STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

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The Role of Conventional Radiosonde Observations in Satellite Data Calibration/Validation: Values & Challenges

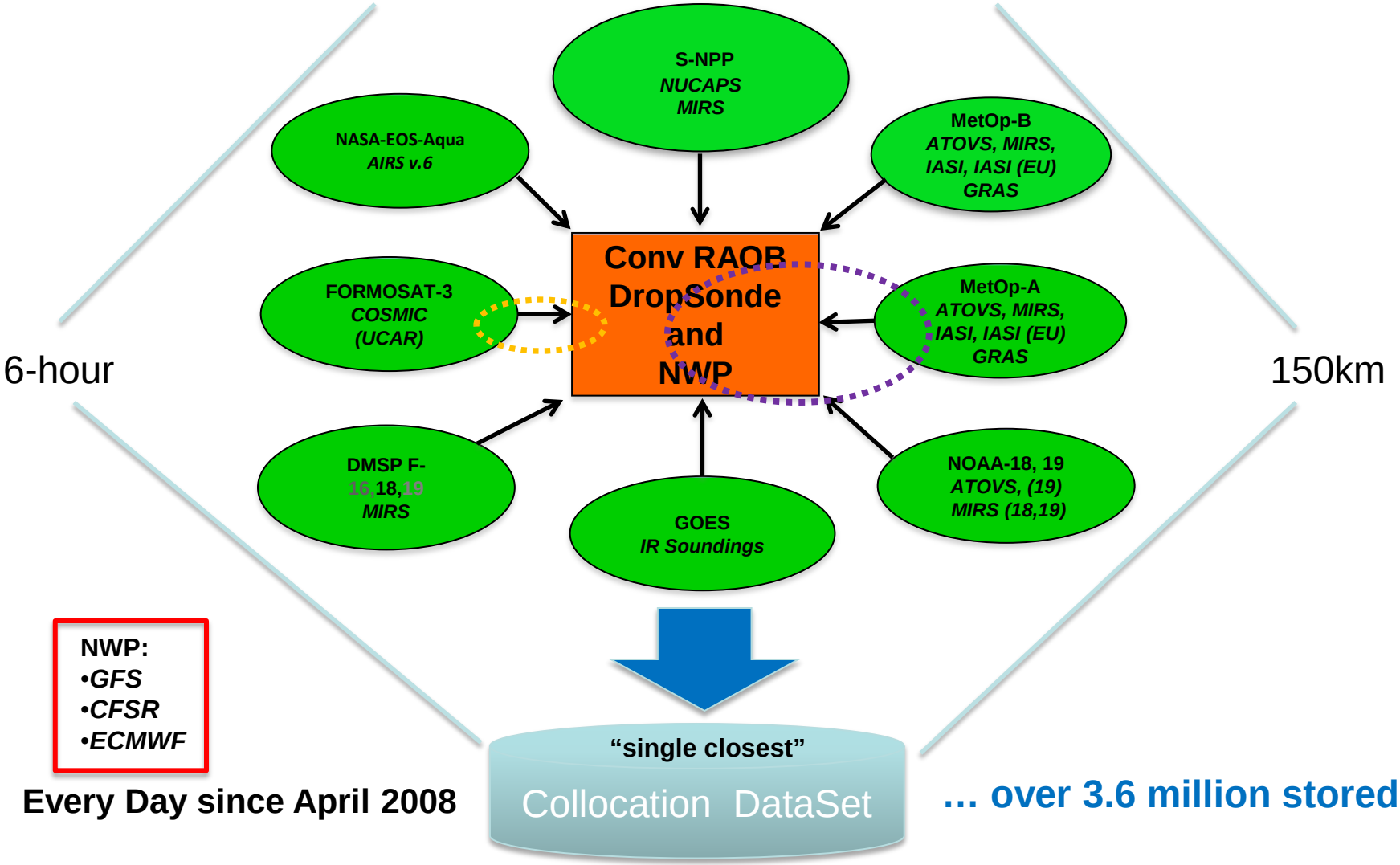
Bomin Sun[1,2] and Tony Reale[1]

1 NOAA/NESDIS/Center for Satellite Applications and Research, College Park, Maryland
2 I.M. Systems Group, Rockville, Maryland

Acknowledgements: Frank Tilley, Mike Pettey, and Charlie Brown at STAR NESDIS

NOAA Products Validation System (NPROVS)

