

# 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”](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

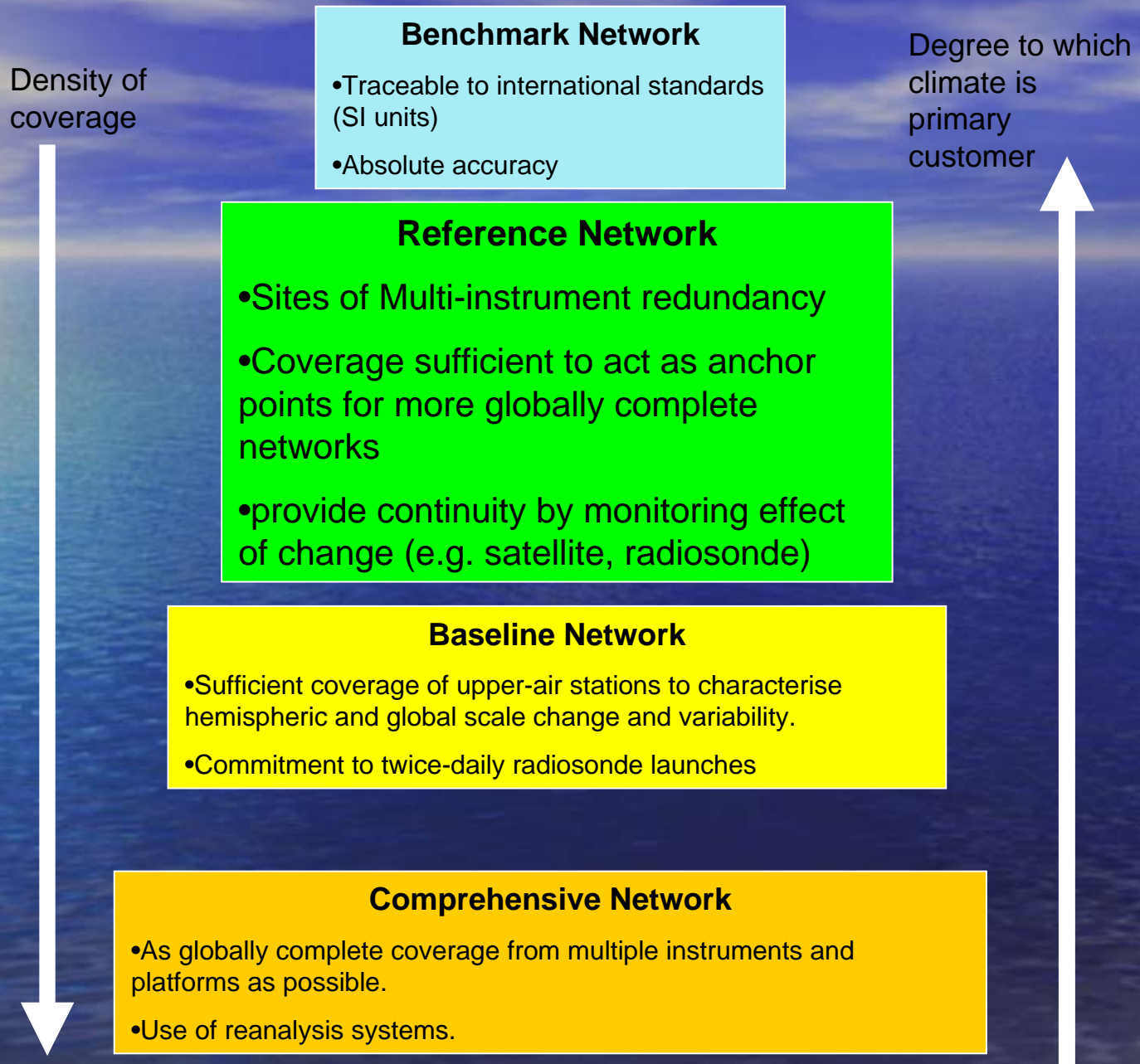
... pursue SUAN *funding* and *agreement* through relevant bodies (NOAA, NASA, WMO, GCOS, etc.)

... 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



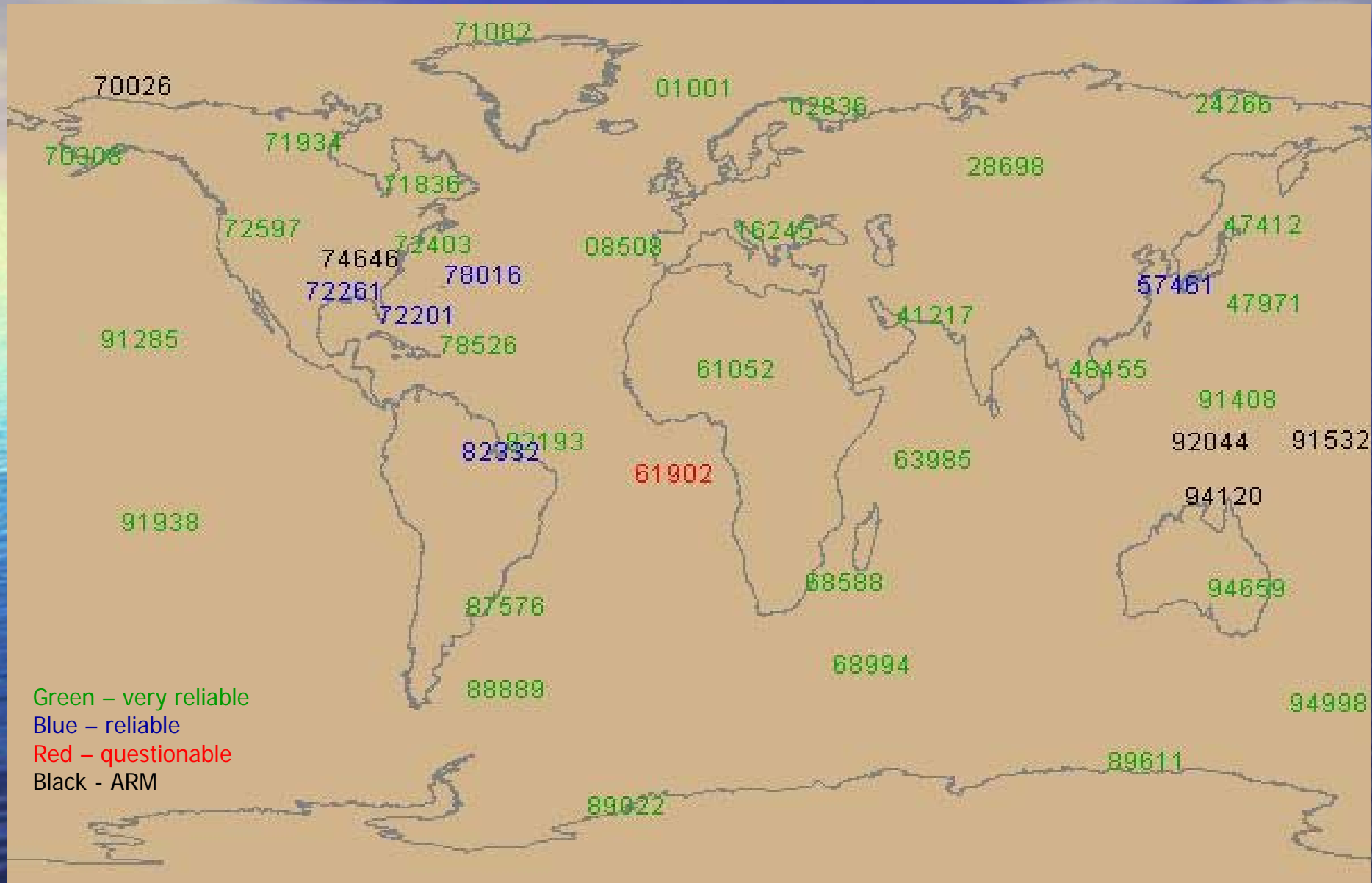
Peter Thorne  
(UKMO)

NOAA/GCOS  
Workshop

Phase-1



# Candidate REFERENCE Network







# 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 !?***



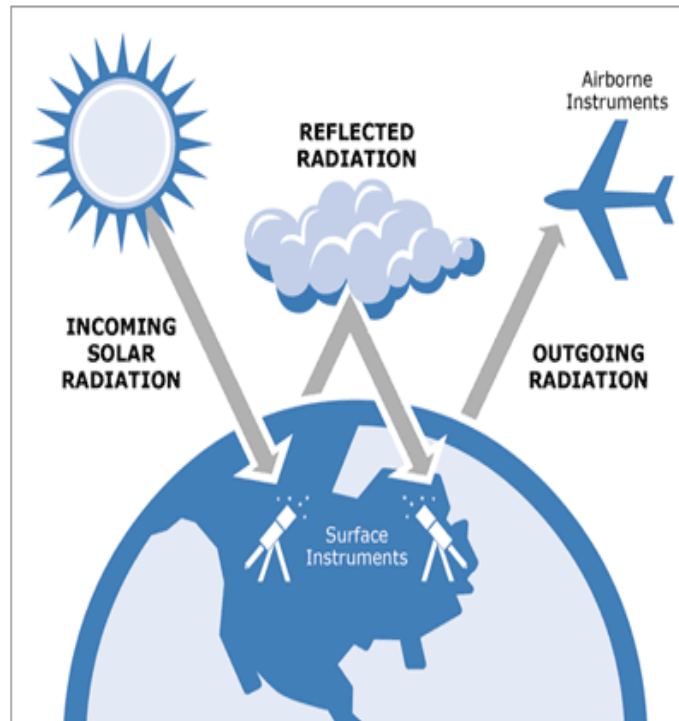
# Super-Sites

## WMO/AOPC in April 2004:

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

## 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 REFERENCE 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
- Flexible 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 ...)*

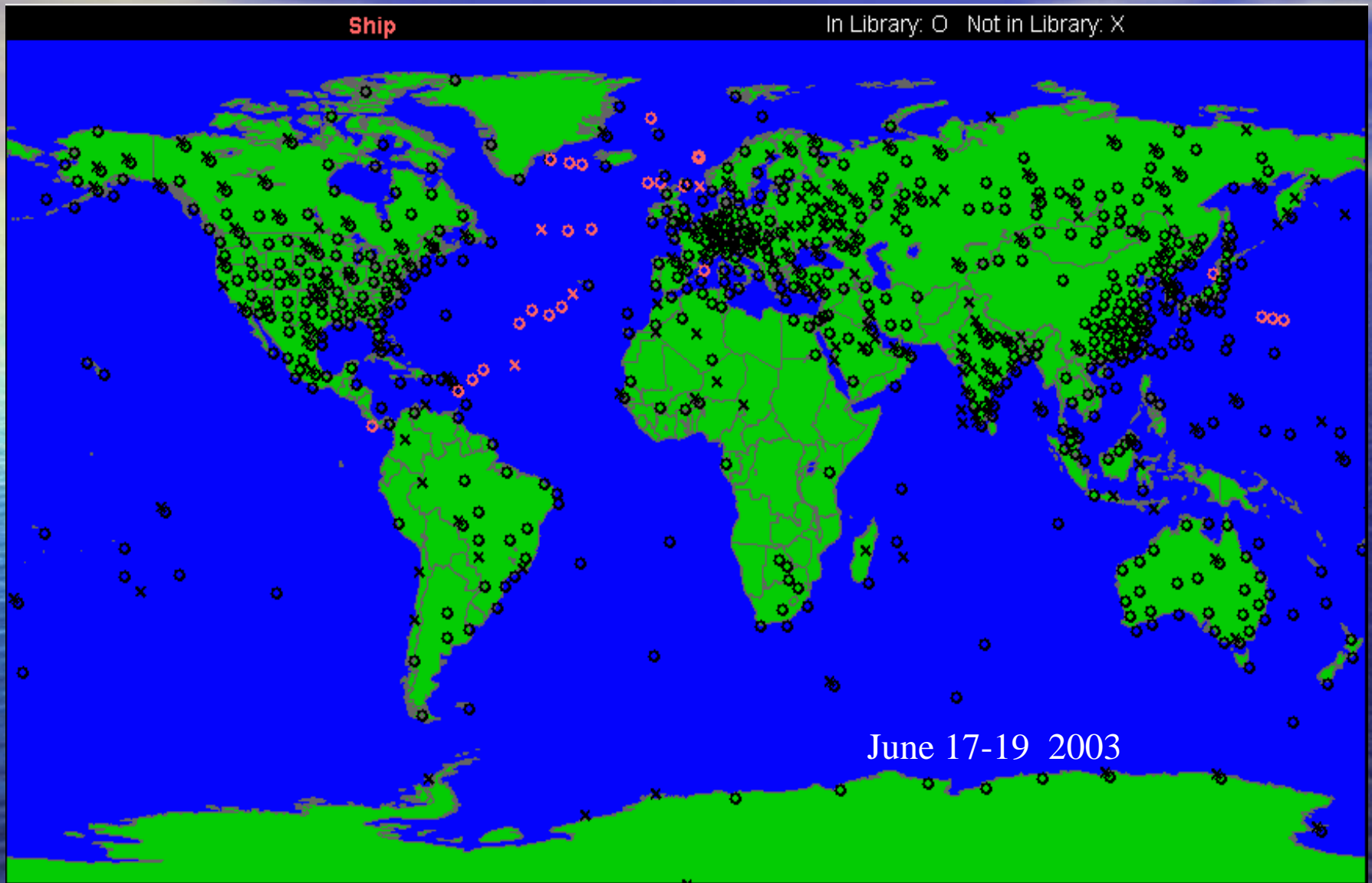
- **NOAA-SEARCH Program Goals :**
  - ***Re-process TOVS for Arctic Climate change*** *(Francis / Schweiger)*
  - Compile Data Base of "Arctic" Collocations to quantify TOVS (and Raob) measurement uncertainty *(Reale; Salazar and Brown Raytheon ITSS)*
- **Status**
  - Radiosondes
    - GTS ... *NCEP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

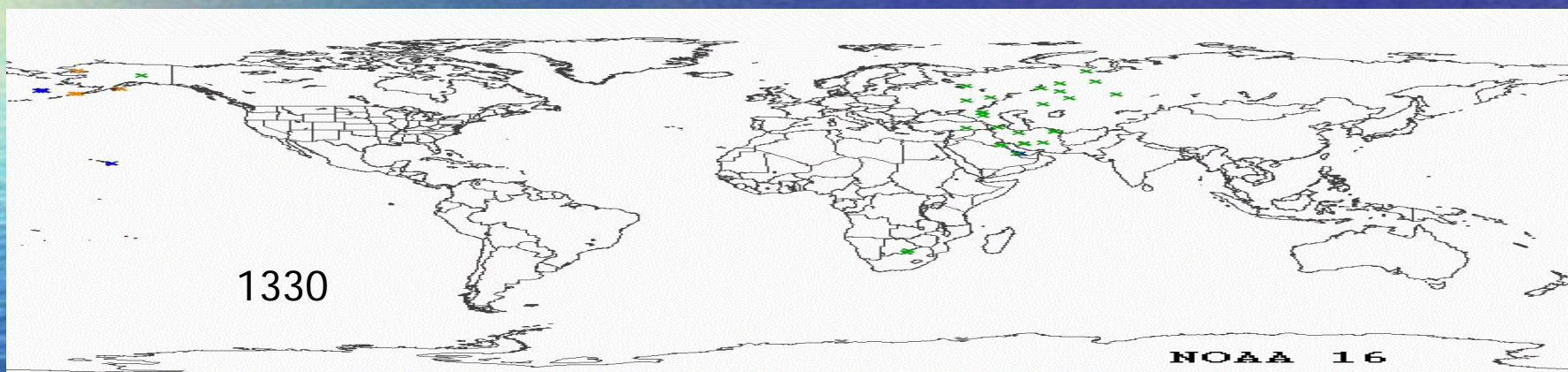
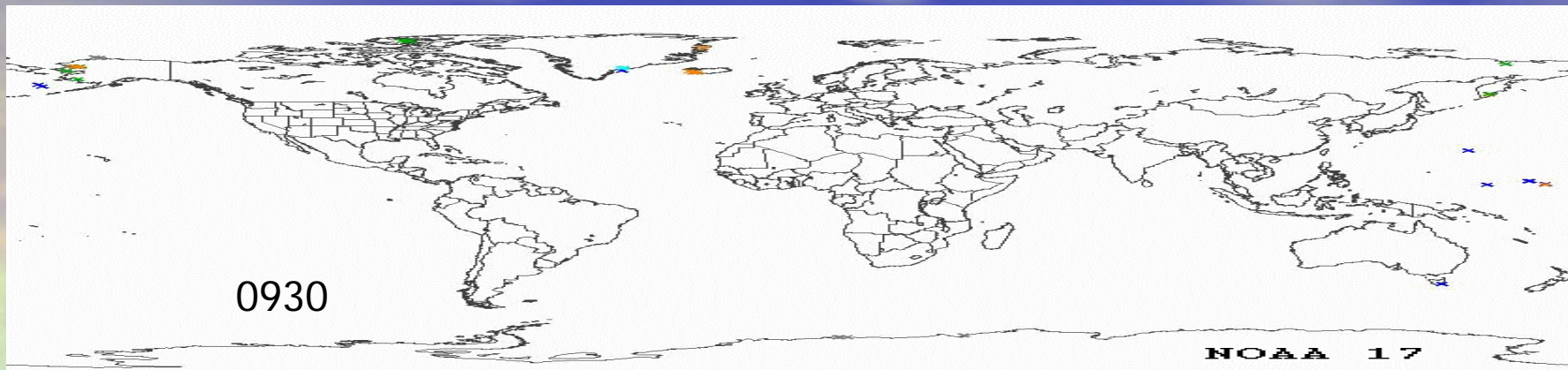
# Global Radiosondes





