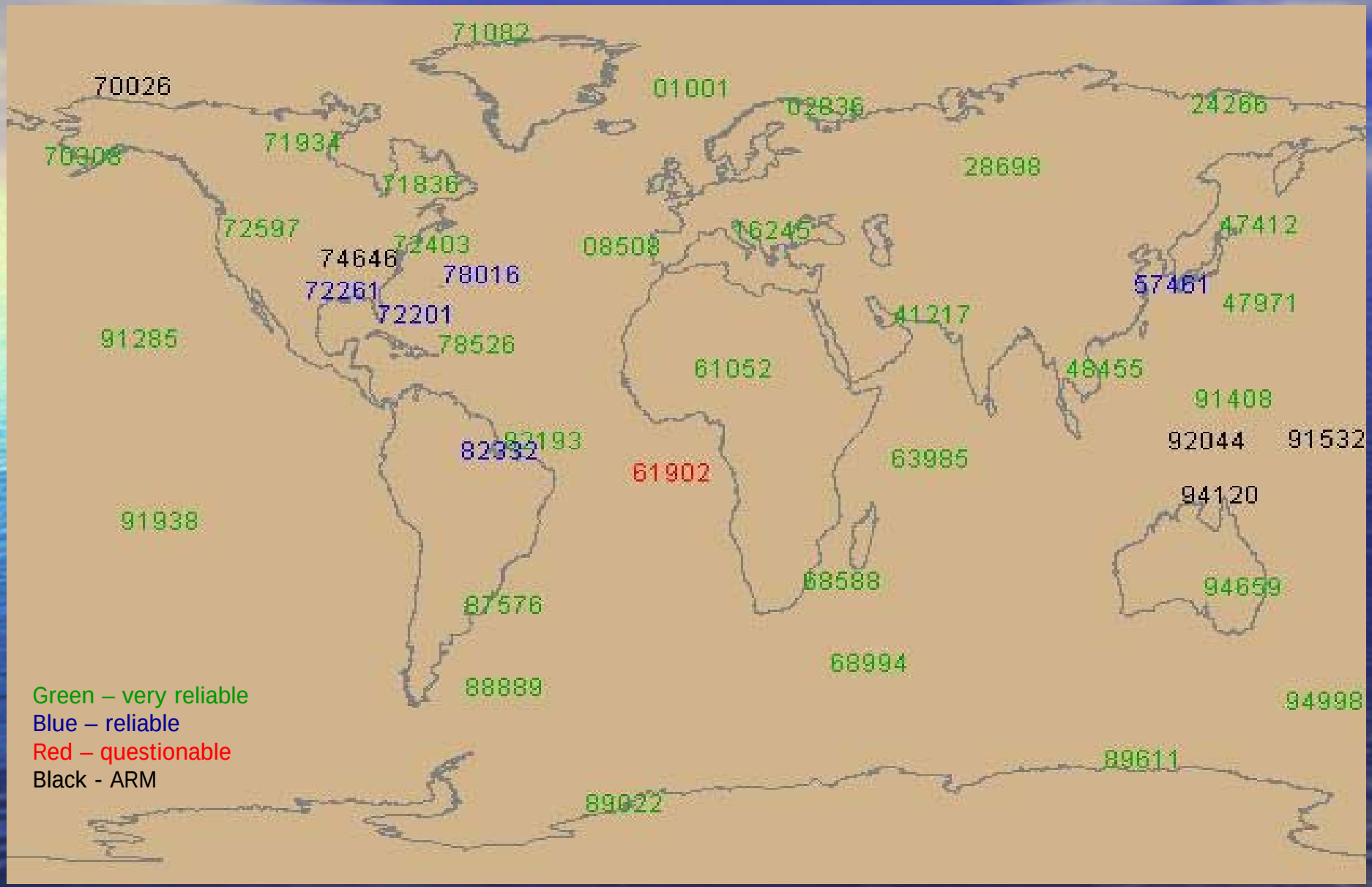
Baseline Network

- Sufficient coverage of upper-air stations to characterise hemispheric and global scale change and variability.
- Commitment to twice-daily radiosonde launches

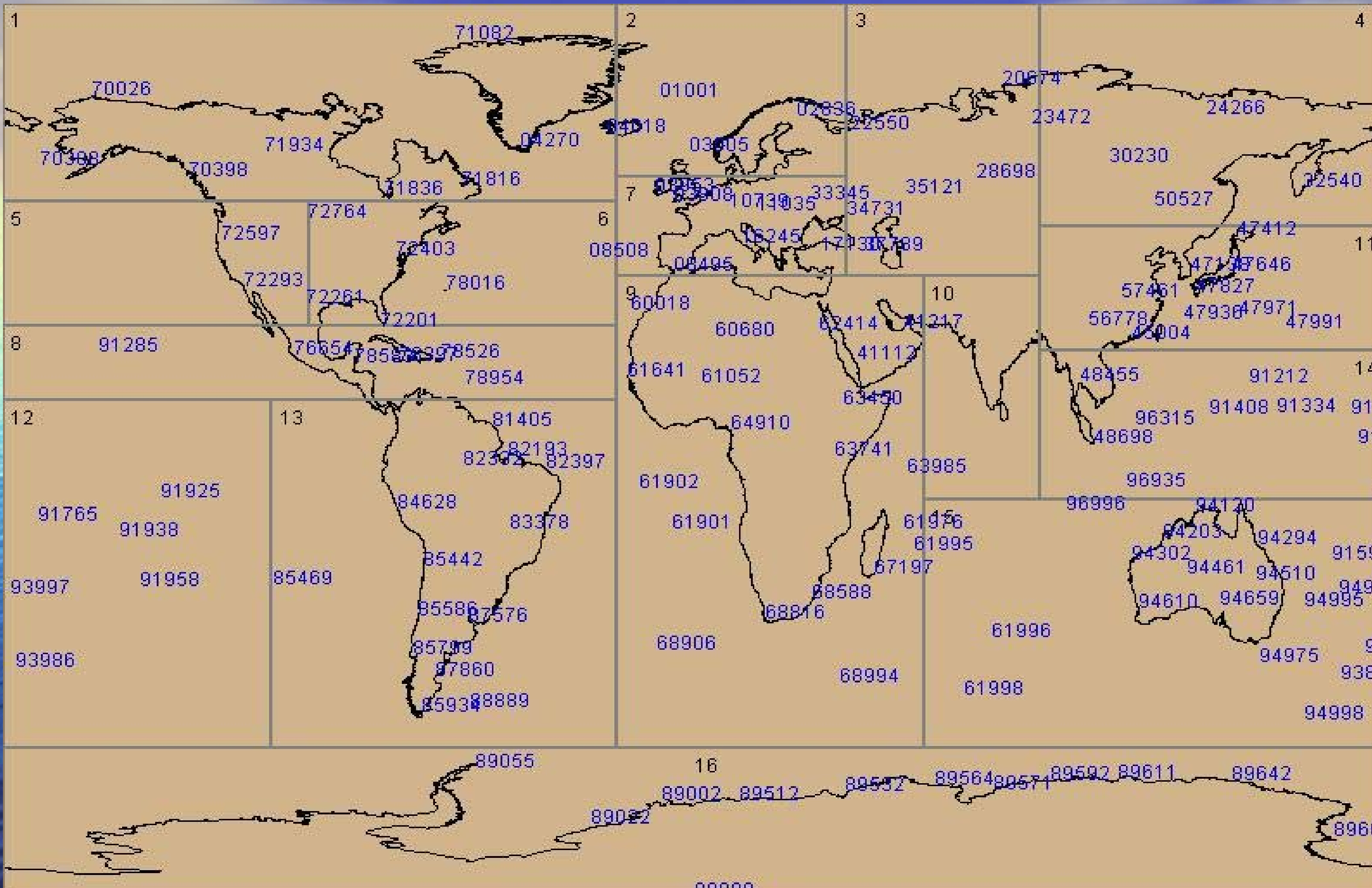
Comprehensive Network

- As globally complete coverage from multiple instruments and platforms as possible.
- Use of reanalysis systems.

Candidate REFERENCE Network



GUAN Sites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34731
4
24266
30230
50527
47412
11
56778
47971
47991
5
72597
72764
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78016
72293
72261
72201
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64910
63741
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10
61902
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61996
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82397
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88889
91925
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89009

CANDIDATE SITE SELECTION

- Subset of "*super-sites*" among GUAN (150) WMO/AOPC (Geneva, April, 2004)
  - Active and Reliable (green, blue, red) (***UKMO, w/McCarthy; NESDIS, w/Tilley***)
  - Global/Robust *(weather and terrain)*
  - Low terrain (500m; 950mb)
  - Non-coastal
- *ARM Sites* (black)
- ***SHIPS !?***

Super-Sites

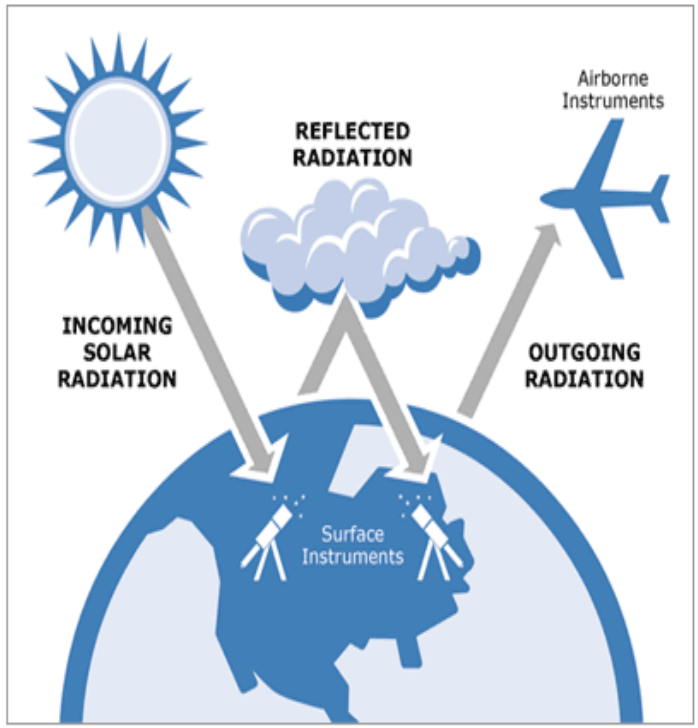
WMO/AOPC in April 2004:

- Standard Reference Sondes
  - Temperature, *moisture, w*ind, surface, ozone ...
  - 5 mb
  - Instrument type ?
- Traceable In-situ Measurements
  - See ARM ... site dependent
- R & D
  - optimal research environment

http://www.arm.gov/measurements/

Measurements

The Atmospheric Radiation Measurement (ARM) Program gathers a wide variety of measurements from many different sources. Each day, the Data Archive stores and distributes large quantities of data collected from these sources. Scientists then use these data to research atmospheric radiation balance and cloud feedback processes, which are critical elements of global climate change.



The ARM Program gathers cloud and radiation measurements from instruments on the ground, attached to aircraft, and sometimes placed on ships.

Measurement Categories

- Shortwave Spectral Radiation
- Cloud Properties
- Surface Meteorology
- Atmospheric Profiling
- Surface Energy Flux
- Aerosols
- Atmospheric Carbon
- Airborne Platforms
- Longwave Spectral Radiation
- Longwave Broadband Radiation
- Shortwave Broadband Radiation

How Many Observations

- 42 sites (plus Ships)

- ***One launch per day!*** ***...*** *minimal requirement , staggered among " **operational satellites** " and orbital nodes*

- 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 about $125K per site)
  - Reduced cost through re-programming of existing resources
  - *1500 sondes x 200 .... $100 million year*

SHIPS ... *islands vs remote ocean*

National science vessels (like NOAA Ronald H Brown) often include automated (ASAP) radiosonde, in-situ measurement (cloud, radiometric, SST) capability … ***optimal platform for REFRENCE network !***

At about $300 per raob, estimated cost less than $100K yearly per member nation …

International Coordination (WMO)

- cultivate national commitments to support internationally accessible polar satellite / upper air data and program(s)
- international oversight (ITSC ...)
- start before 2008 ?

Program To Include:

- Generation/Distribution (NESDIS) of Launch Schedules
  … *i.e., 45 minutes before overpass*
  - Fixed sites
  - Ships
- Metadata Records … launch protocols, data corrections, training, etc
- Network Performance Monitoring/Feedback
- **Data Collection (NESDIS) and Archive (NCDC) …** can *integrate into NESDIS operational support systems (ATOVS, METOP, NPP, NPOESS)*

Program (continued):

- Relational Collocation File Structure (satellite, radiosonde, in-situ ...)
  - see Francis / Schweiger ... Arctic-SEARCH program
- Flexibile and Expansive
  - other satellites (GPS ...)
  - in-situ (site dependent)
  - platforms (ACARS, Dropsondes, ...)
- Accessibility (data, directories, software readers) ... Web-based ?

Collocated Radiosonde and TOVS-1b from 1979

(*correcting the past* ...)

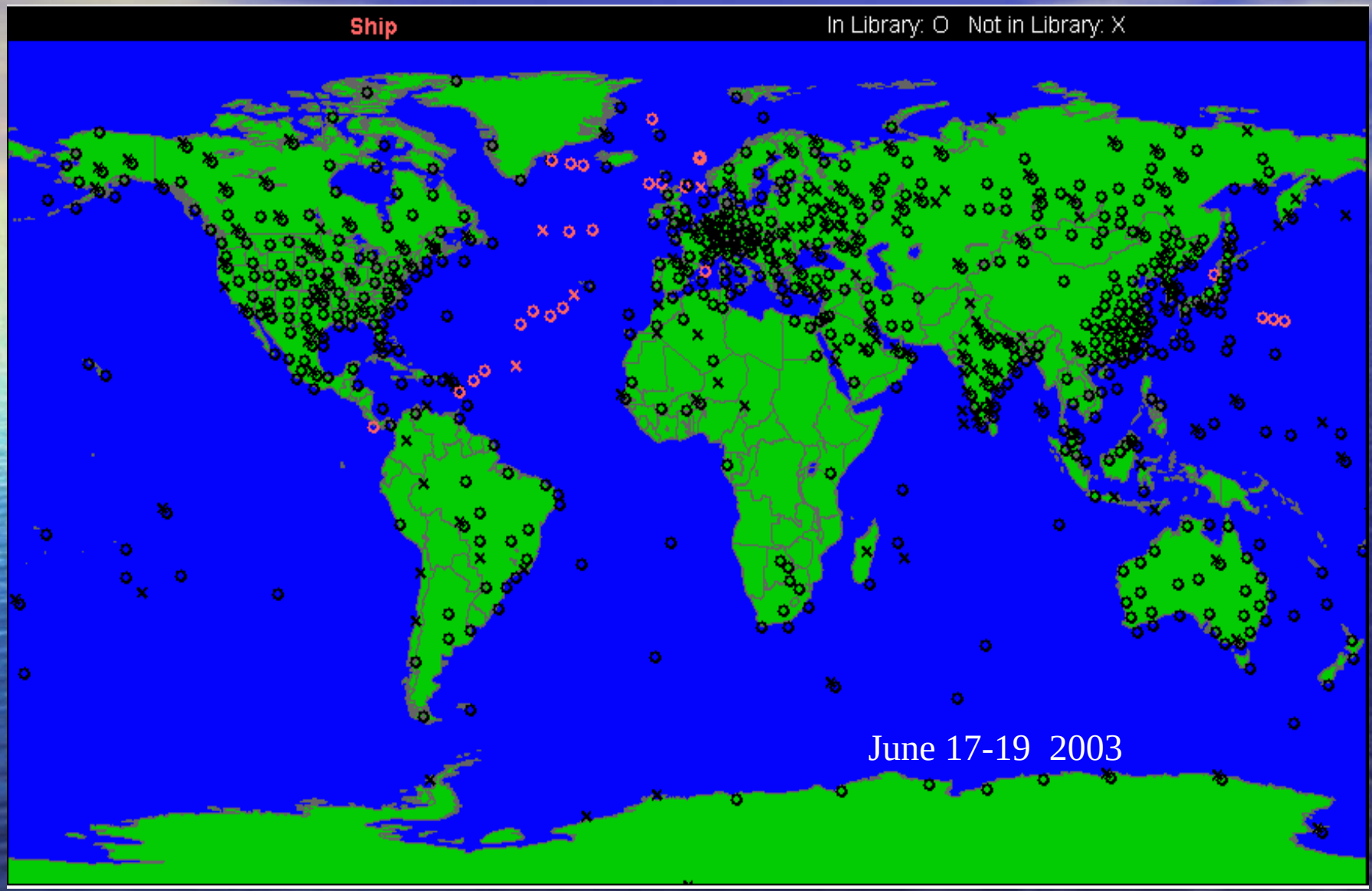
- **NOAA-SEARCH Program Goals :**
  - ***Re-process TOVS for Arctic Climate change*** *(Francis / Schweiger)*
  - Compile Data Base of "Arctic" Collocations to quantify TOVS (and Raob) measurement uncertainty *(Reale; Salazar and Brown Raytheon ITSS)*

- Status
  - Radiosondes
    - GTS ... *NCEP (NOAA), ERA-40 (ECMWF), IGRA (NCDC)*
    - Special Field Experiment
      - ARM
      - JOSS (NCAR)
      - *SHIPS*
      - *Other ?*
  - TOVS Historical 1b-level data (HIRS and MSU)
  - Relational data-base of Arctic Collocations
    http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes/polarsearch

- ***Costly and time consuming process; funding needed:***
  - ***expanded "global' relational database***
  - ***construct operationally (ATOVS, NPP, METOP, NPOESS ...)***