Centralized RAOB and Satellite Product Collocation



Every Day since April 2008

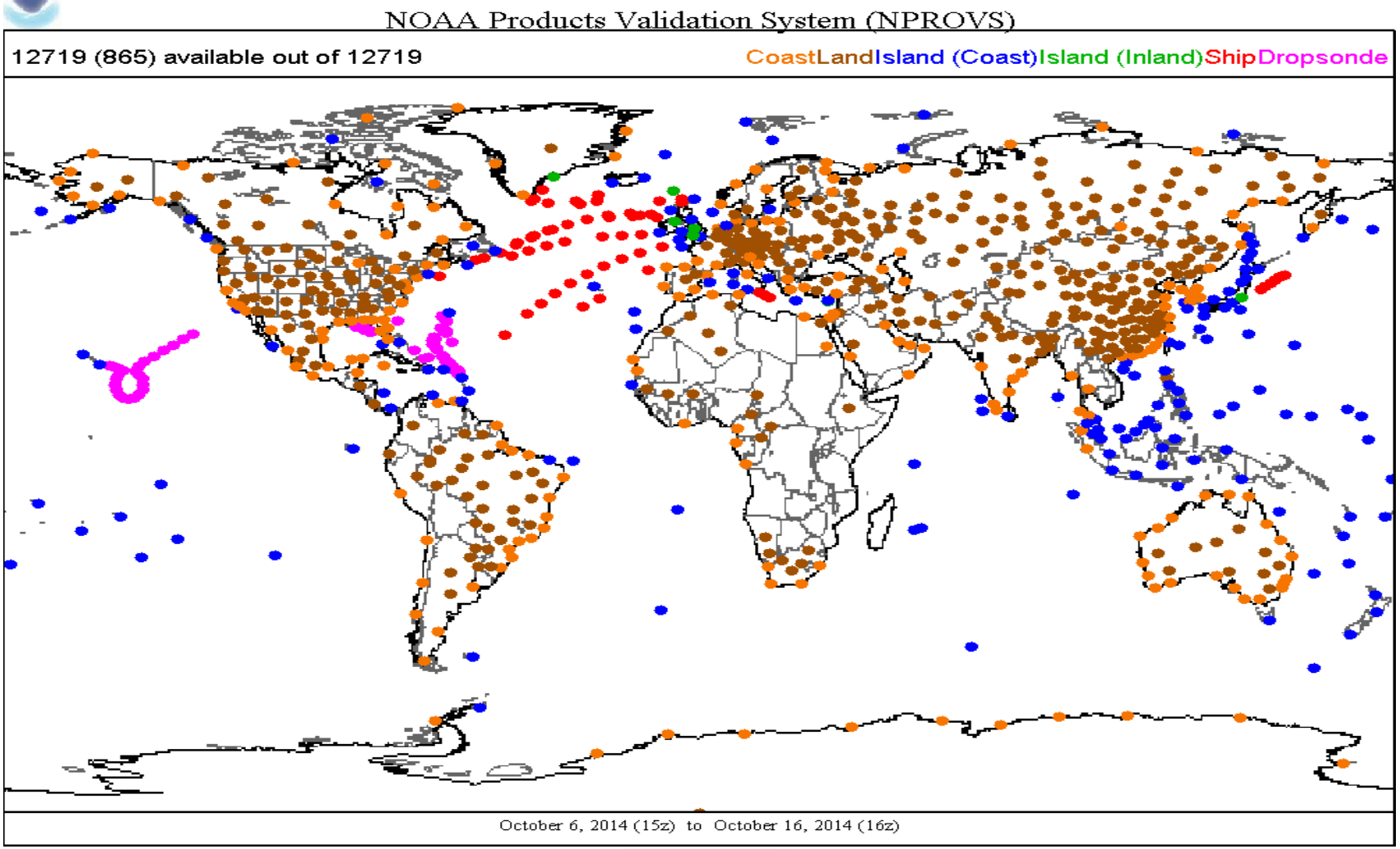
… over 3.6 million stored

https://www.star.nesdis.noaa.gov/smcd/opdb/nprovs

Values of conventional RAOBs in satellite cal/val

- Huge obs. number with little cost (for us)
  - 240 K obs./yr (conventional) *vs*. 8 K obs./yr (GRUAN/Dedicated)
- Independent (relative to NWP) truth data for satellite cal/val
- NPROVS system has practically been approved to be very useful in
  - Products monitoring
  - Analyzing characteristic performance of retrieval products in a variety of weather conditions
  - Indentifying problem areas in retrieval systems in support of algorithm development & improvement

N P R O V S



Typical NPROVS Global Collocation Dataset

Challenges of conventional RAOBs in satellite cal/val

- Measurement accuracy issue
- Spatial & temporal mismatch

JPSS Specification Performance Requirements For Suomi-NPP CrIS/ATMS Sounder EDRs

CrIS/ATMS Atmospheric Vertical Temperature Profile (AVTP)
Measurement Uncertainty – Layer Average Temperature Error

PARAMETER	THRESHOLD
AVTP, Cloud fraction < 50%, surface to 300 hPa	1.6 K / 1-km layer
AVTP, Cloud fraction < 50%, 300–30 hPa	1.5 K / 3-km layer
AVTP, Cloud fraction < 50%, 30–1 hPa	1.5 K / 5-km layer
AVTP, Cloud fraction < 50%, 1–0.5 hPa	3.5 K / 5-km layer
AVTP, Cloud fraction ≥ 50%, surface to 700 hPa	2.5 K / 1-km layer
AVTP, Cloud fraction ≥ 50%, 700–300 hPa	1.5 K / 1-km layer
AVTP, Cloud fraction ≥ 50%, 300–30 hPa	1.5 K / 3-km layer
AVTP, Cloud fraction ≥ 50%, 30–1 hPa	1.5 K / 5-km layer
AVTP, Cloud fraction ≥ 50%, 1–0.5 hPa	3.5 K/ 5-km layer

CrIS/ATMS Atmospheric Vertical Moisture Profile (AVMP)
Measurement Uncertainty – 2-km Layer Average Mixing Ratio % Error

PARAMETER	THRESHOLD
AVMP, Cloud fraction < 50%, surface to 600 hPa	Greater of 20% or 0.2 $g \cdot kg^{-1}$ / 2-km layer
AVMP, Cloud fraction < 50%, 600–300 hPa	Greater of 35% or 0.1 $g \cdot kg^{-1}$ / 2-km layer
AVMP, Cloud fraction < 50%, 300–100 hPa	Greater of 35% or 0.1 $g \cdot kg^{-1}$ / 2-km layer
AVMP, Cloud fraction ≥ 50%, surface to 600 hPa	Greater of 20% of 0.2 $g \cdot kg^{-1}$ / 2-km layer
AVMP, Cloud fraction ≥ 50%, 600–400 hPa	Greater of 40% or 0.1 $g \cdot kg^{-1}$ / 2-km layer
AVMP, Cloud fraction ≥ 50%, 400–100 hPa	Greater of 40% or 0.1 $g \cdot kg^{-1}$ / 2-km layer

Global requirements defined for lower and upper atmosphere subdivided into 1-km and 2-km layers for AVTP and AVMP, respectively.

