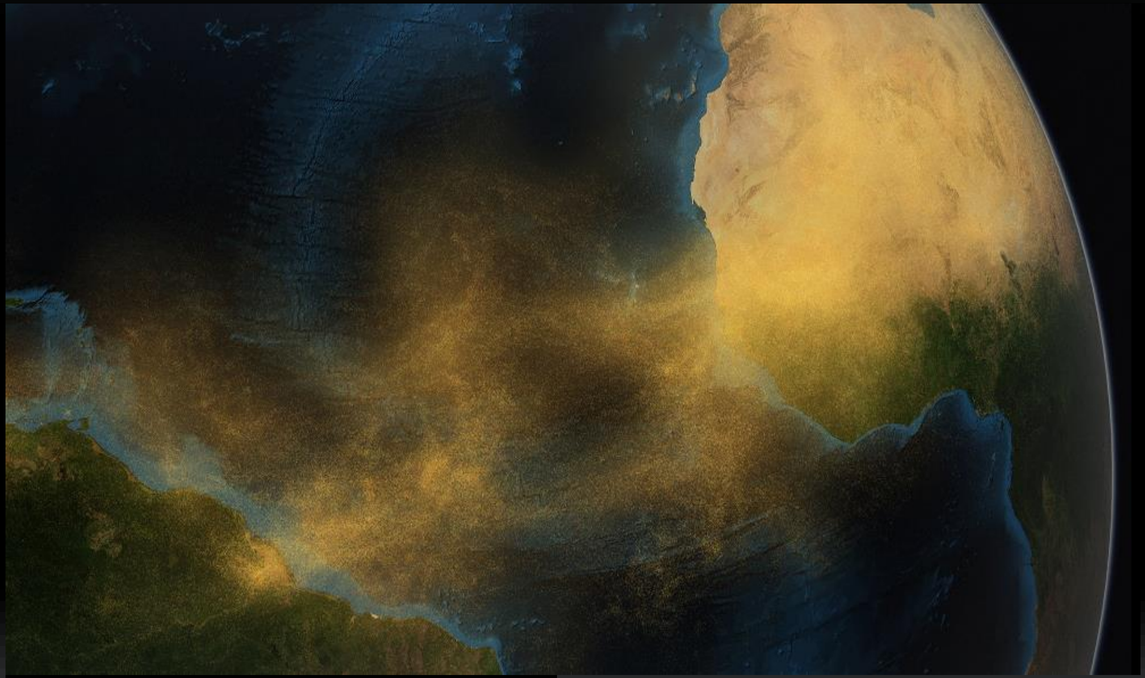
Characterizing 15 Years of Saharan-like, Dry, Well-Mixed Air Layers in North Africa

2A.5



NASA GSFC Data Visualization Studio

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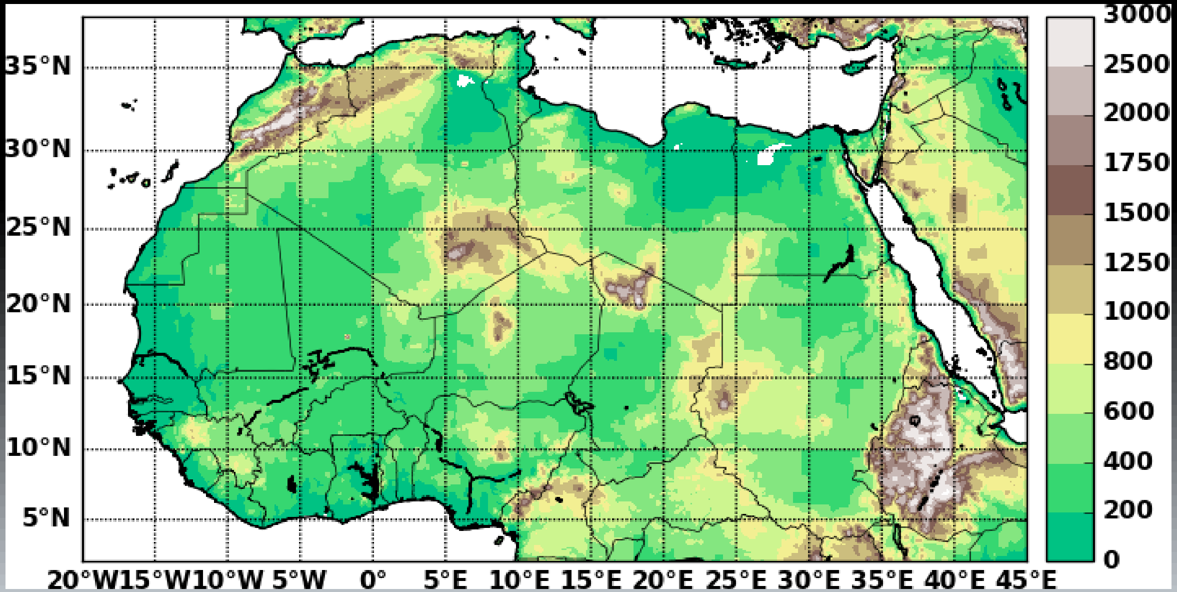
Karen I. Mohr (GSFC), Jainn J. Shi (MSU/GESTAR), Scott A. Braun (GSFC)