# Operational Satellite and Radiosonde Collocations

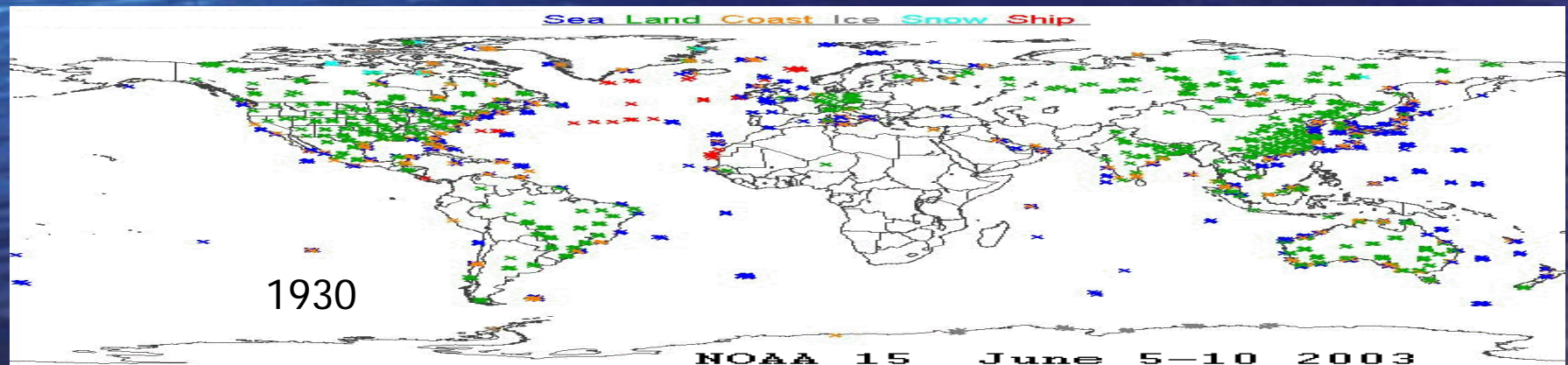
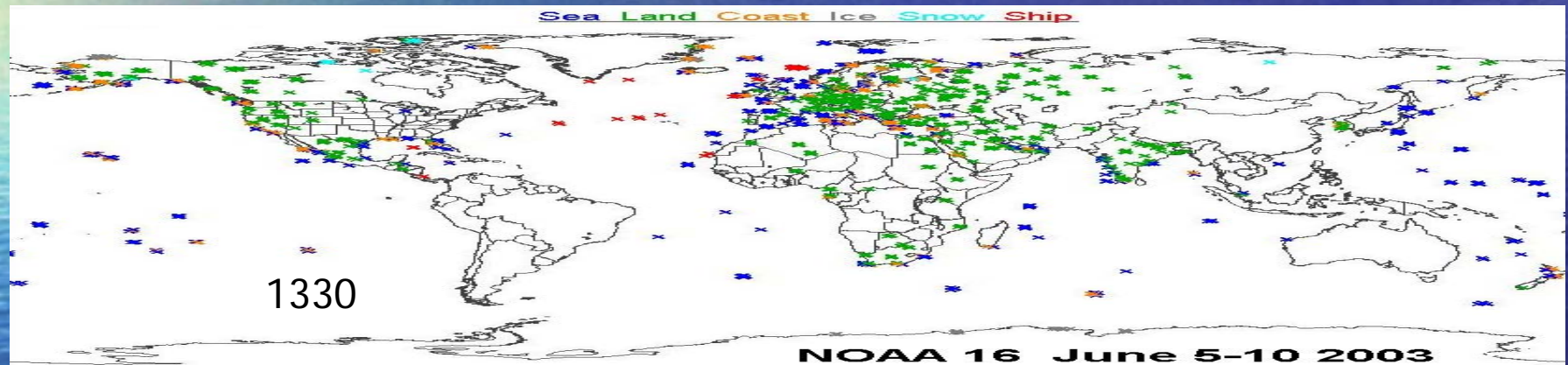
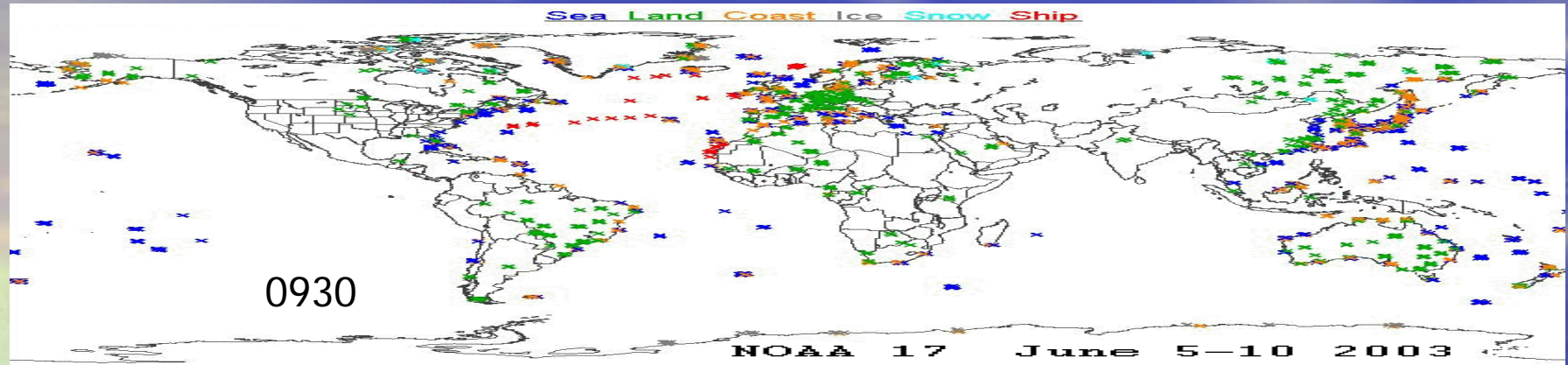
(- 1 hr ; 100km) ... same-same



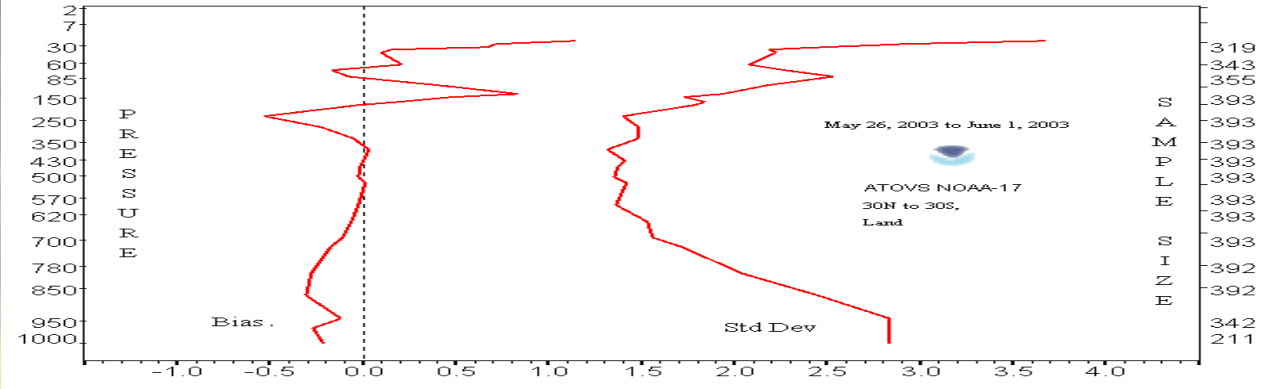


# Operational Satellite and Radiosonde Collocations

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

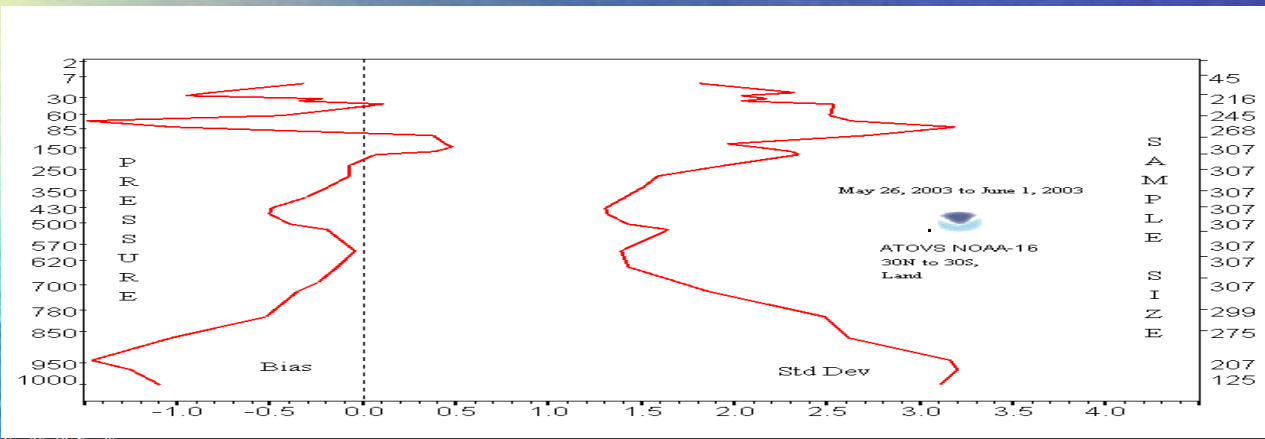




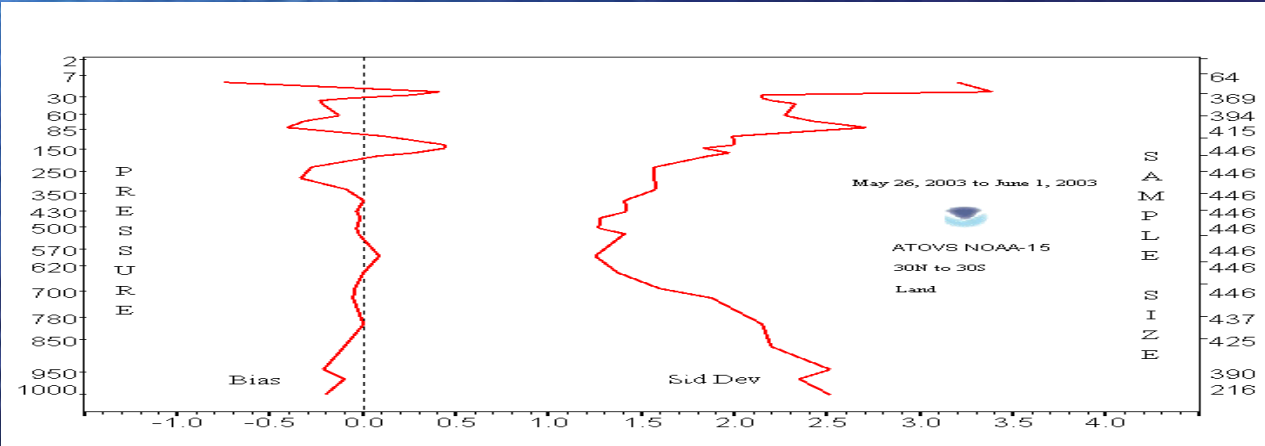


(Satellite – Radiosonde)  
 Temperature statistics

Tropical land  
 (30N to 30S)



June 7-14, 2003



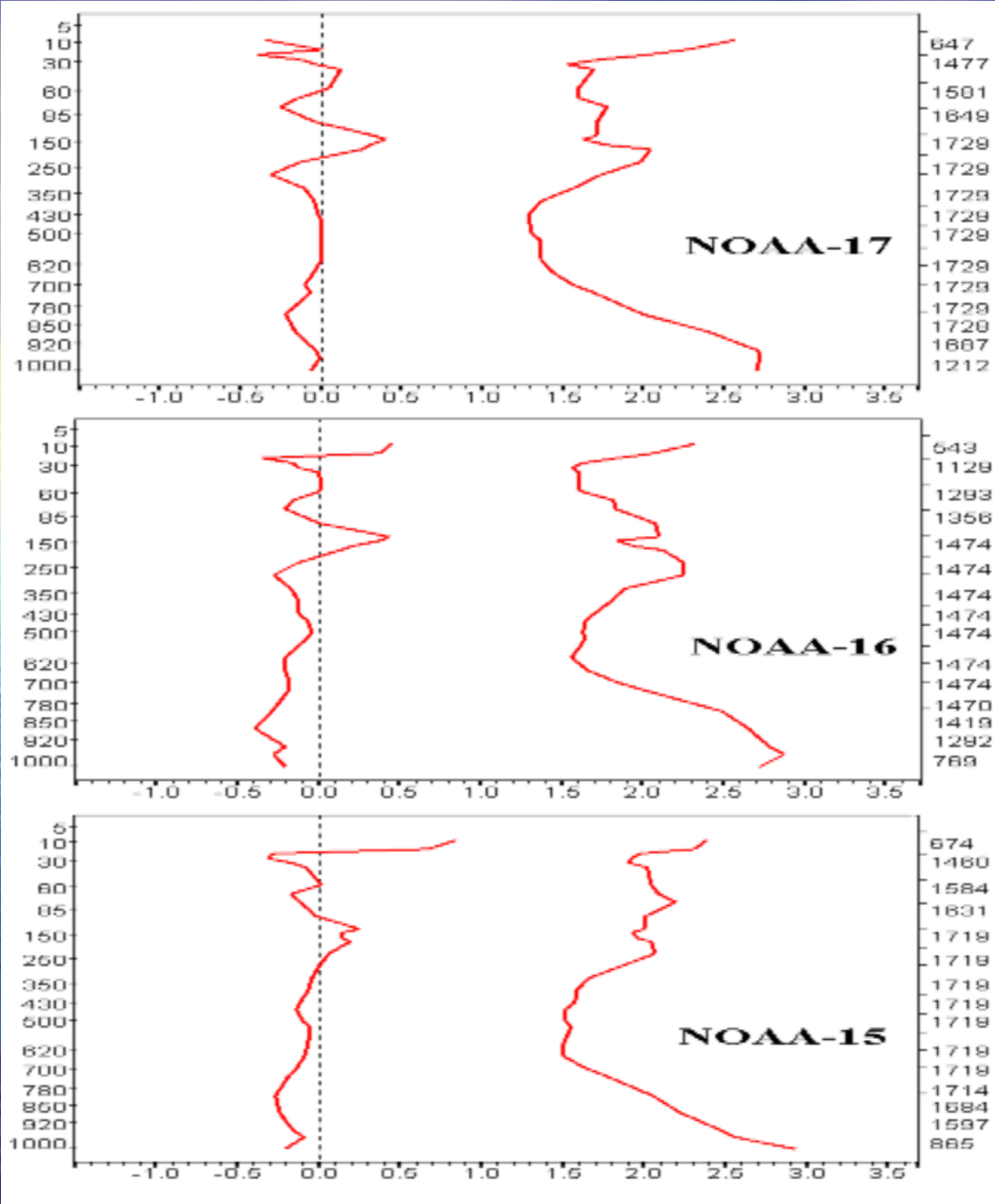
*Results “skewed”  
 by regional  
 sampling bias/error*

...

