Characteristics of Radiosonde Observations and their Impact in Satellite Sounding Product Validation

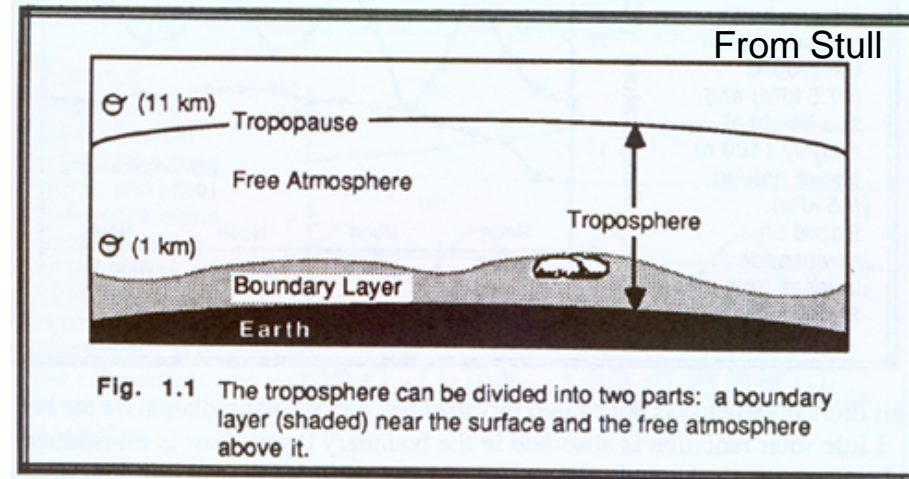Bomin Sun[1,2], Tony Reale[2], Frank Tilley[1,2], and Mike Pettey[1,2]

1   I. M. Systems Group, Inc., Rockville, Maryland
2   NOAA/NESDIS/STAR, College Park, Maryland

Goals

1. What are the RAOB error characteristics & how they are reflected in satellite retrieval validation
   - Temperature
   - Humidity

   Coarse-layer averaging statistics: ~1 km for AVTP and ~2 km for AVMP

2. To what extent that satellite retrieval can detect atmospheric structures shown in RAOBs
   - Atmospheric boundary layer
     – Surface-based inversion
     – Unstable boundary layer
   - Tropopause

   100-lvl retrieval profiles are utilized.

From Stull

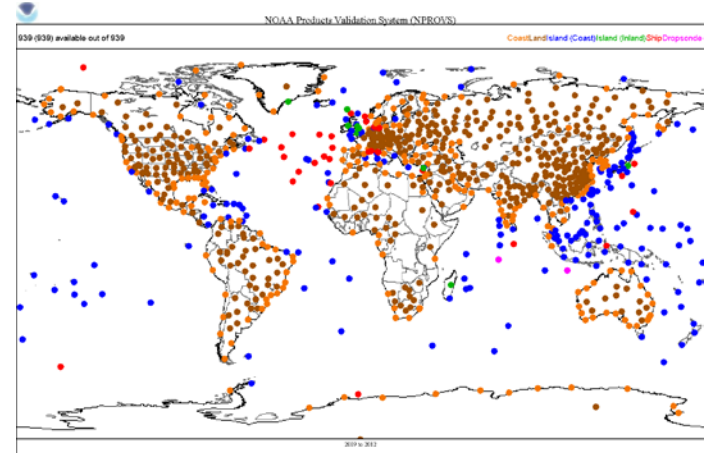Fig. 1.1 The troposphere can be divided into two parts: a boundary layer (shaded) near the surface and the free atmosphere above it.
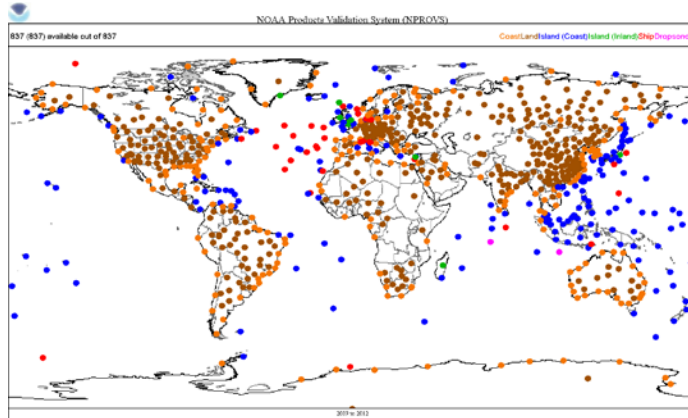
Data

- **MetOp-A 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.**

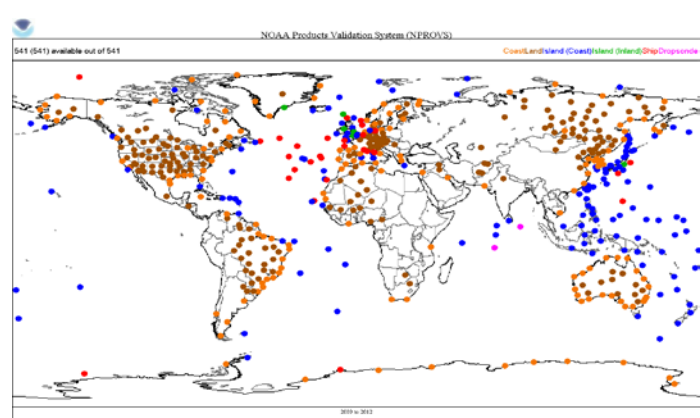Collocations within **6-hr** & 50-km

Sample: 550,500 (939 sites)