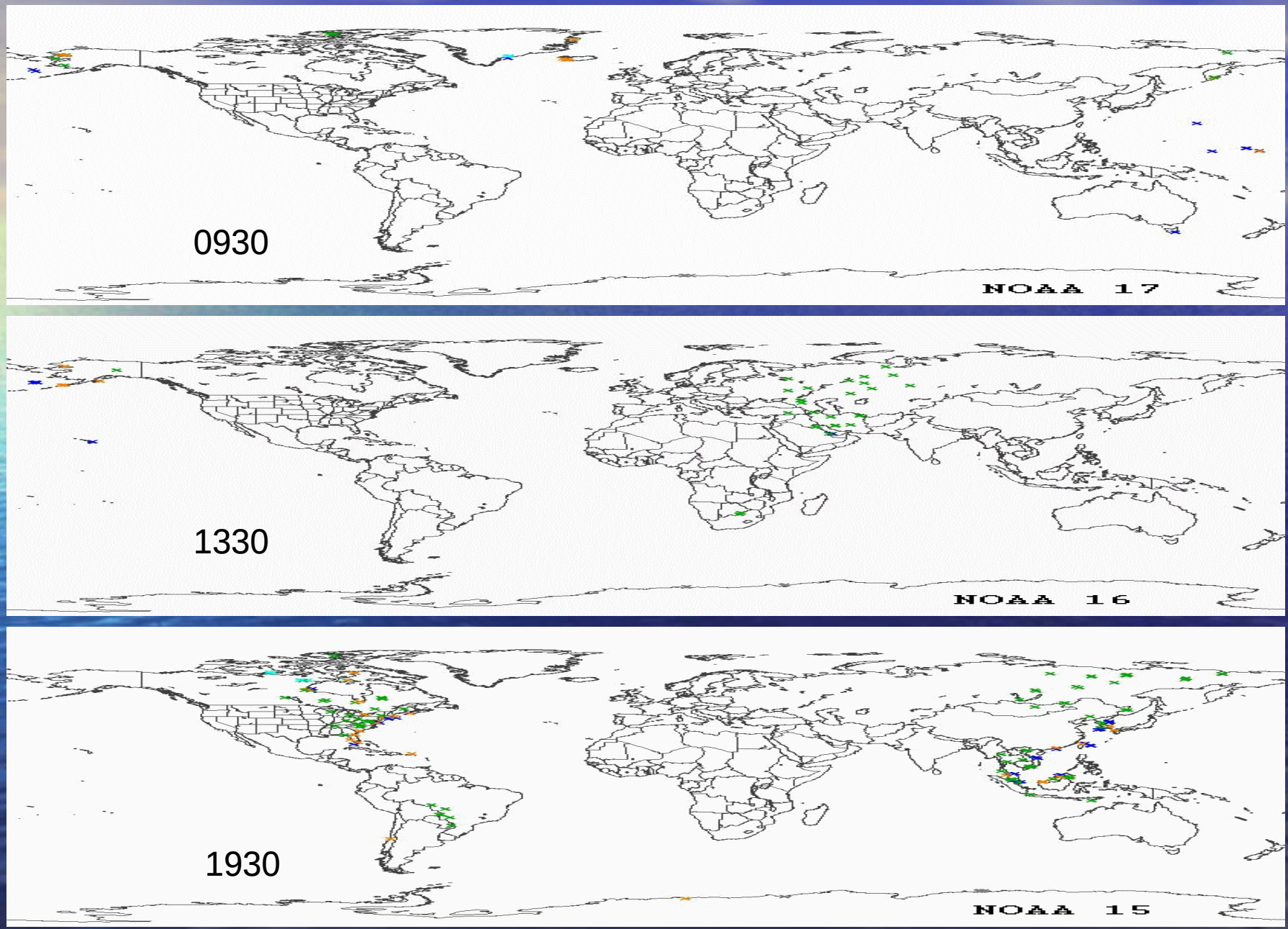
WHY A REFERENCE NETWORK ?

Global Radiosondes



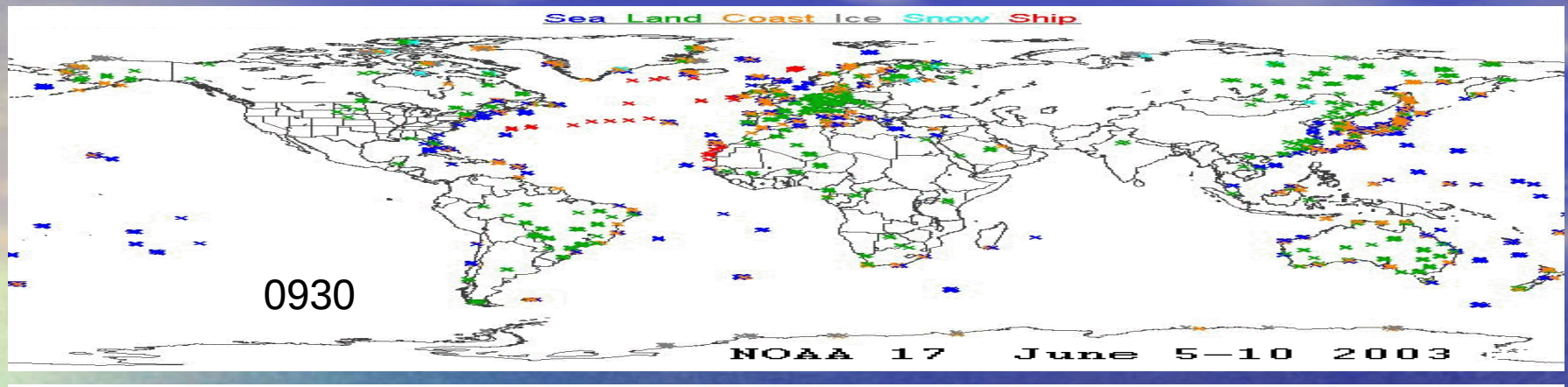
Operational Satellite and Radiosonde Collocations

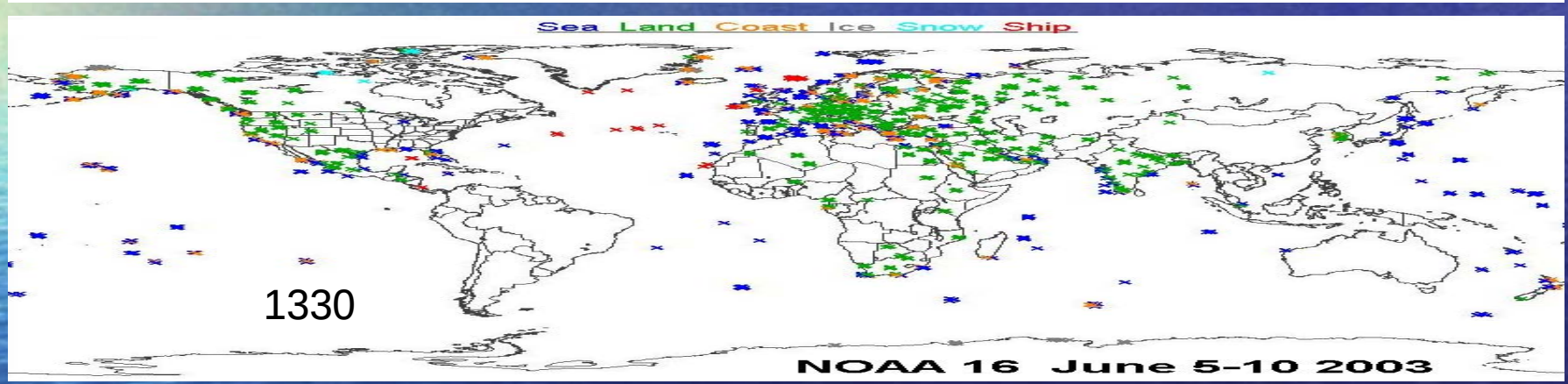
(- 1 hr ; 100km) ... same-same

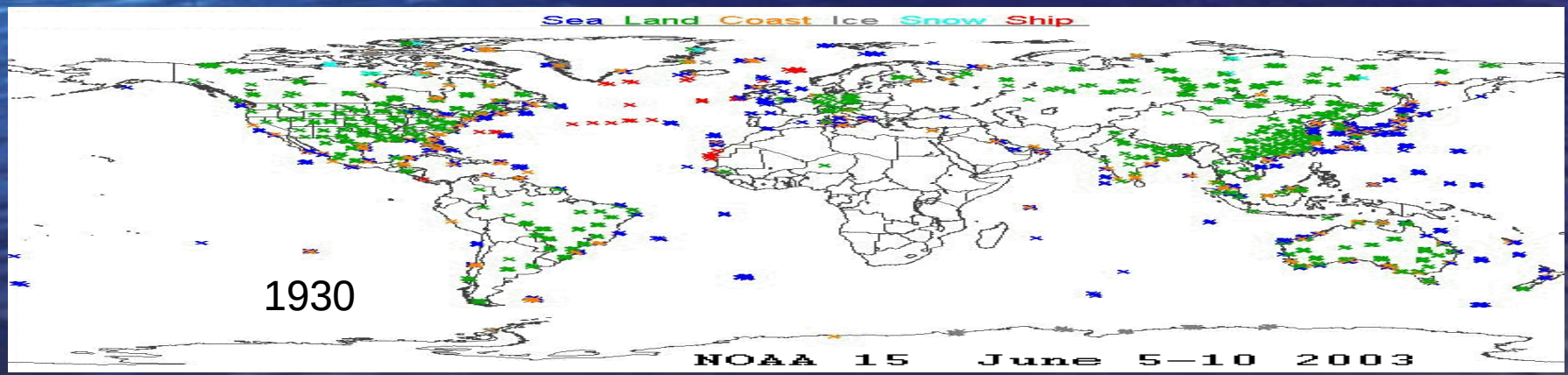


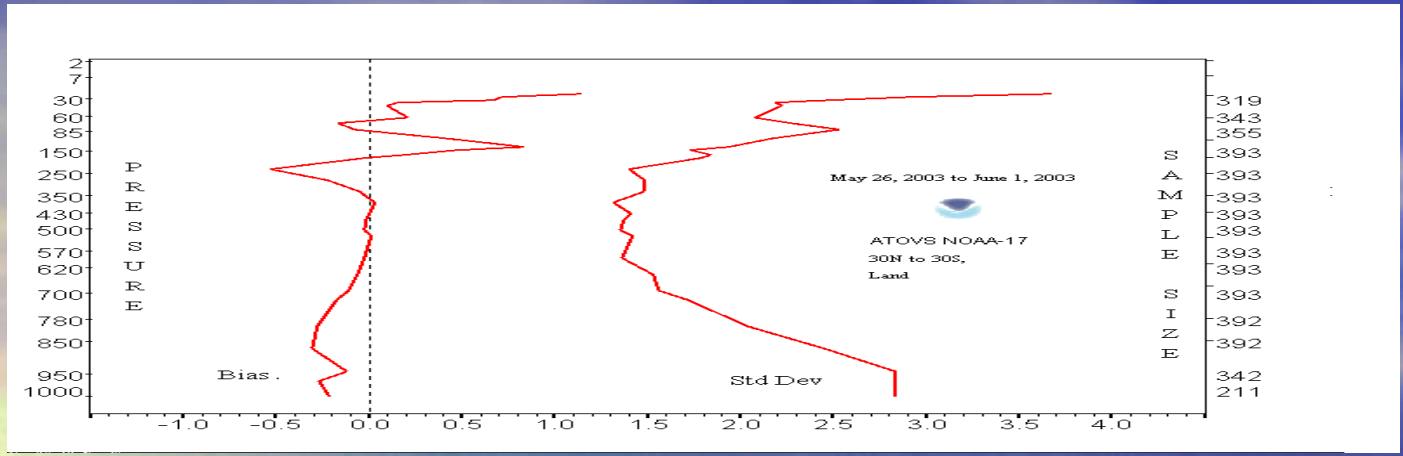
Operational Satellite and Radiosonde Collocations

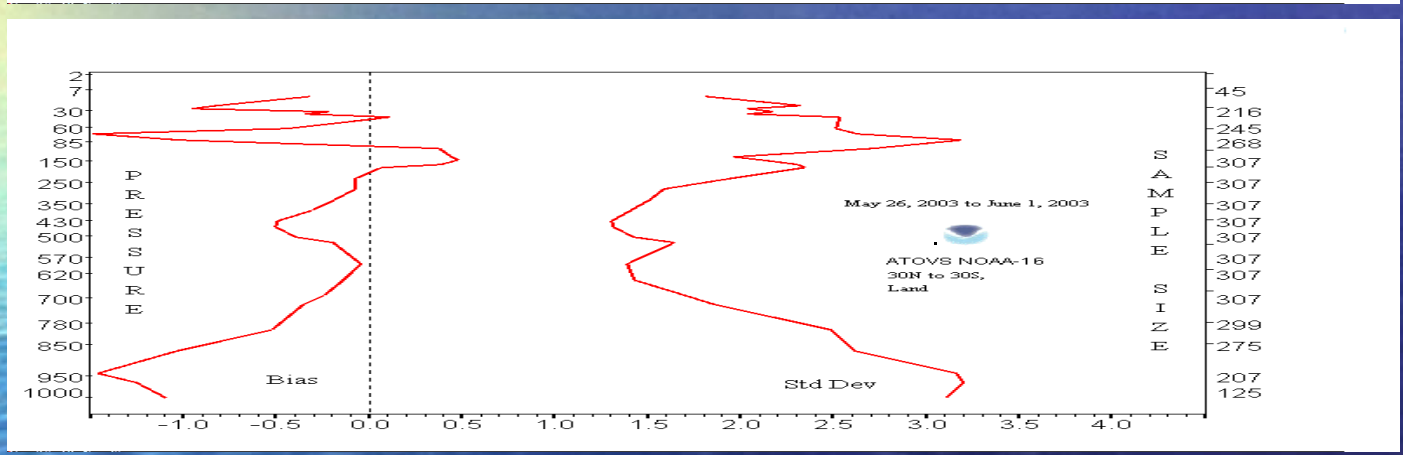
(+/- 5hrs sea, +/- 3hrs land; 100km)

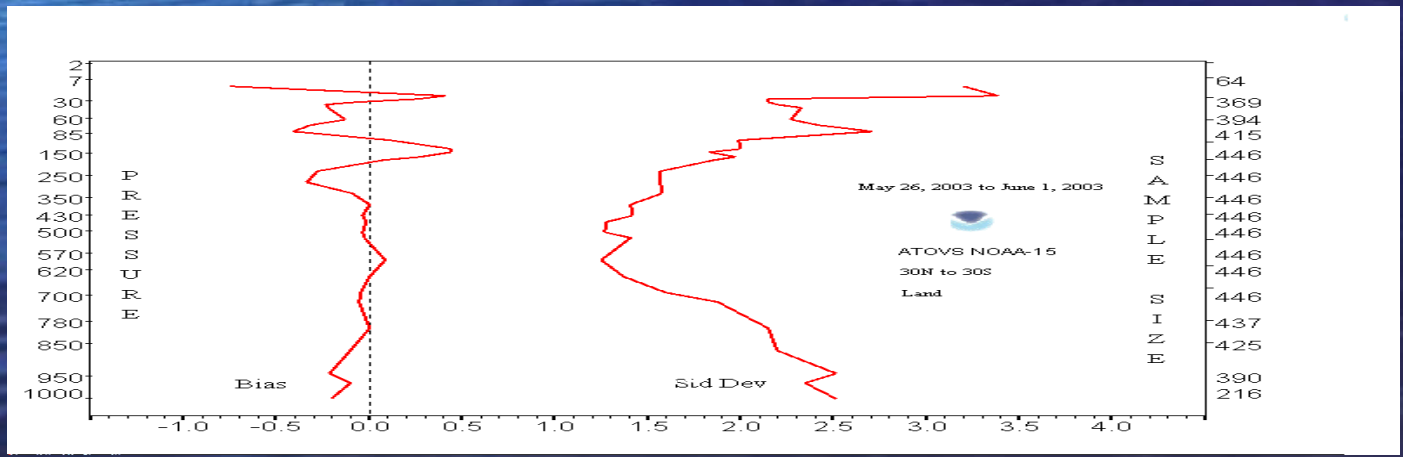










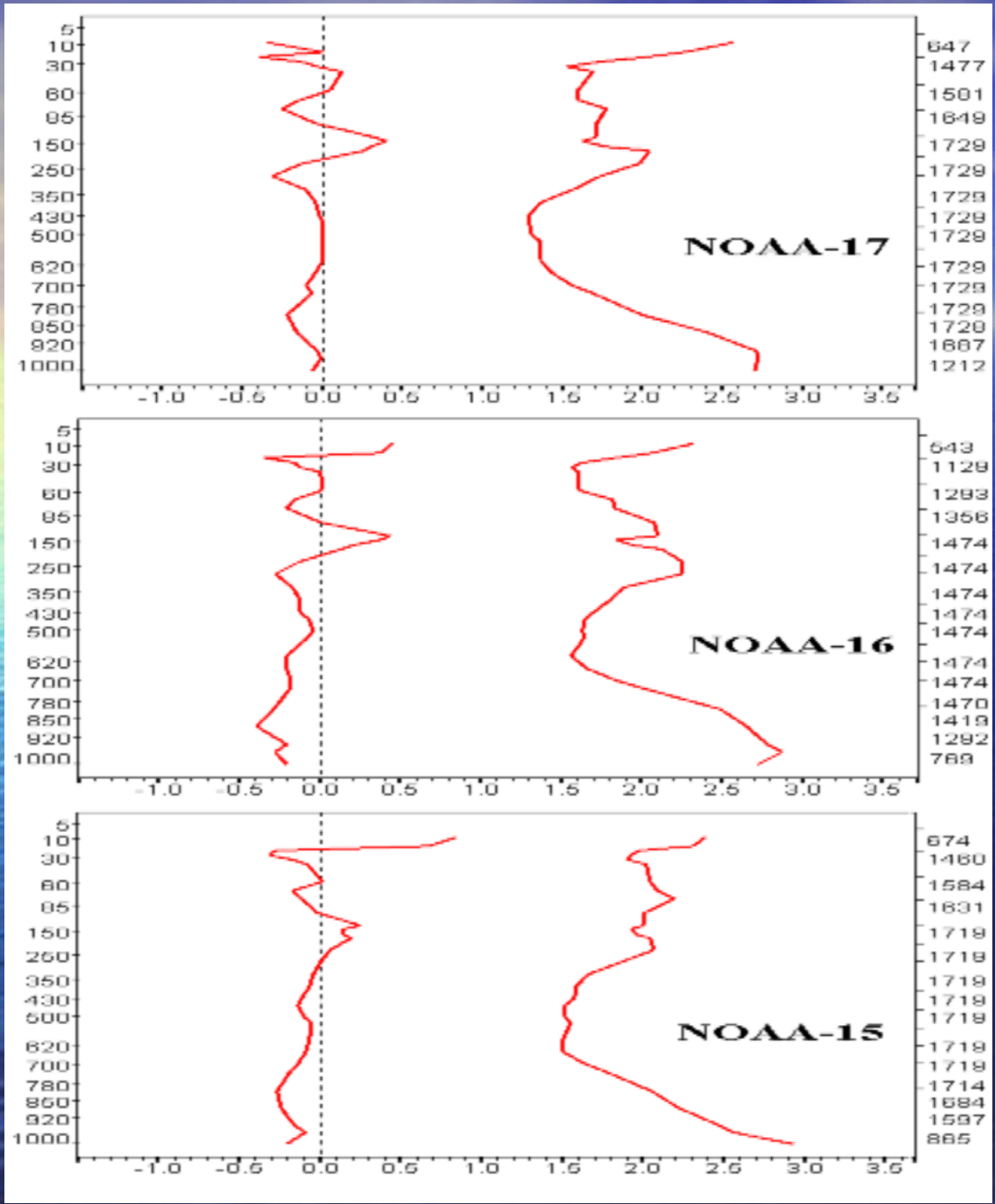


(Satellite – Radiosonde)
Temperature statistics

Tropical land
(30N to 30S)