(Satellite – Radiosonde)  
Temperature statistics

60N to 60S

June 7-14, 2003

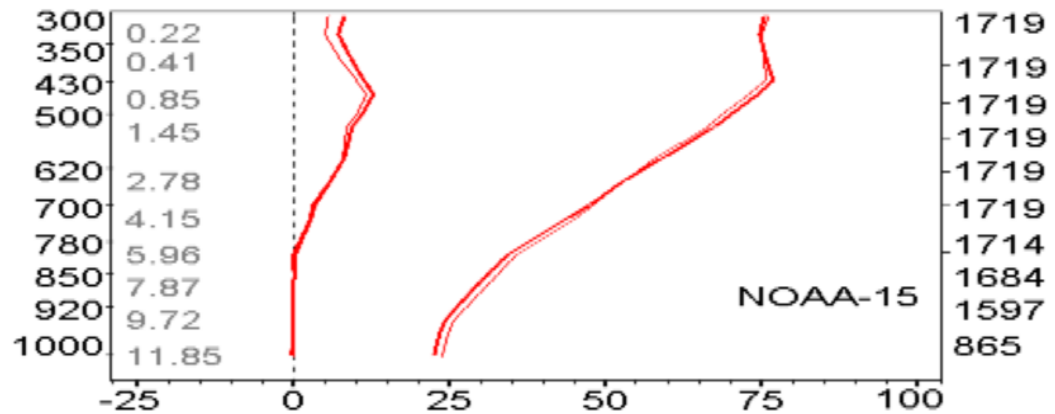
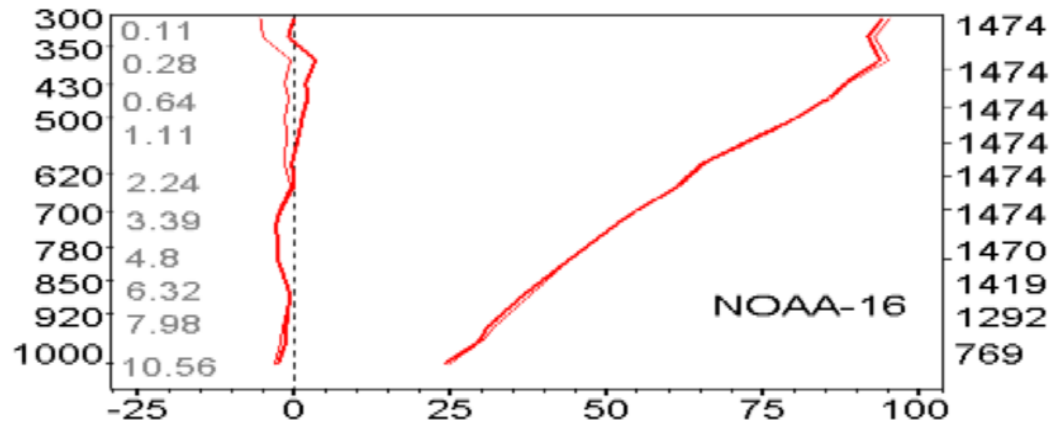
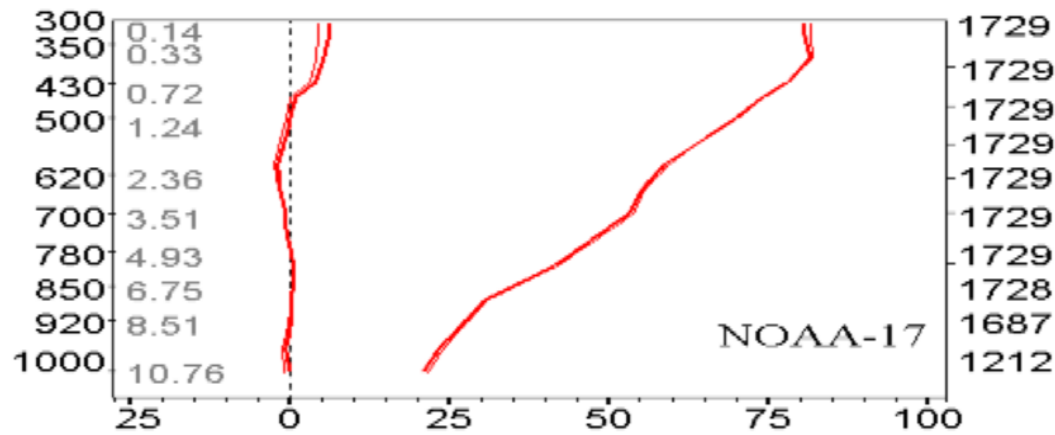


*Larger samples beat down  
the noise but differences  
remain ...*

*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

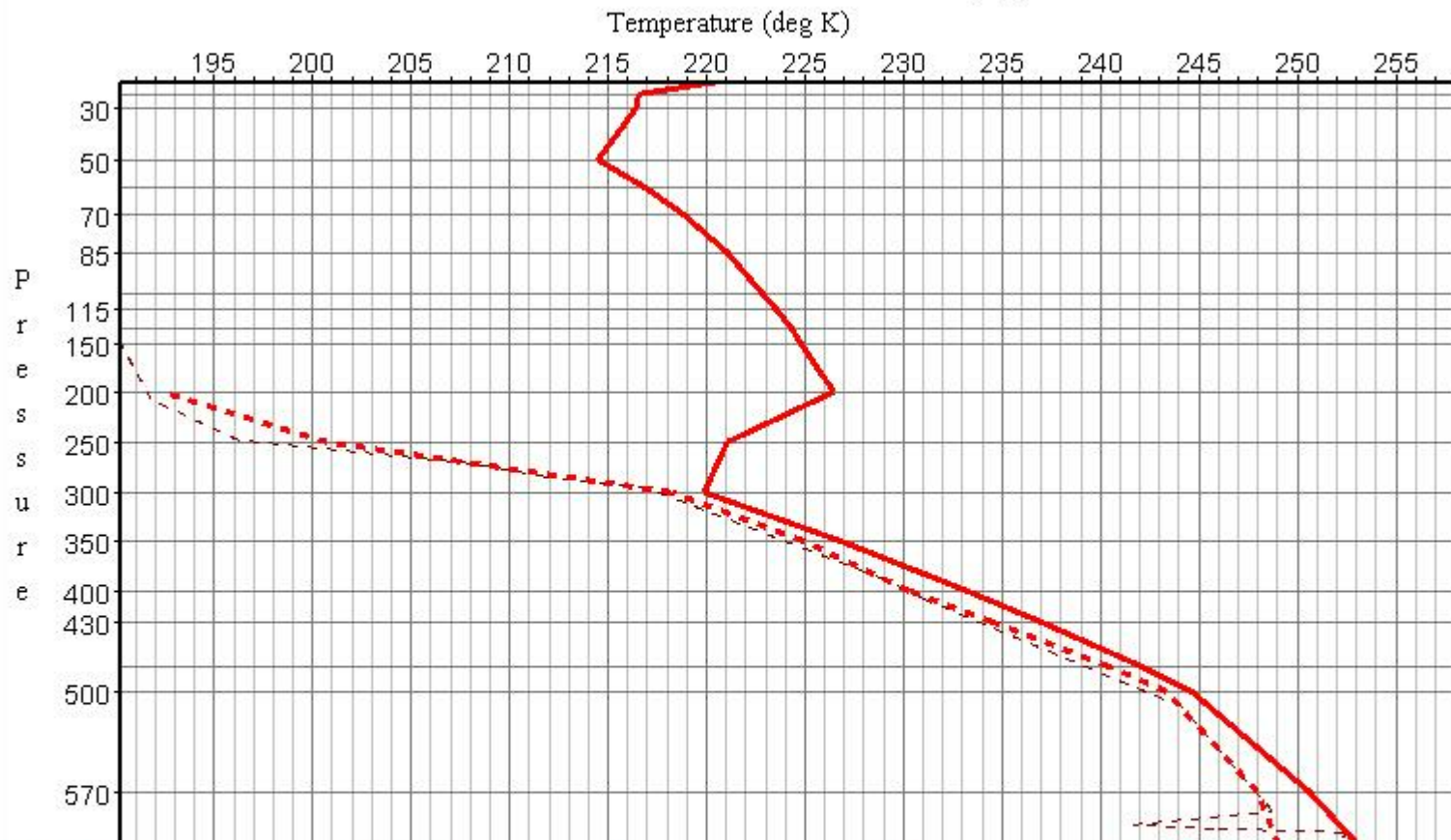
CURRENT

RADIOSONDE MEASUREMENTS

ARE PROBLEMATIC



# NOAA/NESDIS Matched Profile Display



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:  
 Day/Night:  
 Cloud Mask:  
 Library Flag:  
 Raob TPW:  
 ATOVS N16 (A2 - RMS) TPW:

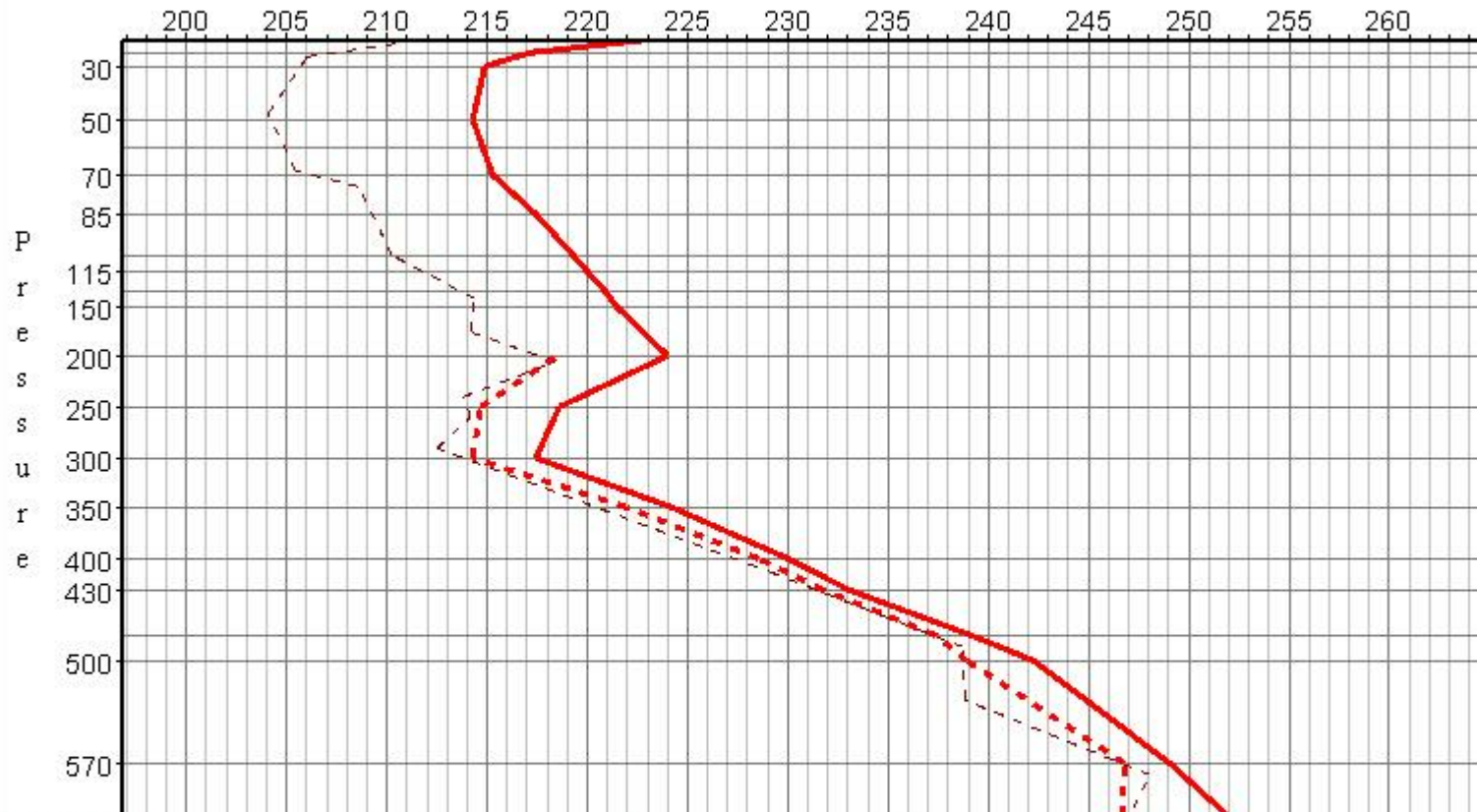
Land  
 Night  
 Cloudy  
 Not in lib  
 117.76 mm  
 15.11 mm

Radiosonde: 2836  
 Significant Level

Temp      DewT  
 ———      - - - -  
 - - - -      - - - -

# NOAA/NESDIS Matched Profile Display

Temperature (deg K)



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

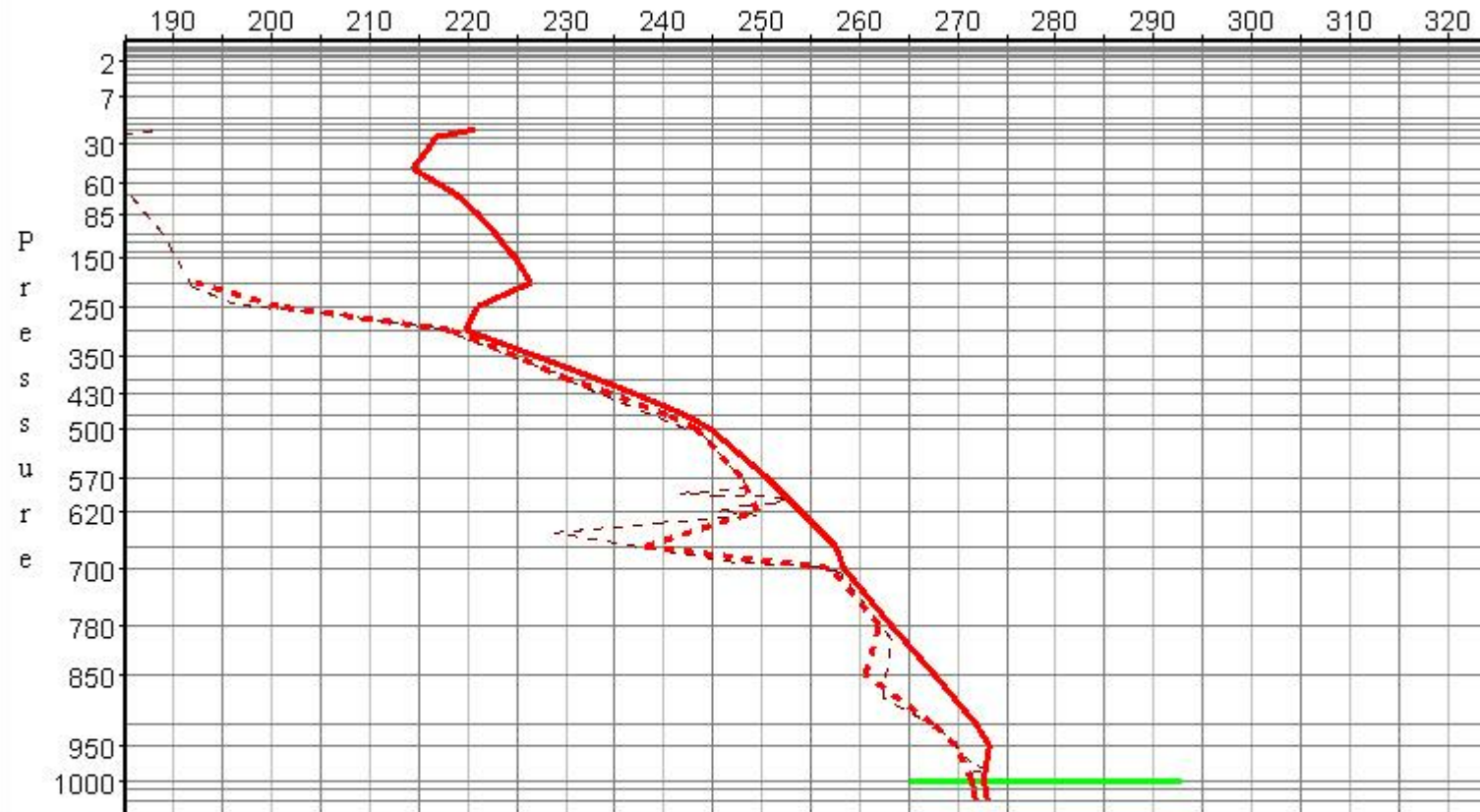
Radiosonde: 22217  
 Significant Level

Temp	DewT



# NOAA/NESDIS Matched Profile Display

Temperature (deg K)