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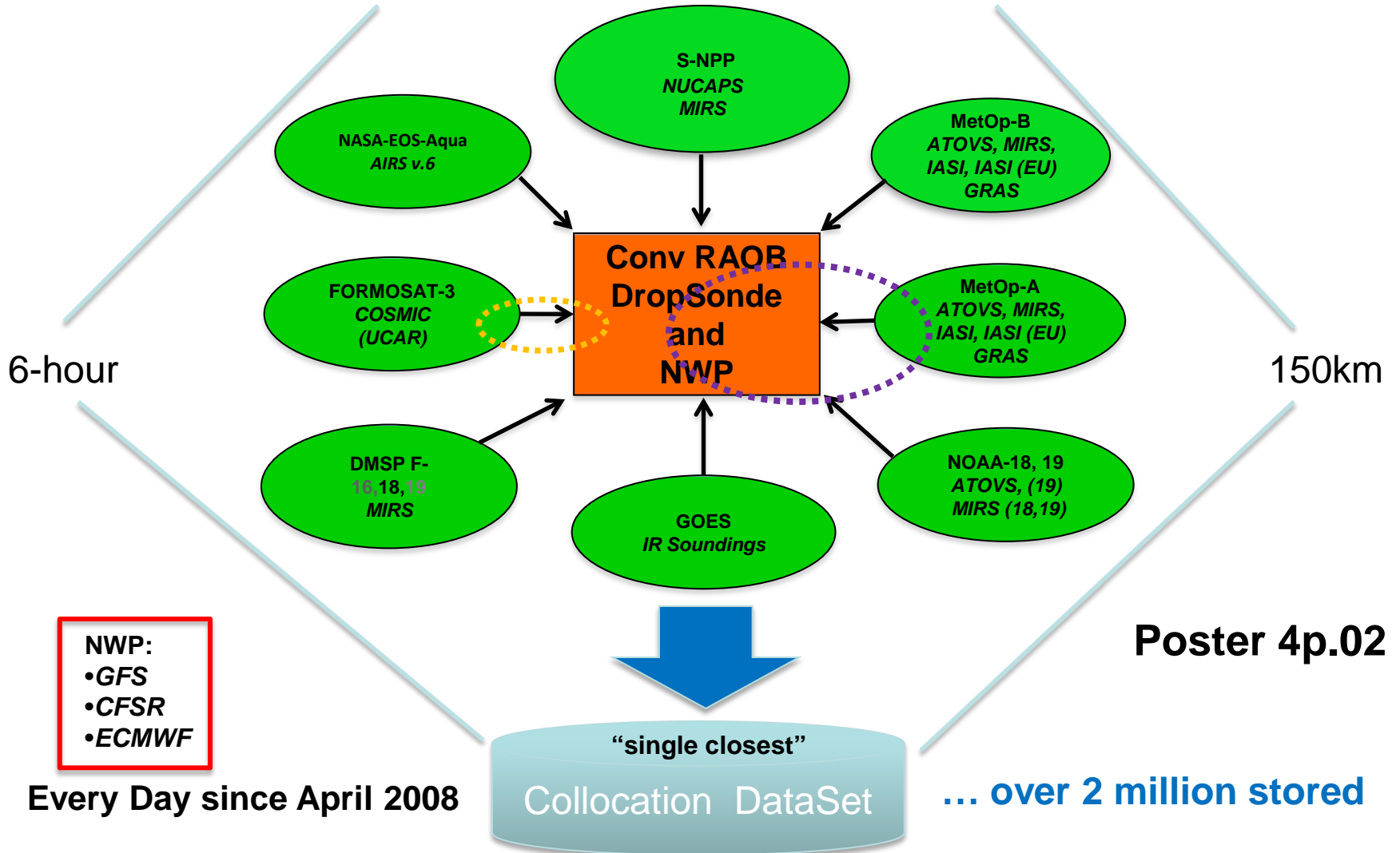

Sample: 313,500 (837 sites)

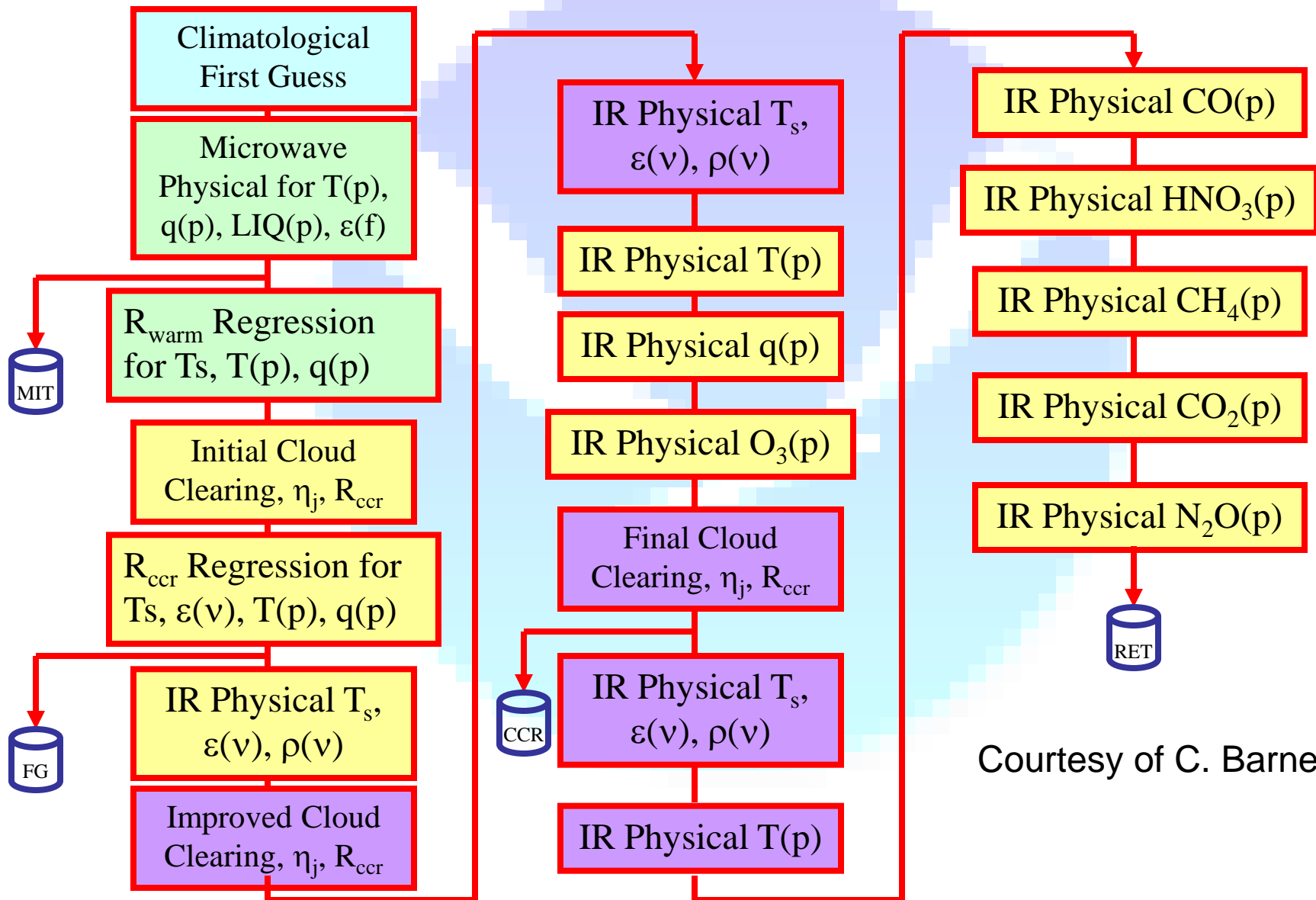Collocations within **1-hr** & 50-km

Sample: 99,000 (541 sites)

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NOAA Products Validation System (NPROVS)

Centralized RAOB and Satellite Product Collocation

S-NPP
NUCAPS
MIRS

NASA-EOS-Aqua
AIRS v.6

MetOp-B
ATOVS, MIRS,
IASI, IASI (EU)
GRAS

Conv RAOB
DropSonde
and
NWP

FORMOSAT-3
COSMIC
(UCAR)

MetOp-A
ATOVS, MIRS,
IASI, IASI (EU)
GRAS

DMSP F-
16,**18**,19
MIRS

GOES
IR Soundings

NOAA-18, 19
ATOVS, (19)
MIRS (18,19)

6-hour

150km

Poster 4p.02

NWP:
- *GFS*
- *CFSR*
- *ECMWF*

"single closest"

