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Sequential Radiosonde Launches and Their Use in Satellite Sounding Data Validation

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Outline

- Overview of satellite sounding data validation
  - Sensor measurements
  - Retrieval profile products
- Sequential sonde launches at the ARM sites targeting
  - SNPP (launch date:10/28/2011; local equator crossing time: 1:30pm/1:30am; sounders: CrIS & ATMS)
  - NOAA20 (launch date: 11/18/2017; local equator crossing time: 1:30pm/1:30am; sounders: CrIS & ATMS)
  - NOAA-21 just launched
- NUCAPS sounding products validation
  - Sequential sondes vs synoptic sondes
  - Profiles interpolated from sequential sondes (to exact satellite overpass times) vs. individual sequential sondes
- Discussion on balloon drift impact on sounding data validation
- Summary and path forward

Hierarchical methodology for sounding data validation

Validation is the process of ascribing uncertainty to radiances and retrieved quantities through comparison with correlative observations.

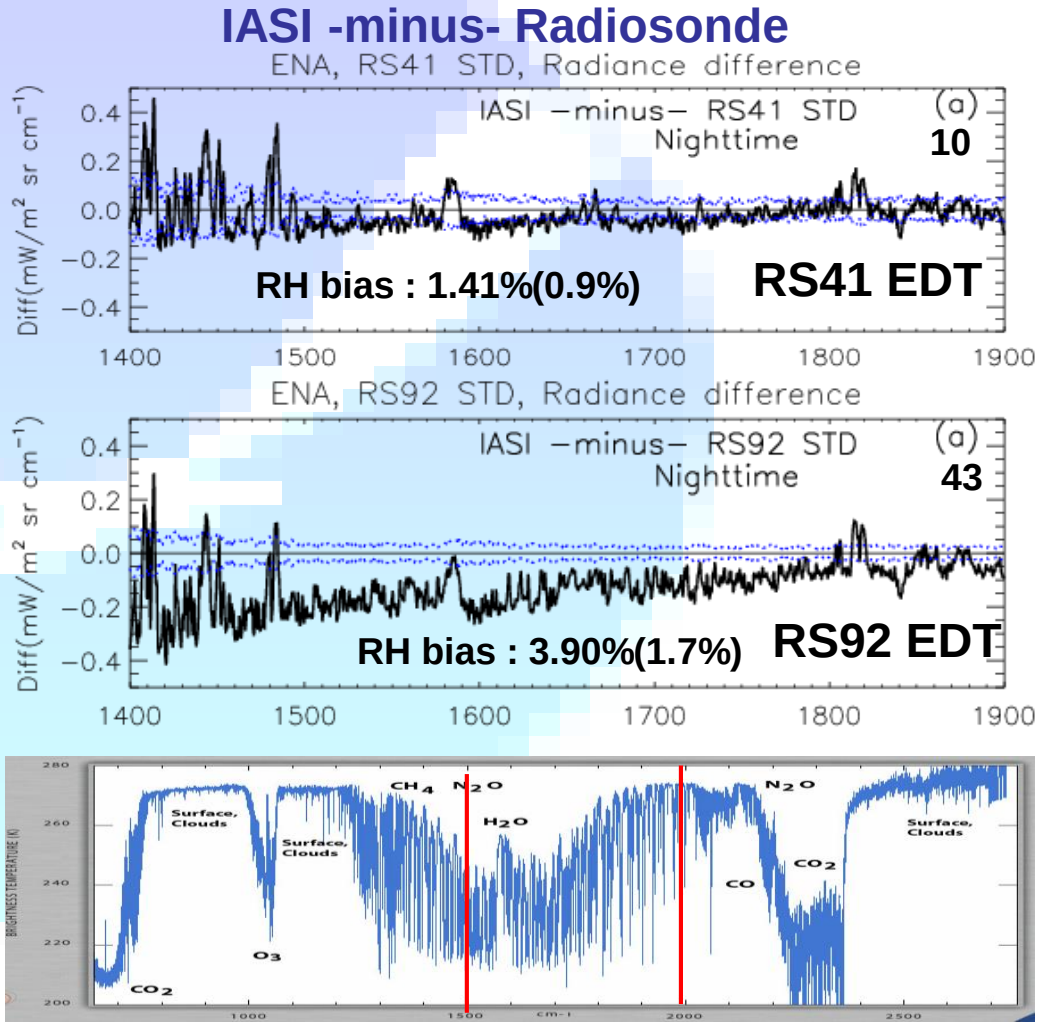
- Instruments: CrIS/ATMS (SNPP and NOAA20), AIRS/AMSU (Aqua), IASI/AMSU/MHS (MetOp-A/B/C)
- Products: NOAA Unique Combined Atmospheric Processing System (NUCAPS), NASA AIRS, EUMETSAT IASI

1. Numerical Weather Prediction (NWP) Global Comparisons
   Globally complete samples; Limitation: not truth observations
2. Conventional radiosonde Matchup Assessments
   Readily available and big samples; Limitation: different sonde models, mismatch errors from satellite overpass, skewed towards NH
3. Dedicated (land- and ship-based) radiosonde campaign assessments
   Minimized mismatch, GRUAN-processed, not assimilated into NWP; Limitation: sparse geographic coverage/ small sample size

(Cross-) validation of radiosonde vs satellite sensor measurements

(IASI MetOp-B overpass ENA is used as an example)

- Radiosonde vs. IASI in the upper tropospheric humidity sensitivity band (1400-1900 cm^{-1}).
- Compute radiances for the radiosonde profiles using LBL **RTM** for **cloud-free** scenes.
- Compare the radiosonde-computed radiances (CAL) with IASI measurements (OBS) in the context of measurement noise and collocation uncertainty.
- ***In support of GRUAN RS92-to-RS41 transition and support of GSICS***

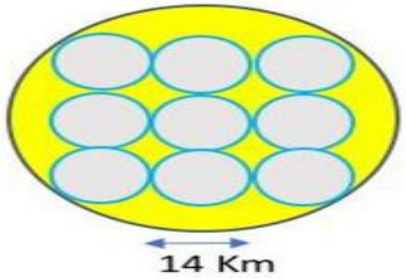


IASI MetOp-B spectrum

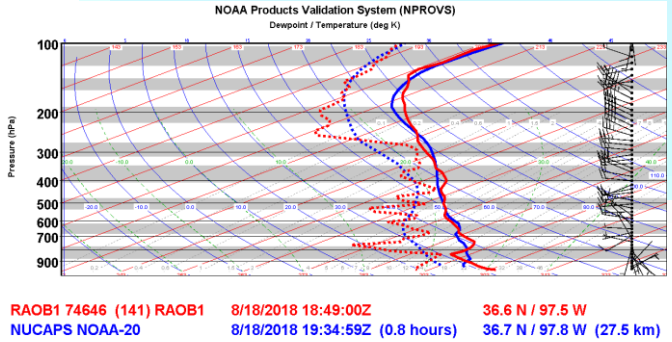
Satellite sounding products validation

(NUCAPS product validation is used as an example)