Outline

1. Accuracy issue

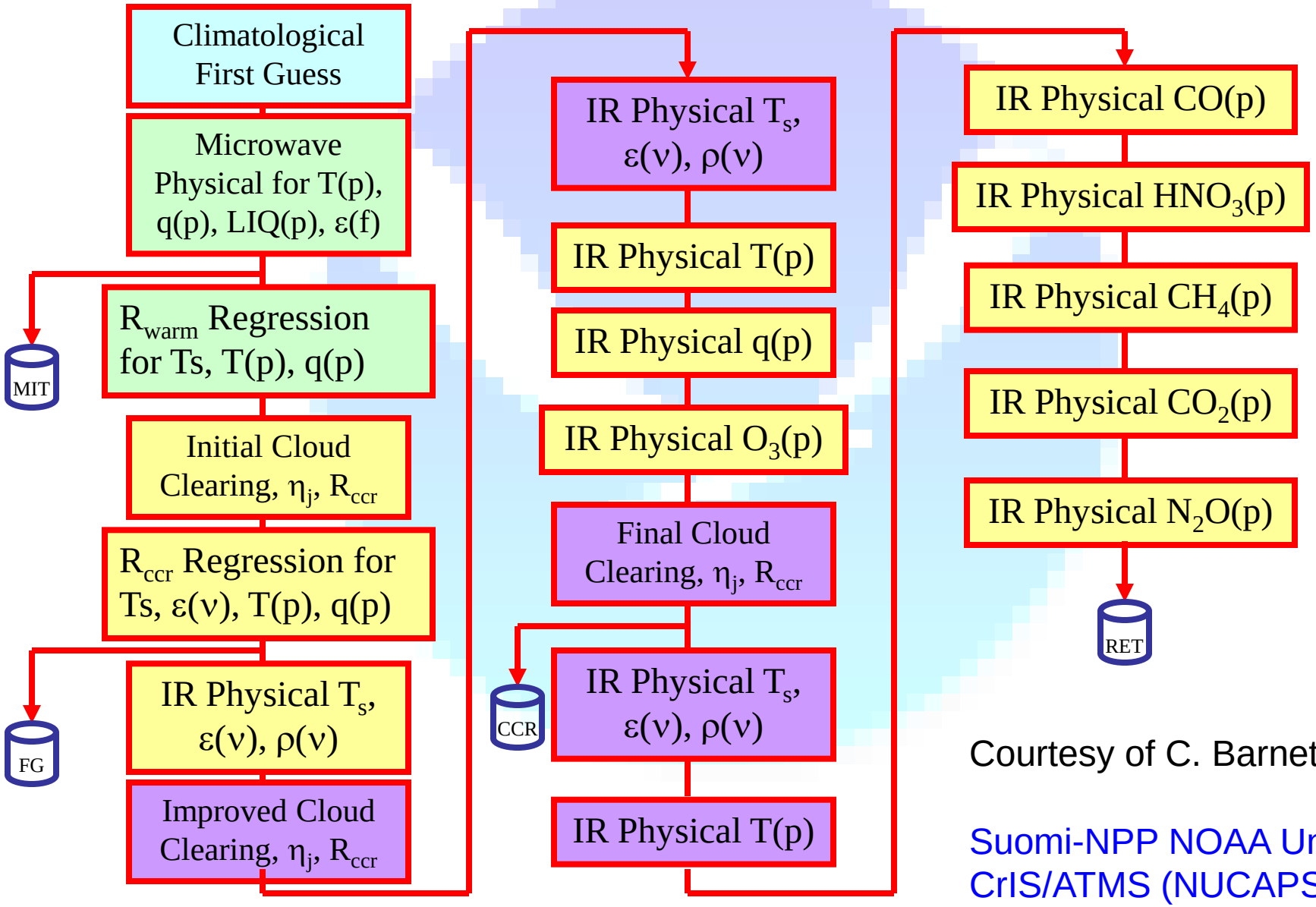
   Error characteristics & how they are reflected in satellite retrieval validation

   - Temperature
   - Humidity

2. Spatial & temporal mismatch

Three-year RAOB-IASI collocation dataset collected via NPROVS is used to illustrate the issues and their impacts in the validation

Simplified flow diagram of the NOAA IASI retrieval algorithm



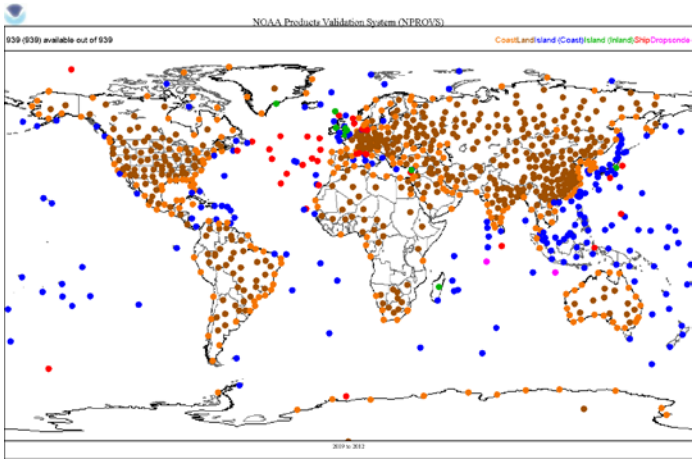
Courtesy of C. Barnet

Suomi-NPP NOAA Unique CrIS/ATMS (NUCAPS)

Data

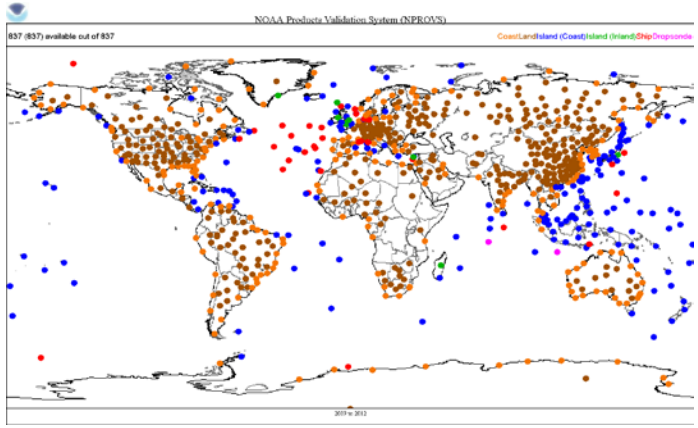
- **MetOp-A Infrared Atmospheric Sounding Interferometer (IASI) L2 sounding product developed by NOAA NESDIS.**
- **Three-yr (2010-2012) RAOB-IASI collocations collected via NPROVS.**
- **q*c-accepted* IR+MW IASI retrieval profiles.**

Collocations within **6-hr** & 50-km



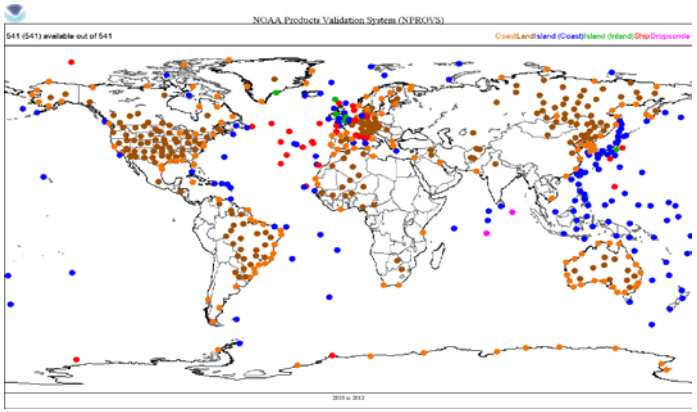
Sample: 550,500 (939 sites)

Collocations within **3-hr** & 50-km



Sample: 313,500 (837 sites)

Collocations within **1-hr** & 50-km



Sample: 99,000 (541 sites)

RAOB Accuracy Impact in Validation

- RAOB measurement accuracy characteristics and impact on satellite validation
  - Temperature
  - Humidity