Collocation DataSet

Every Day since April 2008

… over 2 million stored

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

Simplified flow diagram of the NOAA IASI retrieval algorithm

Climatological First Guess

Microwave Physical for $T(p)$, $q(p)$, $LIQ(p)$, $\varepsilon(f)$

R_{warm} Regression for Ts, $T(p)$, $q(p)$

MIT

Initial Cloud Clearing, η_j, R_{ccr}

R_{ccr} Regression for Ts, $\varepsilon(\nu)$, $T(p)$, $q(p)$

FG

IR Physical T_s, $\varepsilon(\nu)$, $\rho(\nu)$

Improved Cloud Clearing, η_j, R_{ccr}

IR Physical T_s, $\varepsilon(\nu)$, $\rho(\nu)$

IR Physical $T(p)$

IR Physical $q(p)$

IR Physical $O_3(p)$

Final Cloud Clearing, η_j, R_{ccr}

CCR

IR Physical T_s, $\varepsilon(\nu)$, $\rho(\nu)$

IR Physical $T(p)$

IR Physical $CO(p)$

IR Physical $HNO_3(p)$

IR Physical $CH_4(p)$

IR Physical $CO_2(p)$

IR Physical $N_2O(p)$

RET

Courtesy of C. Barnet

RAOB Accuracy Impact in Validation

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

Errors in RAOB T and Impact in Validation

Radiosonde T error

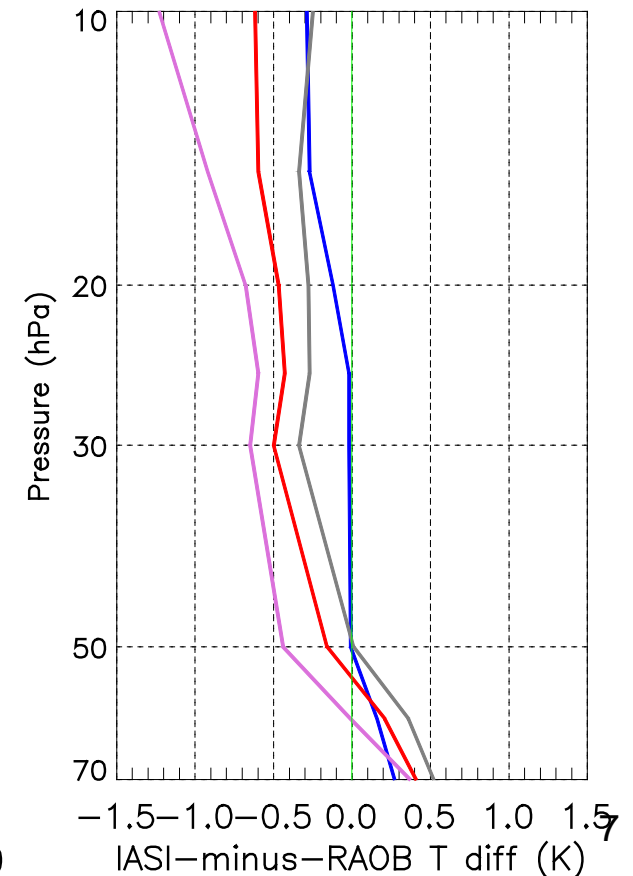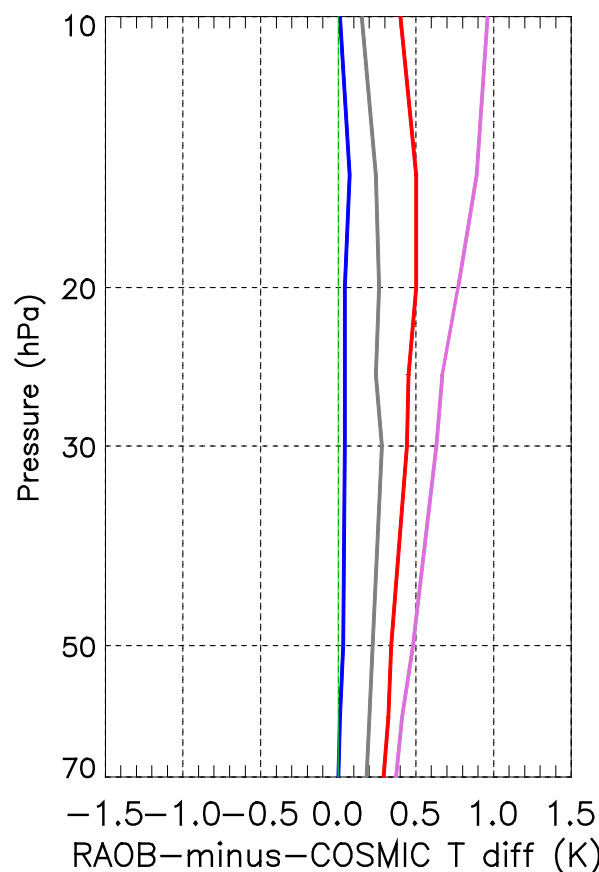**IASI-minus-RAOB T diff.**

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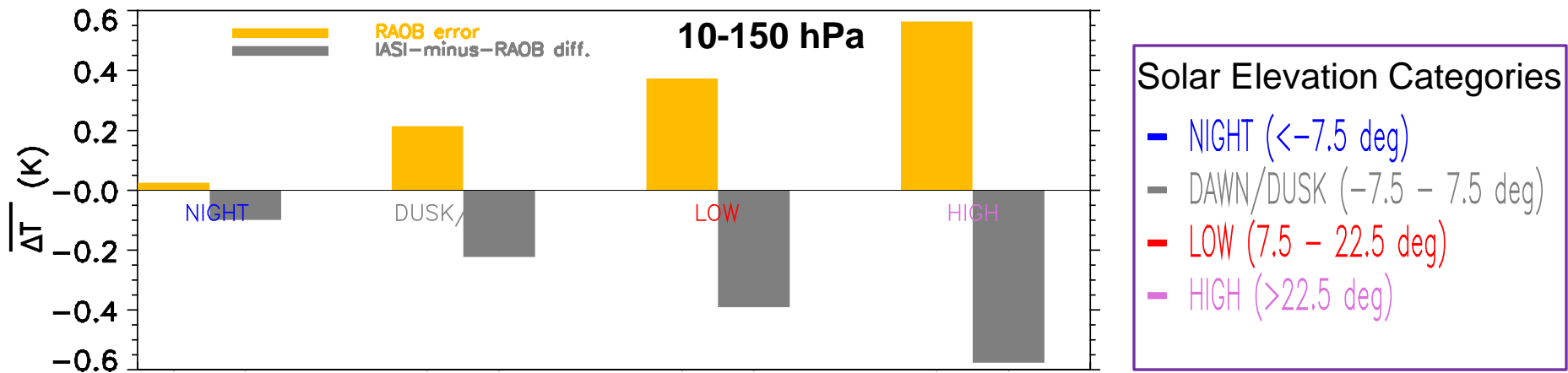- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 − 7.5 deg)
- LOW (7.5 − 22.5 deg)
- HIGH (>22.5 deg)

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

Collaborating with NCEP to improve their radiosonde "RADCOR" in DA.