June 7-14, 2003

Results "skewed" by regional sampling bias/error …



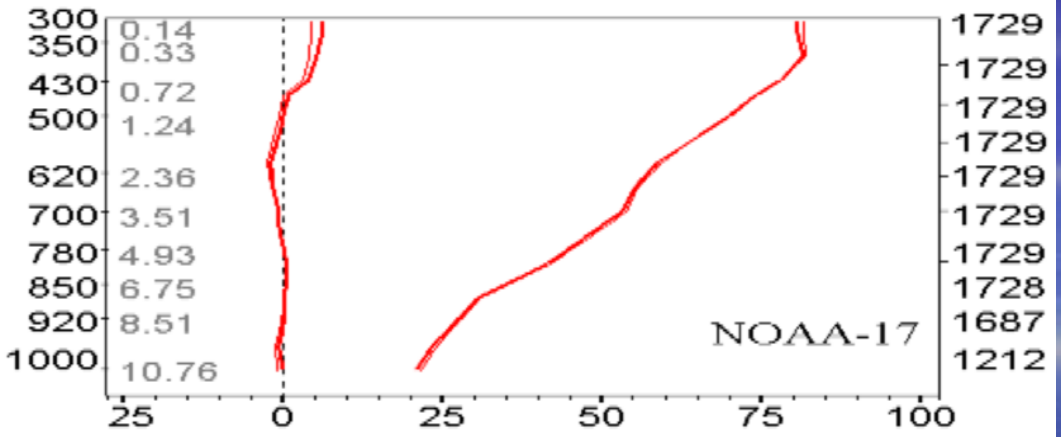
(Satellite – Radiosonde)
Temperature statistics

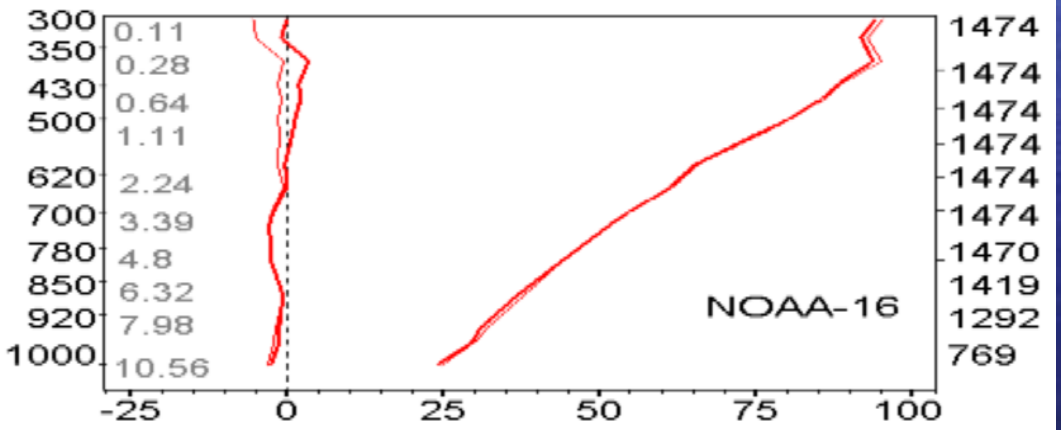
60N to 60S

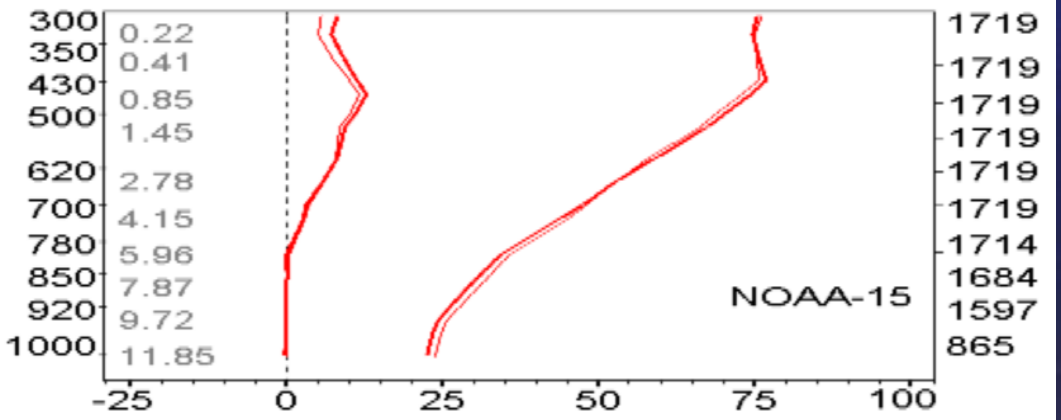
June 7-14, 2003

Larger samples beat down the noise but differences remain ...

Information Not Same-Same







(Satellite – Radiosonde)
Moisture Statistics (%)

60N to 60S

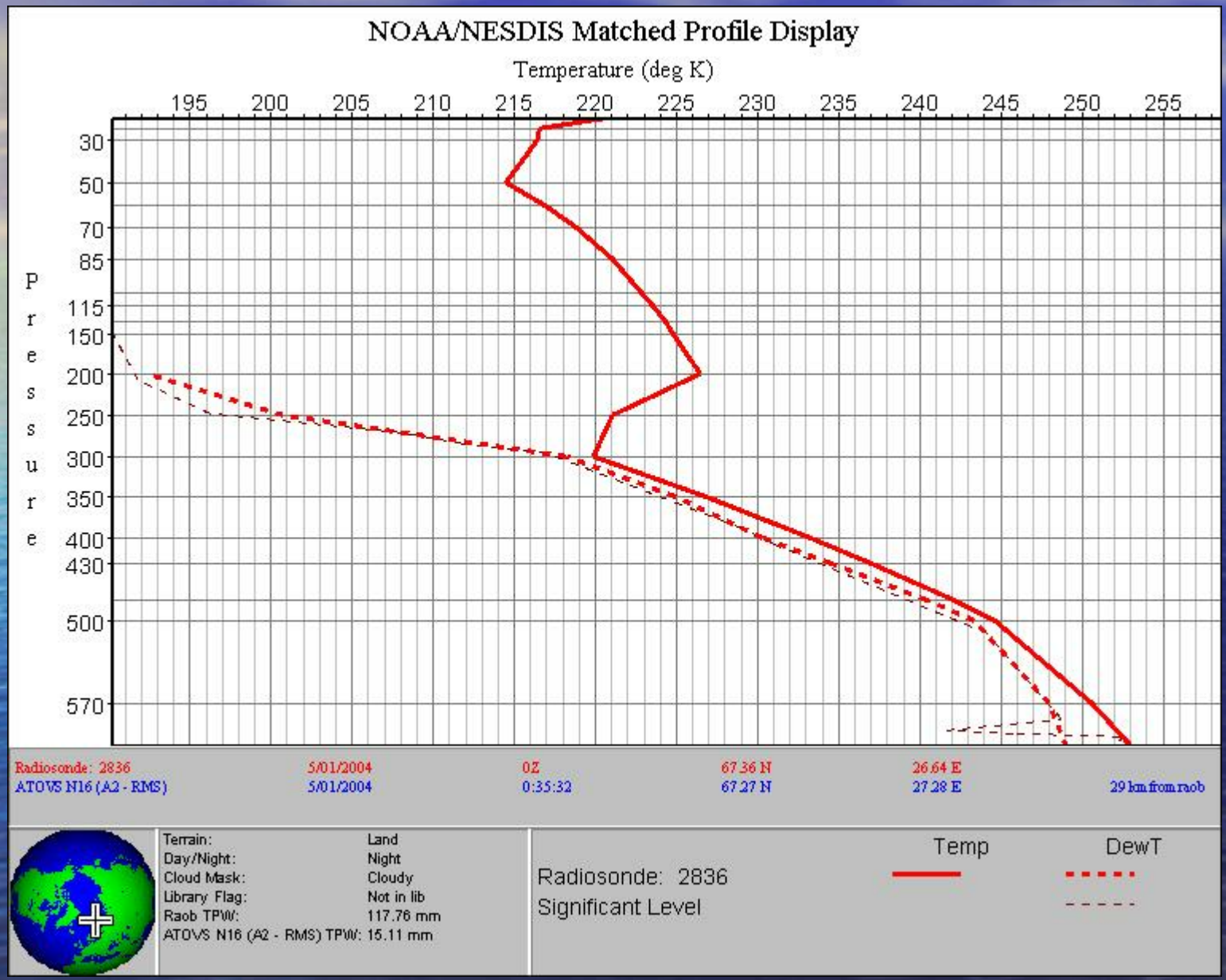
June 7-14, 2003

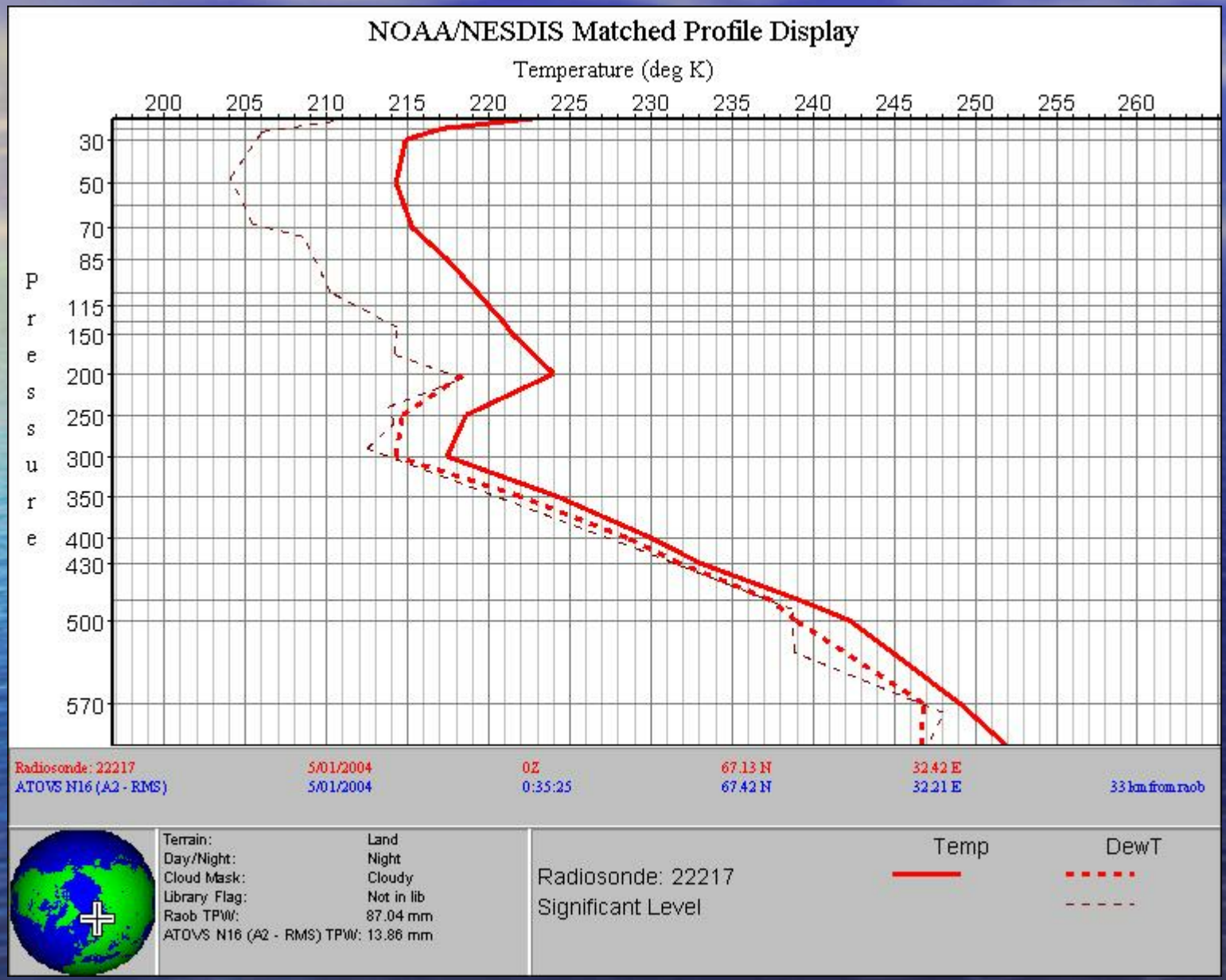
... *differences (upper atmosphere) not indicative of satellite product /sensor performance*