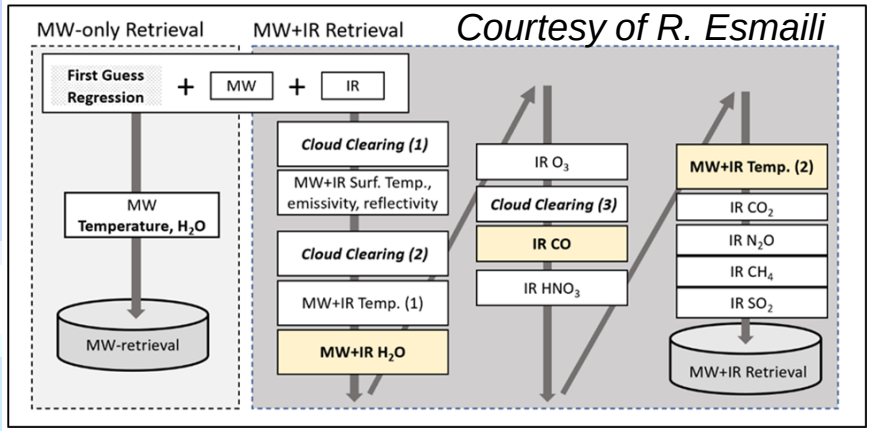
- NUCAPS retrievals are derived from infrared (CrIS) combined microwave (ATMS) sounders; **Retrievals have 100 vertical levels.**
- JPSS Level 1 performance requirements: ~1.5 K RMS in **1 km layers for temperature**, and 20-35% RMS **in 2 km layers for water vapor concentration**.
- *High-density radiosonde profiles need to be converted to "coarse layers" before they are used to validate satellite profiles.*
- *Retrievals are made at FOR (3x3 FOVs with horizontal resolution ~ 50 km at nadir). Note, RAOBs are point measurements drifting while ascending.*

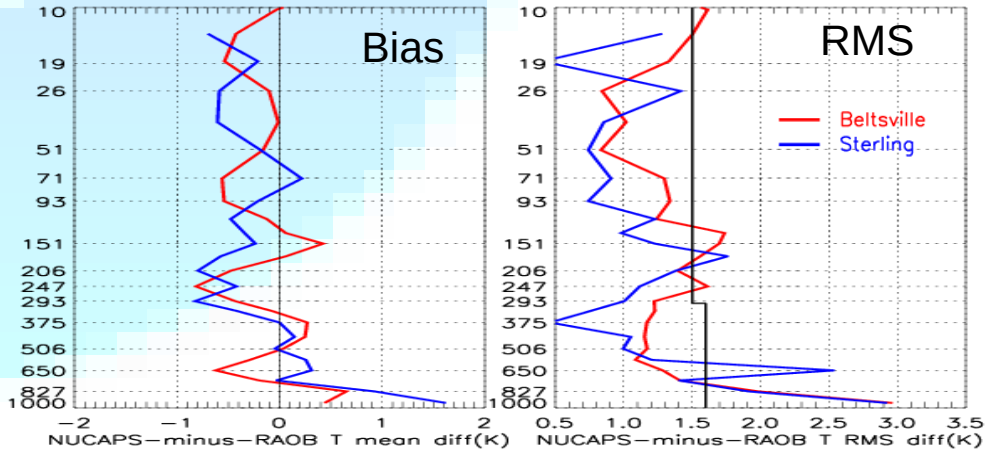


1FOR = 3x3 FOVs, CrIS



NOAA Unique Combined Atmospheric Processing System (NUCAPS) retrieval algorithm schematic





8 dedicated sonds at Sterling for SNPP

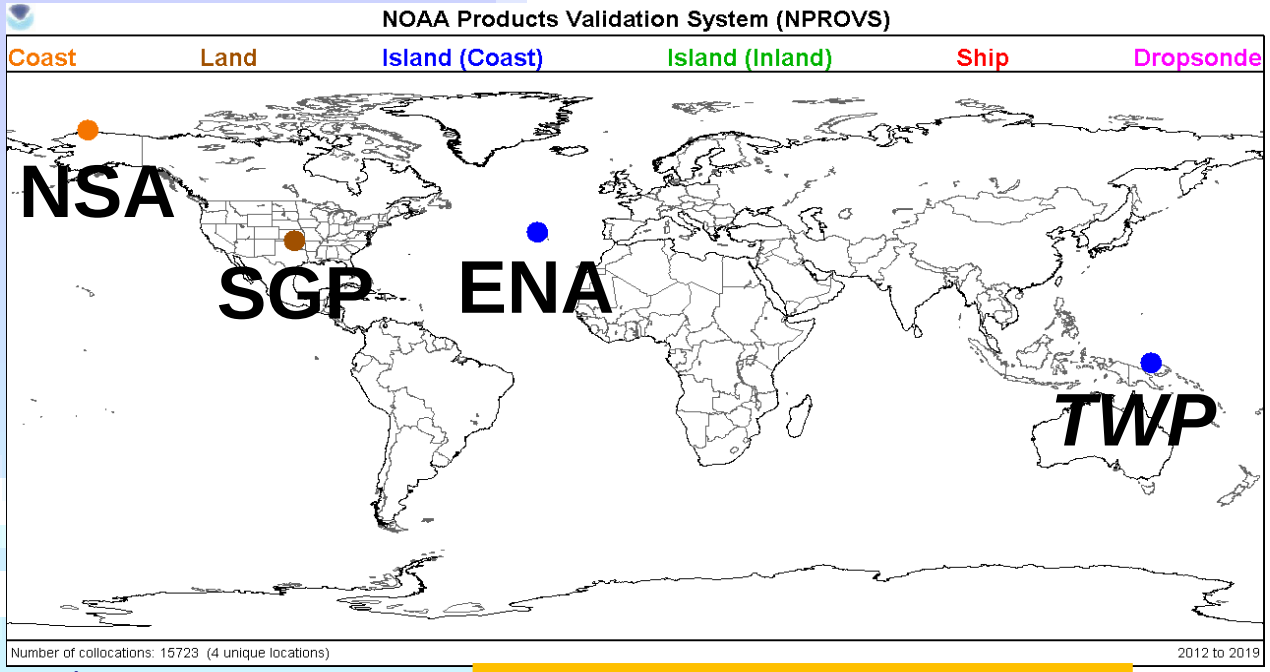
90 dedicated sondes at Beltsville for SNPP

Sun et al. (2017, JSTARS)

Dedicated radiosonde launches at the ARM sites

- Standard ARM/JPSS launches at
  - SGP
  - NSA
  - ENA
  - *TWP*
- RIVAL at ARM sites

(dual Vaisala RS92/RS41 comparison)



- Single launch: 15-min prior to satellite overpass
- Sequential launches: 45-min (1st sonde) and 5-min (2nd sonde) prior to satellite overpass.
- **Interpolate/extrapolate the sequential sondes into the exact overpass times.**