RAOB Temperature error impact in validation

For 10-150 hPa

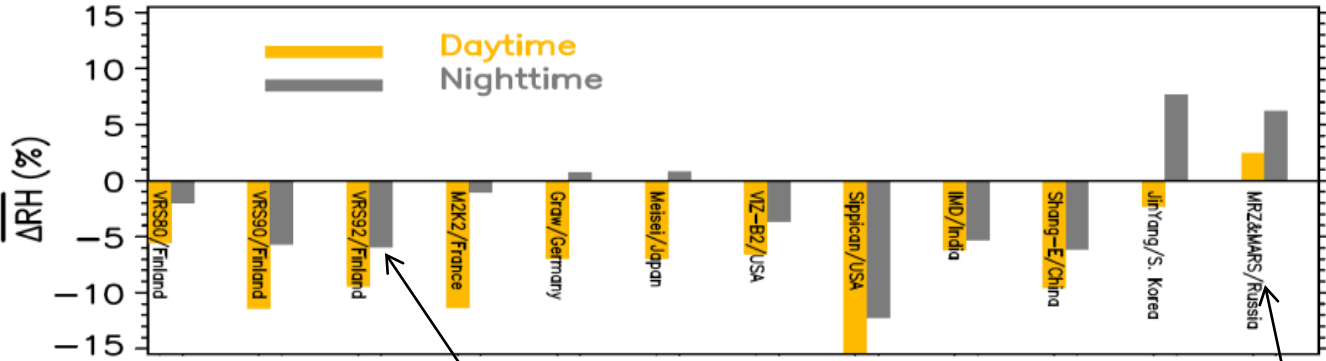|	**All-day**	**Daytime (Low+High)**
RAOB temperature error:	**0.27 K**	**0.49 K**
IASI-minus-RAOB difference:	**-0.32 K**	**-0.50K**

"Cold bias" in IASI-minus-RAOB at UTLS is largely due to warm bias in RAOB

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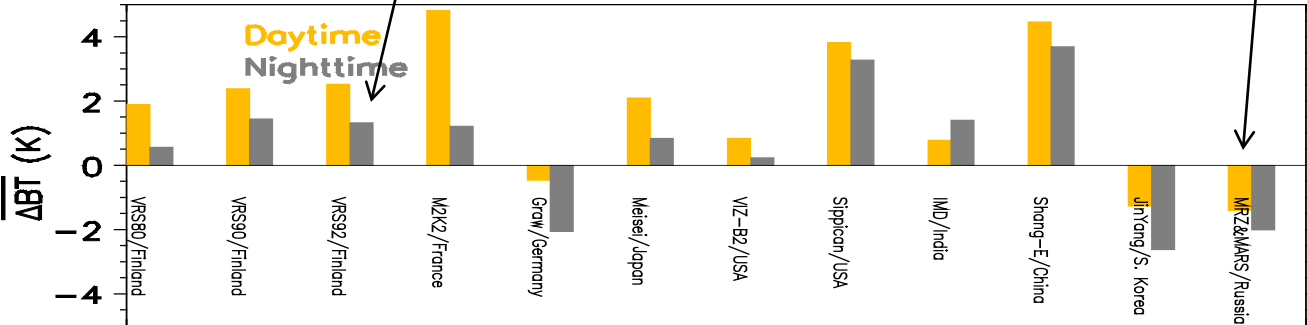# Radiosonde type relative humidity (RH) bias

RAOB 300 hPa RH bias

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

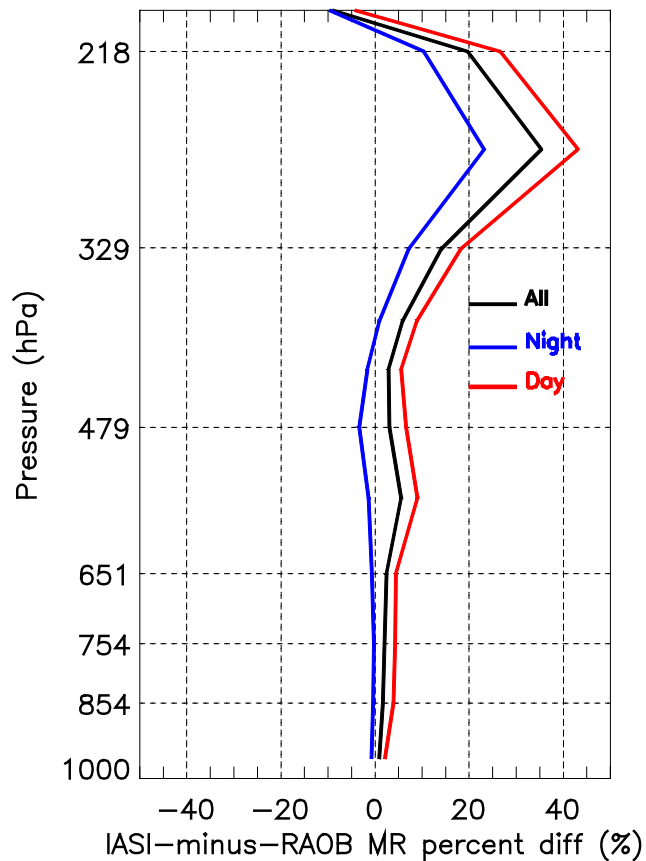Russian sonde is one of the few exceptions, showing a wet bias.

RS92

MRZ

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

Sun et al. (2010, JGR)

RAOB humidity error impact in validation

IASI-minus-RAOB water vapor mixing ratio diff.

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

This bias largely leads to a "wet bias" in satellite data validated.