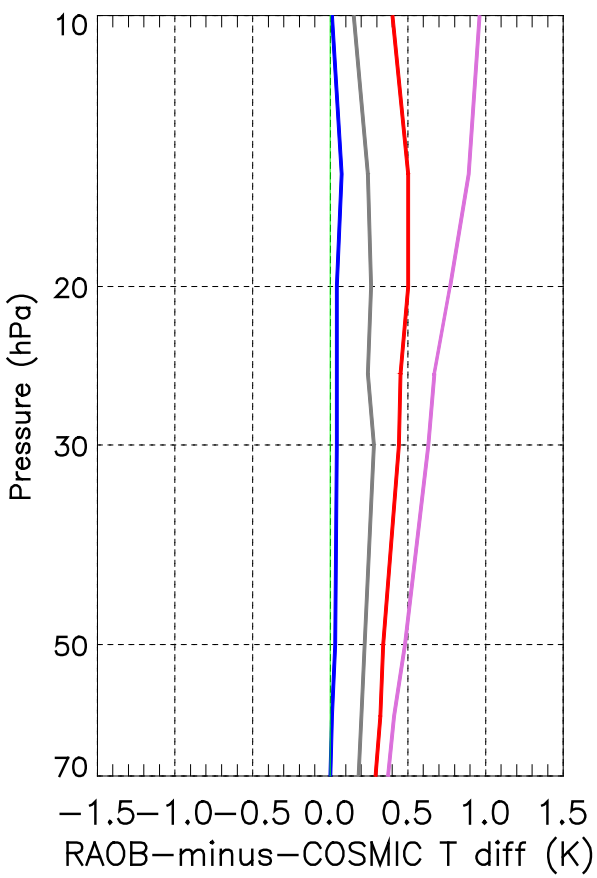
Errors in RAOB T and Impact in Validation

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)

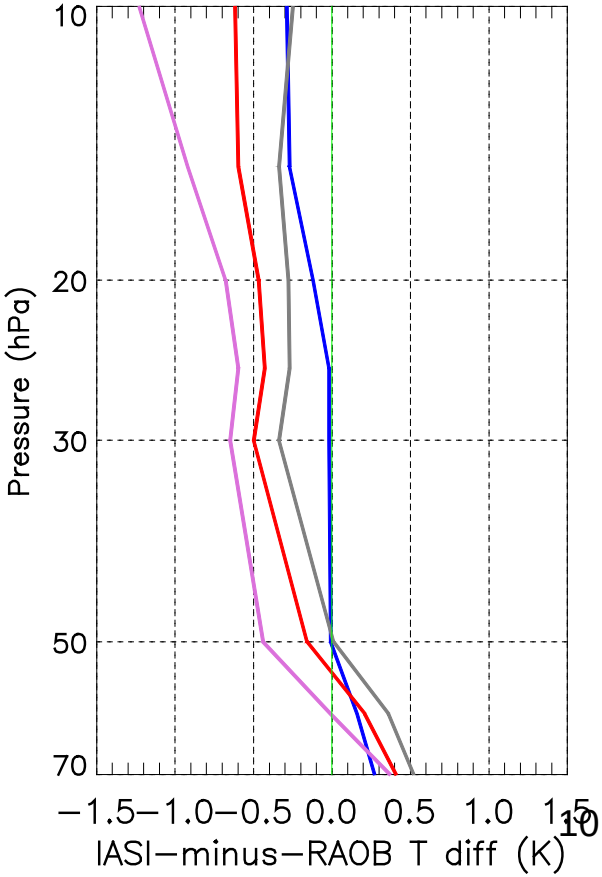
Radiosonde temperature radiation-induced errors (Sun et al.,2013, JGR).

Collaborating with NCEP to improve their radiosonde “RADCOR” in DA.

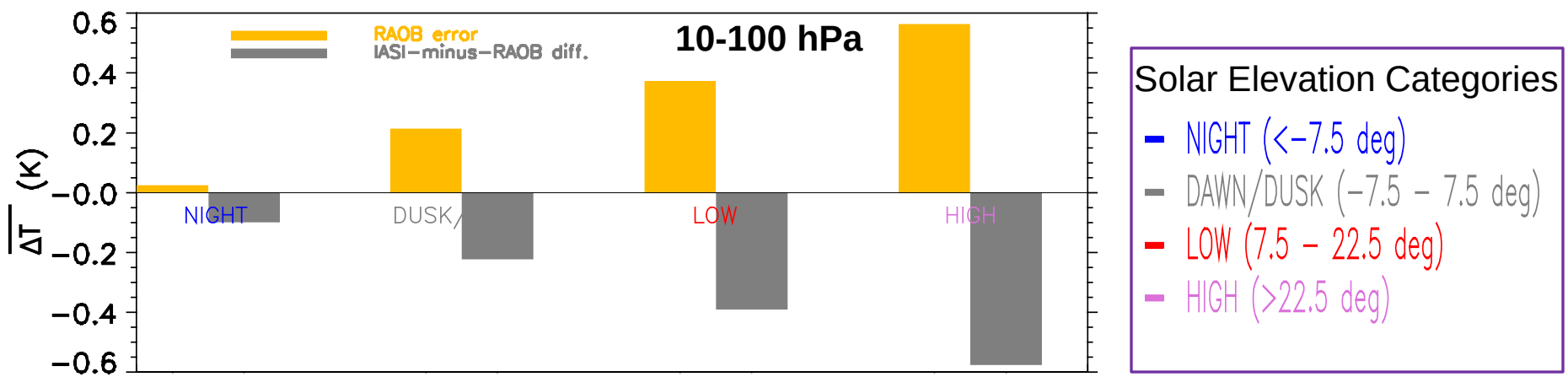
Radiosonde T error



IASI-minus-RAOB T diff.



RAOB Temperature error impact in validation



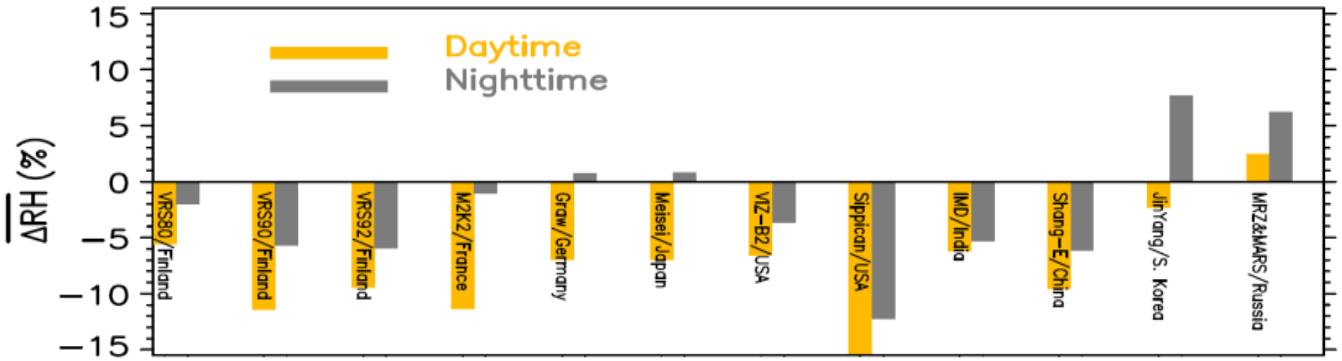
For 10-100 hPa

	All-day
RAOB error:	**0.27 K**
IASI-minus-RAOB difference:	**-0.32 K**

"Cold bias" in IASI in UTLS is likely an artifact reflecting the warm RAOB T bias.