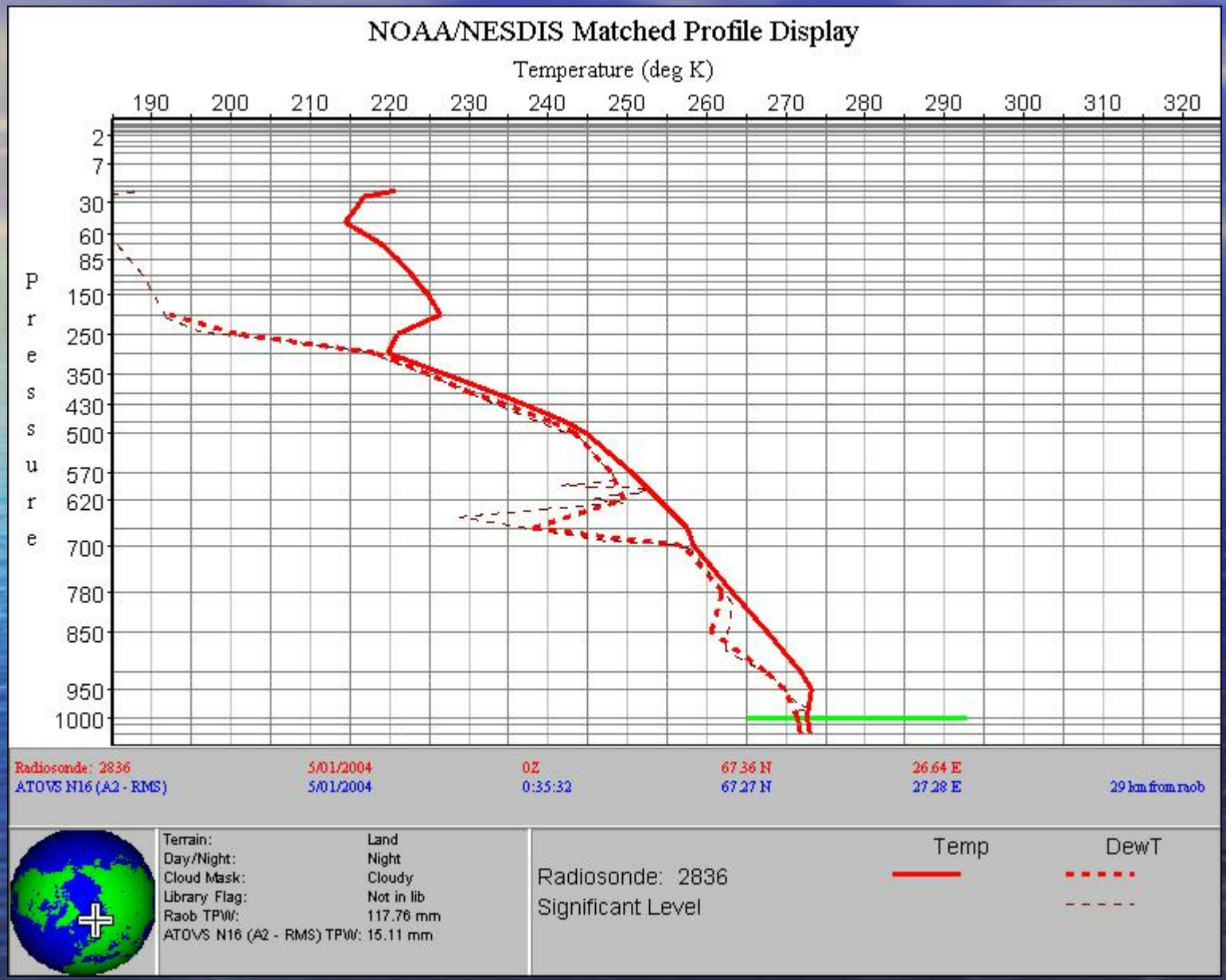
CURRENT

RADIOSONDE MEASUREMENTS

ARE PROBLEMATIC


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
Radiosonde: 2836 5/01/2004 0Z 67.36 N 26.64 E
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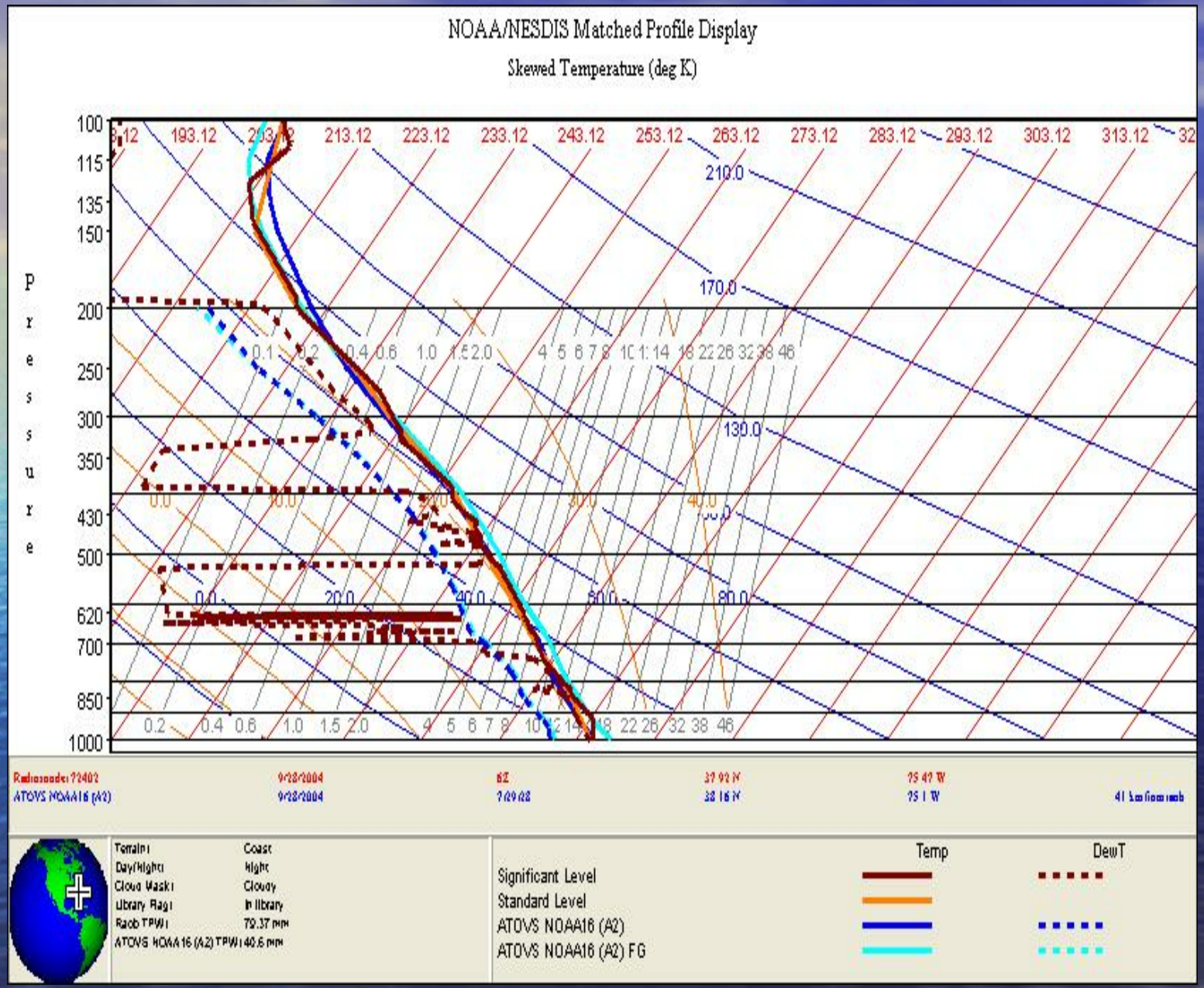
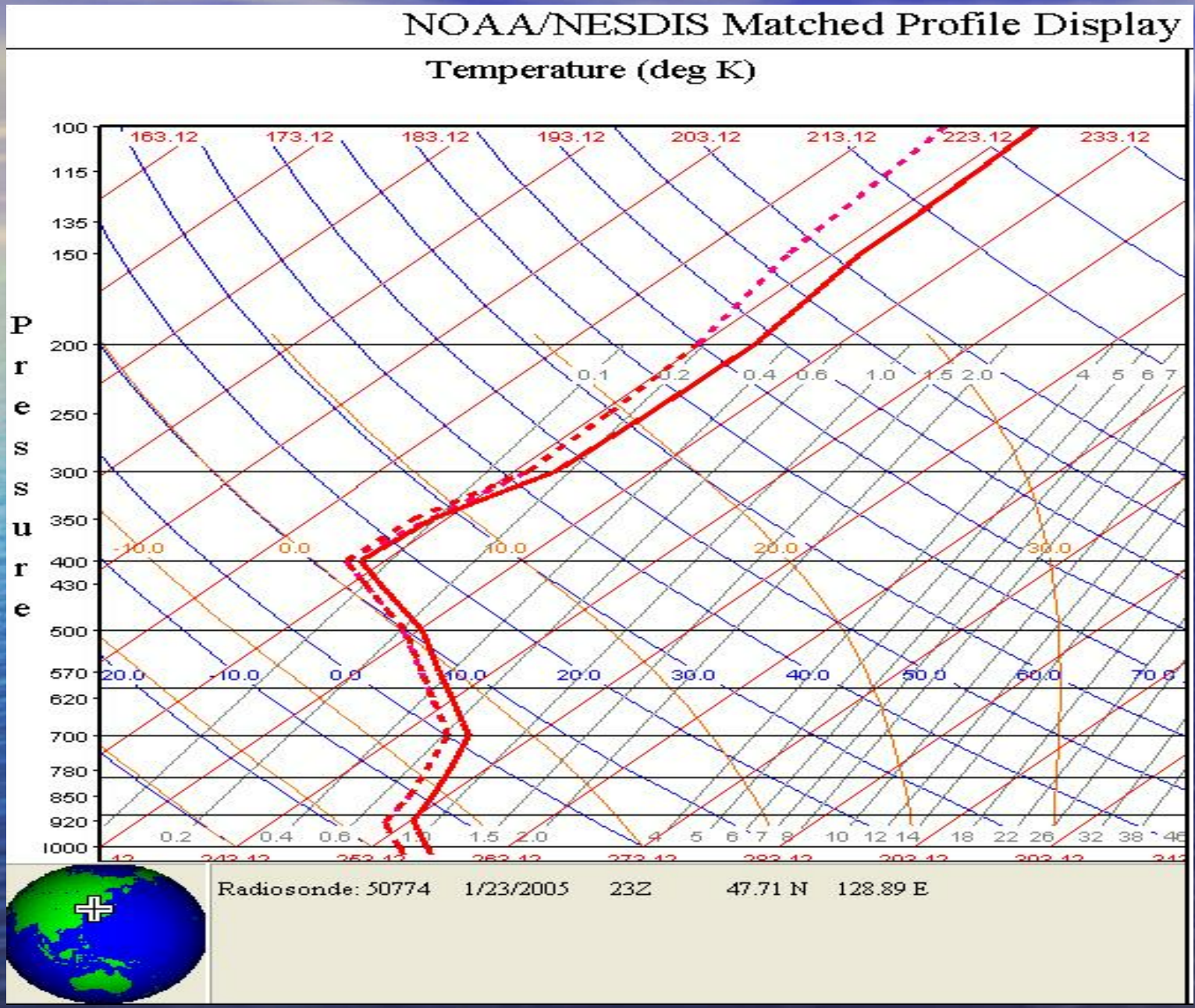
Significant Level
Temp
DewT


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 72.37 mm
ATOVS NOAA16 (A2) TPW 40.6 mm
Temp
DewT
Significant Level
Standard Level
ATOVS NOAA16 (A2)
ATOVS NOAA16 (A2) FG

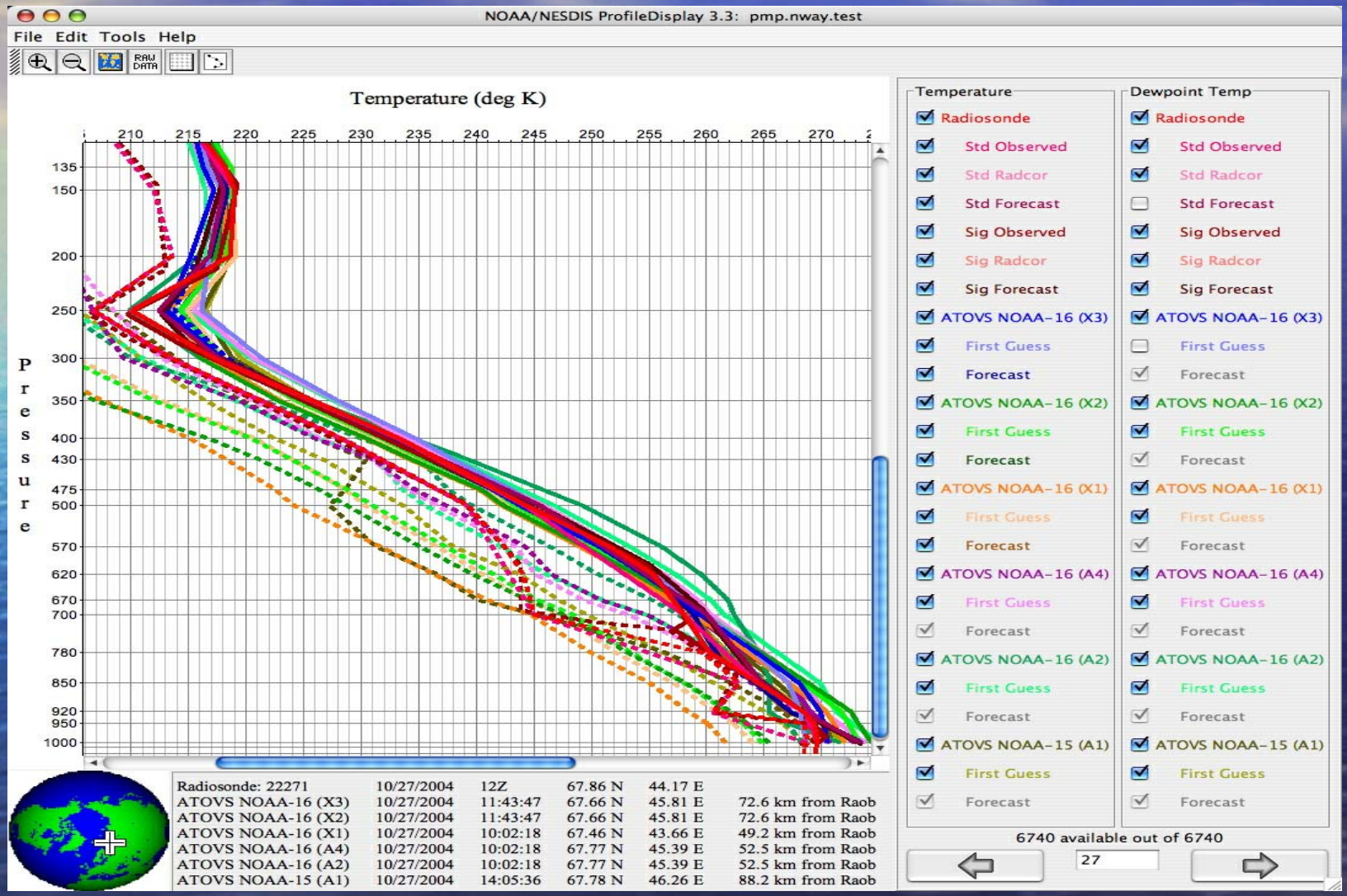

NOAA/NESDIS Matched Profile Display
Temperature (deg K)
Pressure
100
115
135
150
200
250
300
350
400
430
500
570
620
700
780
850
920
1000
163.12
173.12
183.12
193.12
203.12
213.12
223.12
233.12
-10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Radiosonde: 50774 1/23/2005 23Z 47.71 N 128.89 E

Existing Data are Difficult to Use

- Coordination lacking among various platforms (satellite, radiosonde, in-situ, field experiments, ...)
- Incomplete Meta data records
- Processing errors (need original data ...)
- Formatting nightmare
- Lacks traceability (uncertainty unknown)
- Not same-same

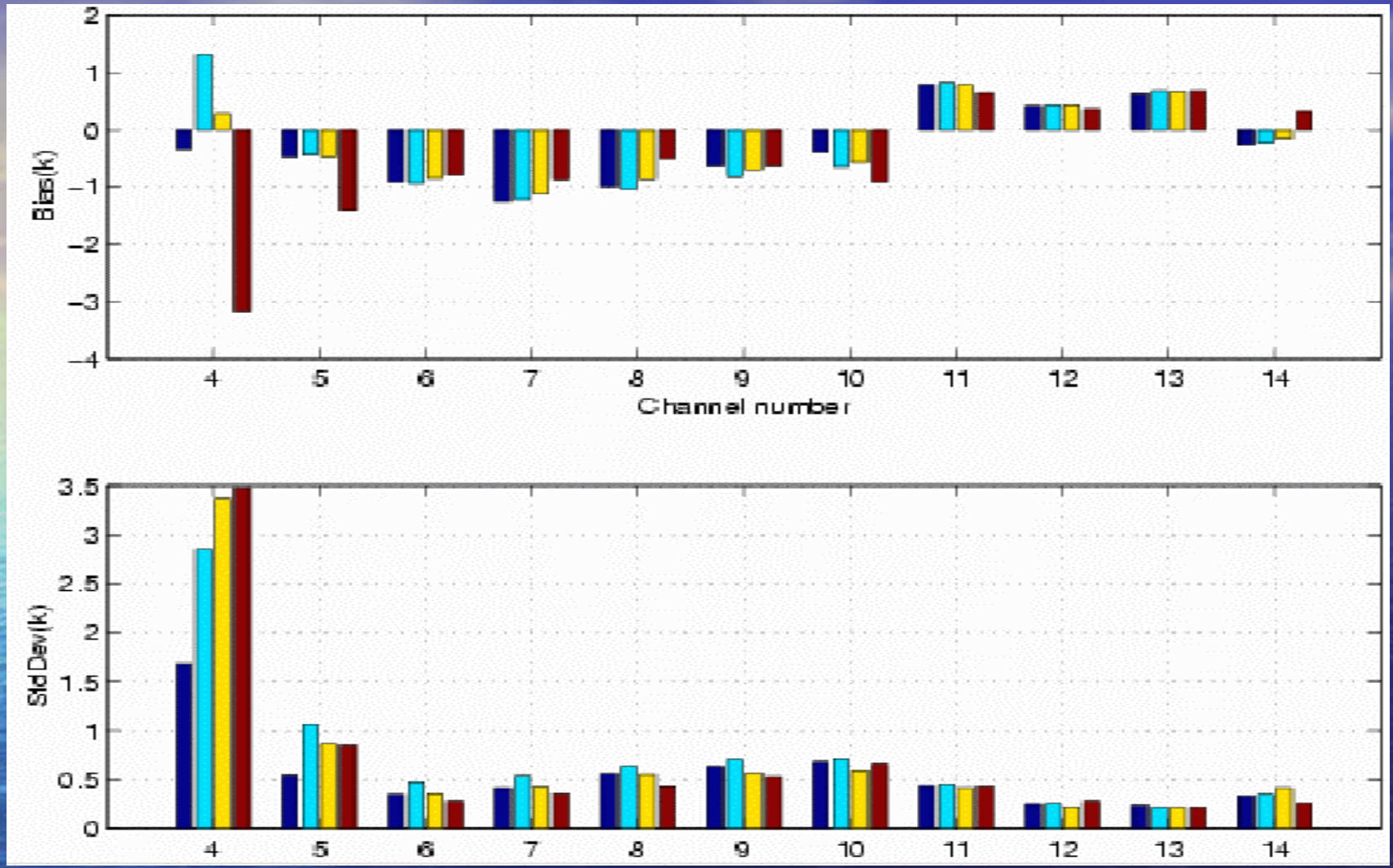
Compare individual profiles from ***Radiosonde, Satellite*** and ***NWP*** platforms

(… uncertainty rules)



WHO IS IMPACTED?

- ***Operational Data Providers***
  - satellite measurement/product systems require *collocated radiosonde and satellite observations for Tuning/Validation ...*
- ***Scientific Community***
  - radiative transfer (RT) models require coincident/accurate T, H20 and Radiometric profiles *"key to absolute accuracy" ...*
- ***Users***
  - climatologists undermined by (long-term) un-resolved uncertainties among critical upper air observing platforms such as radiosonde, satellite ...