Recommend: use nighttime data

However, conventional RAOBs are useful in satellite product validation

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

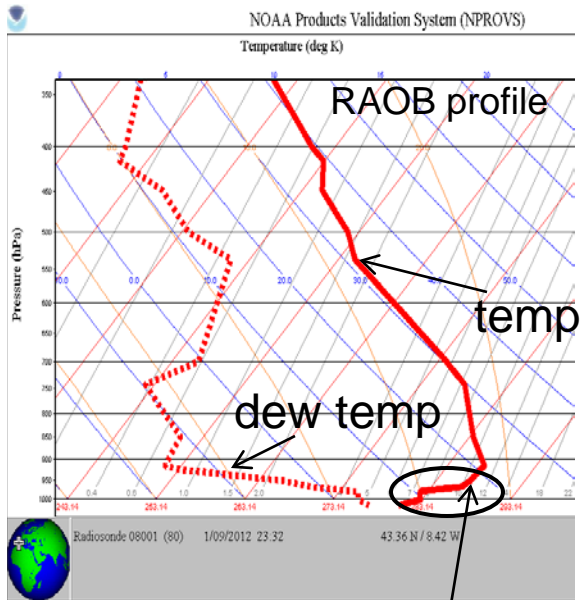Relative humidity vs. Cloud fraction (based on 3-yr data)
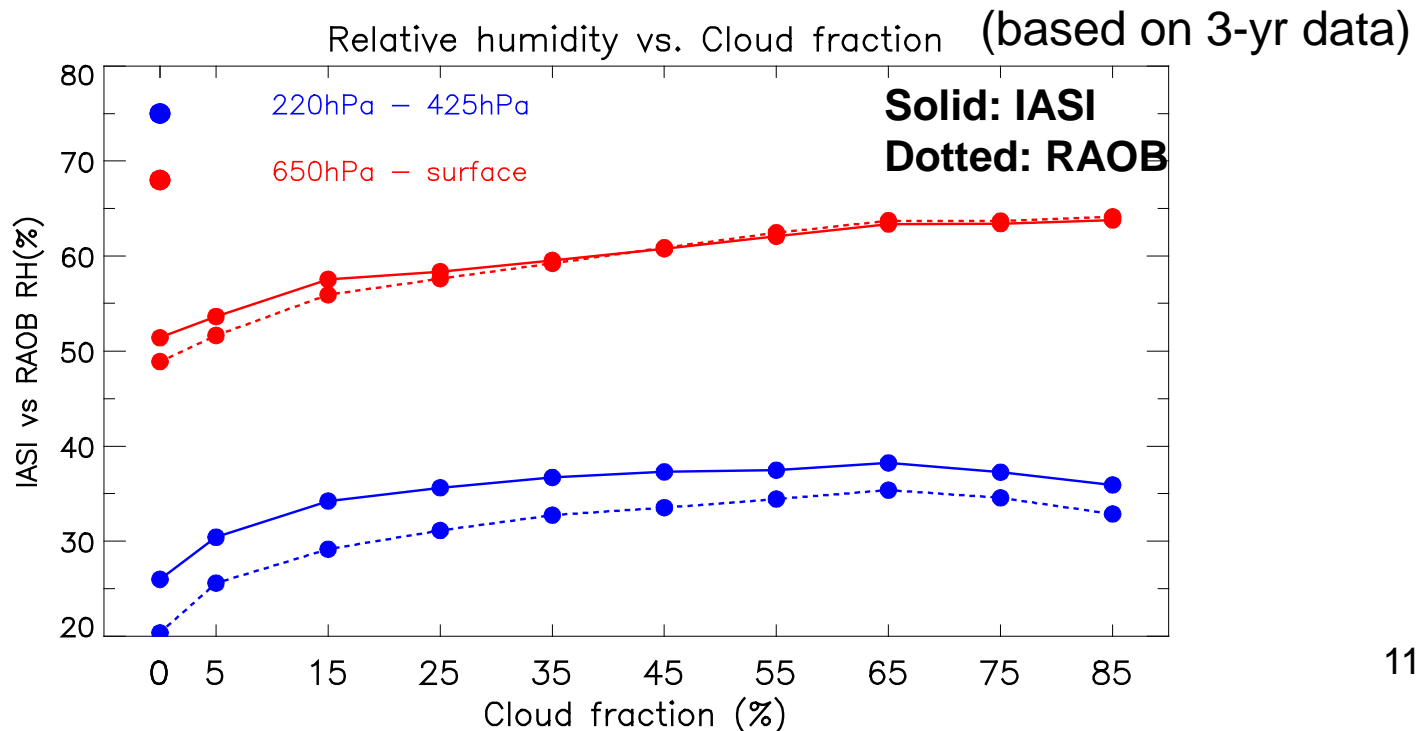
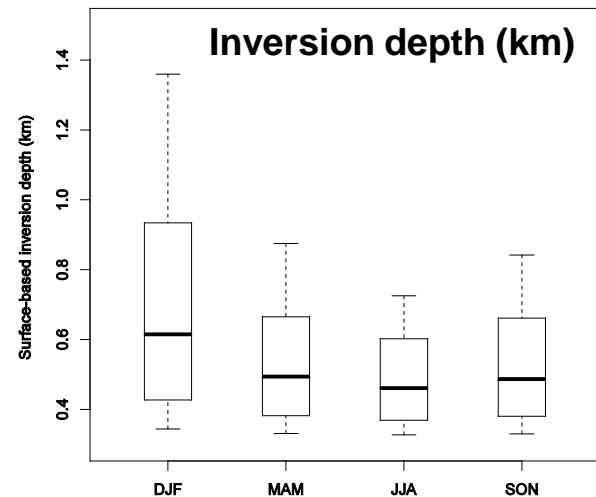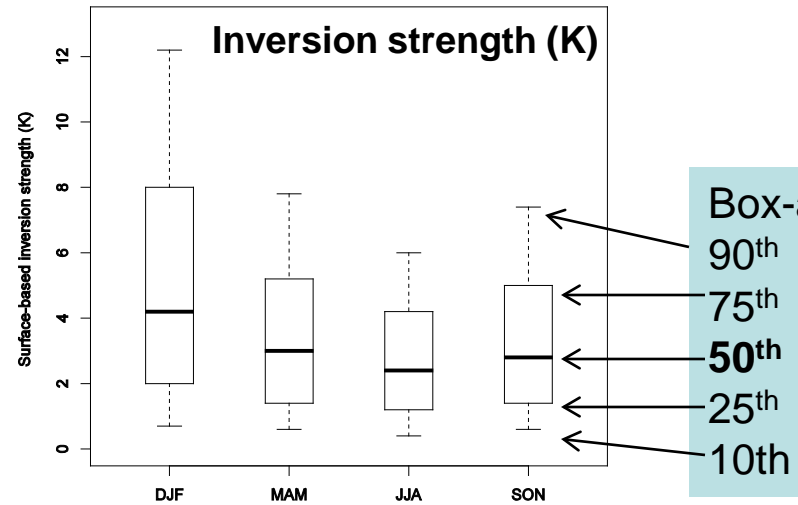# RAOB *vs.* IASI atmospheric structure

- Atmospheric structure features in RAOB *vs.* IASI retrieval profiles
  - Surface inversion
  - Unstable boundary layer (surface-based inversion cases excluded)
  - Tropopause

Surface-based temperature inversion statistics in RAOBs

Based on 3-yr global data (445,000 profiles)

NOAA Products Validation System (NPROVS)

Temperature (deg K)

RAOB profile

temp

dew temp

Radiosonde 08001 (80)   1/09/2012 23:32   43.36 N / 8.42 W

Surface inversion layer
Depth: 876 m
Strength: 6.2 K

Inversion strength (K)

Box-and-Whisky:
90th
75th
50th
25th
10th

DJF   MAM   JJA   SON

Inversion depth (km)

DJF   MAM   JJA   SON

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Surface-based inversion statistics: RAOB *vs*. IASI

Diff. in inversion strength

54% of IASI are within 0.75 K of RAOB

Percent(%) of sample

IASI−minus−RAOB Inversion strength difference (K)

Based on 3-yr RAOB-IASI collocations within 1-hr window
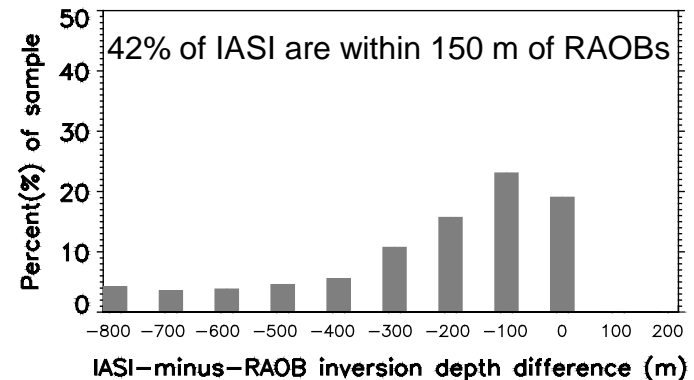
RAOB Inversion   IASI Inversion
YES (100)   ⟶   YES (51)