Radiosonde type relative humidity (RH) bias

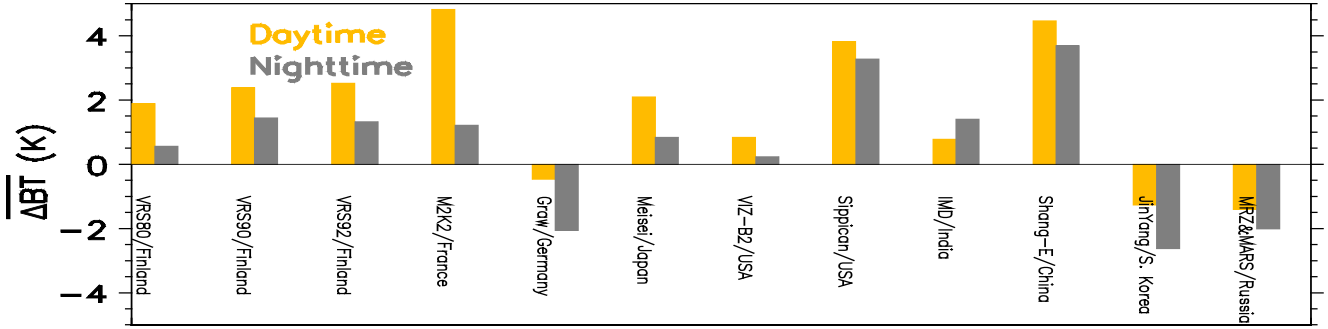
RAOB 300 hPa RH bias



Most sonde types have a dry bias at upper levels particularly during daytime

Daytime: 7.2% dry bias
Nightime: 3.3% dry bias

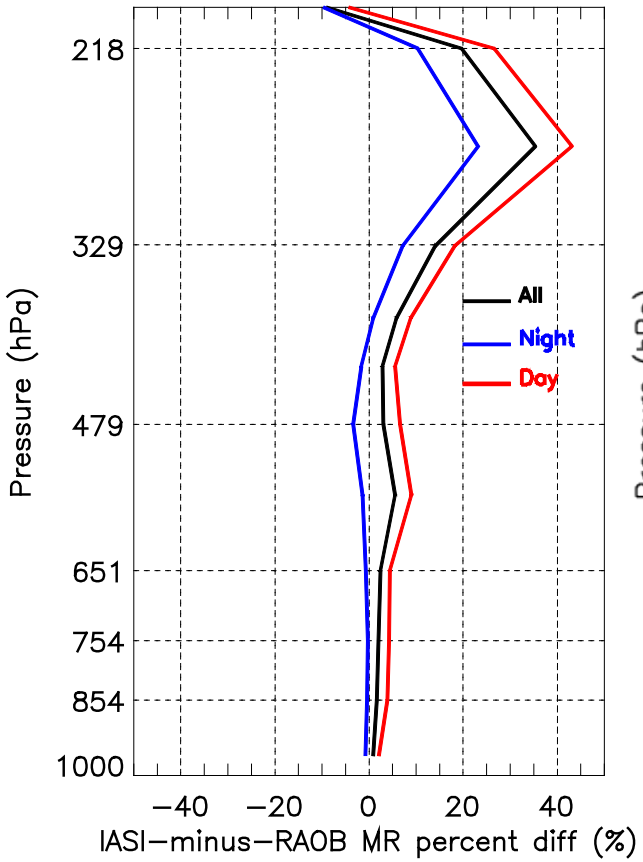
Calculated RAOB BT -minus-satellite observed BT for 183+/- 1 GHz



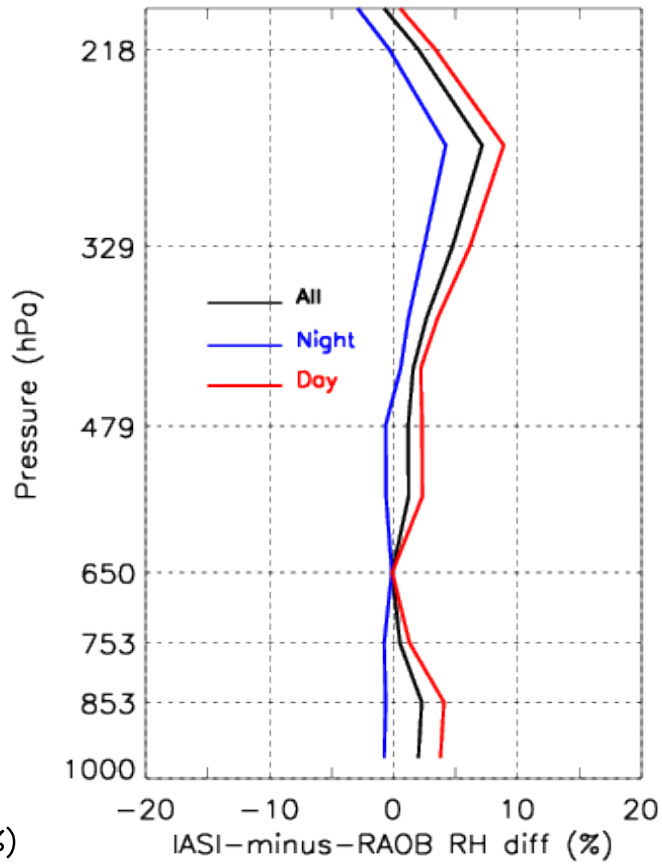
RAOB humidity error impact in validation

IASI-minus-RAOB water vapor diff.

Mixing ratio



Relative humidity



RAOB humidity tends to have a dry bias particularly at the upper level during daytime.