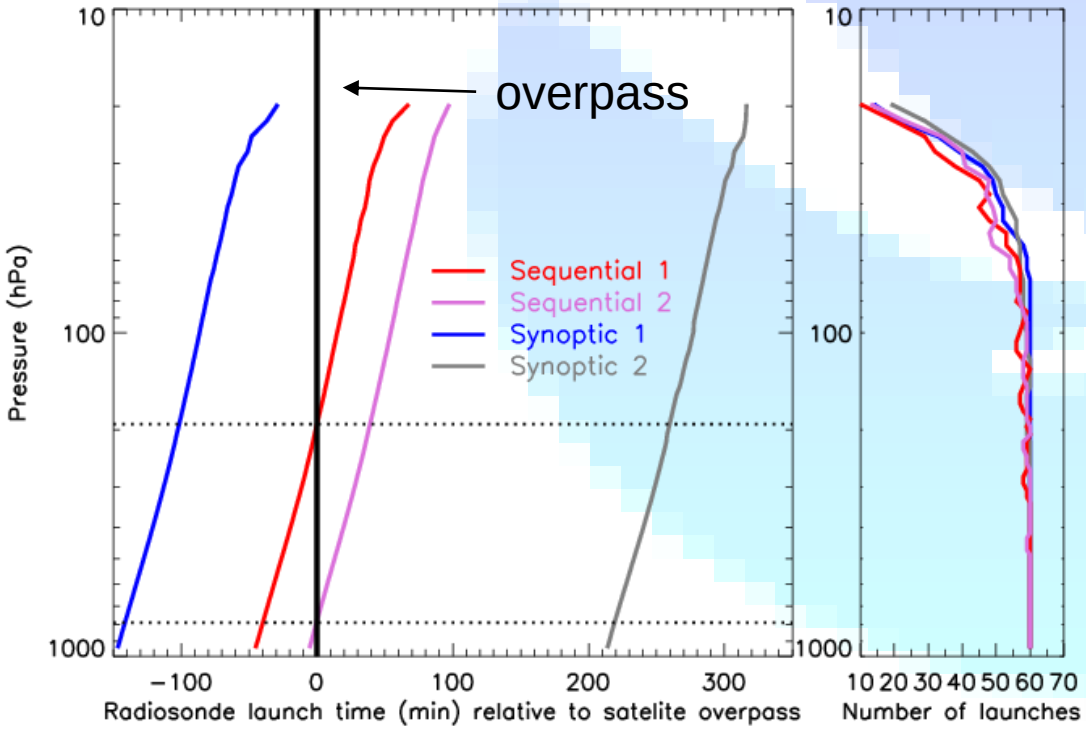
Tobin et al. (2006, JGR) on *Site atmospheric state best estimates*

Standard ARM/JPSS:
- *Single launch*
- *Sequential launch*

RIVAL:
- *Dual launch*
- *Dual + single launch*

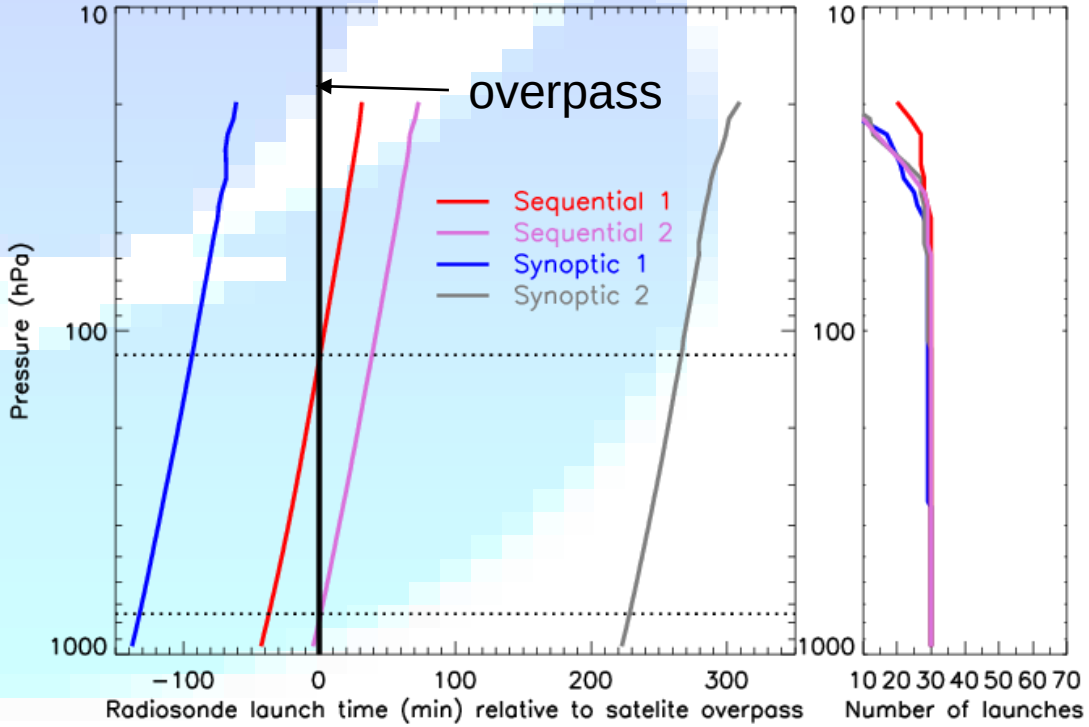
Sequential radiosonde launches at SGP

Sequential RAOB launches (**RS92 GDP) for SNPP**
2/7/2015 to 9/7/2017 (60 pairs)



30 (30) pairs for early afternoon (early morning) launch

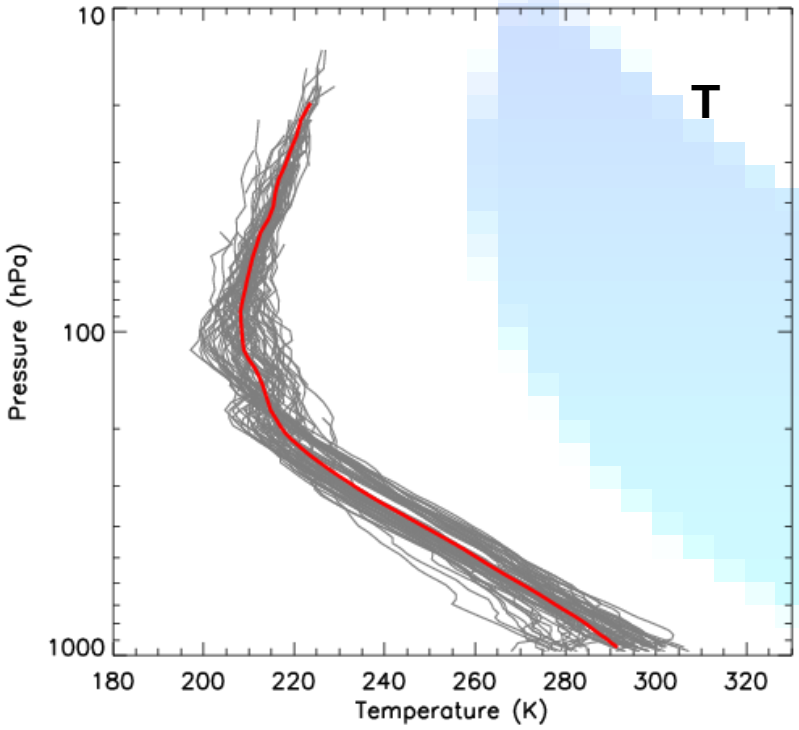
Sequential RAOB launches (**RS41 EDT) for NOAA20**
2/13/2018 to 1/4/2021 (30 pairs)