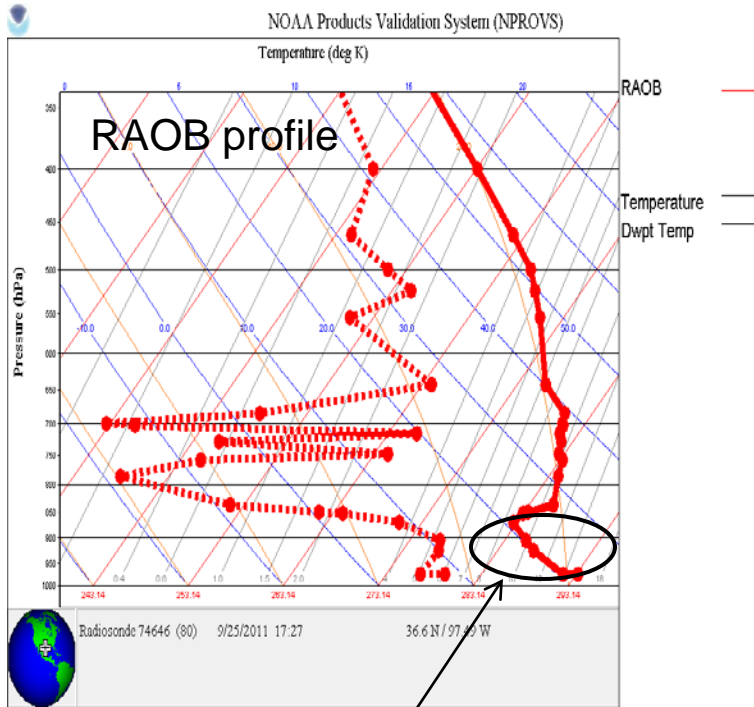RAOB Inversion   IASI Inversion
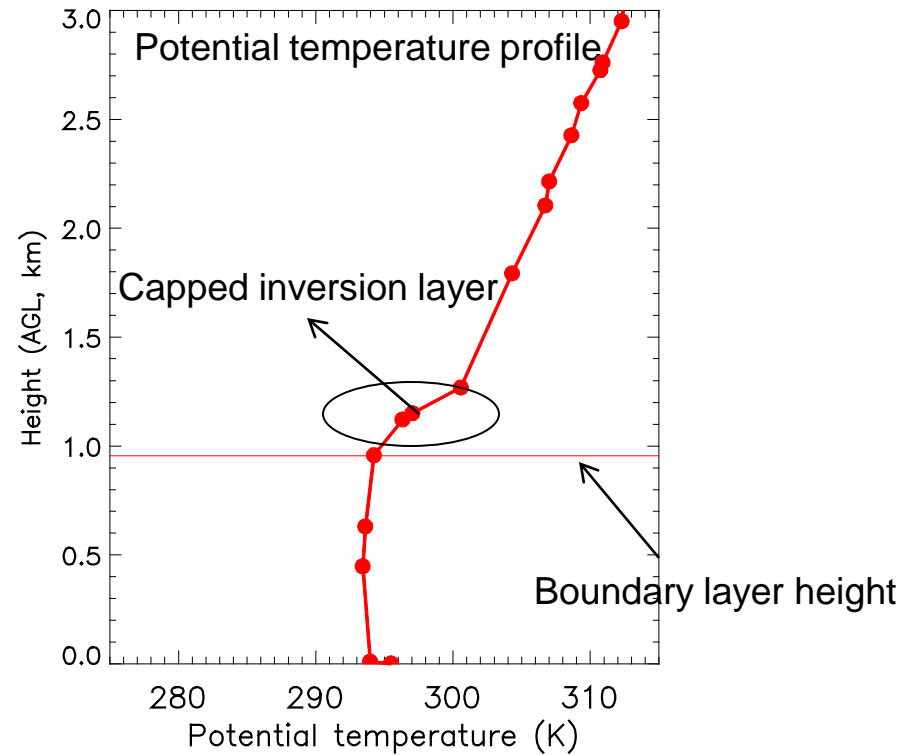NO (100)   ⟶   NO (88)

Diff. in inversion depth

42% of IASI are within 150 m of RAOBs

Percent(%) of sample

IASI−minus−RAOB inversion depth difference (m)

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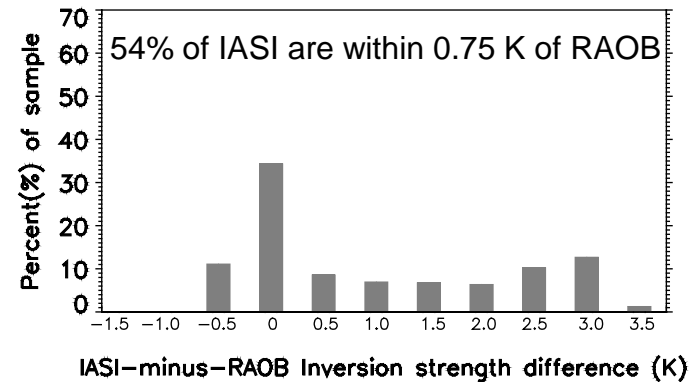
Detection of convective/unstable boundary layer

RAOB profile

Unstable boundary layer

Potential temperature profile
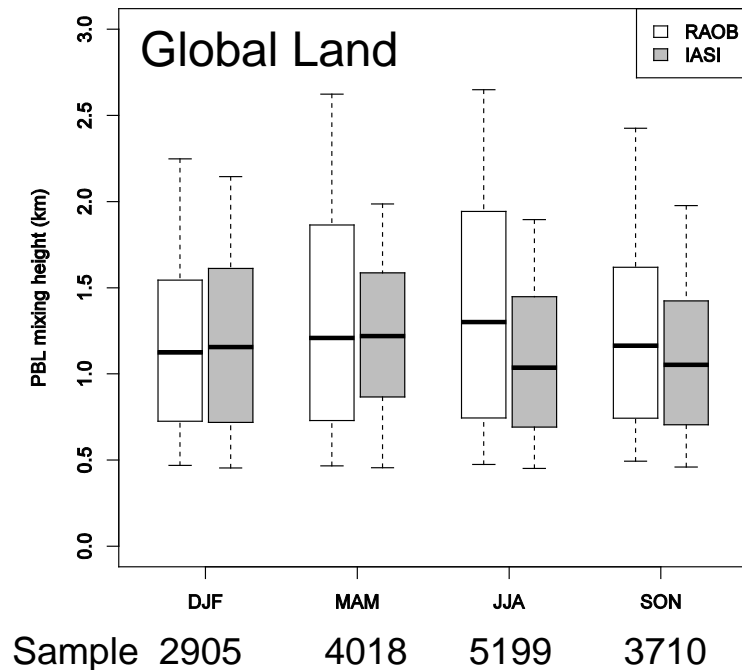
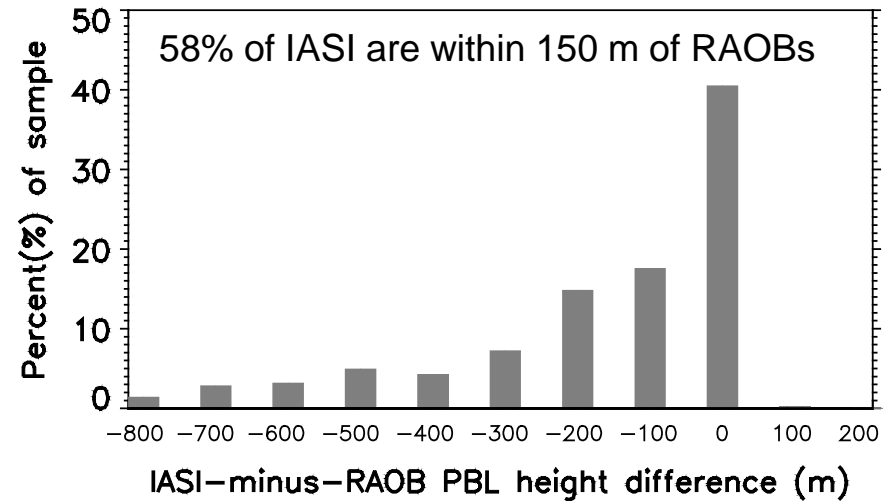Capped inversion layer

Boundary layer height

RAOB *vs.* IASI unstable boundary layer height (with surface inversion cases excluded)

Unstable boundary layer height statistics


Diff. in boundary layer height

RAOB and IASI Time Difference Matters in boundary layer detection comparison

RAOB and IASI within 3-hr diff.