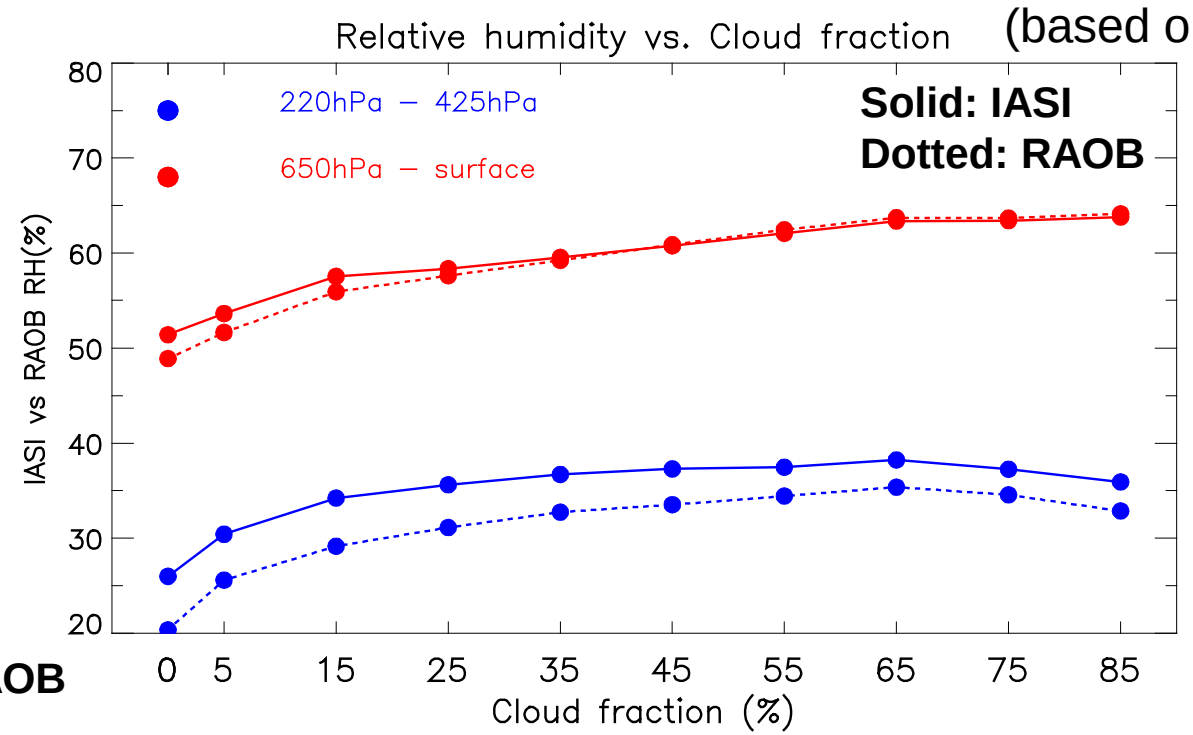
To a certain degree, this bias leads to a “wet bias” in satellite data validated.

Recommend: use nighttime data

Conventional RAOBs are useful but errors need to be taken care of for accurate satellite assessment

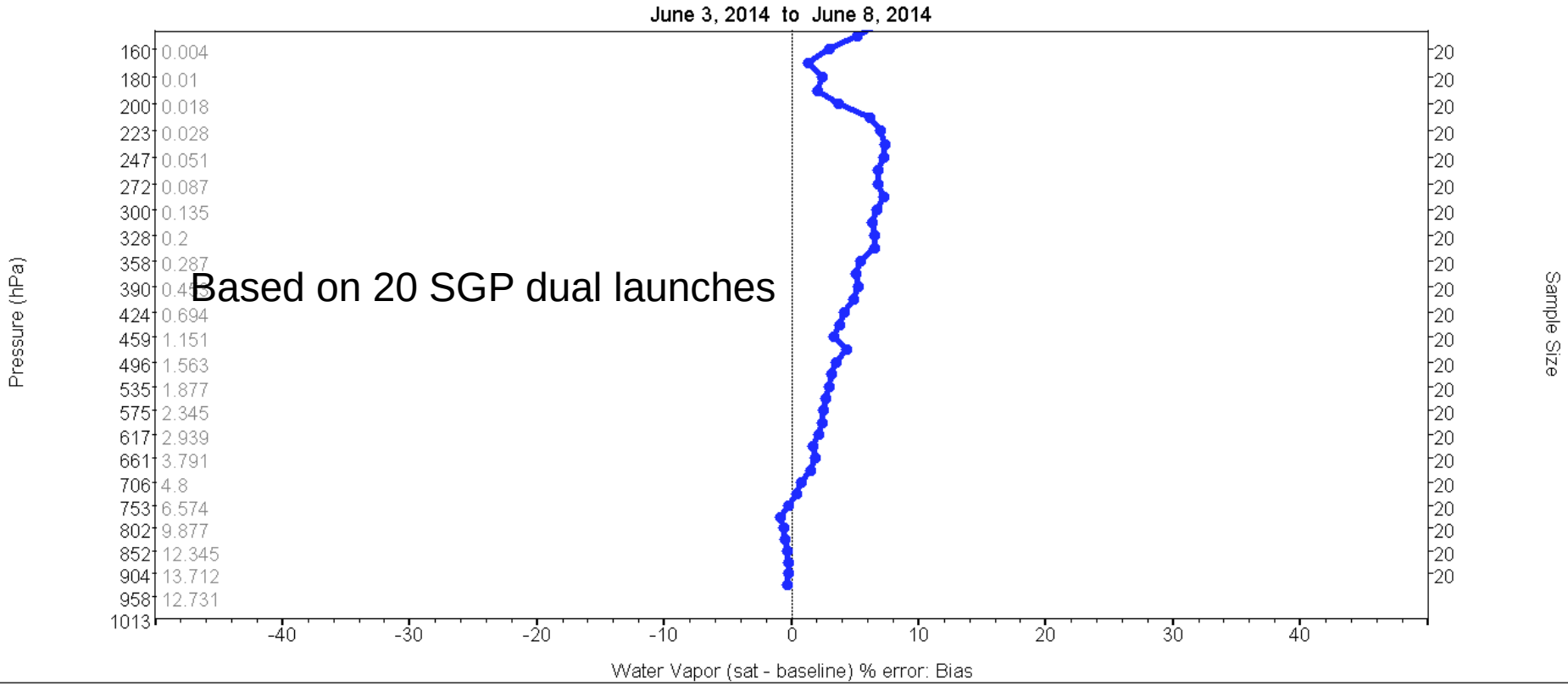
An example: as the independent data source verifying the consistency among cloud, temperature and humidity in the IASI retrieval system

(based on 3-yr data)