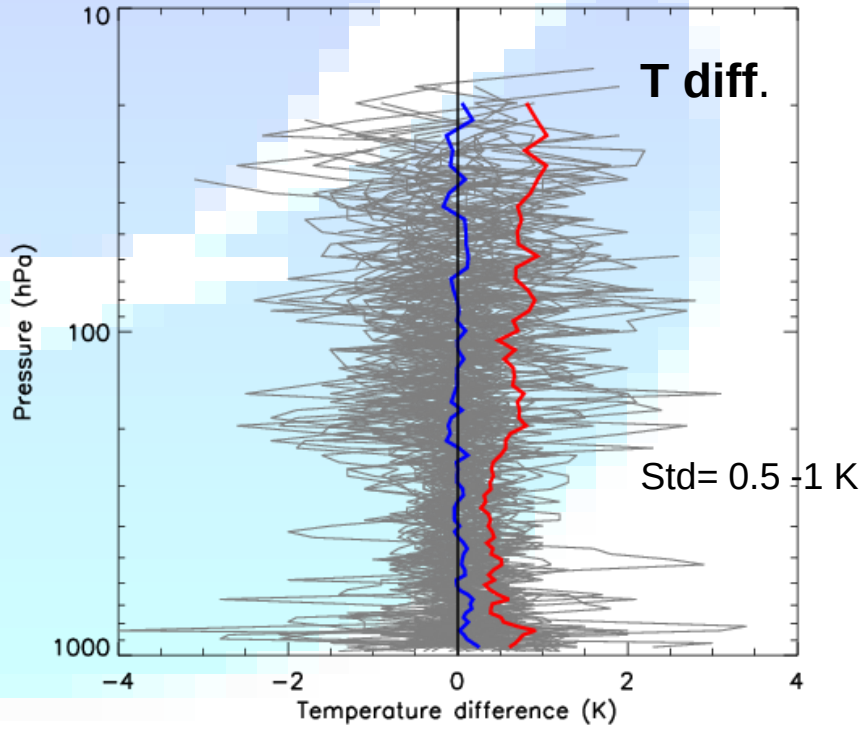
17 (13) pairs for early afternoon (early morning) launch