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

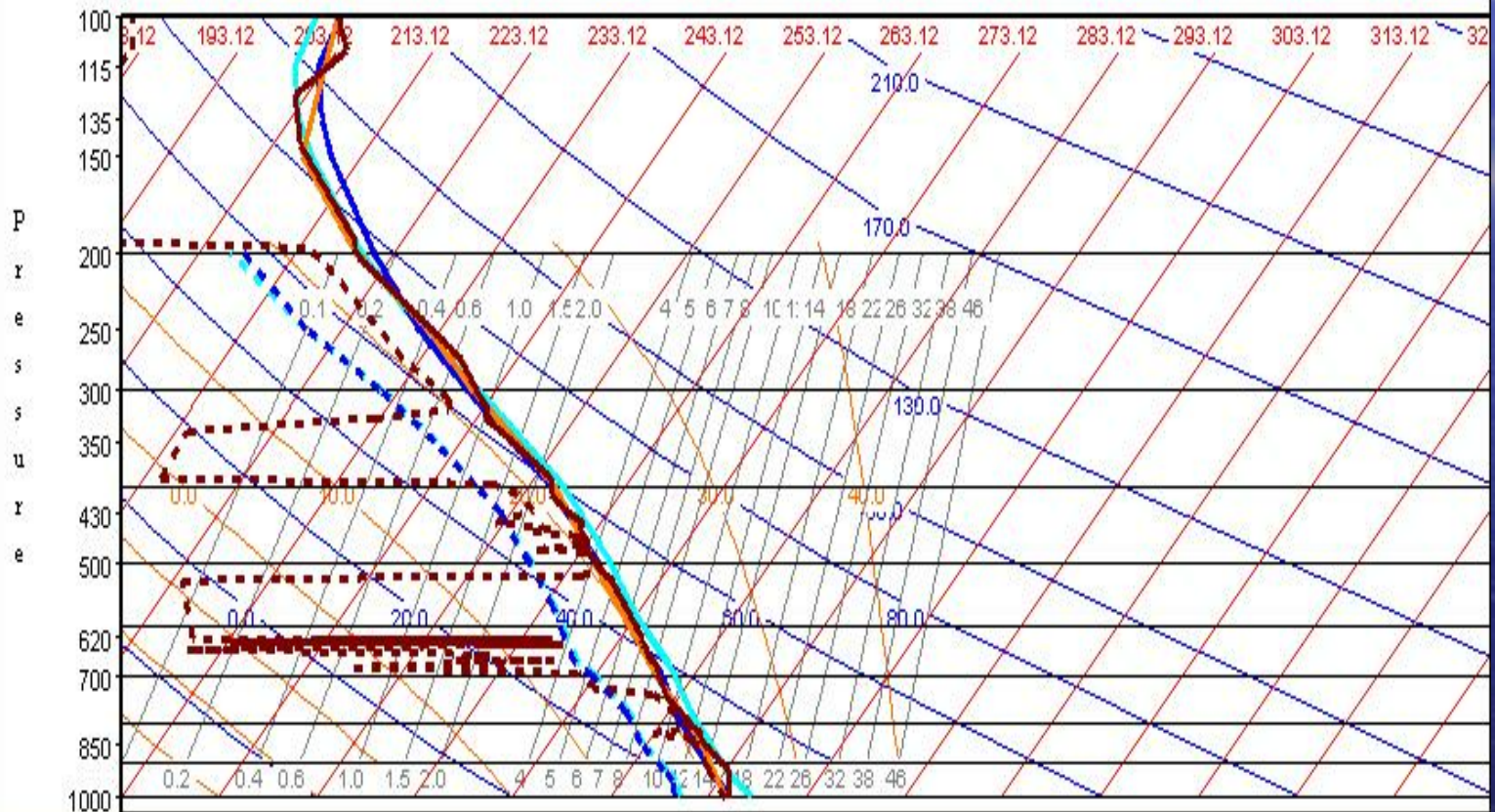


Terrain:	Land
Day/Night:	Night
Cloud Mask:	Cloudy
Library Flag:	Not in lib
Raob TPW:	117.76 mm
ATOVS N16 (A2 - RMS) TPW:	15.11 mm

Radiosonde: 2836	Temp	DewT
Significant Level		

# NOAA/NESDIS Matched Profile Display

Skewed Temperature (deg K)



Radiosonde: 72402                      9/28/2004                      62                      37.92 N                      75.47 W  
 ATOVS NOAA16 (A2)                      9/28/2004                      7:09:08                      38.16 N                      75.1 W                      41 km from sub



Terrain:	Coast
Day/Night:	Night
Cloud Mask:	Cloudy
Library Flag:	In library
Raob TPW:	79.37 mm
ATOVS NOAA16 (A2) TPW:	40.6 mm

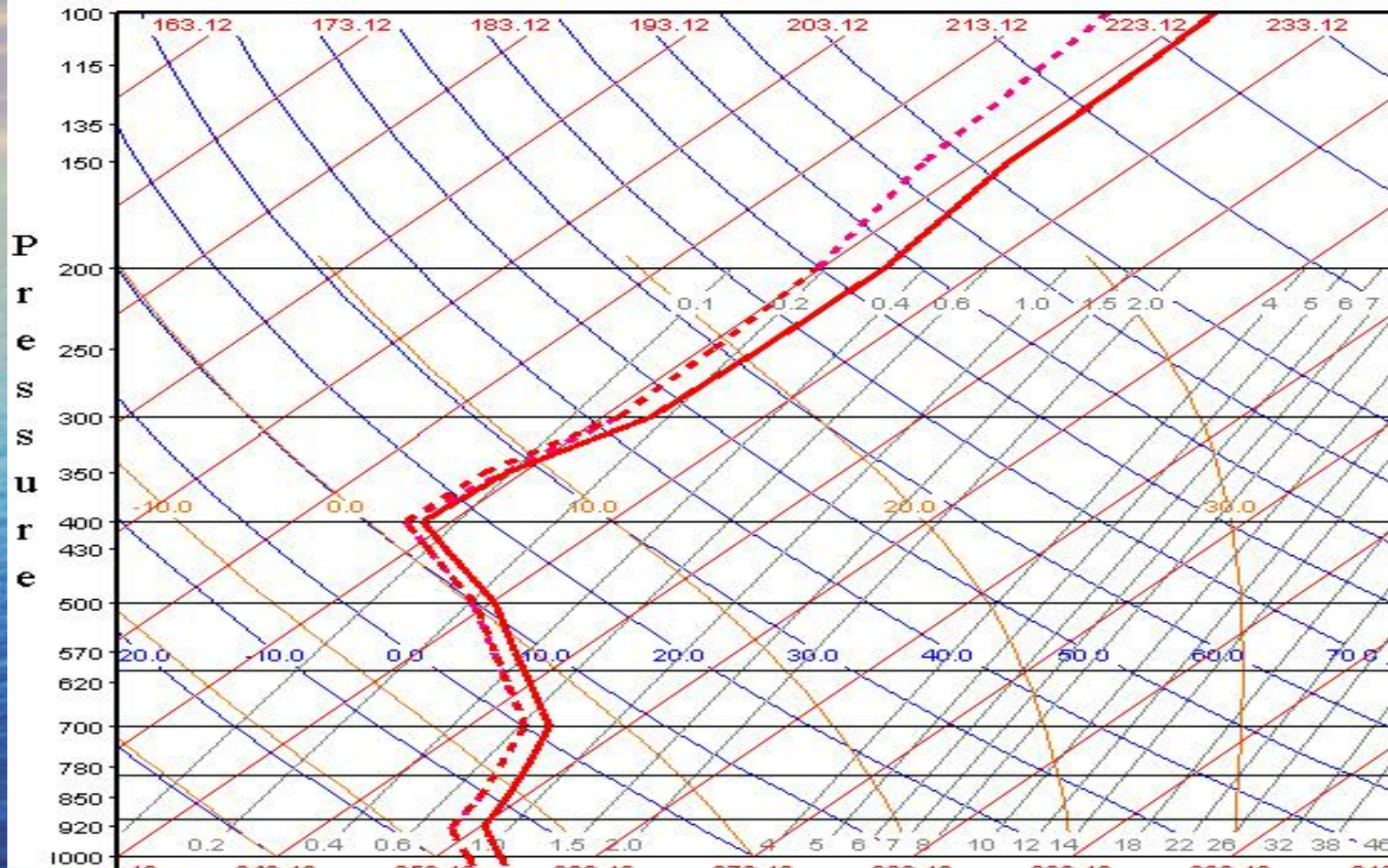
Significant Level  
 Standard Level  
 ATOVS NOAA16 (A2)  
 ATOVS NOAA16 (A2) FG

Temp	DewT



# NOAA/NESDIS Matched Profile Display

## Temperature (deg K)



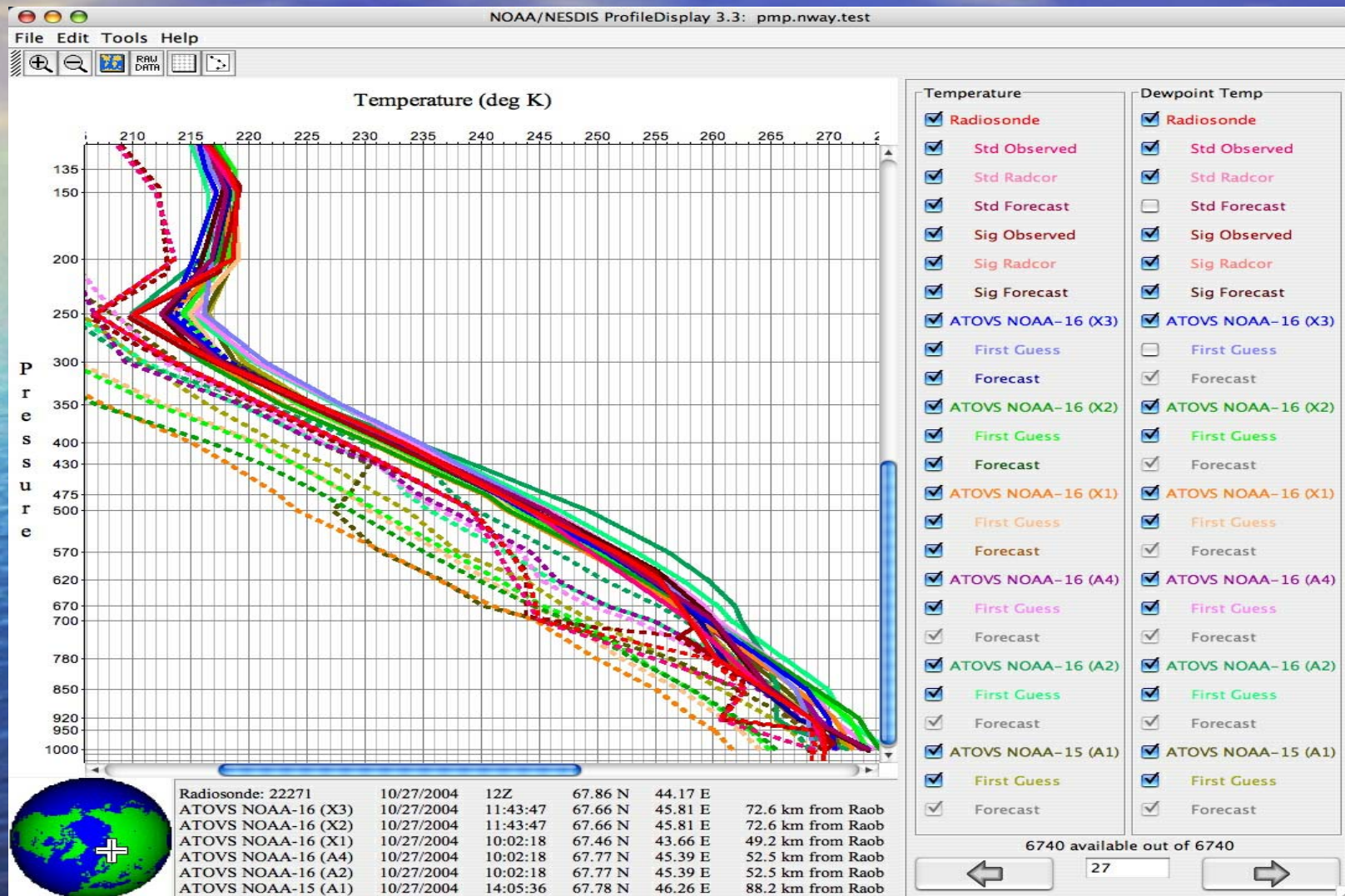
Radiosonde: 50774 1/23/2005 23Z 47.71 N 128.89 E

# 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



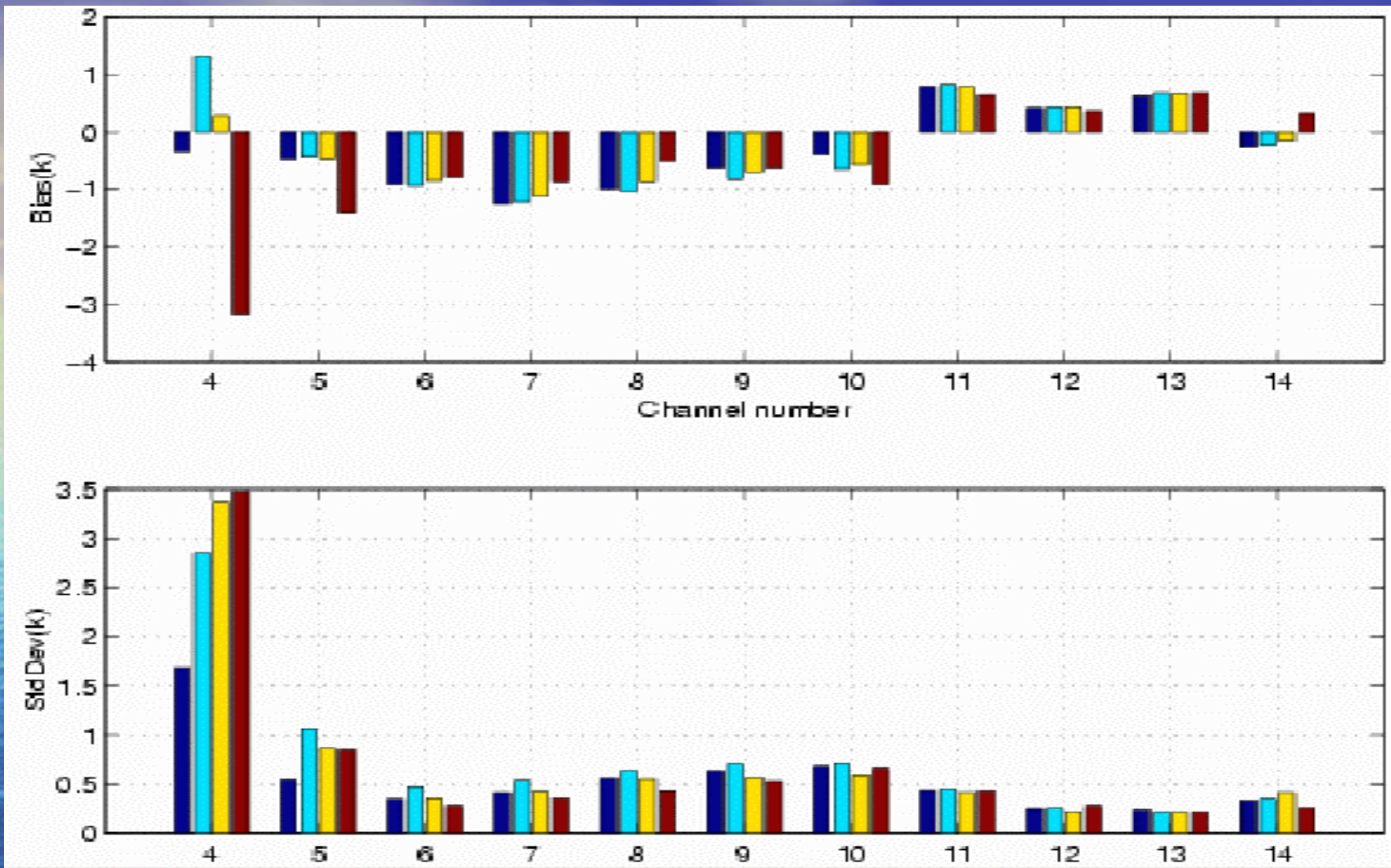
# Compare individual profiles from *Radiosonde*, *Satellite* and *NWP* platforms (... uncertainty rules)