"Calculated (from Raob and RT) minus Observed (from satellite)" for AMSU-A (channels 4 to 14, NOAA-16; Land, Ice and Snow, and Coast) are basis of RT-bias coefficients

Climate Users

Problems Include:

- Sensor Bias
  - Systematic per satellite
  - Sensor response changes
  - Satellite drift
  - Radiosondes
- Science Bias
  - RT model
  - Processing Approach

End Result:

"Uncertainty Outweighs the Signal"

Climate Applications Formula

(... i.e., from SEARCH)

Real-time" Database Compilation Effort

... satellite data and collocated ground truth

(compiled during satellite operational lifetime)

to serve as input for

"Retrospective" Climate Processing

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

(at conclusion of satellite operational lifetime)

… *also benefits* Radiosonde Program

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

- ***REFERENCE sites would support :***
  - ***radiosonde validation (including non-Reference sondes)***
  - ***radiation and inter-sonde "corrections"***
  - ***new technology development (ie, upper level H2O, …)***
  - ***balloon drift and local weather impacts***
  - ***dual and sequential launch experiments …***
  - ***aircraft overflights***

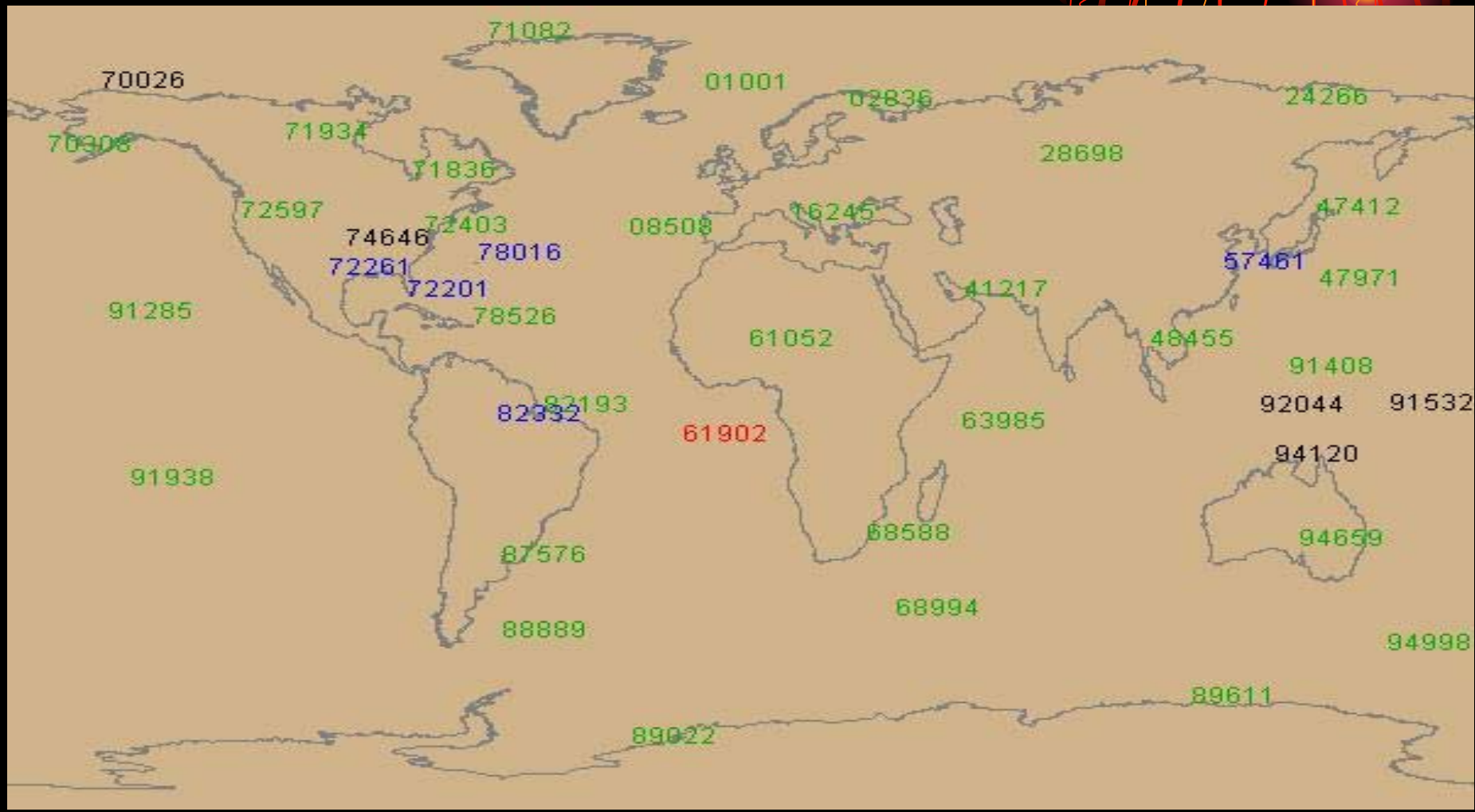
... *even* NWP

- Significant positive impact of satellite data on NWP reported over past several years
- However, associated data assimilation and adjustment techniques cannot segregate RT and NWP model bias/error ...
- ***Proposed Reference Network can potentially segregate such errors ...***

REFERENCE provides STABILITY

- "Long-term" record of critical upper air observations benefits current and future generations ... *connecting the dots*
- ... optimal scenario for characterizing long-term series of observations ...
- if we had such a database today (i.e., that spanned operational TOVS era-1979), could we better utilize the data ?
- ***Positive Impacts on Climate (and NWP) ...***

OPERATIONAL = REFERENCE



EXTRAS

Reference Upper Air Network

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International Symposium of
Remote Sensing and Space Technology
For Multidisciplinary Research and Applications
Beijing, China
May 23-24, 2005

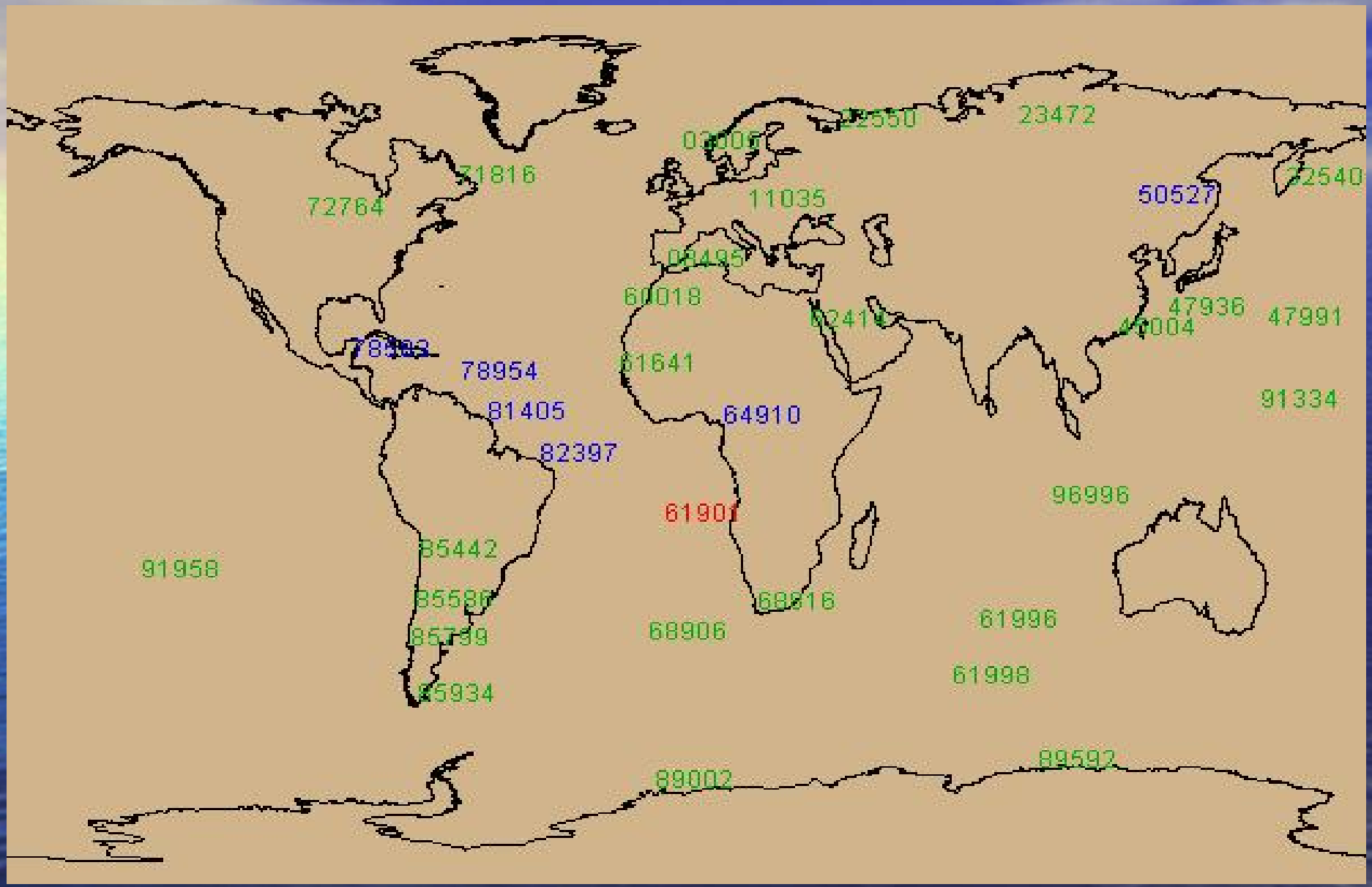
ID	T	Lat	Long	Z	UKMO		NES(D)	NES(A)		Alternates
01001	S	70.9	-8.7	10	100	G	14/14	11/13		03005
02836	L	67.4	26.6	179	92	G	14/14	12/13		22550
08508	S	38.7	-27.1	113	98	G	7/8	12/12		60018
16245	L	41.7	12.4	32	95	G	25/25	27/27		08495, 11035
24266	L	67.6	133.4	138	90	G	7/7	6/7		
28698	L	54.9	73.4	90	100	G	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

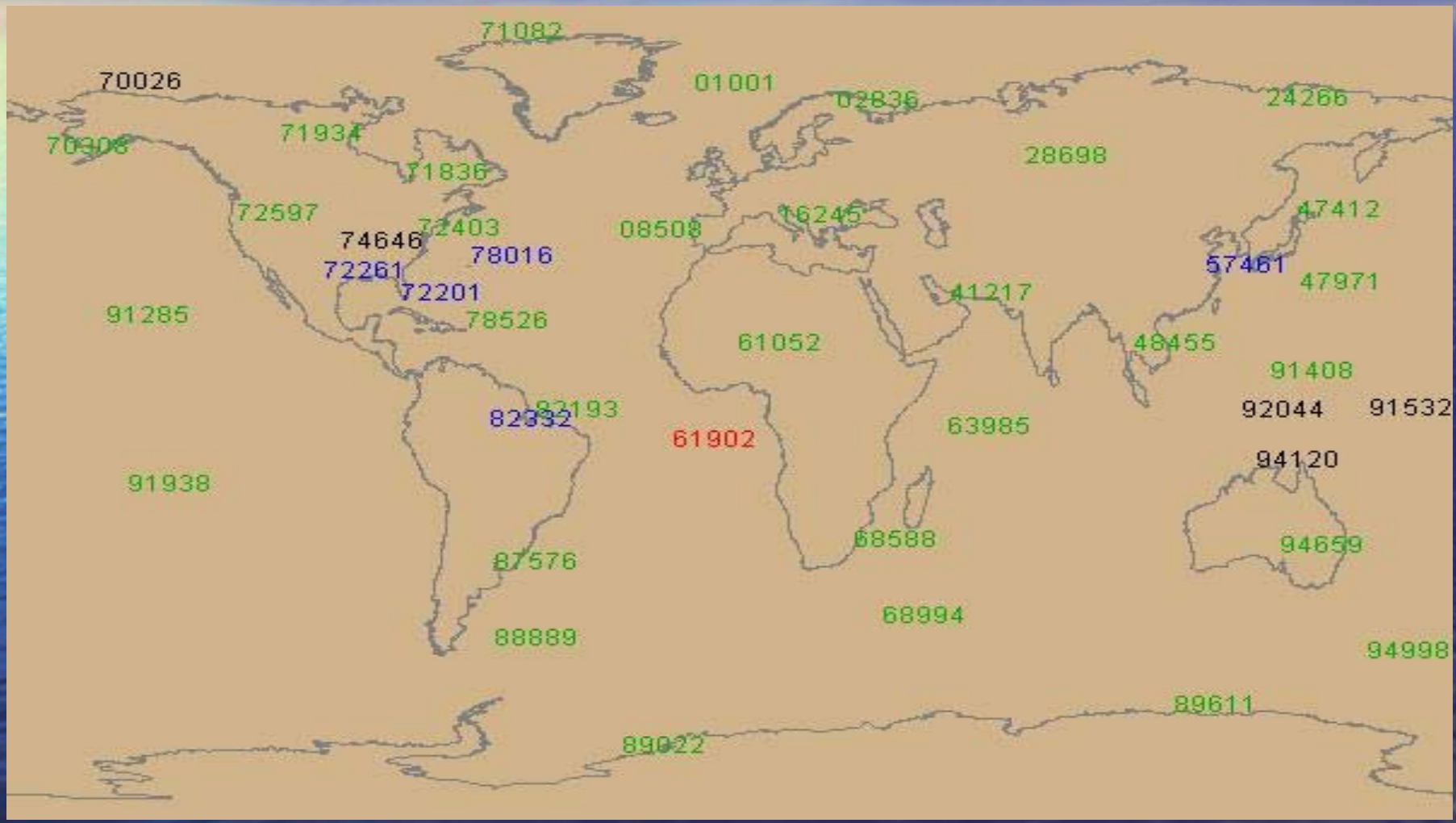
Alternate Sites

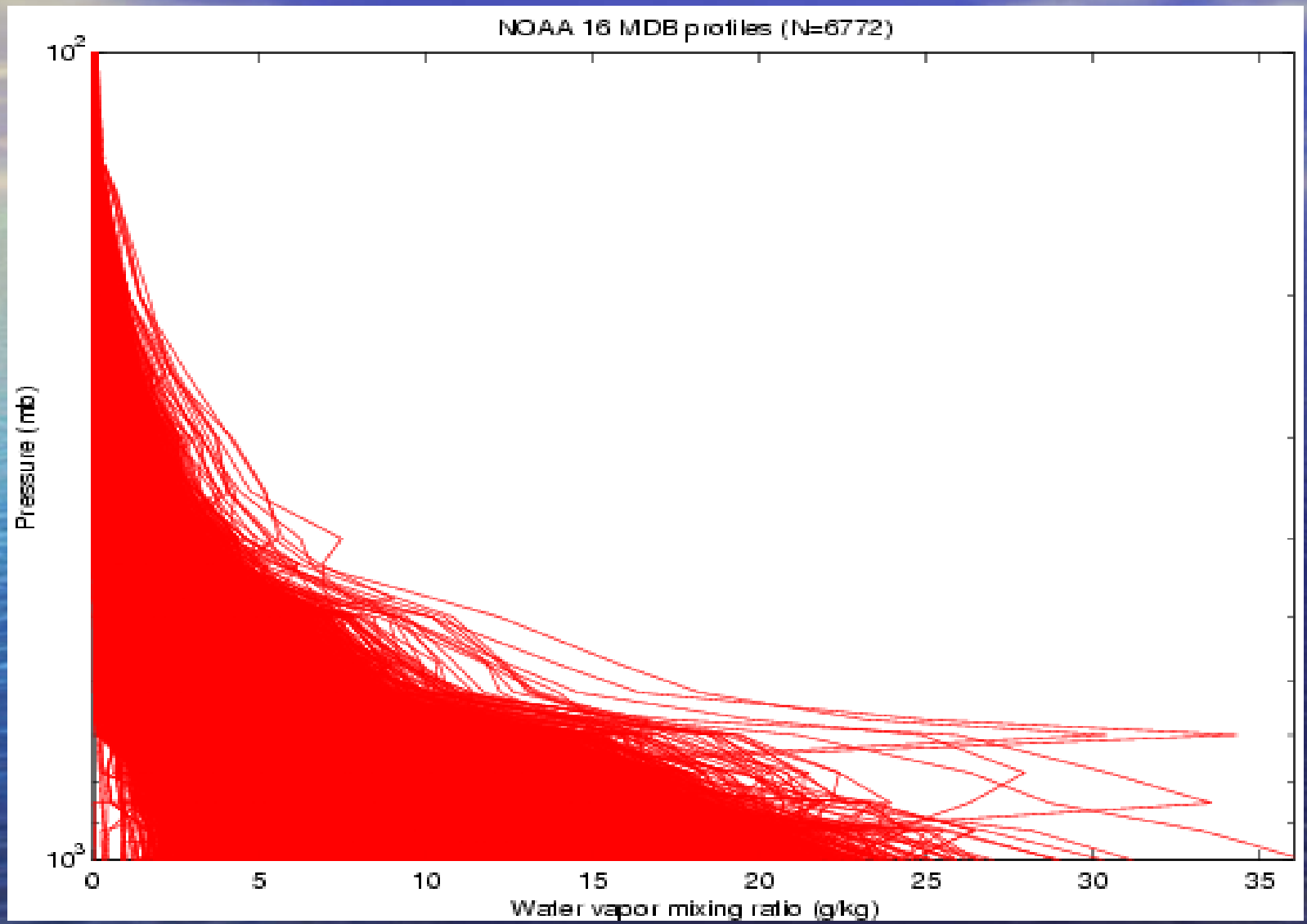


RT Models

- 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, NWP, Climate...) vs observed (from satellite) radiance ...
- ***SUAN sites optimal in support of long-term RT model validation and development ...***