Air temperature at SGP based on 60 RAOB profiles for SNPP

Air temperature profiles of sequential Sonde 1



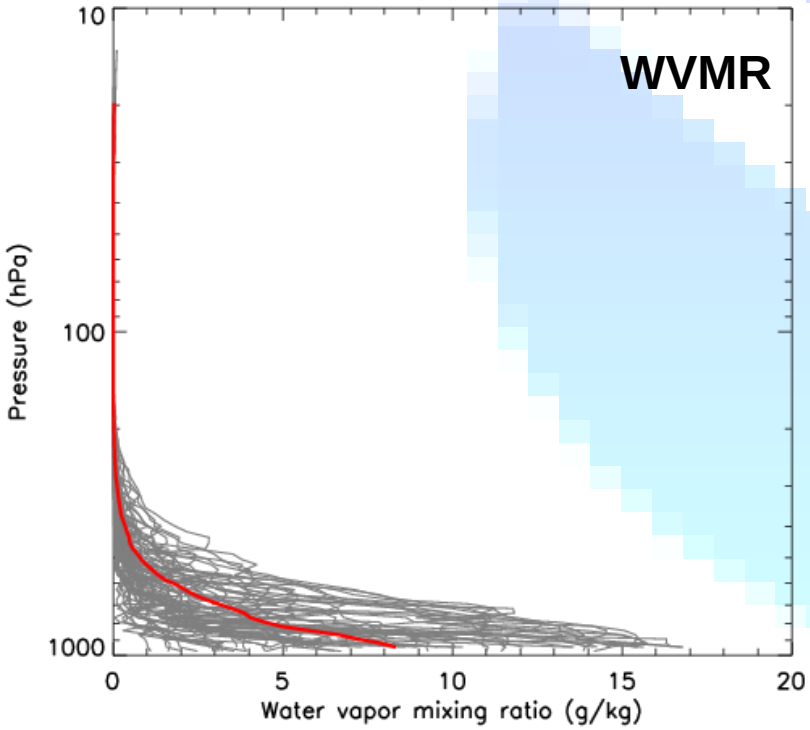
Sequential Sonde 2 minus Sonde 1



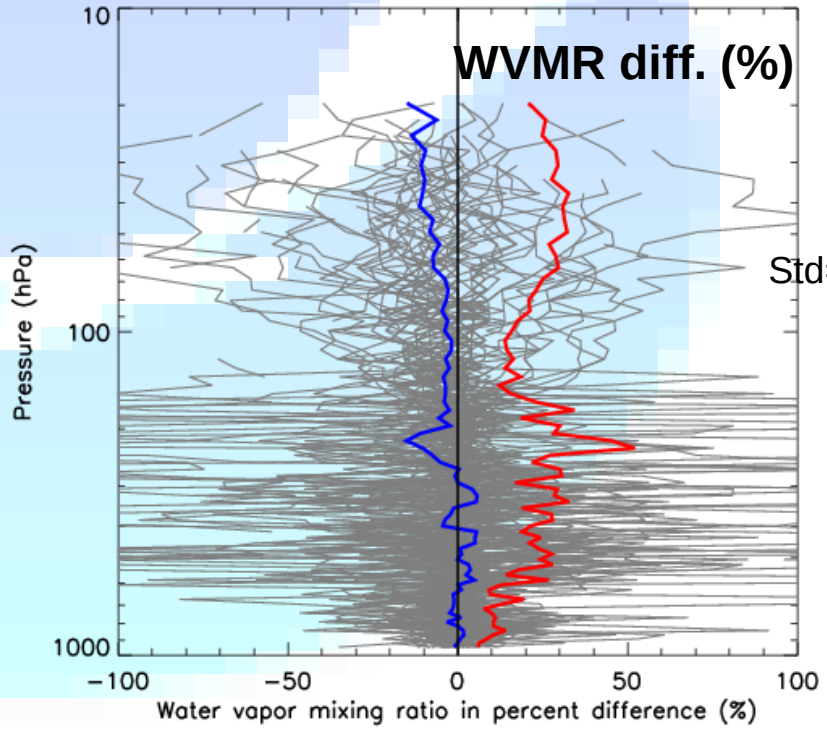
Std= 0.5 -1 K

Water vapor MR at SGP based on 60 RAOB profiles for SNPP

Water vapor mixing ratio profiles of sequential Sonde 1



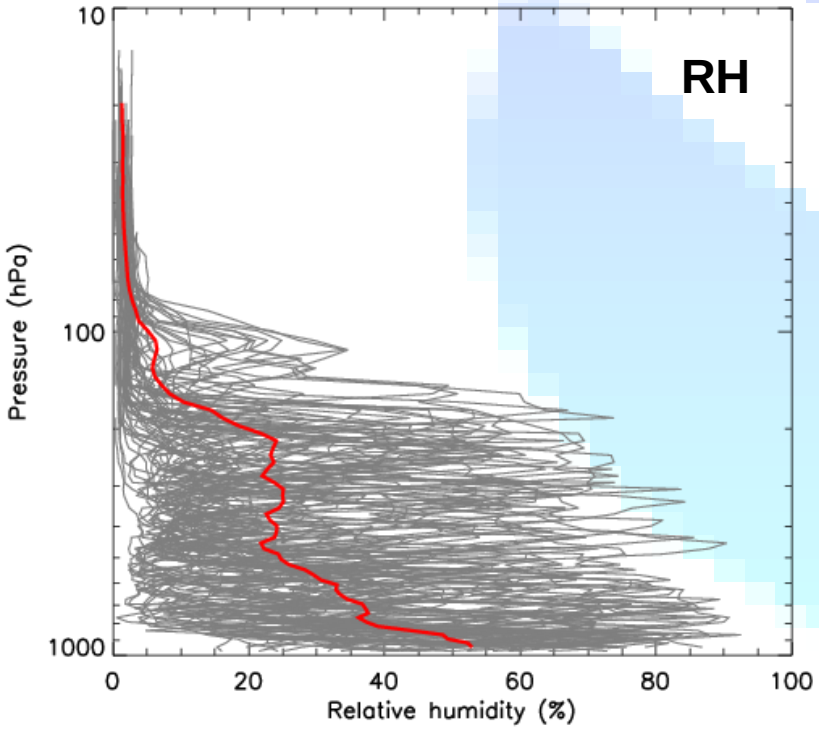
Sequential Sonde 2 minus Sonde 1



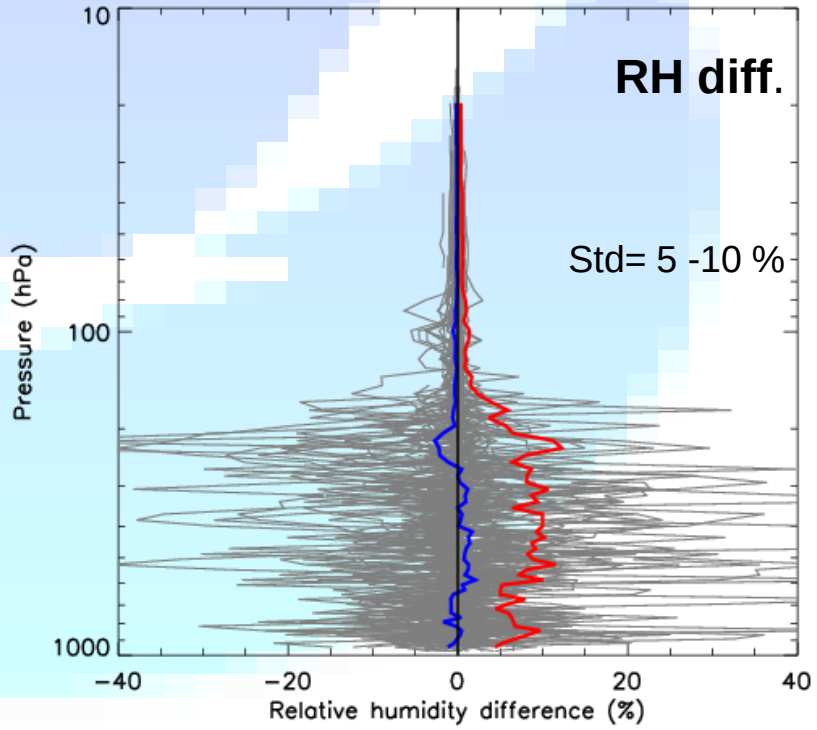
Std= 10 -30 %

Relative humidity at SGP based on 60 RAOB profiles for SNPP