RAOB Inversion   IASI Inversion
YES (33829) ————————→ YES 42%

Unstable boundary layer height
RAOB median height is 1241 m, higher than IASI by 239 m.

RAOB and IASI within 1-hr

RAOB Inversion   IASI Inversion
YES (11455) ————————→ YES 51%

Unstable boundary layer height
RAOB median height: 1203 m, higher than IASI by 80 m.

RAOB and IASI within 0.5-hr or less?

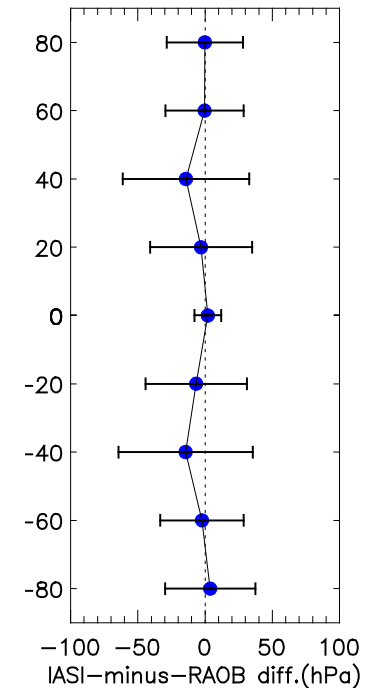# RAOB *vs.* IASI tropopause pressure based on 3-yr collocation data

Occurrence probability distribution

Bimodal pattern
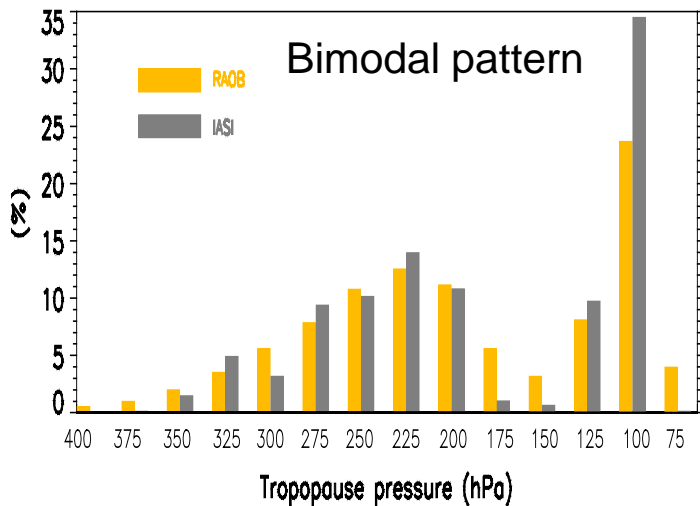
Latitudinal variation
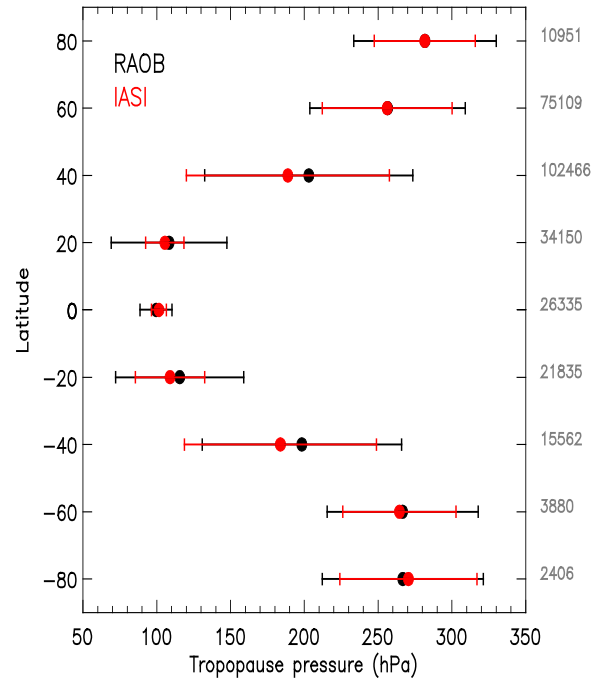
IASI-minus-RAOB dif.

Based on 3-yr data, tropopause in IASI is 6.1 (±42.9) hPa higher than in RAOB.
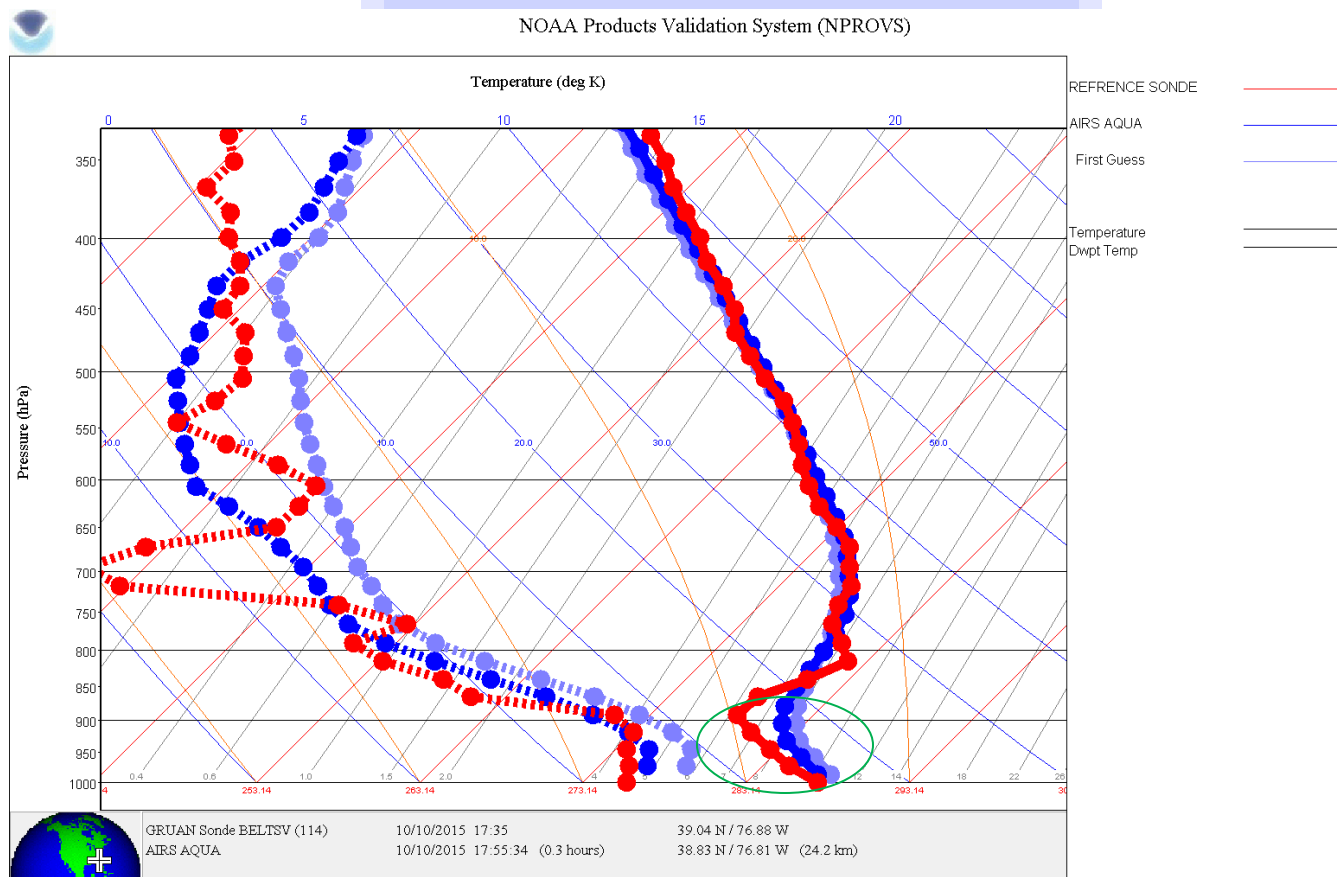
Summary