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

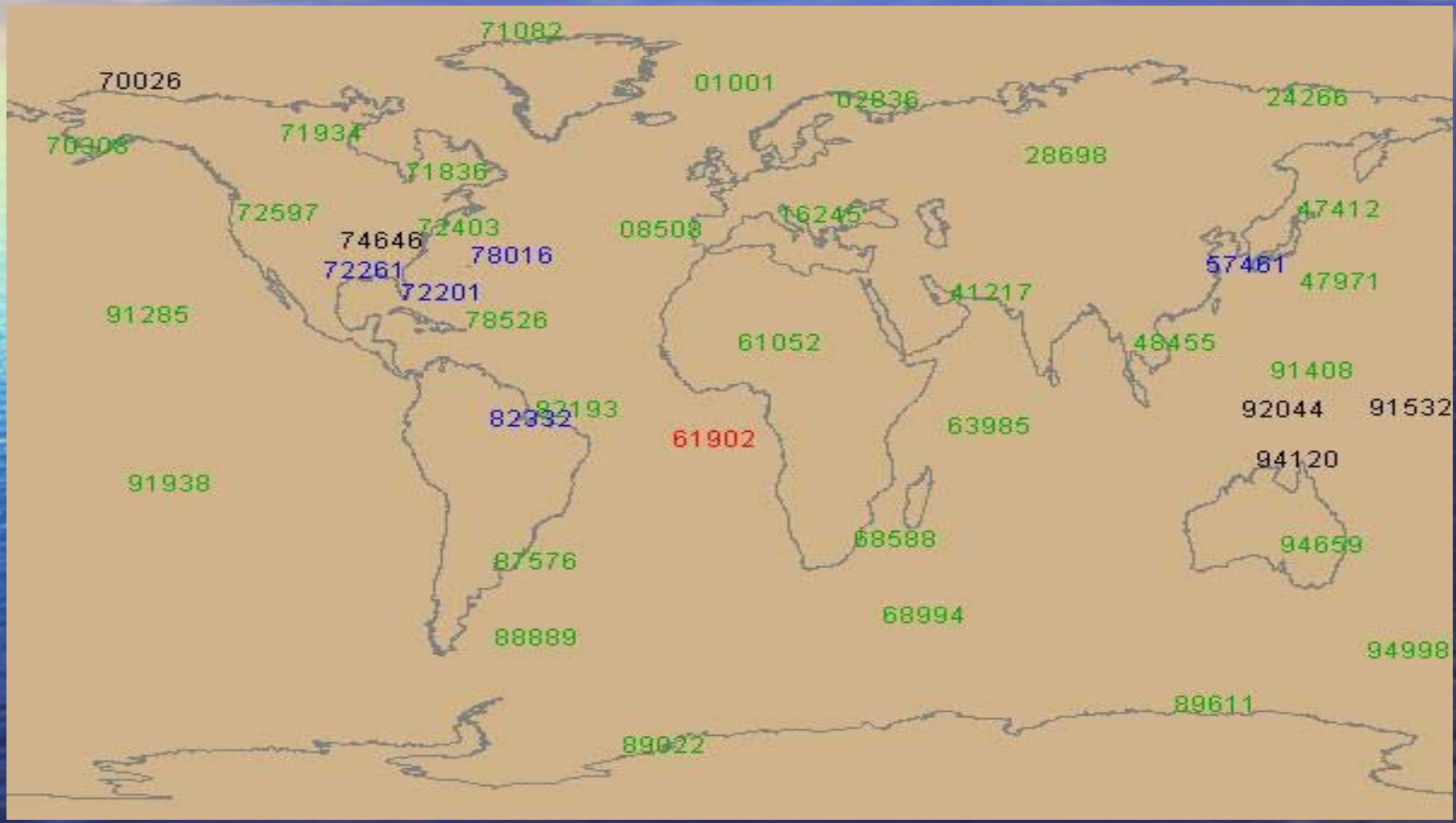


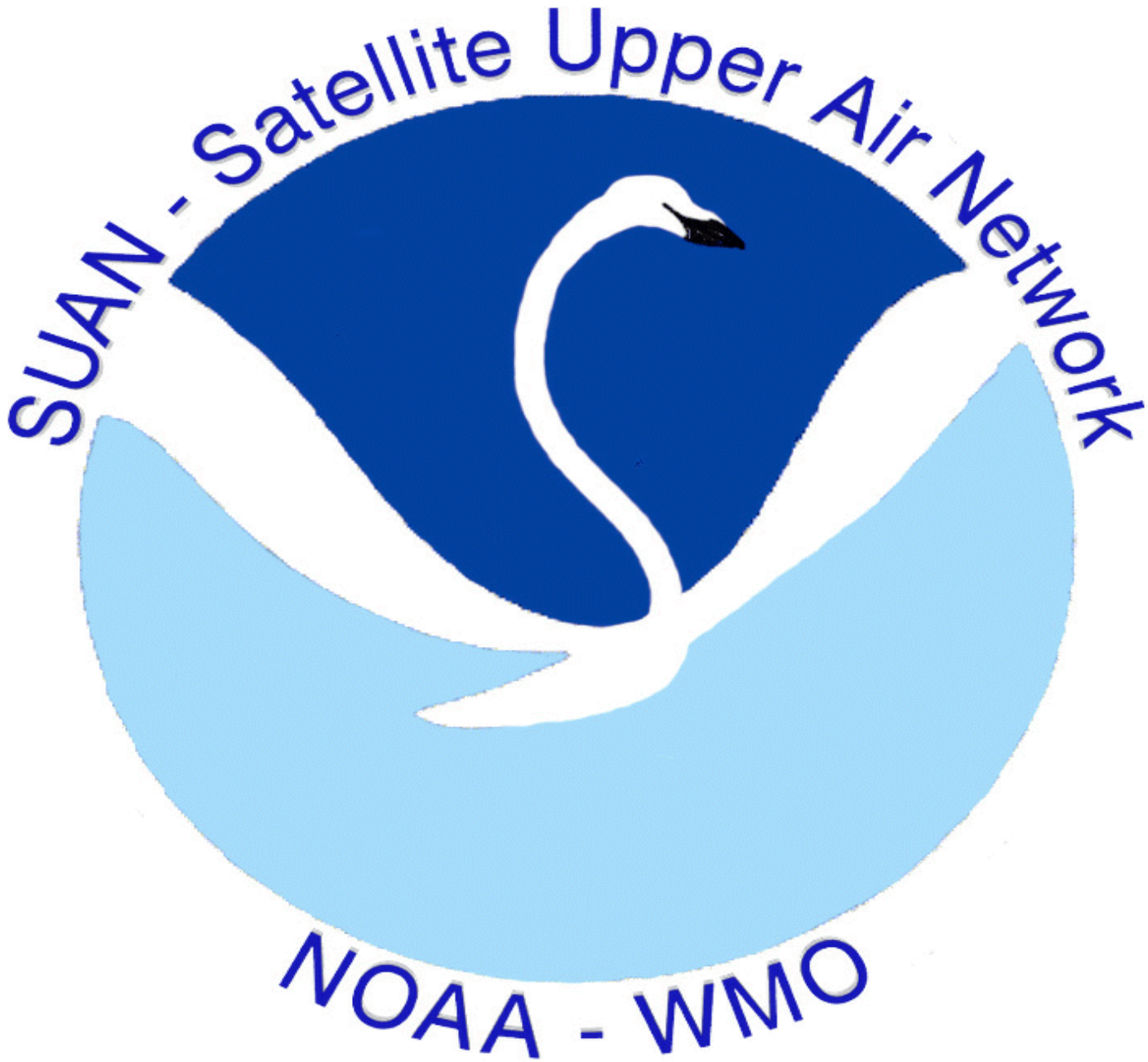

NOAA 16 MDB profiles (N=6772)
10^2
10^3
Pressure (mb)
0
5
10
15
20
25
30
35
Water vapor mixing ratio (g/kg)

WHY SUAN ?

- ***Operational Polar Satellite***
  - Measurements/Products require (*long-term*) "standardized" 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 "REFERENCE " Dataset Needed (since 1979 ...)***
  - currently available collocated radiosonde (+ in-situ) and satellite observations are ***Not Adequate***

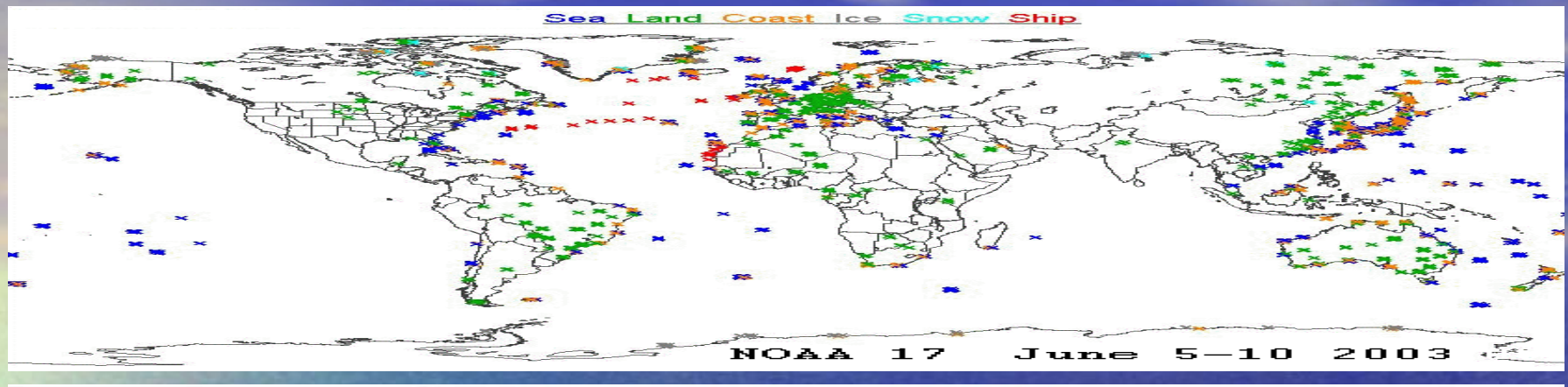
SUAN can provide "long-term" records which "anchor" satellite and radiosonde performance (over time) for more effective utilization in retrospective climate applications …

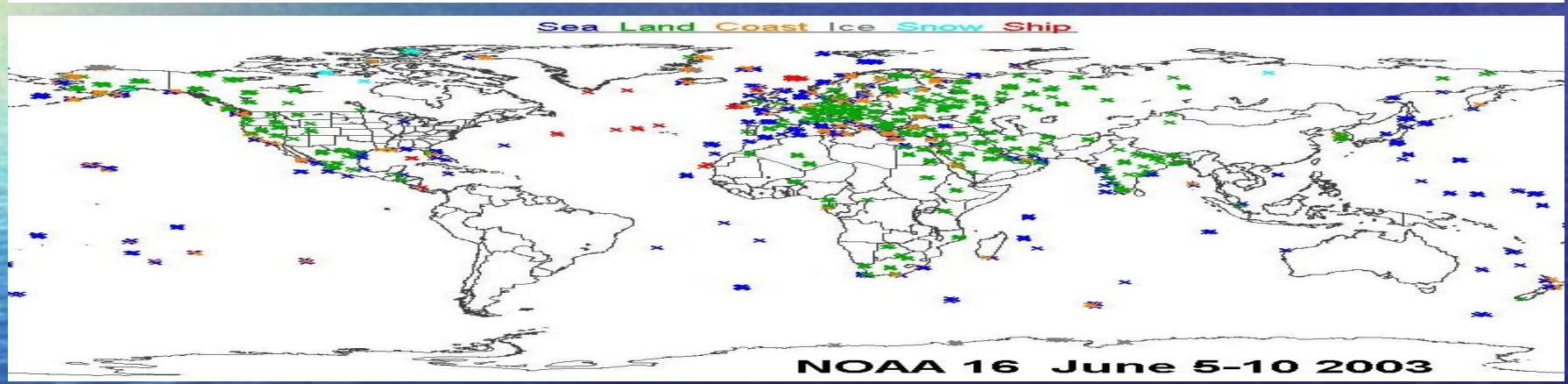


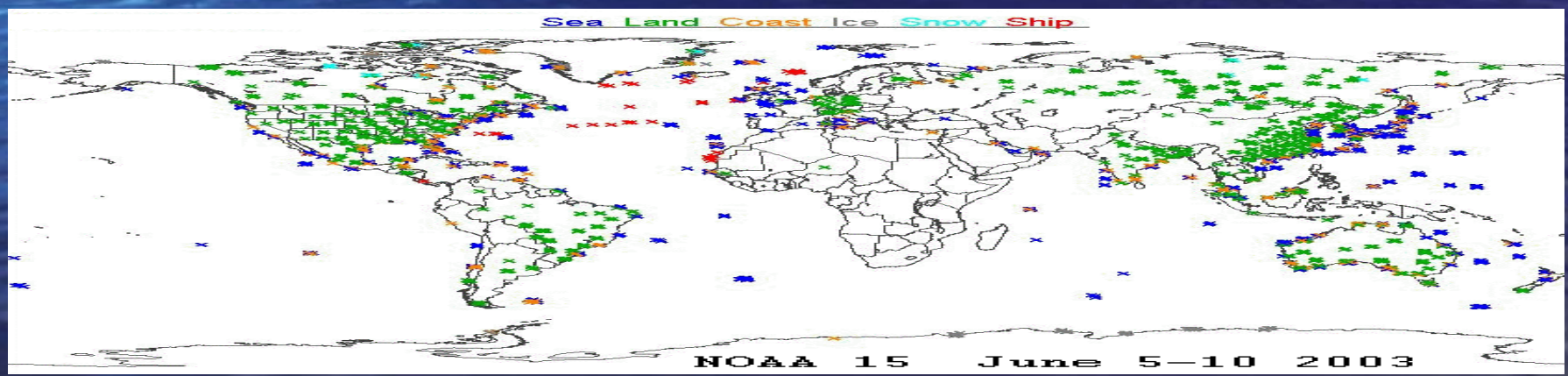

SUAN - Satellite Upper Air Network
NOAA - WMO

Operational Satellite and Radiosonde Collocations

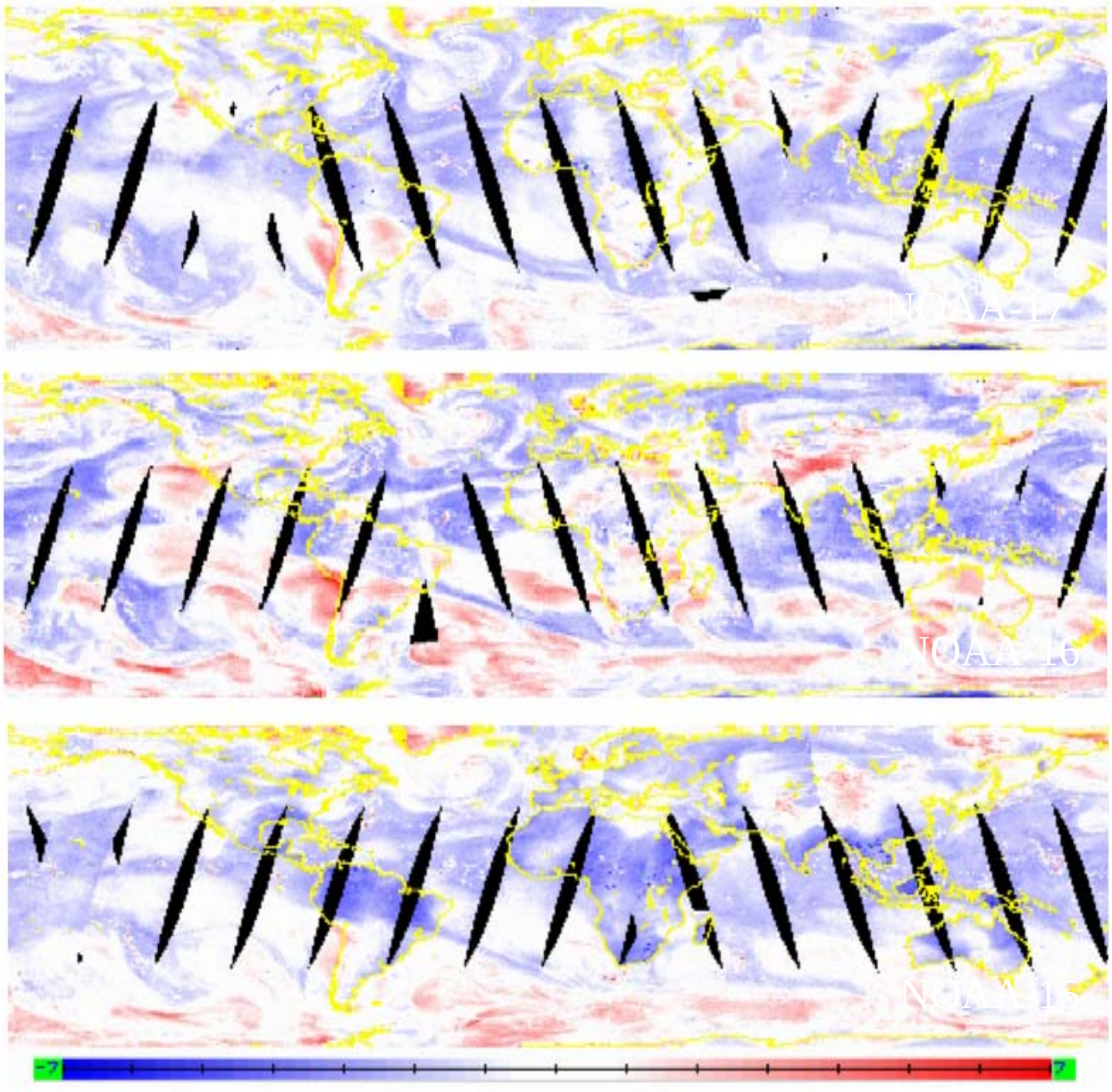
(+/- 5hrs sea, +/- 3hrs land; 100km)