Relative humidity profiles of sequential Sonde 1



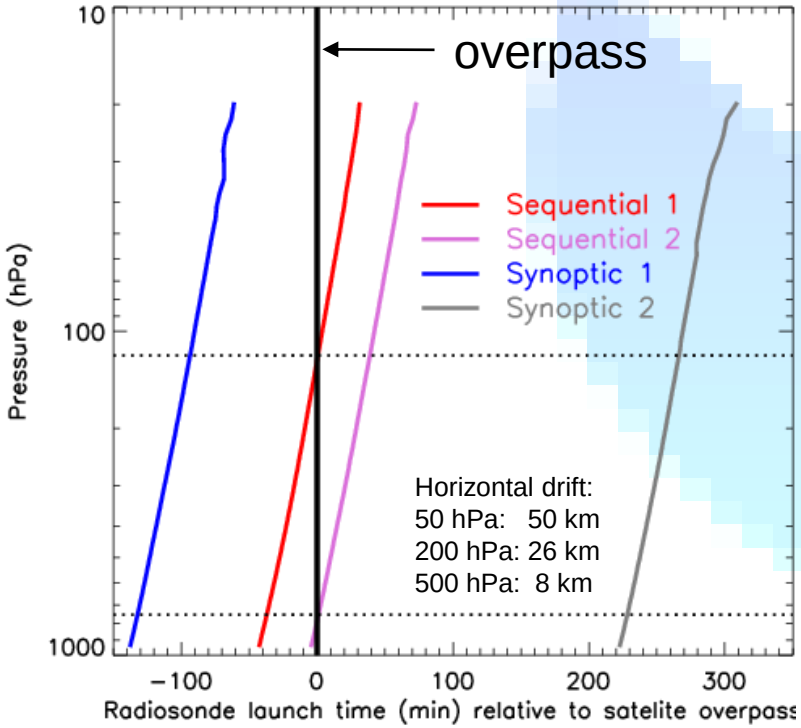
Sequential Sonde 2 minus Sonde 1



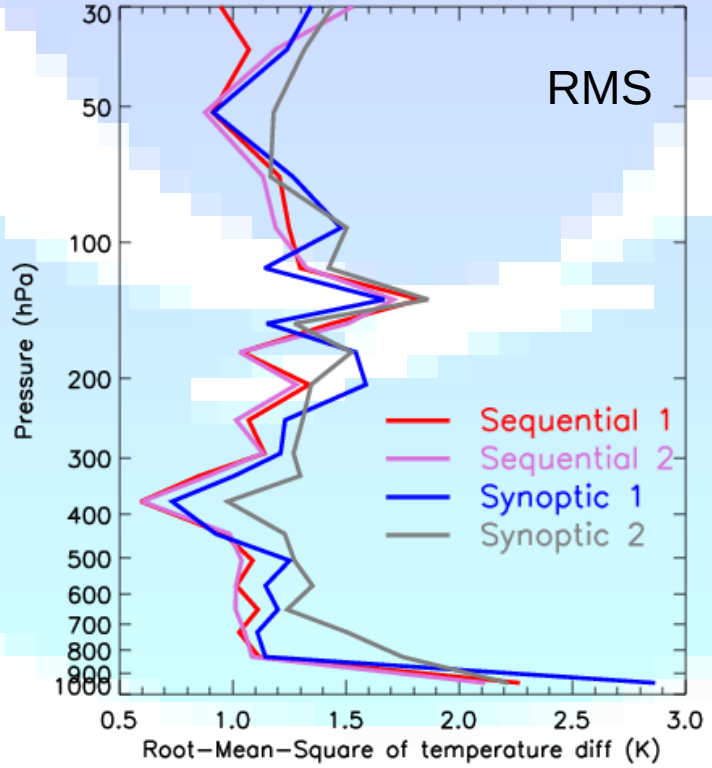
NUCAPS NOAA20 temperature retrieval validation

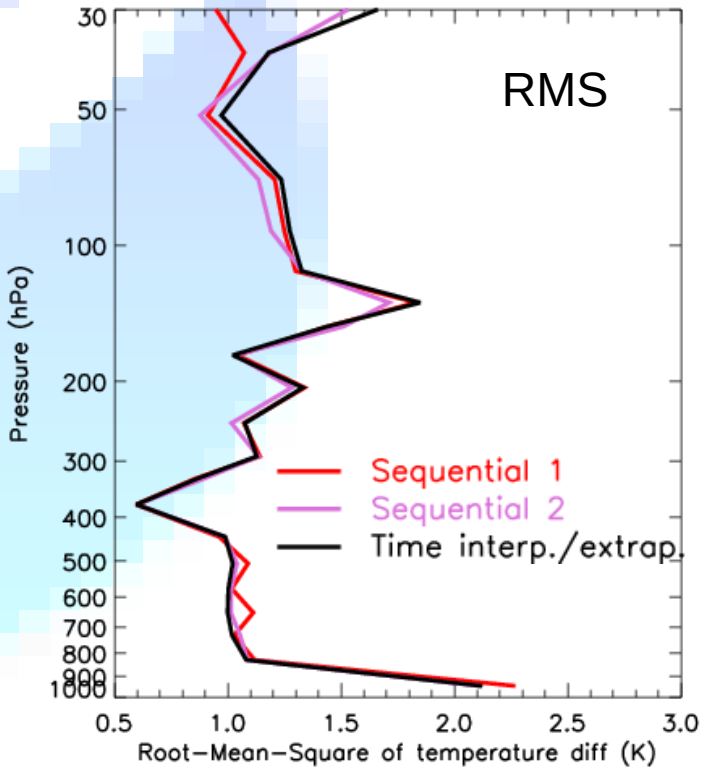
Satellite-RAOB collocations: 30

RAOB observation time relative to NOAA20 overpass time



NUCAPS NOAA20 -minus- RAOB RMS (K) temperature



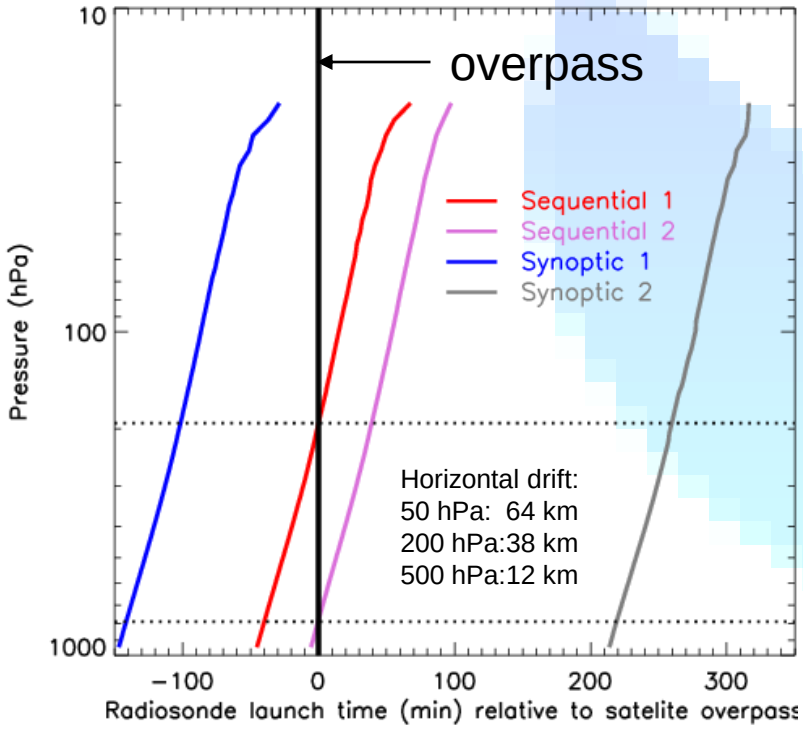


Dedicated sondes improve the validation accuracy

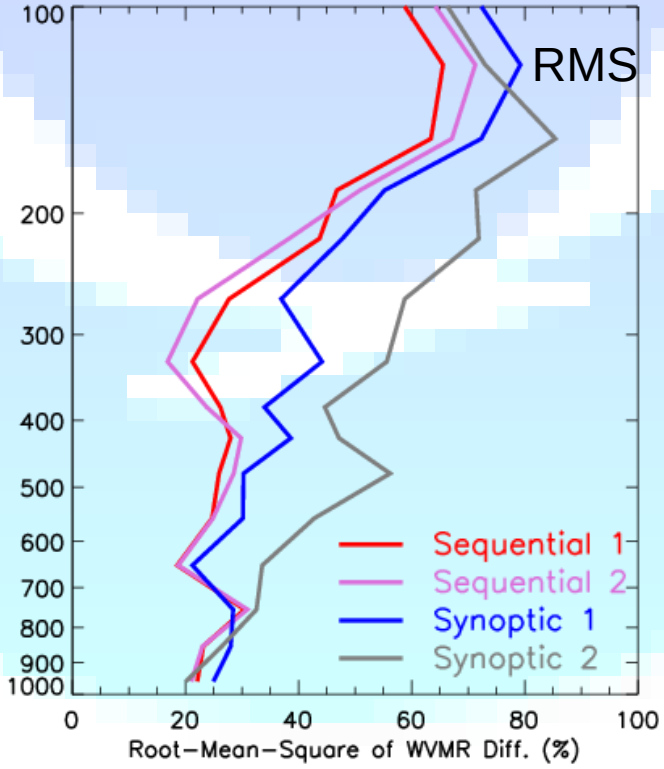
NUCAPS SNPP water vapor MR retrieval validation