# 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, H<sub>2</sub>O 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, H<sub>2</sub>O, 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

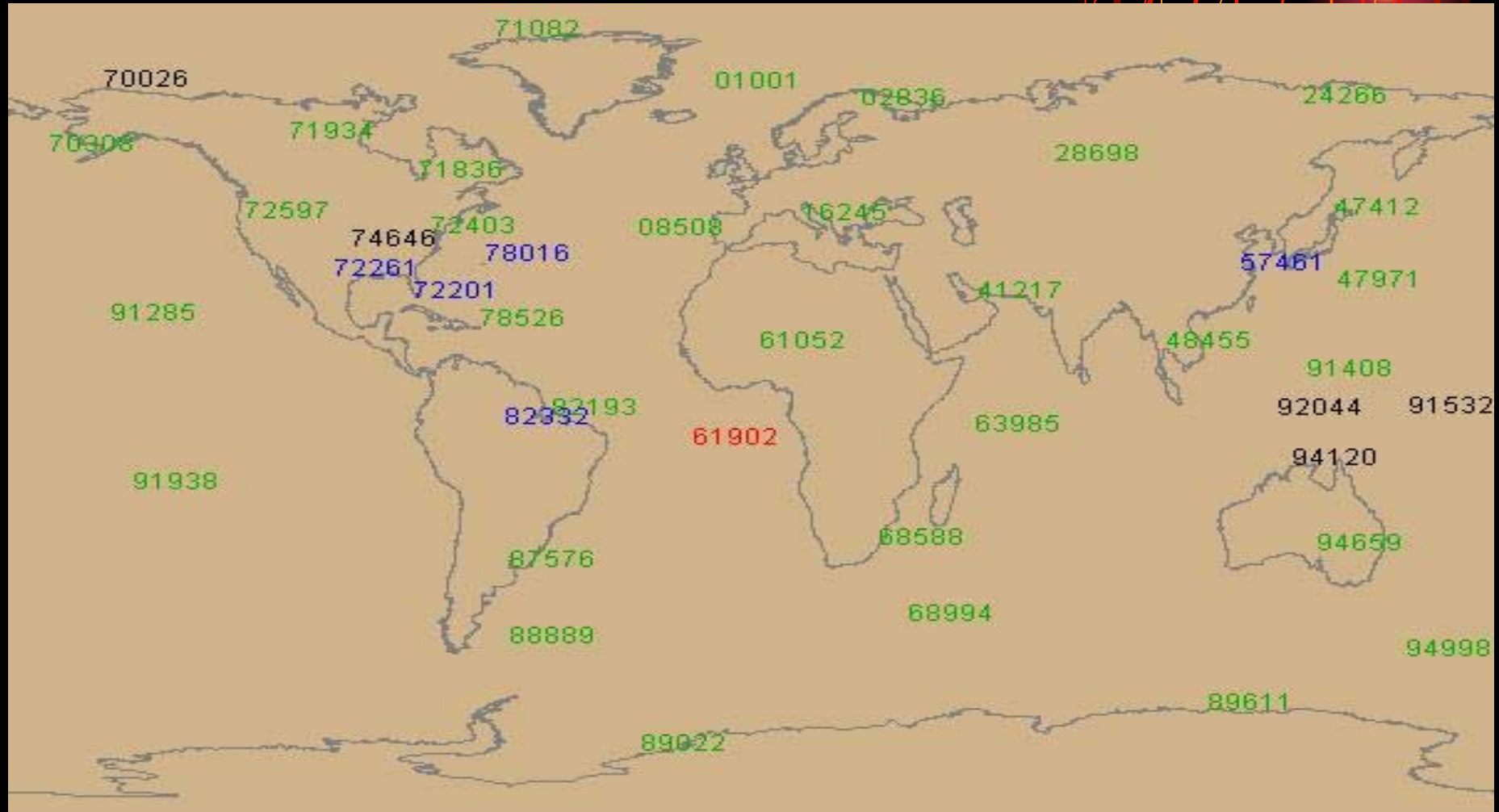
- Significant positive impact of satellite data on NWP reported over past several years
- However, associated data assimilation and adjustment techniques cannot segregate RT and NWP model bias/error ...
- *Proposed Reference Network can potentially segregate such errors ...*

# 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		

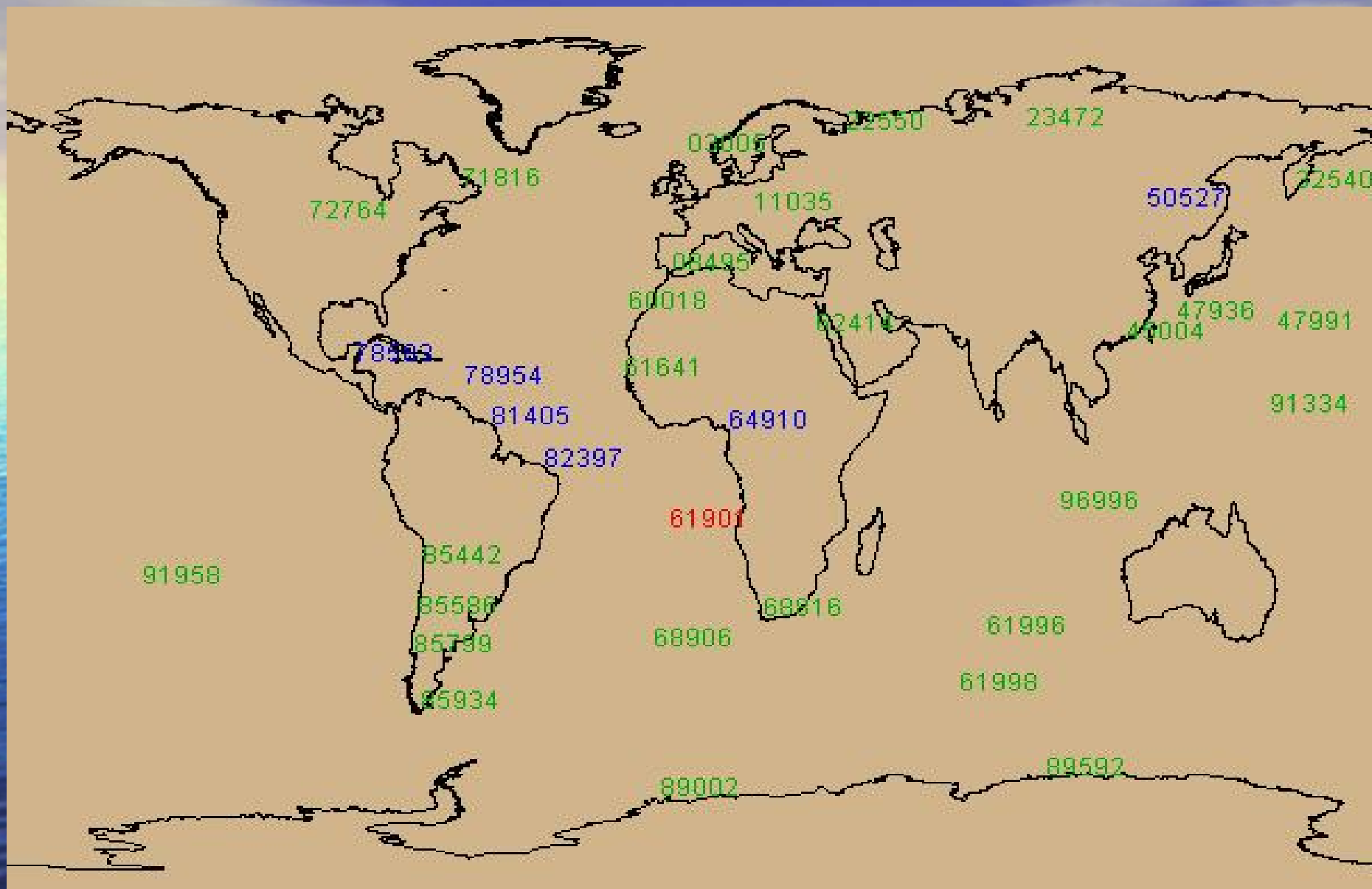
# indicates current  
NWS sites (11)