4.5% drier in RAOB

Water vapor mixing ratio percent diff RS41-minus-RS92



Baseline: Sonde

Sonde

Thanks Donna Holdridge for providing the data

Summary

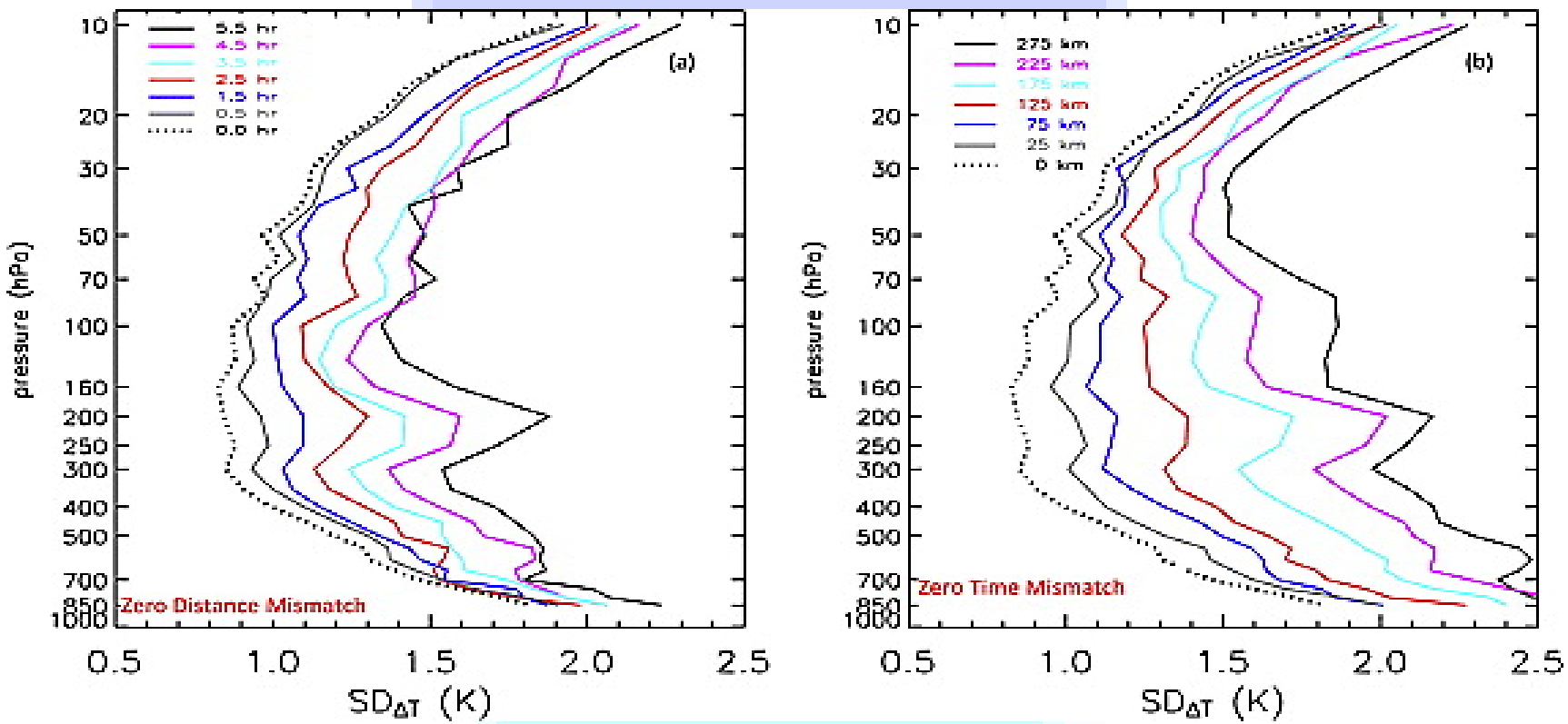
- Conventional RAOBs are useful in retrieval product evaluation on individual variables and the physical consistency of different variables as well.

- RAOB accuracy issues include T warm bias at UTLS and humidity dry bias in cold & dry environment; time mismatch with satellite overpass

- NPROVS (conventional RAOBs as the anchor) complements NPROVS + (GRUAN/dedicated RAOBs as the anchor) in satellite products ca/val.

- Need to bring other “truth” datasets into our cal/val system ,including other GPS RO products and ground ancillary measurements.

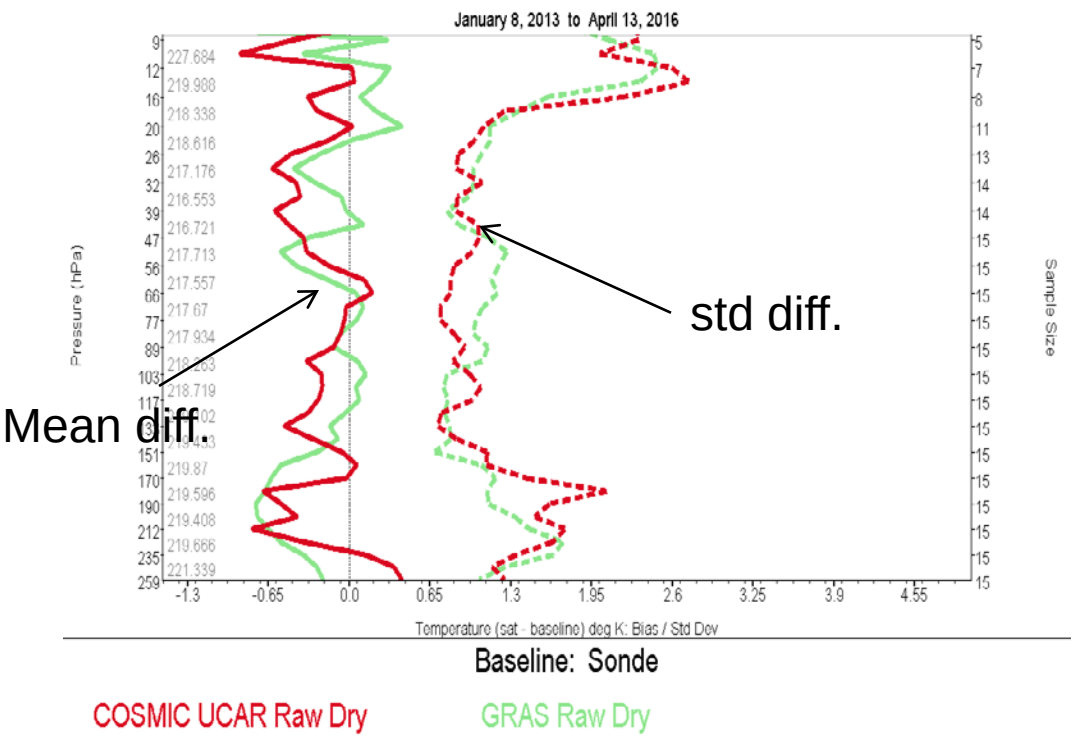
Validation uncertainty associated with collocation mismatch (Sun et al. 2010)