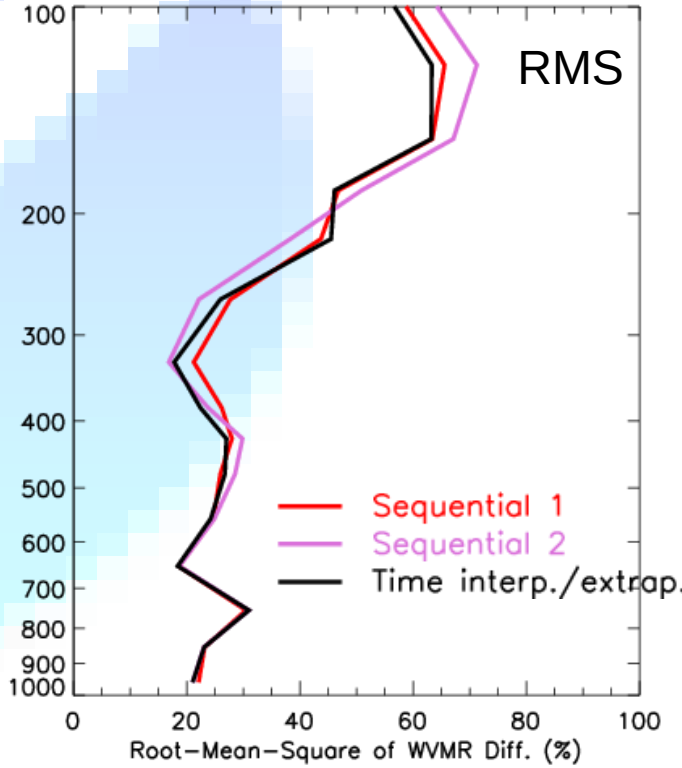
Satellite-RAOB collocation sample: 60

RAOB observation time relative to SNPP overpass



NUCAPS SNPP minus RAOB RMS (%) water vapor MR (%)



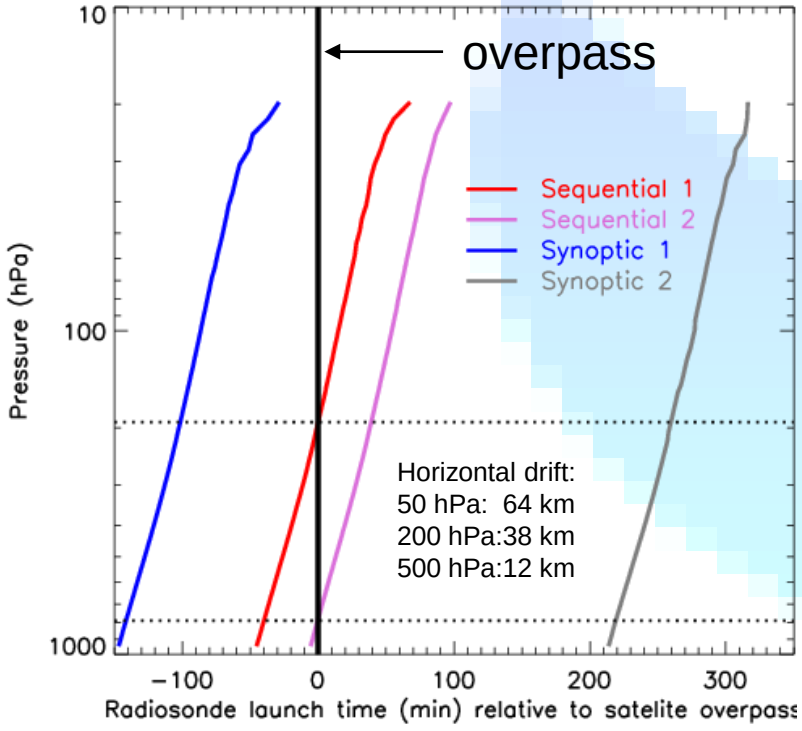


Dedicated sondes improve the validation accuracy

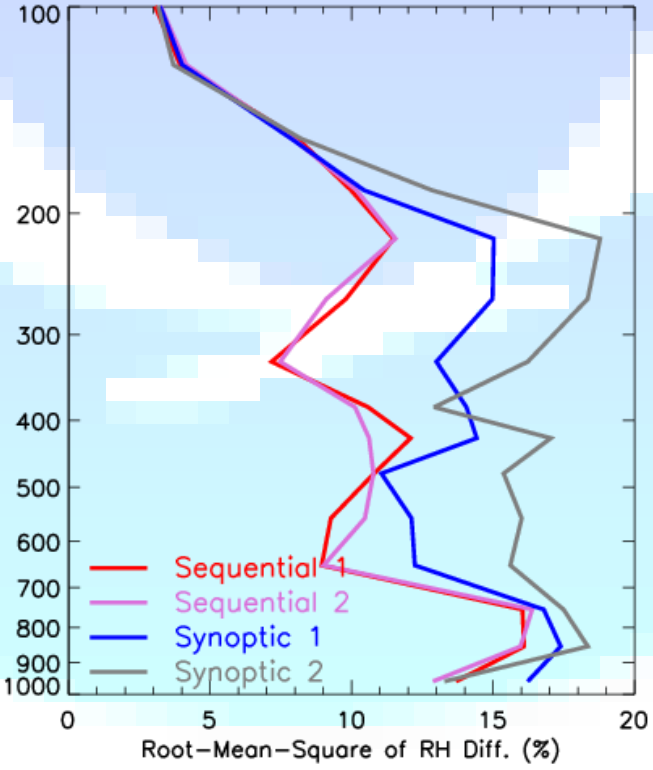
NUCAPS SNPP relative humidity retrieval validation