RT Bias Adjustments



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

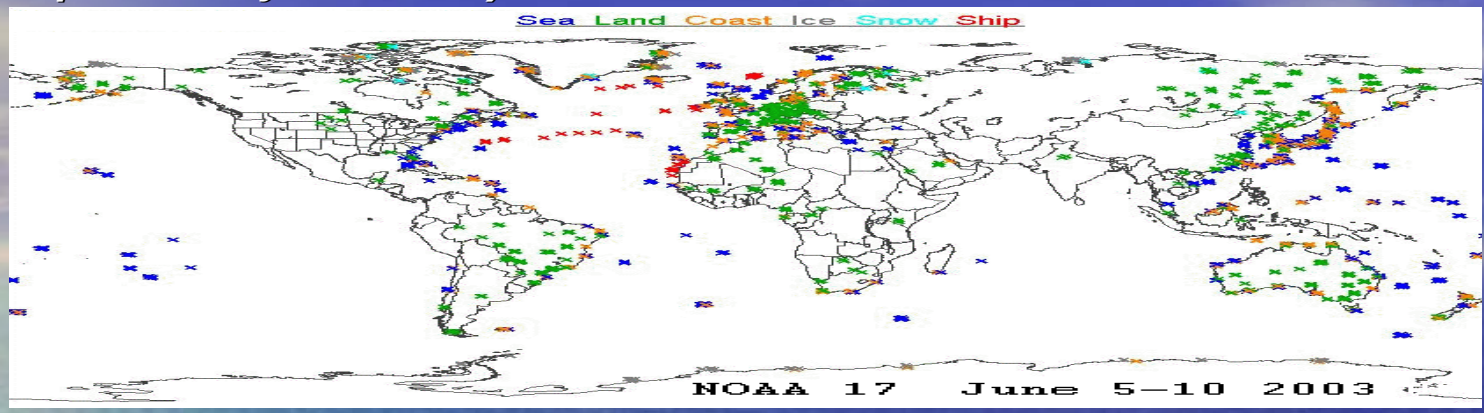
12-hour time composites

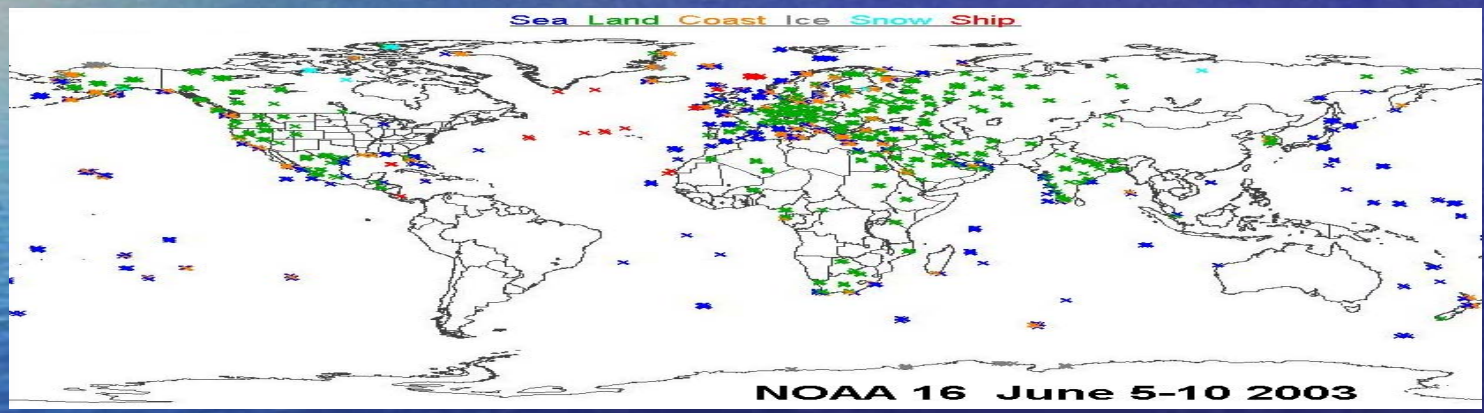
Adjustments as ***regressed from collocated satellite and radiosonde data*** **and applied during operational processing …**

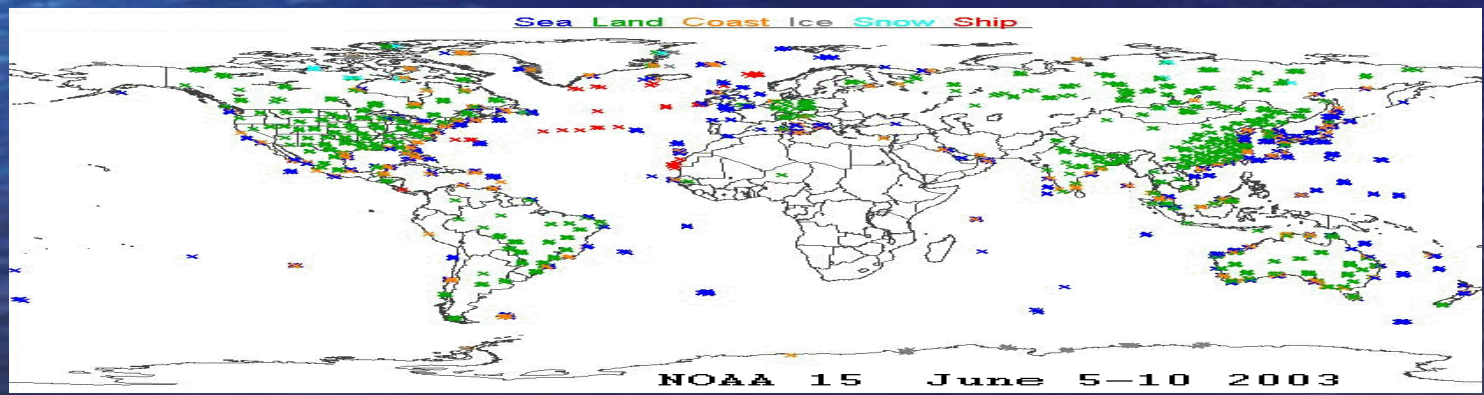
Magnitude and inter-satellite variability "skewed" by systematic radiosonde sampling differences,

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

(used operationally at NESDIS)

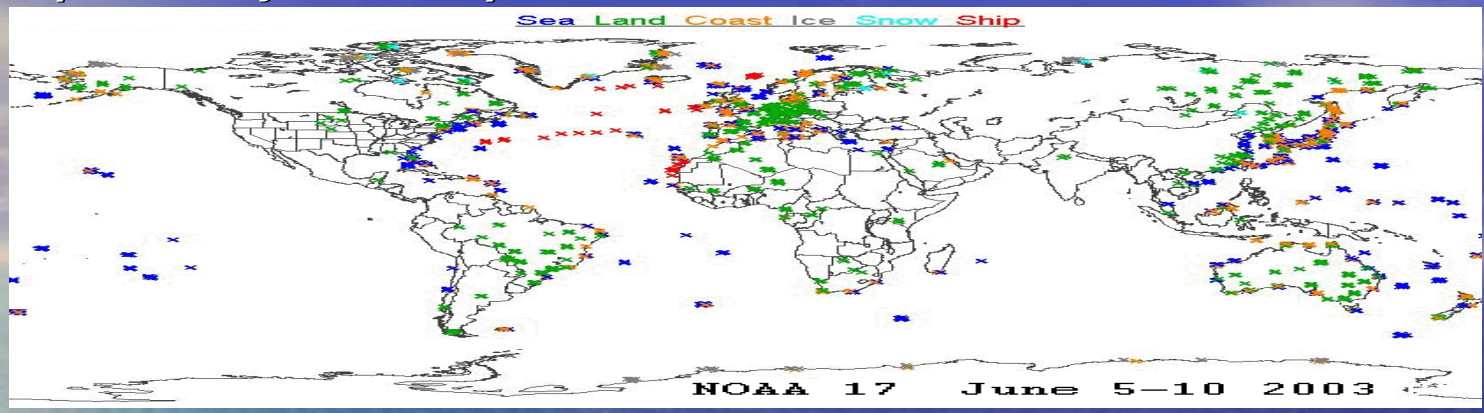


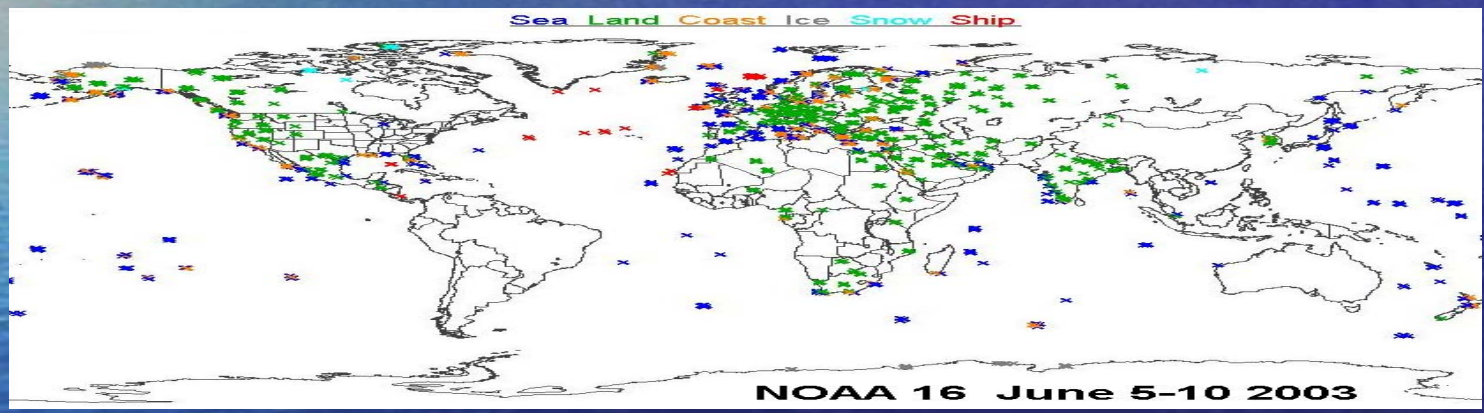


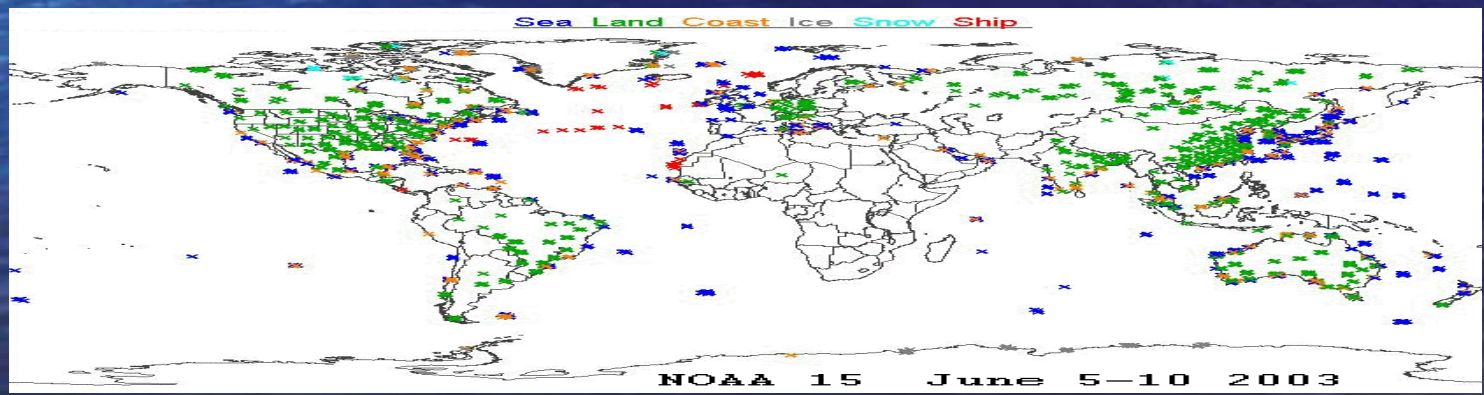


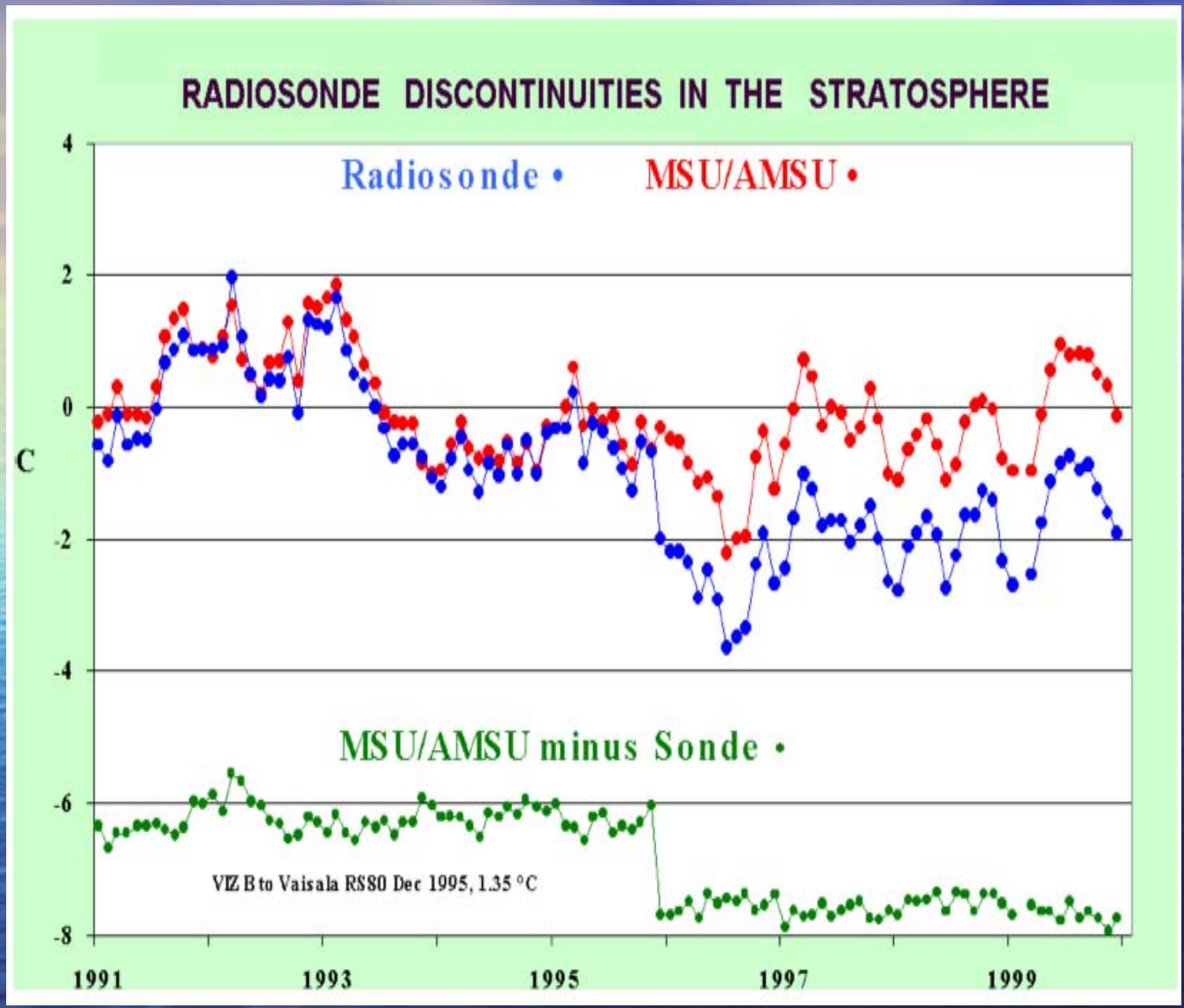
SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

(used operationally at NESDIS)



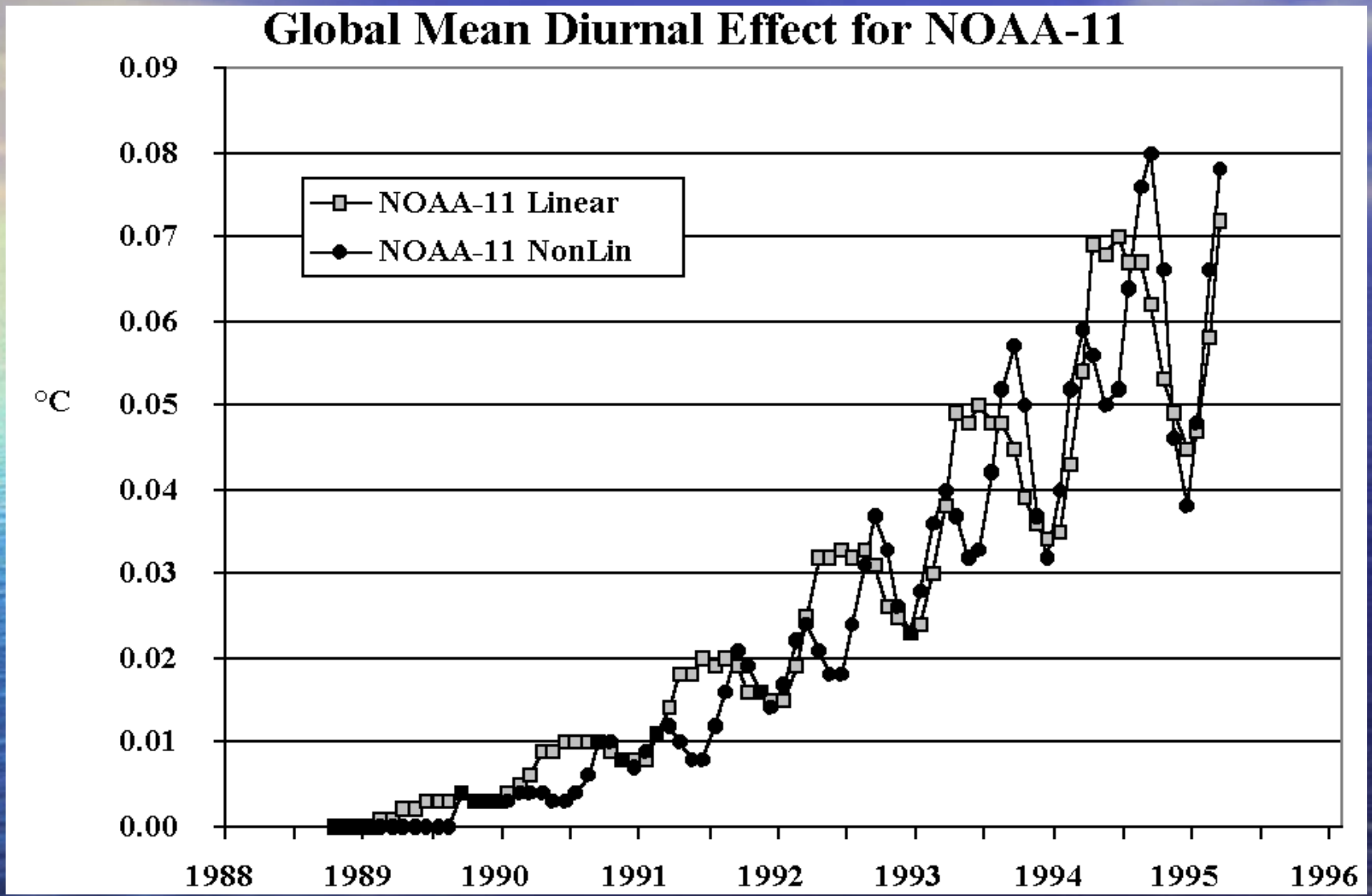






Satellites can serve as transfers standards to monitor radiosondes

VIZ B to Vaisala (RS80) at Chuuck Island


Global Mean Diurnal Effect for NOAA-11
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
°C
NOAA-11 Linear
NOAA-11 NonLin
1988
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)***