# ARM sites (5)

20 Sea  
18 Land  
4 Sea-Ice



# Alternate Sites

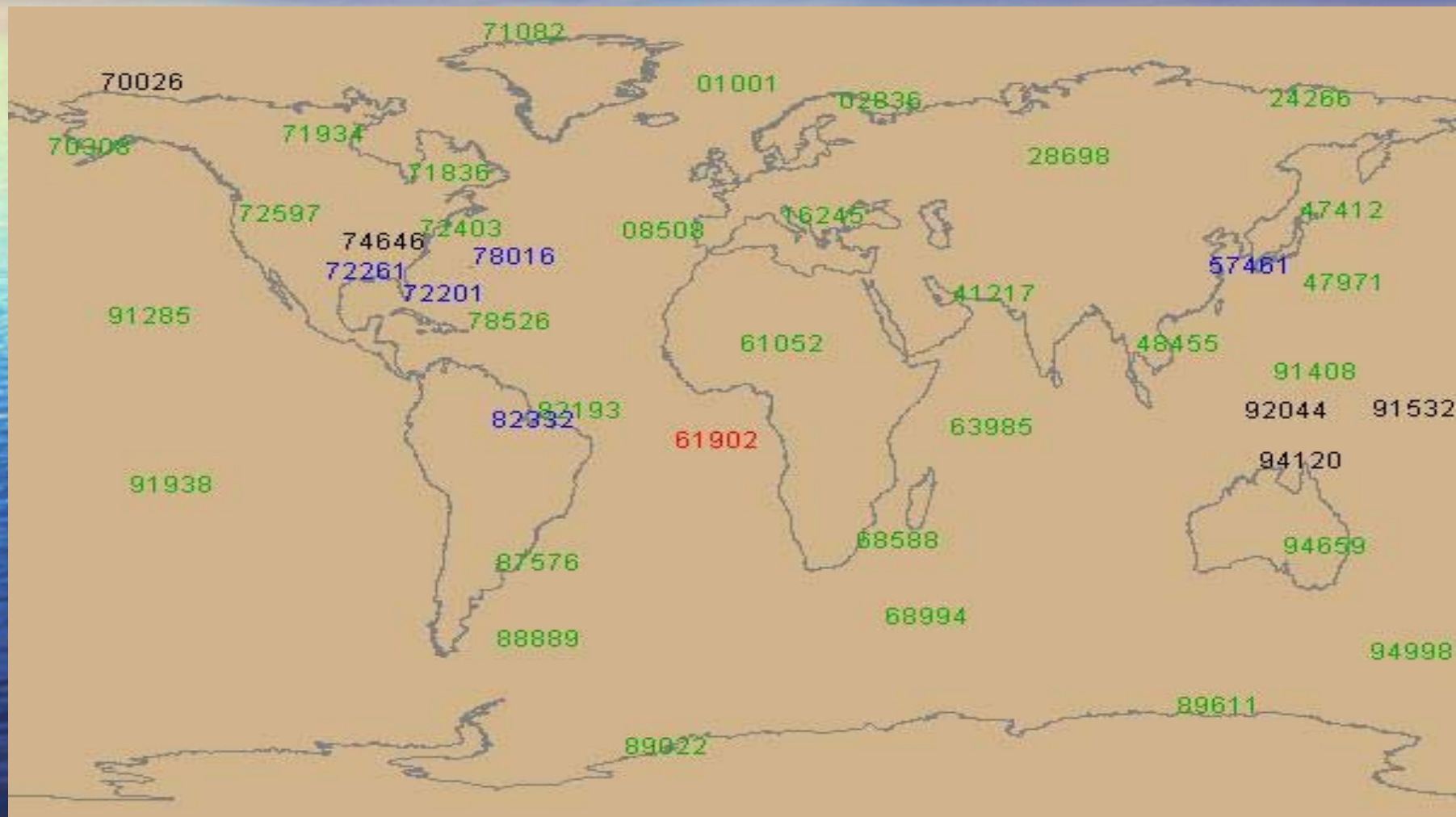


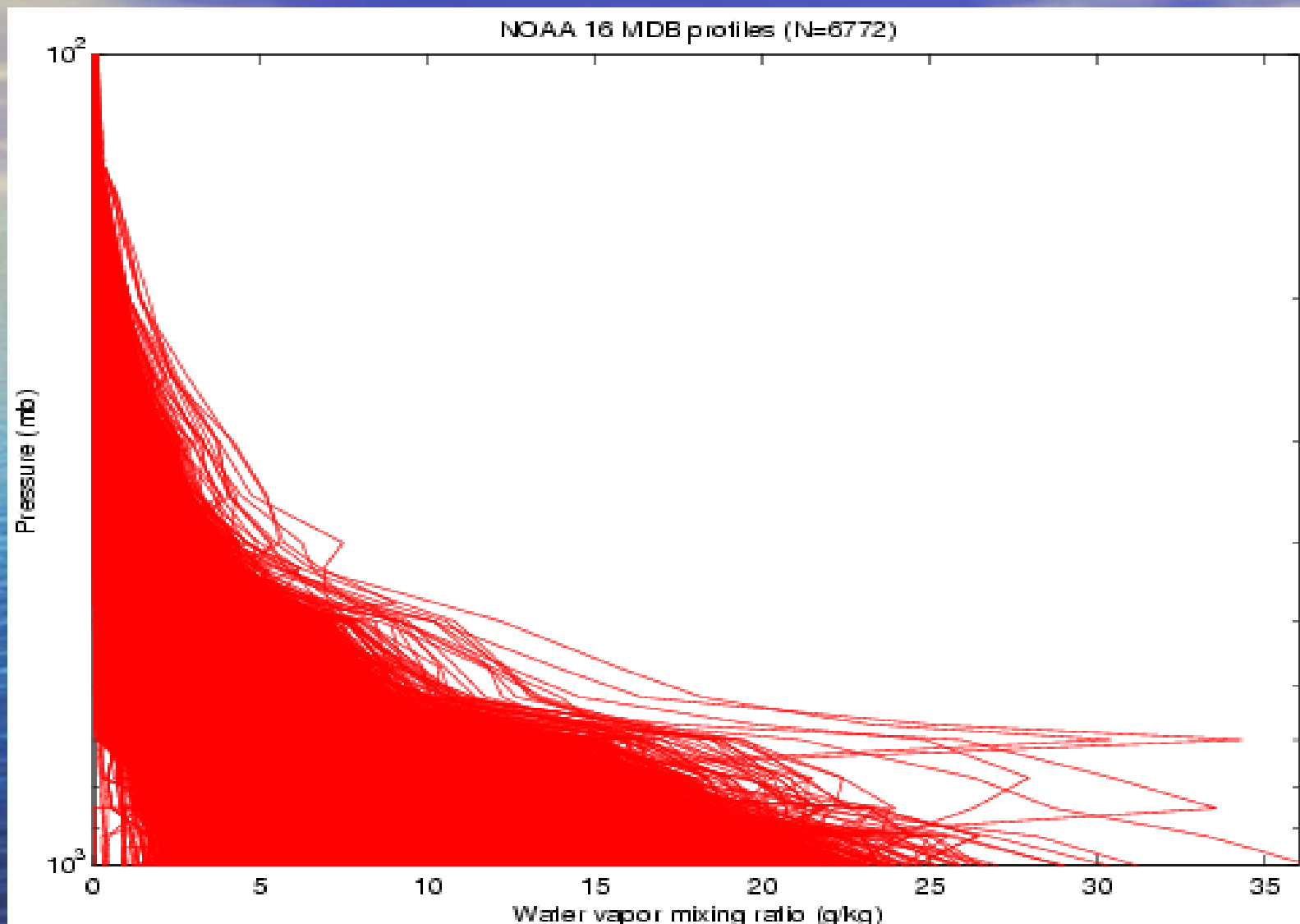
# RT Models

- 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



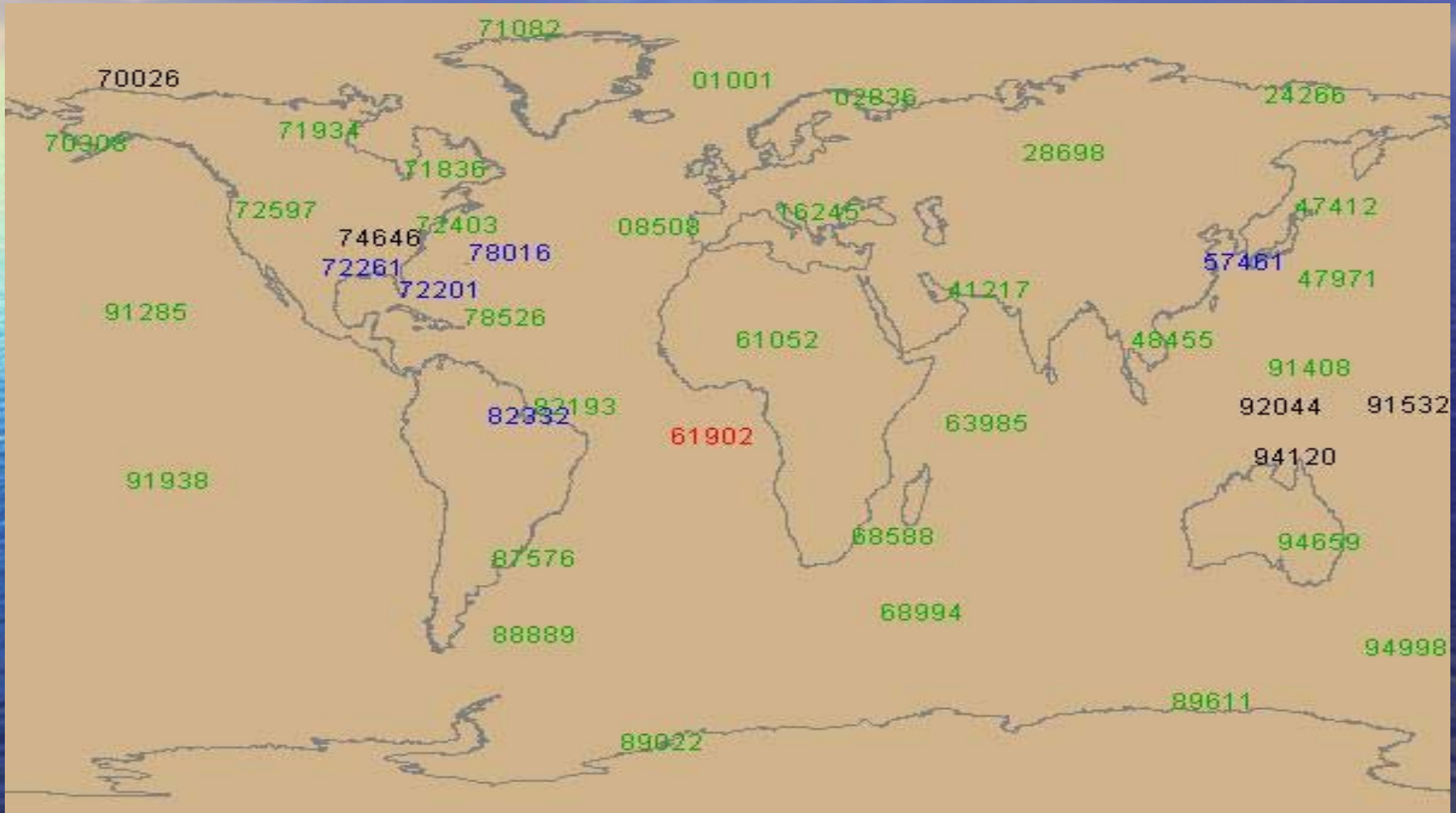




# WHY SUAN ?

- ***Operational Polar Satellite***
  - Measurements/Products require (*long-term*) “standardized” Monitoring/Tuning ... *using colocated radiosonde and satellite observations*
- ***Radiative Transfer (RT) models***
  - require coincident T, H<sub>2</sub>O 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 colocated 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

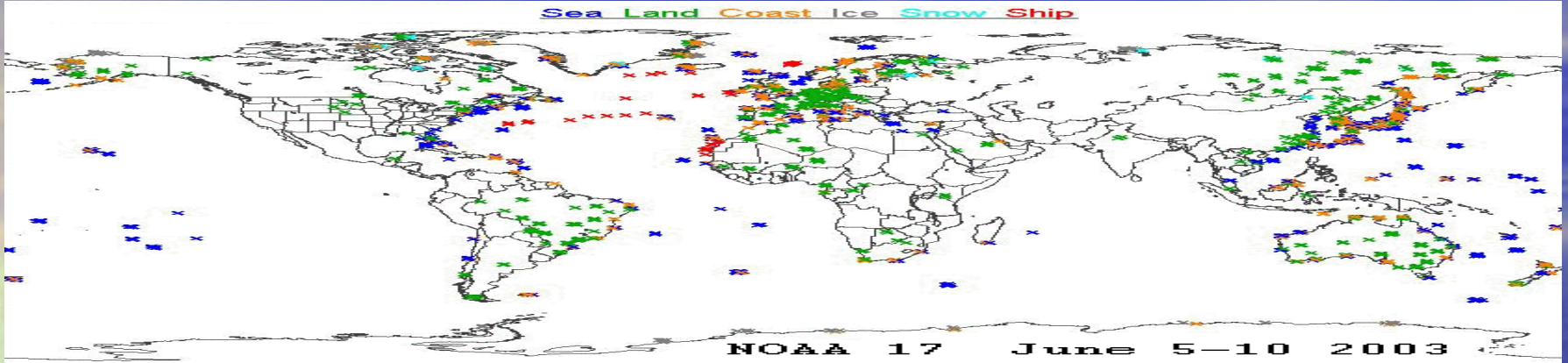




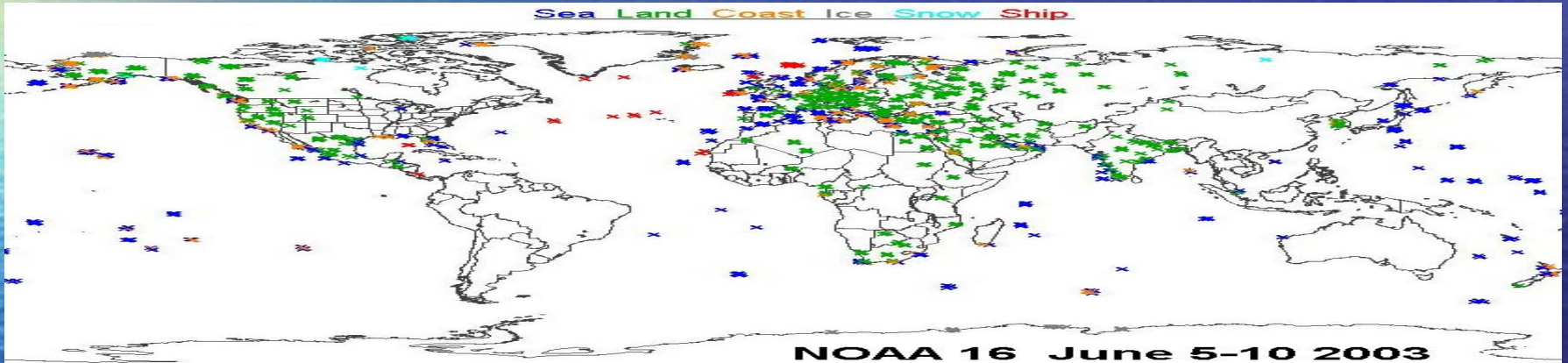
# Operational Satellite and Radiosonde Collocations

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

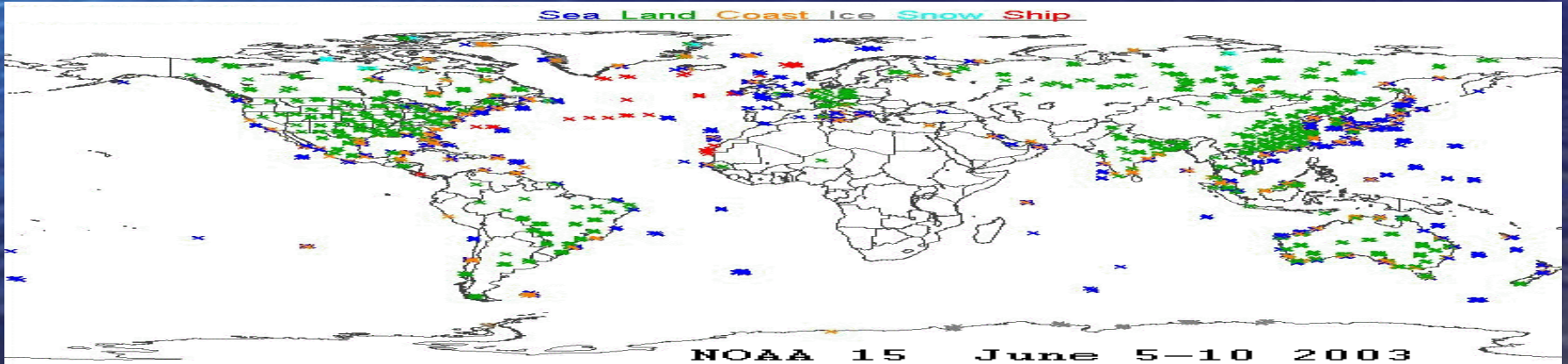
Sea Land Coast Ice Snow Ship



Sea Land Coast Ice Snow Ship

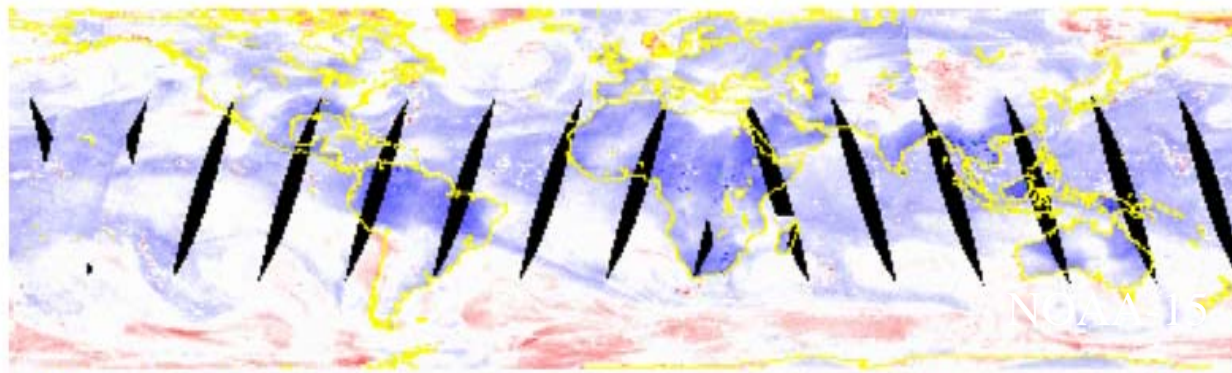
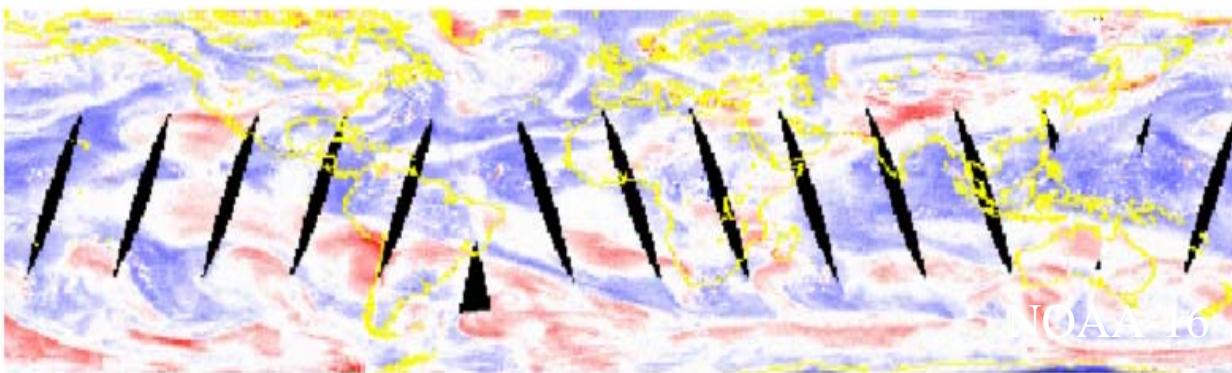
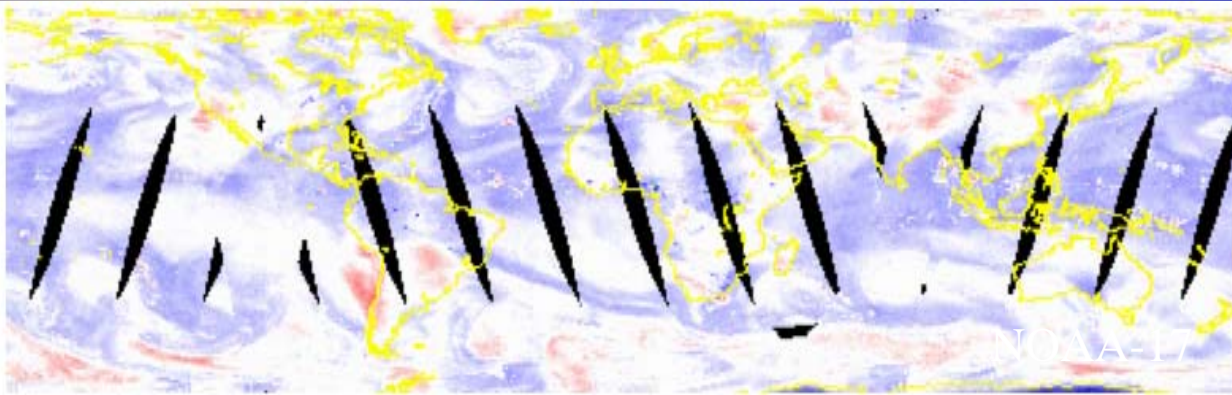


Sea Land Coast Ice Snow Ship





# RT Bias Adjustments



*AMSU-B at 183 +/- 1 GHz*  
(upper tropospheric moisture)