- 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.

- IASI retrievals can basically capture the climatological characteristics of atmospheric structures (i.e., surface inversion, boundary layer height, and tropopause) shown in radiosonde profiles, but

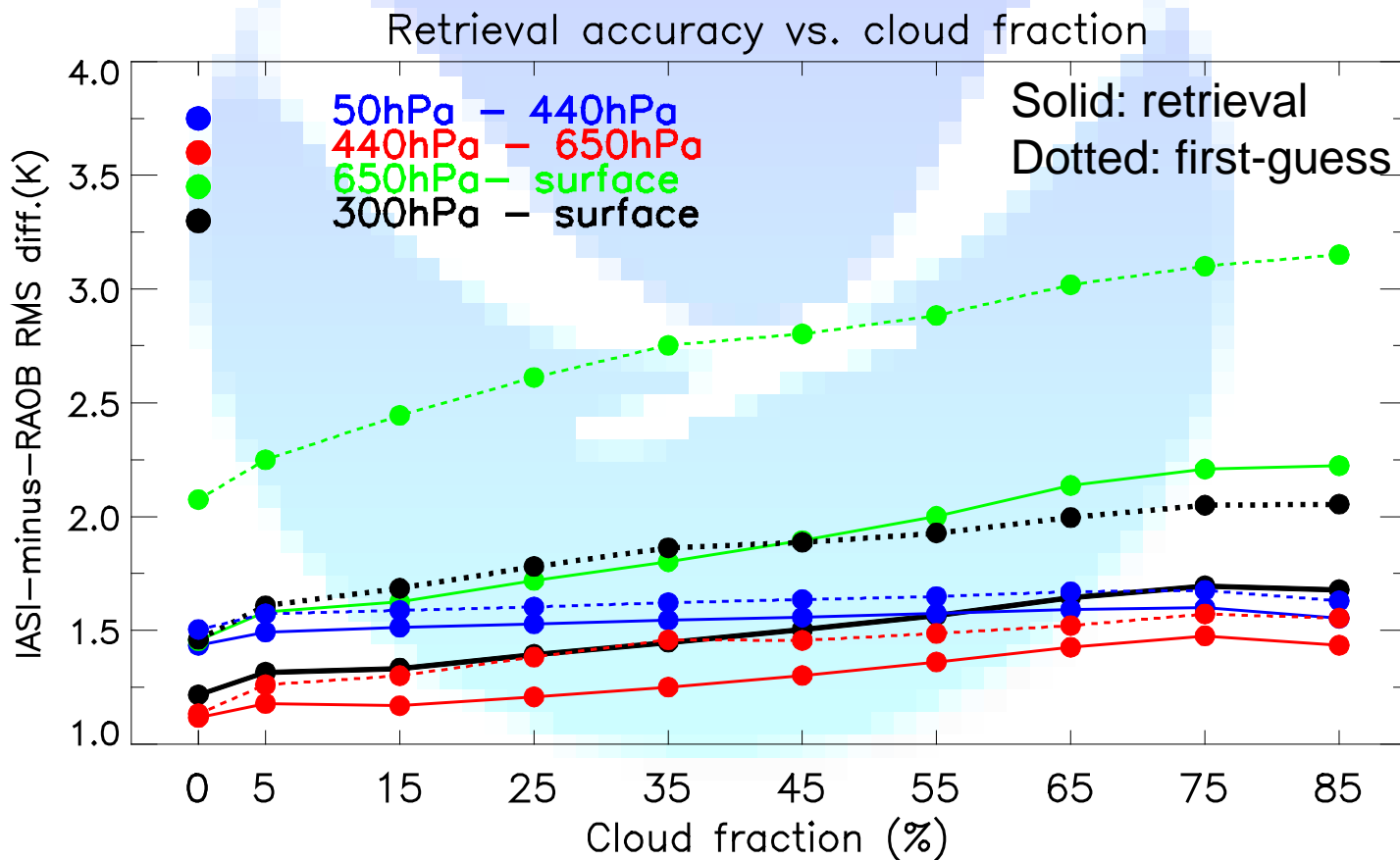- Challenge is there for the structure detection on individual profile basis.

Final retrieval and its first-guess *vs.* radiosonde

AIRS overpass 18 minutes after RS92 launch at Beltsville

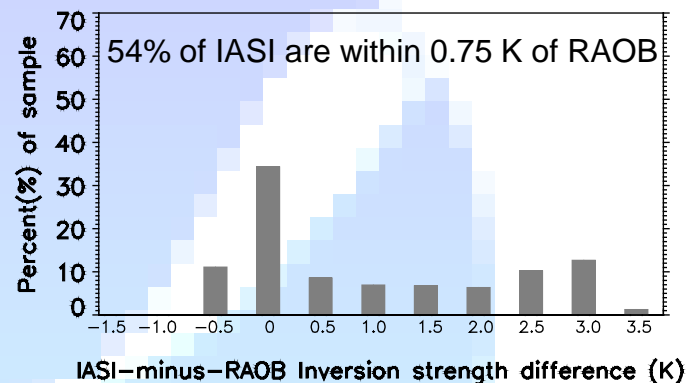# IASI retrieval *vs.* its first-guess

Retrieval accuracy vs. cloud fraction

Legend:
- 50hPa − 440hPa
- 440hPa − 650hPa
- 650hPa− surface
- 300hPa − surface

Solid: retrieval
Dotted: first-guess

IASI−minus−RAOB RMS diff.(K)

Cloud fraction (%)

Surface-based inversion statistics: RAOB *vs.* IASI

Diff. in inversion strength

54% of IASI are within 0.75 K of RAOB

Based on 3-yr RAOB-IASI collocations within 1-hr window

RAOB Inversion	IASI Inversion
YES (11455)	→ YES (51%)
RAOB Inversion	IASI Inversion
NO (77725)	→ NO (88%)

Diff. in inversion depth

42% of IASI are within 150 m of RAOBs