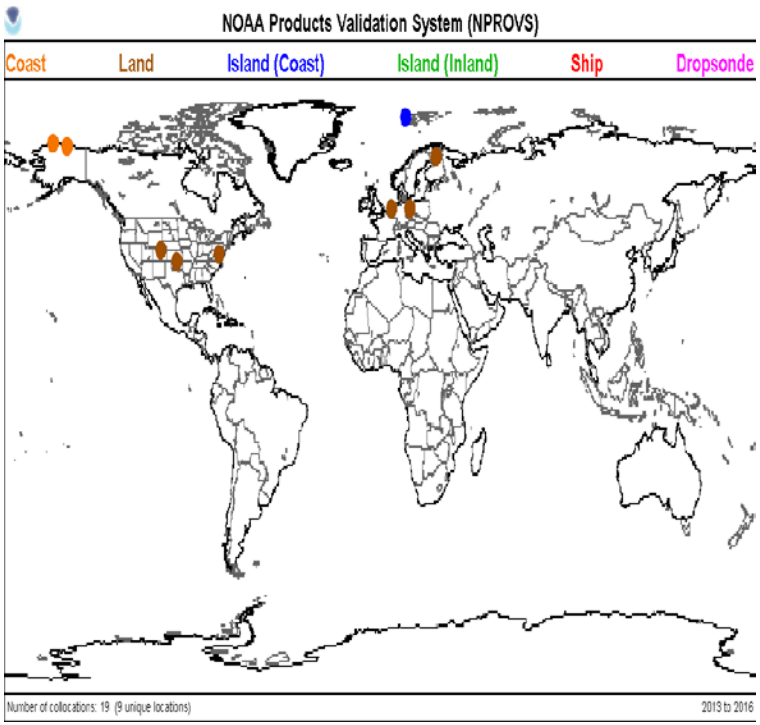
Dependence of $SD_{\Delta T}$ on time and distance collocation mismatch shows that collocation uncertainty increases as mismatch time or distance increases, due to atmospheric variability. Greatest mismatch uncertainty is in the lower troposphere where atmospheric variability is high and stratosphere where sonde measurement uncertainty is large.

UCAR COSMIC – EU GRAS – GRUAN comparison

Tdry difference relative to GRUAN T



Collocations (3 hr/150 km)

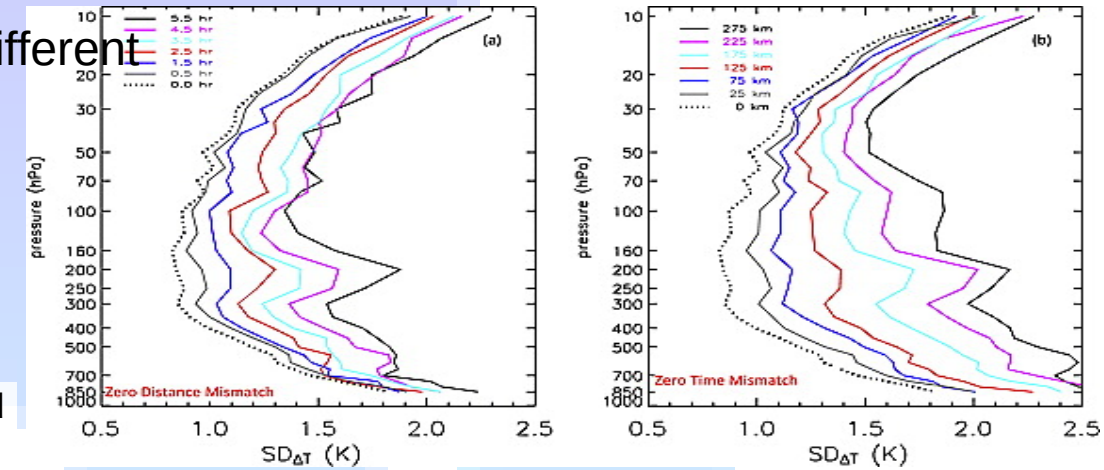


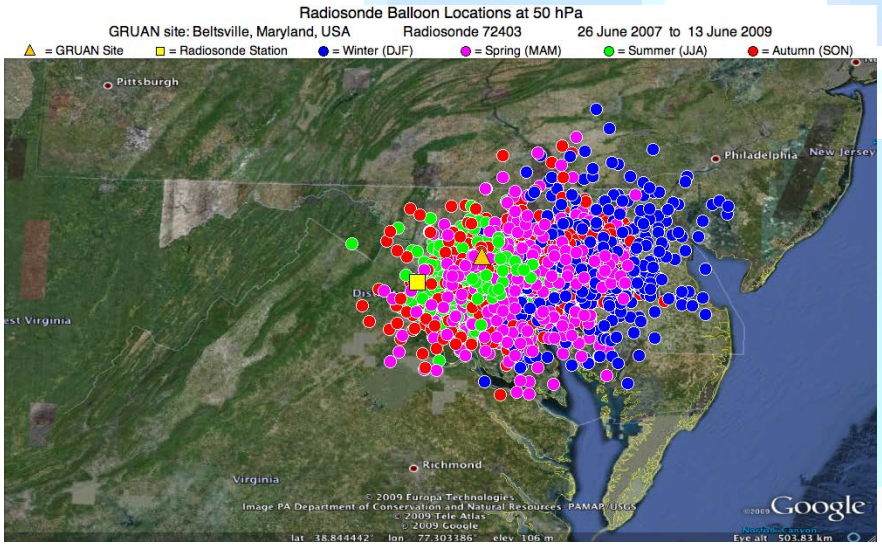
"Robust" evaluation of Satellite retrieval product

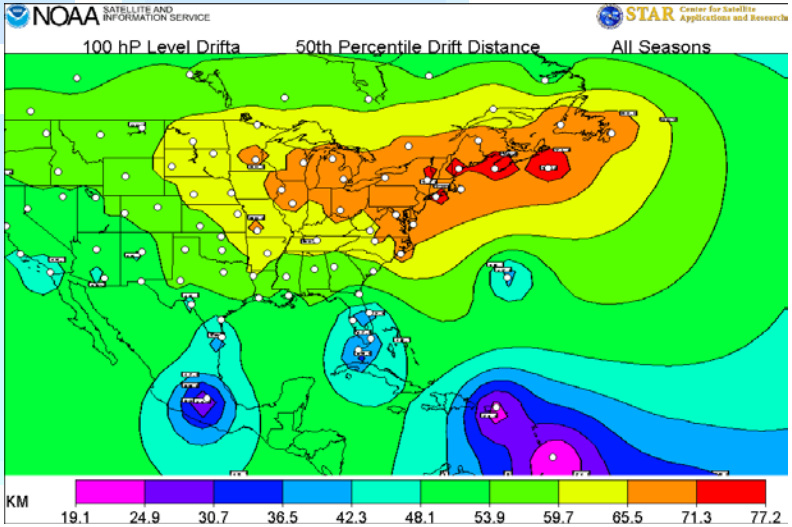
GRUAN reference Measurement principles: Two observations on different platforms are consistent if

$$\left|m_1 - m_2\right| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

Where (σ) is the atmospheric variability From time/space, and u is the uncertainty of variable m.







Example of drift analysis based on 2 years raob observations stored within NPROVS … 50th percentile drift distance at 100mb for all seasons