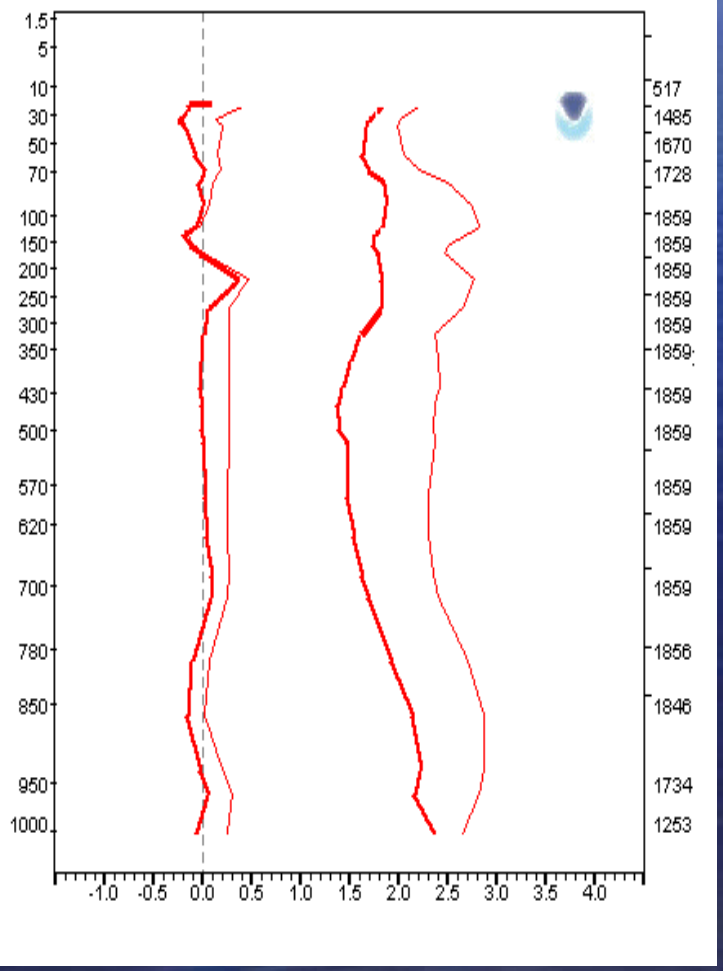
- GTS Radiosondes ... (NCEP, ERA-40, IGRA...)
- Special Field Experiment Radiosondes:
  - ARM
  - JOSS (NCAR)
  - *SHIPS*
  - *Other ?*

- TOVS historical 1b-level data

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

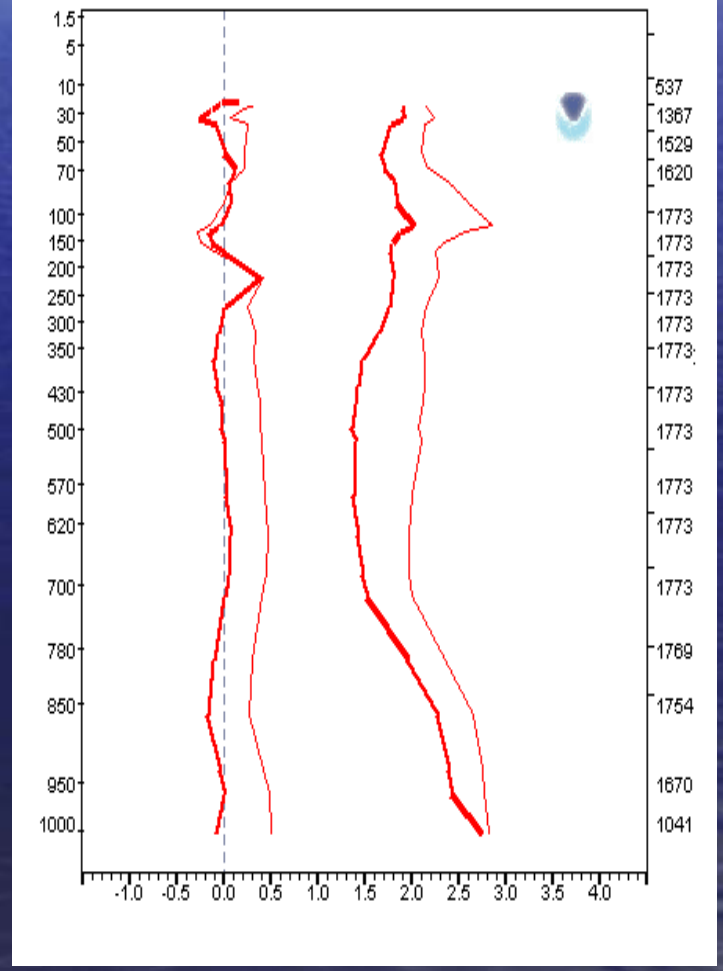
Accuracy Statistics vs Radiosondes
(*Guess (light)* **vs** *Retrieval (heavy)*)

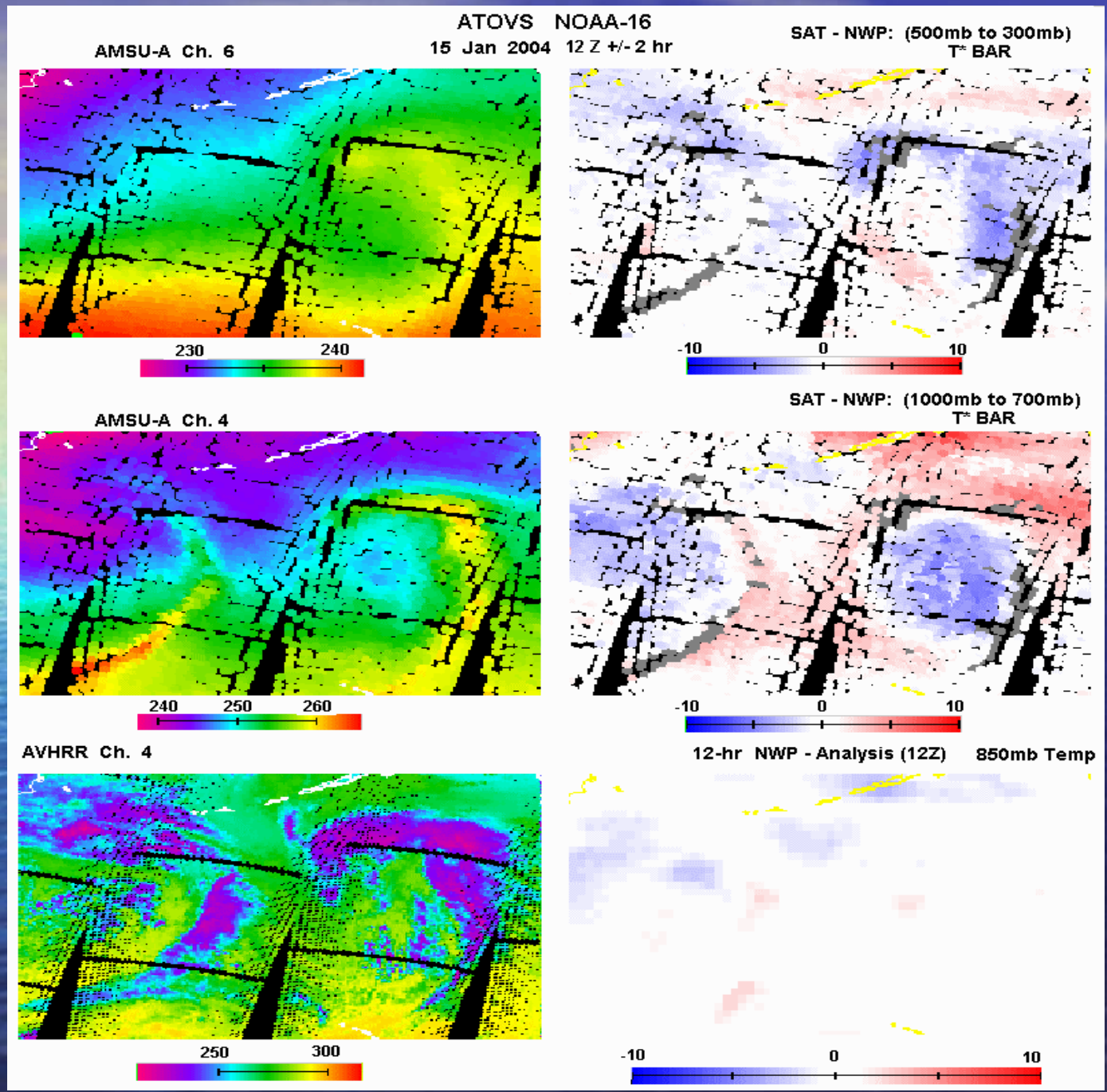
Tuning to Errors



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

NOAA-16
(60N to 60S)





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

leading to improved satellite data impact in frontal zones?

Climate

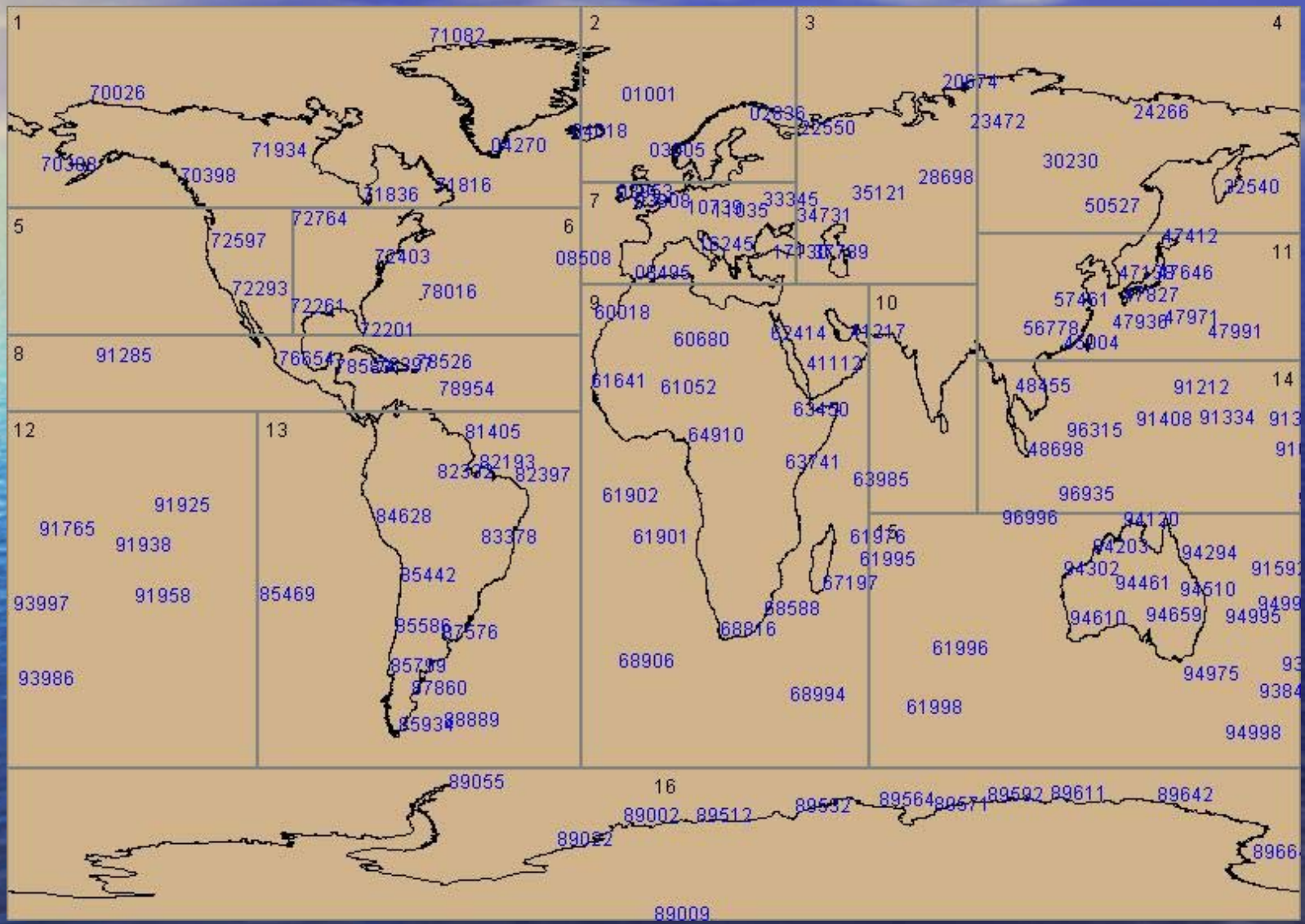
The Problem:

- 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


1
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71082
70026
71934
70398
71836
71816
04270
01001
20674
23472
24266
30230
28698
35121
50527
72764
72597
72403
72293
72261
72201
78016
08508
34731
47412
47646
57461
47827
47936
47971
47991
56778
60018
60680
61641
61052
41112
48455
91212
91408
91334
96315
48698
91285
78954
78526
81405
82193
82397
91925
91765
91938
84628
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61902
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96996
94120
94203
94294
94302
94461
94610
94659
94995
91592
85442
85469
91958
93997
85586
87576
85789
87860
93986
85934
88889
68906
68994
68588
68816
67197
61995
61996
61998
94975
94998
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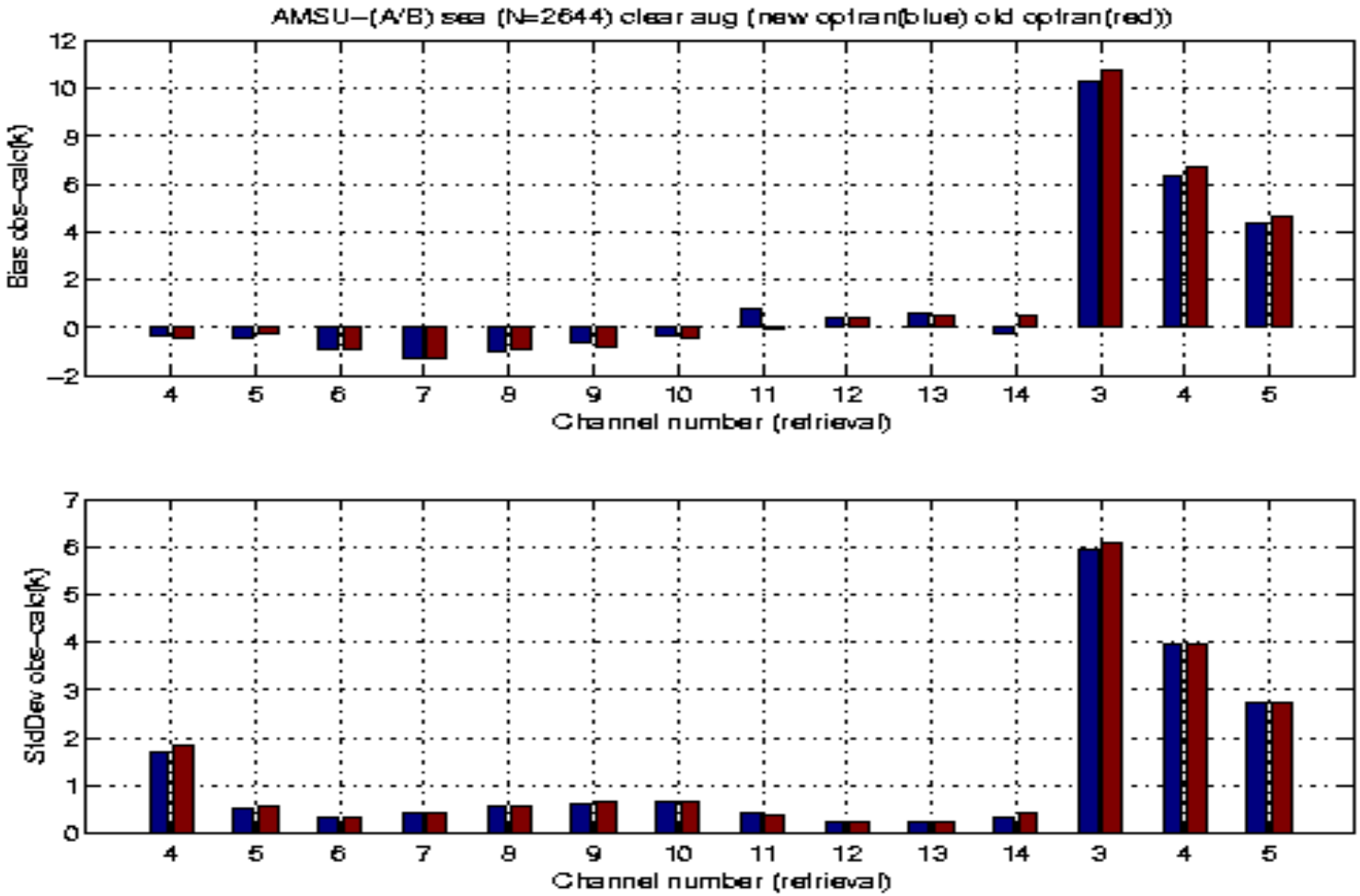
89611
89642
89009

AMSU Sounding Channels



International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.