12-hour time composites

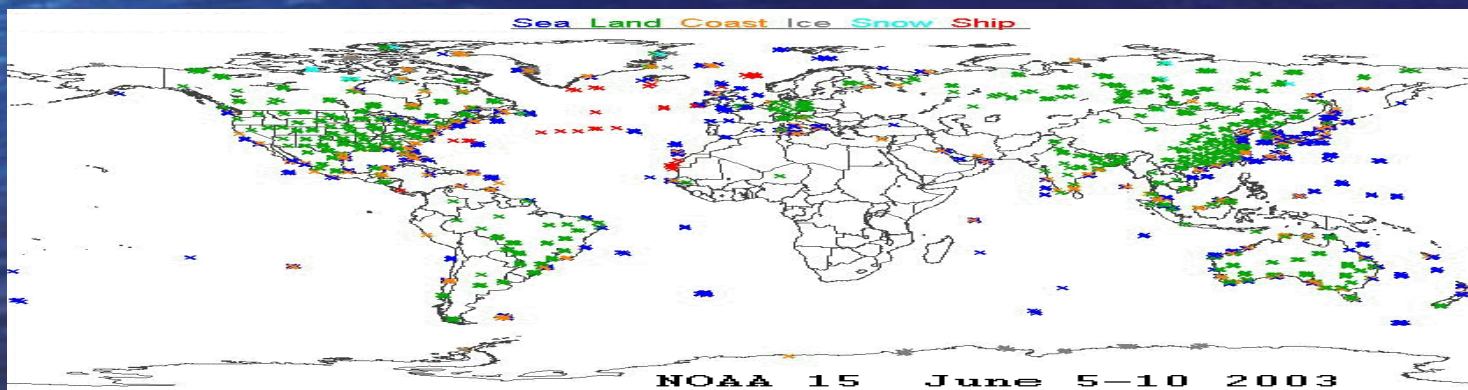
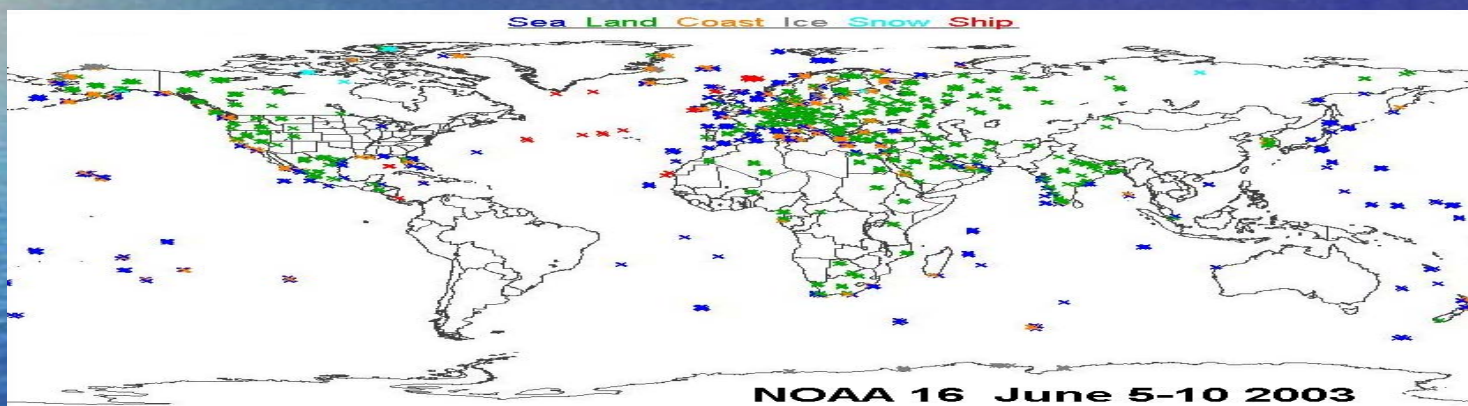
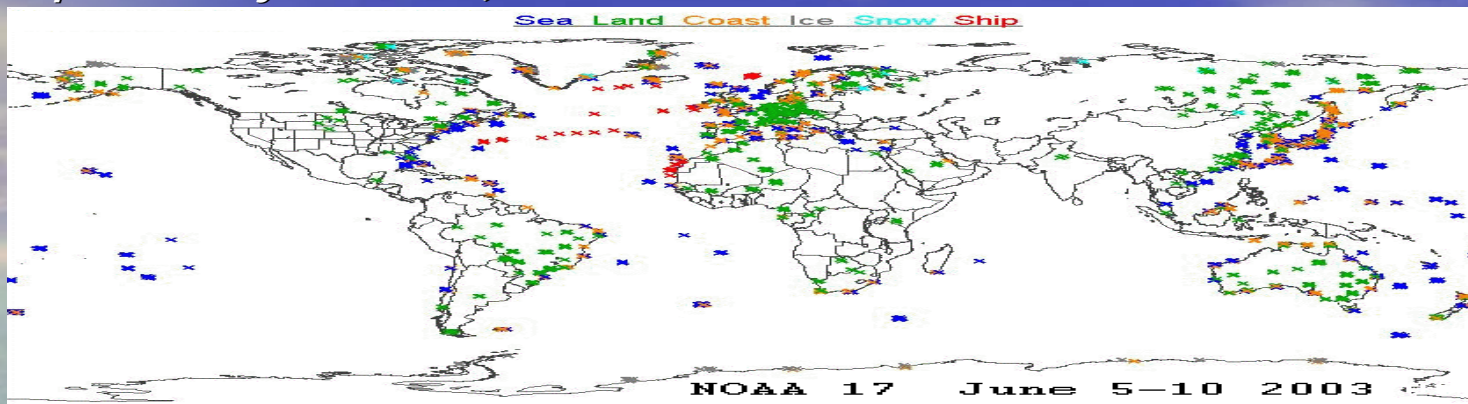
Adjustments as *regressed from collocated satellite and radiosonde data* and applied during operational processing ...

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



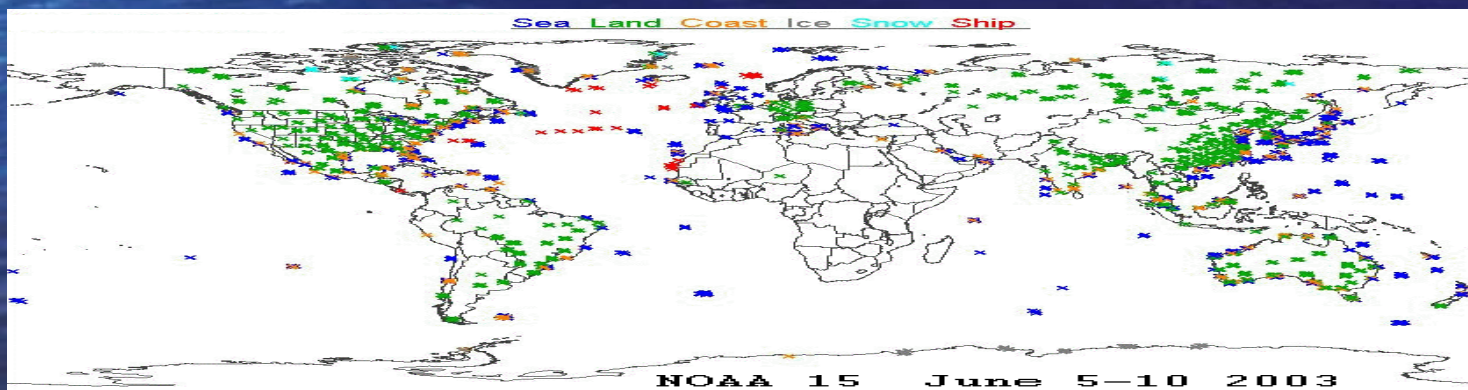
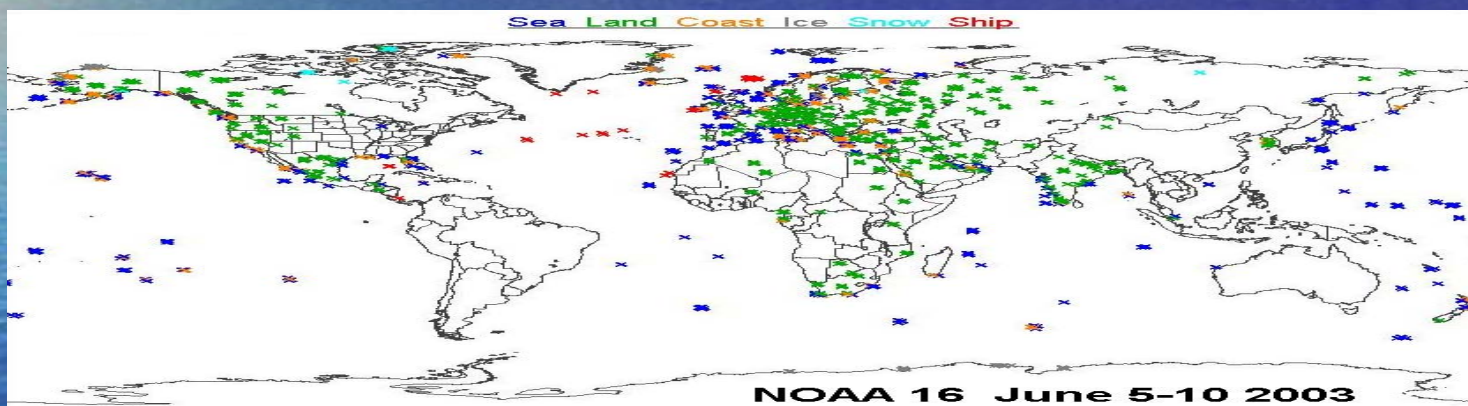
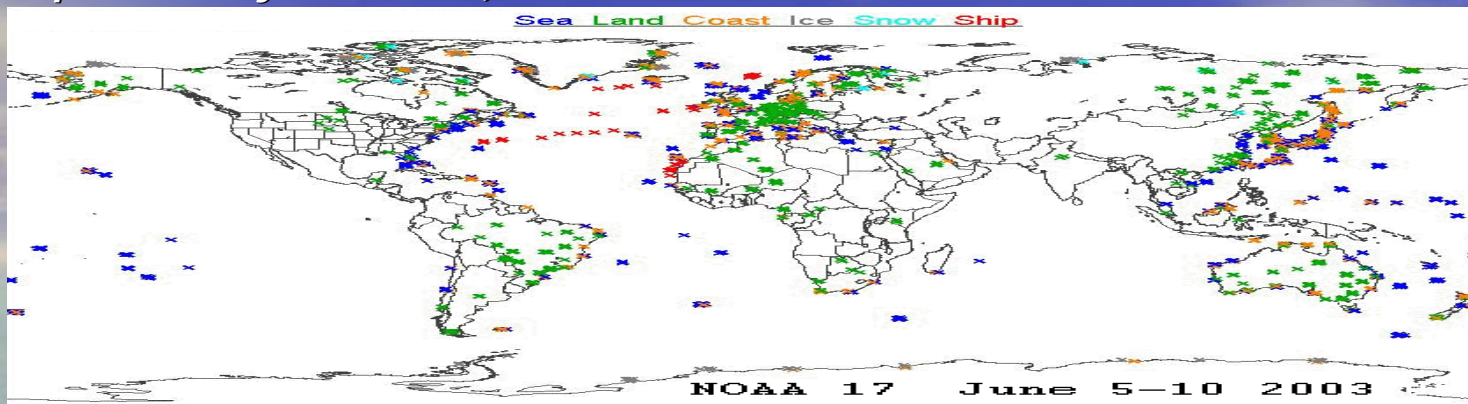
# SATELLITE COLLOCATIONS (+/- 3hrs, land; +/- 5hrs, sea)

*(used operationally at NESDIS)*



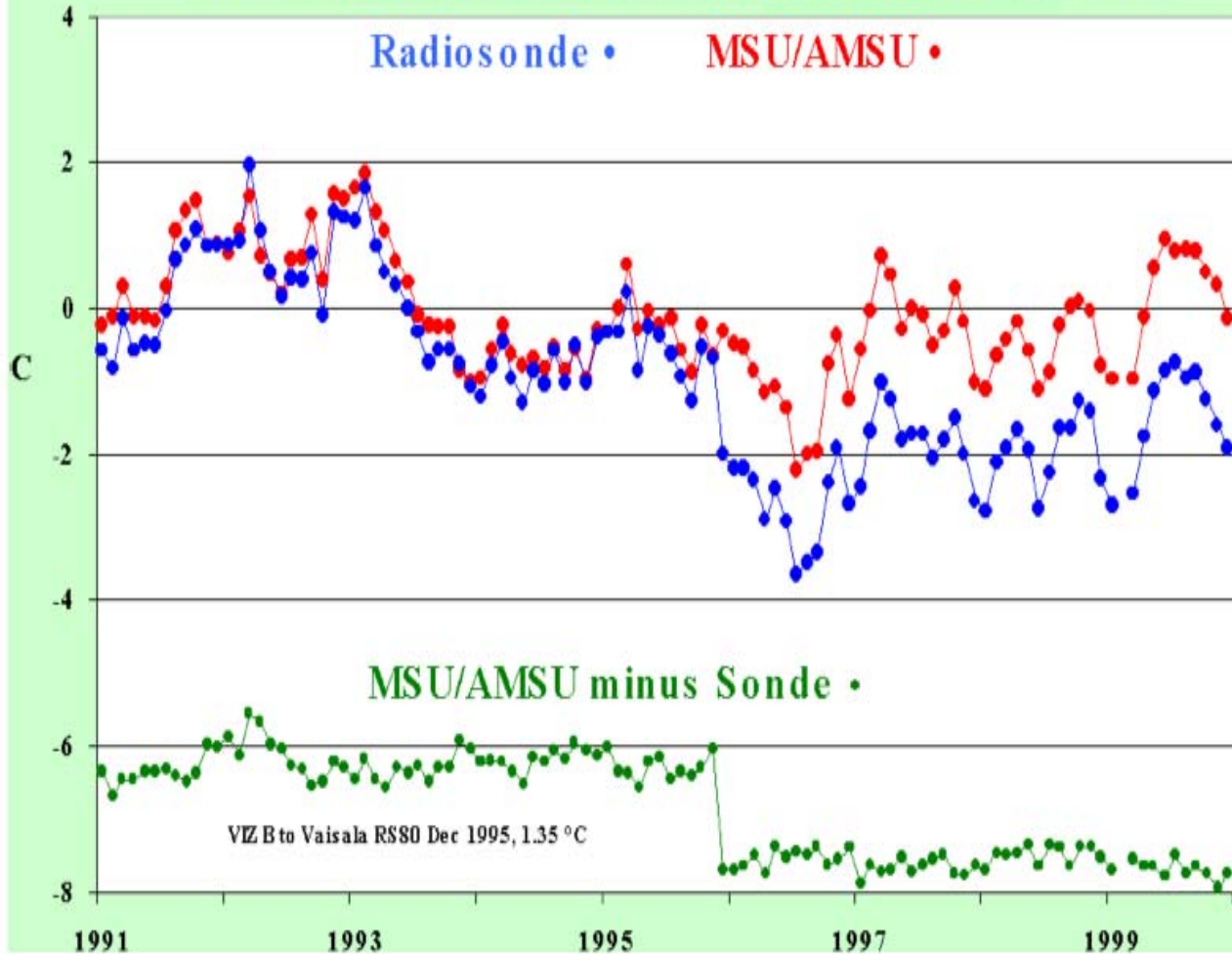
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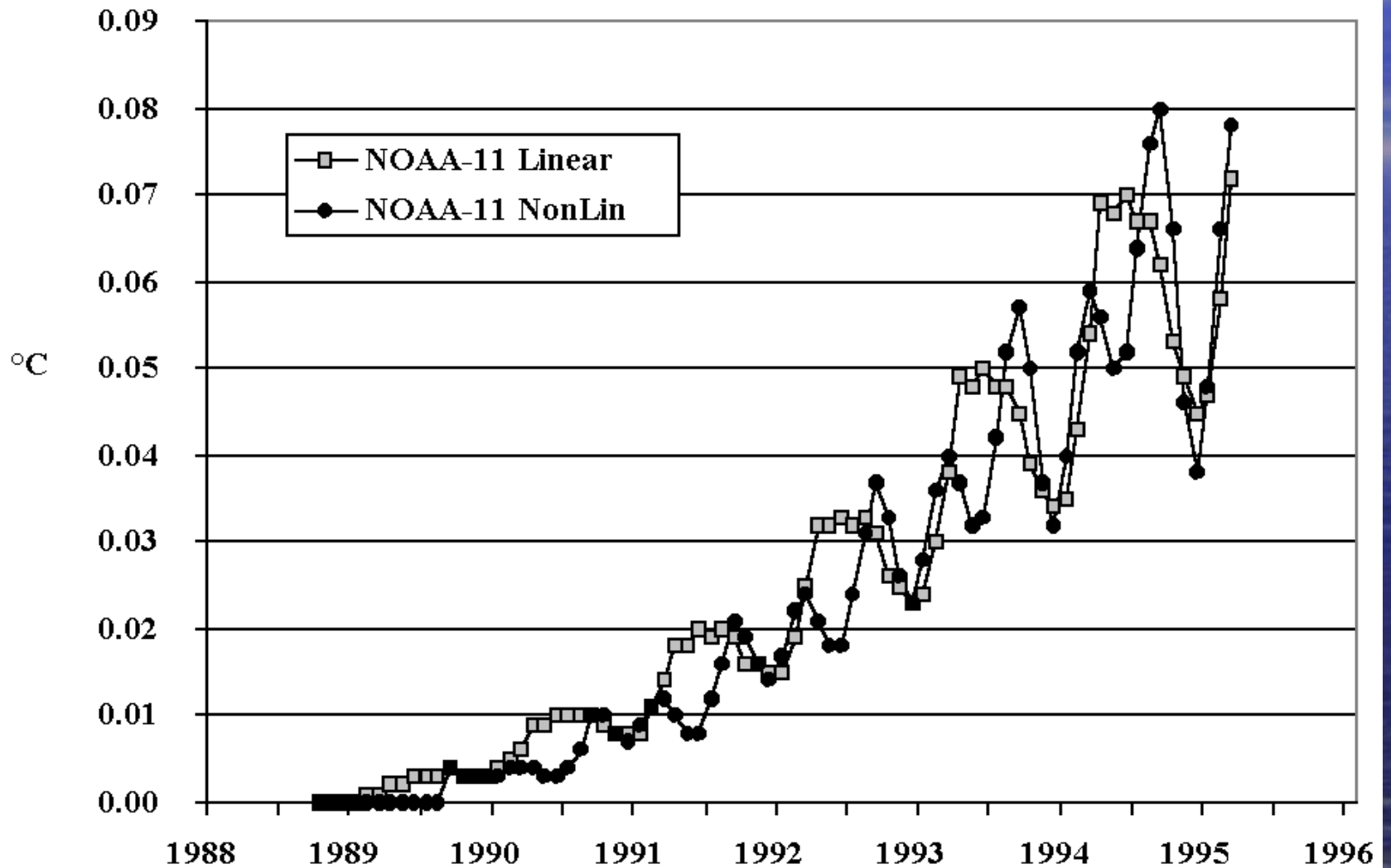
## RADIOSONDE DISCONTINUITIES IN THE STRATOSPHERE