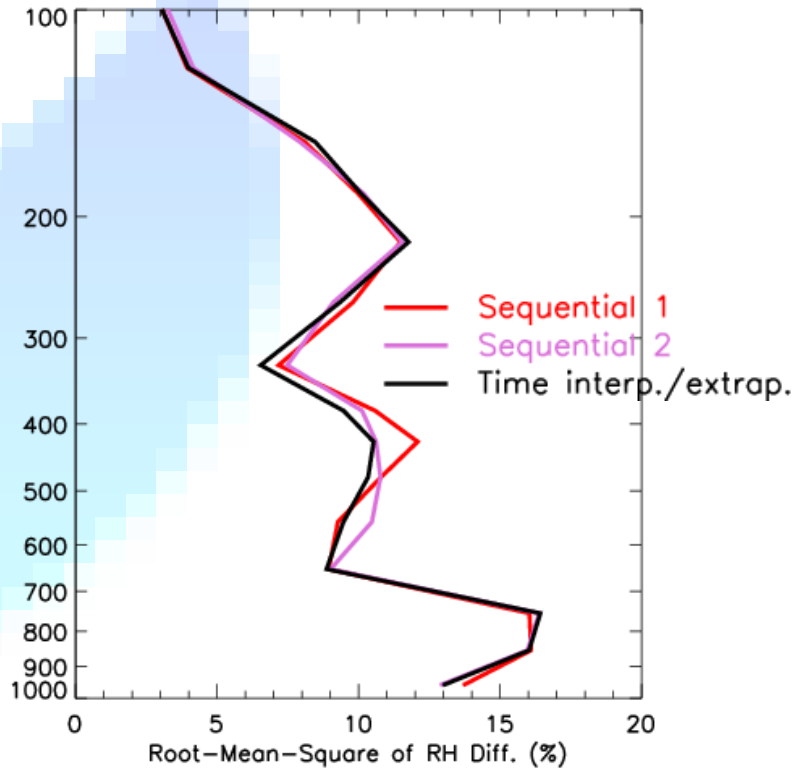
Satellite-RAOB collocation sample: 60

RAOB observation time relative to SNPP overpass



NUCAPS SNPP minus RAOB RMS (%) relative humidity



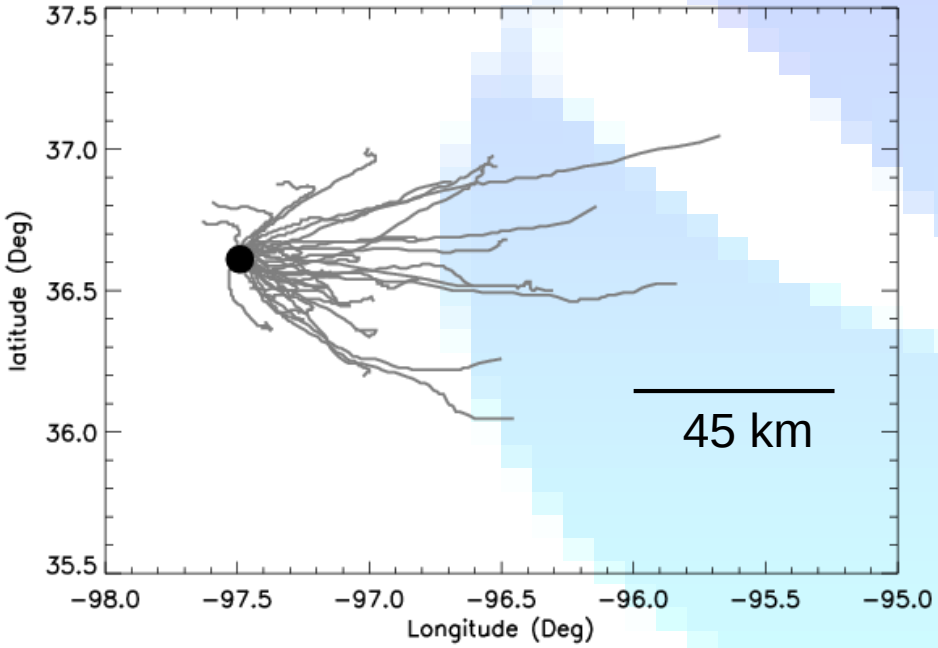


Dedicated sondes improve the validation accuracy

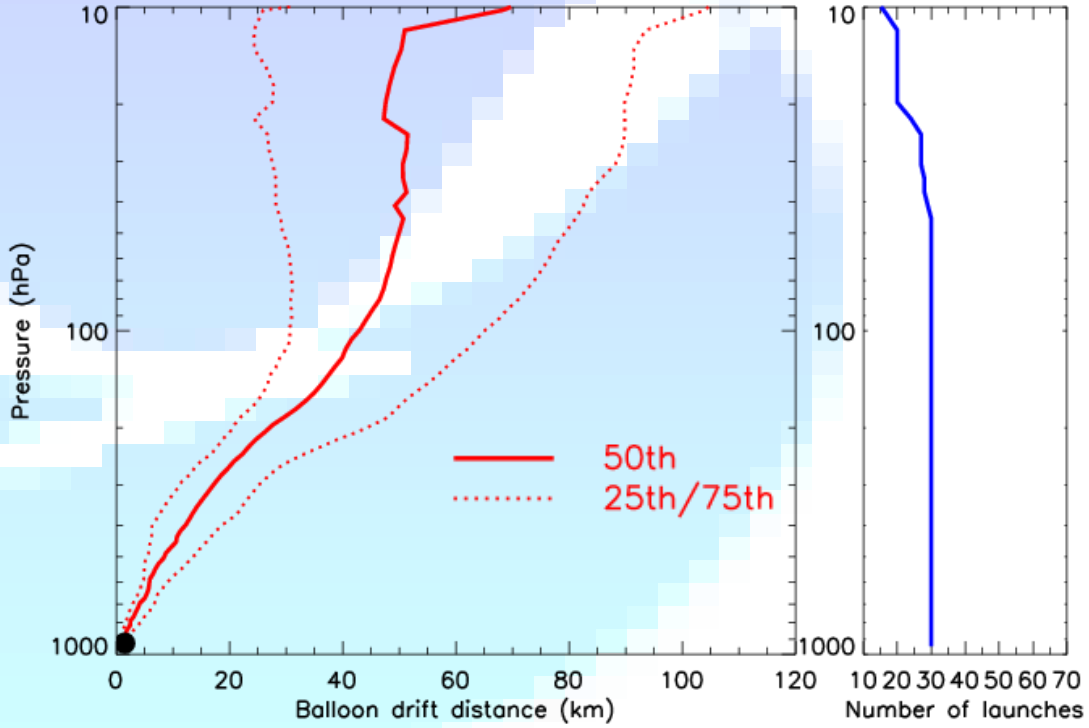
Radiosonde balloon drift statistics at SGP

Sequential Sonde 1 for NOAA20, 30 profiles

Horizonal drift



Vertical change in balloon drift (km)



How to quantify Impact of balloon drift on the validation of a) satellite retrievals and b) satellite radiances?

Note: a) The horizontal resolution for satellite retrieval is 50-km, and for IR radiance pixel is 14-km, and
b) The uncertainty for retrieval products is much bigger than the IR radiance measurements

Preliminary results

- Sequential radiosondes targeted for NOAA satellites at SGP are analyzed in terms of their use in NUCAPS sounding products validation
  - 60 pairs of sequential sondes (RS92 GDP) for SNPP during 2/7/2015 to 9/7/2017
  - 30 pairs of sequential sondes (RS41 EDT) for NOAA20 during 2/13/2018 to 1/4/2021

- The sequential sondes, either the earlier or latter launch, significantly improve the NUCAPS validation accuracy.

- The profiles time interpolated/extrapolated from the sequential sondes (to the exact overpass times) appear to improve slightly the product validation accuracy in the troposphere.

Path forward

- *Impact of spatial inconsistency between dedicated sondes and satellite data (ie, balloon drift, point vs area) will be explored.*

- *Use of GRUAN dedicated sondes in satellite radiance data validation via RT modelling (GSICS).*

- *Utilizing sequential sondes to investigate small-scale water vapor turbulence within satellite pixels (with Xavier C.)*