Satellites can serve as transfers standards to monitor radiosondes

VIZ B to Vaisala (RS80) at Chuuck Island

## Global Mean Diurnal Effect for NOAA-11





Collocated Radiosonde and Satellite Observations  
provide basis for the

*Monitoring  
Validating and  
Tuning*

*of Operational Satellite Data Systems*

*(... critical for climate retrieval problem)*

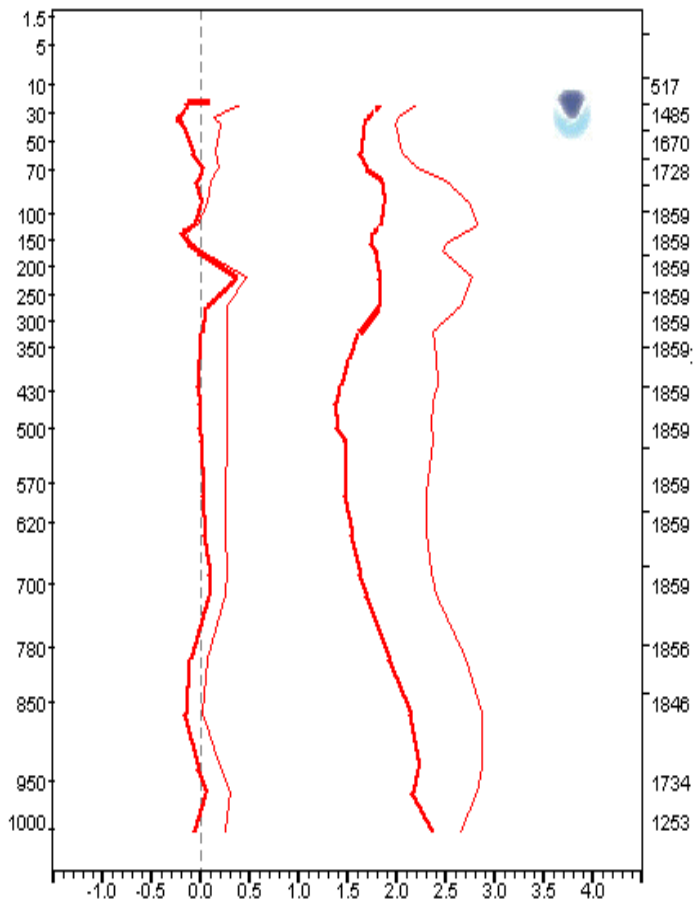
# Radiosonde and TOVS-1b Collocation History from 1979 (*... correcting the past ...*)

- *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*



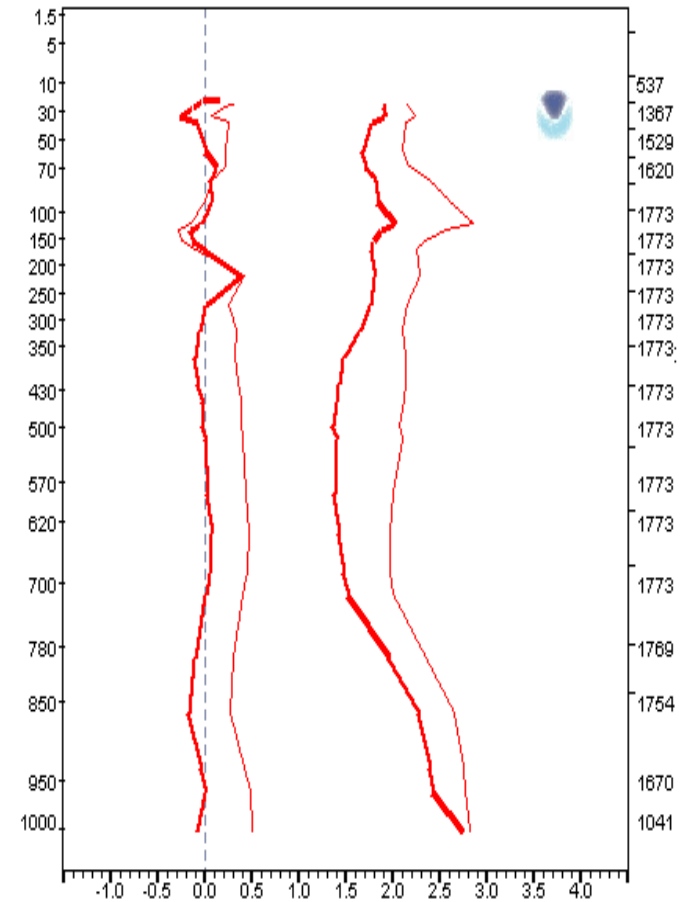
# Accuracy Statistics vs Radiosondes (*Guess (light)* vs *Retrieval (heavy)*)

## Tuning to Errors



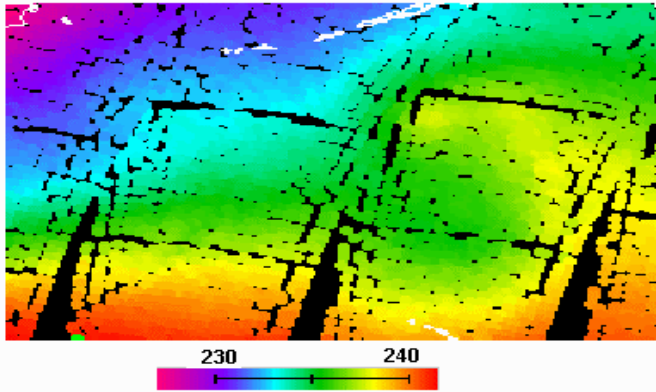
Collocations  
provide  
independent  
validation (heavy)  
and tuning (light)  
per satellite

NOAA-16  
(60N to 60S)

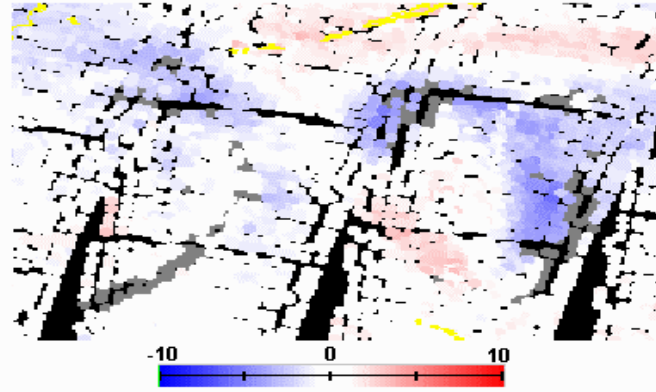


ATOVS NOAA-16  
15 Jan 2004 12 Z +/- 2 hr

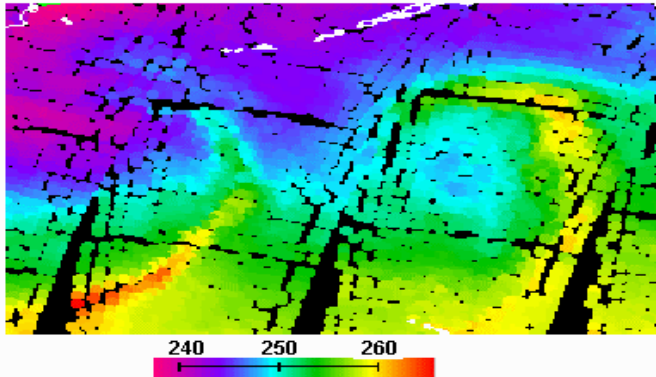
AMSU-A Ch. 6



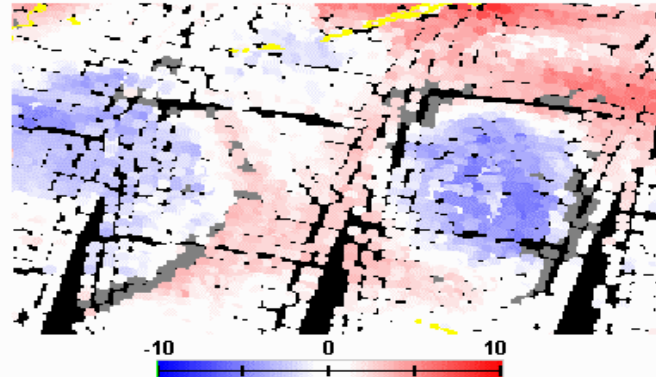
SAT - NWP: (500mb to 300mb)  
T° BAR



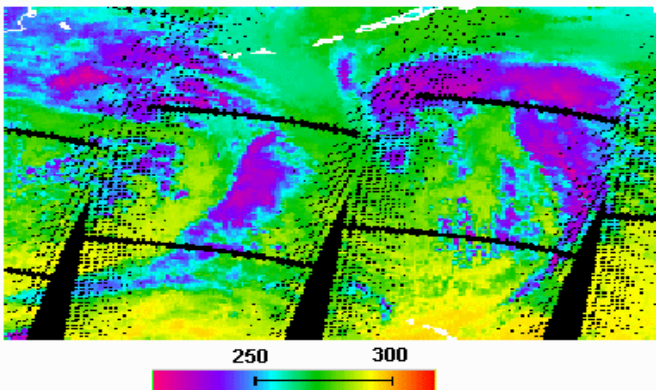
AMSU-A Ch. 4



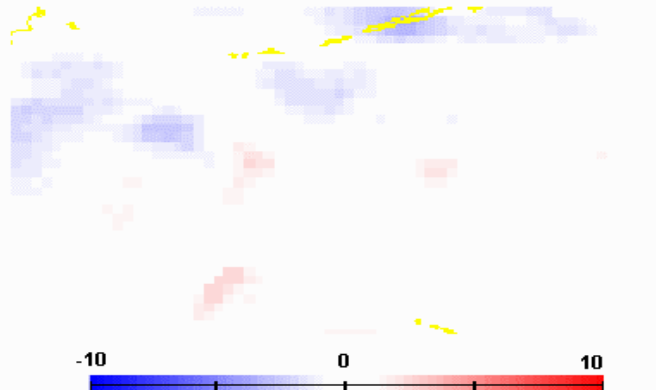
SAT - NWP: (1000mb to 700mb)  
T° BAR



AVHRR Ch. 4



12-hr NWP - Analysis (12Z) 850mb Temp



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

*leading to improved satellite data impact in frontal zones?*



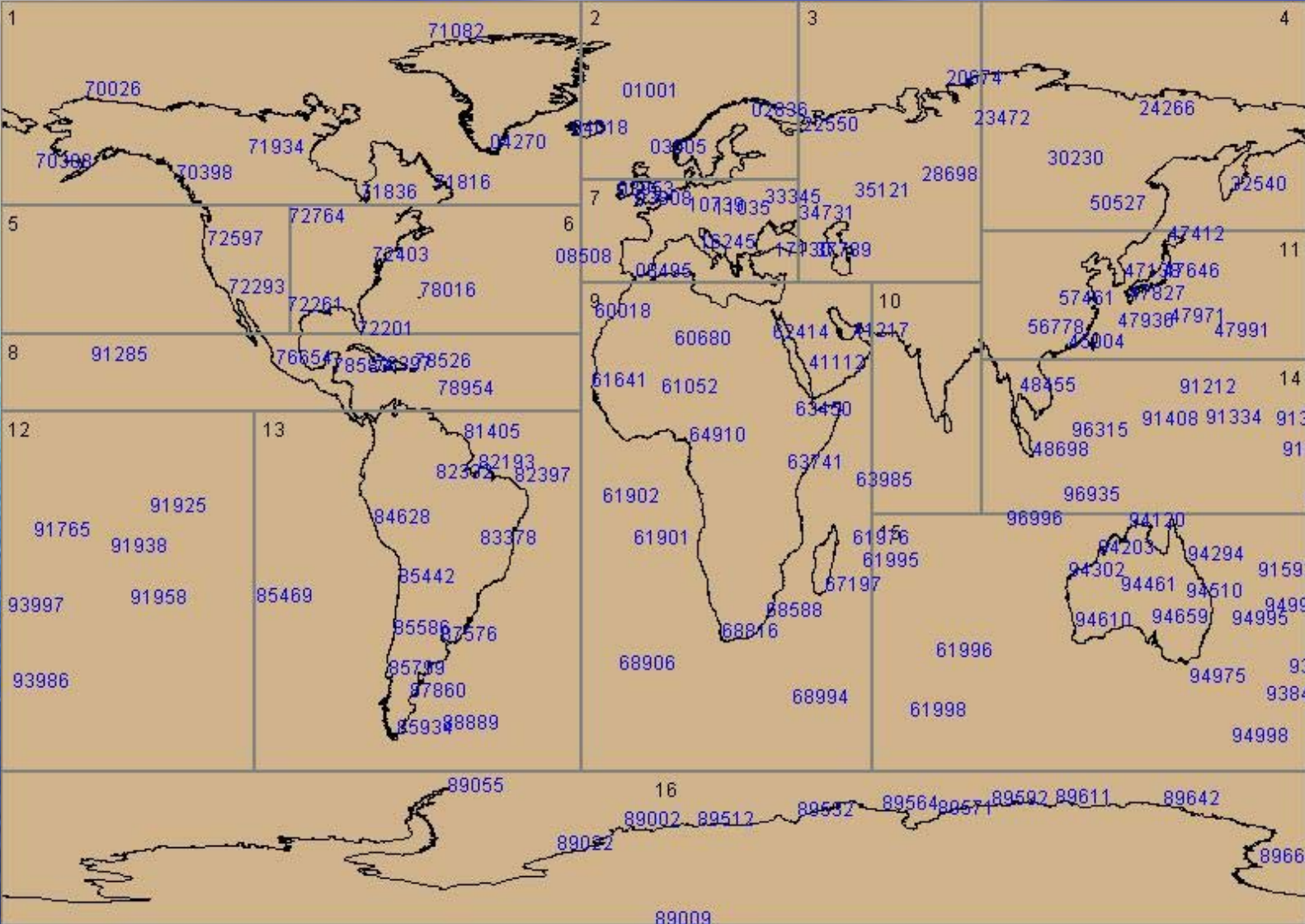
# Climate

## 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





# AMSU Sounding Channels