33rd Conference on Climate Variability and Change (13 January 2020)

North Africa's Climate System (1)

- Vast piece of real estate
  - Spans Equator to 39N, 20W to 50E
  - ~15 million km^2
- Diverse ecosystems
  - Rainforests to savannas to Desert
  - Sahara 9.4 million km^2 ~ US
- Diverse topography (Sea-level to 3000m+)

Source: dailymail.co.uk

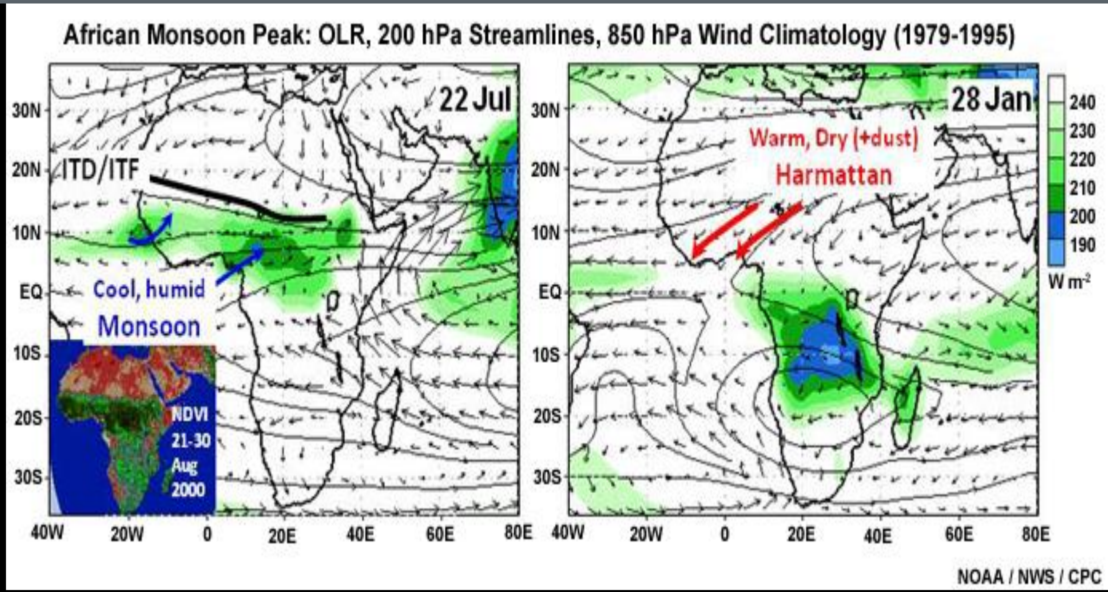


Messager et al. 2009

North Africa’s Complex Climate System (2)

- Monsoon (W. African Rainbelt Complex)
- Strong thermal contrasts (African Easterly Jet)
- African easterly waves (AEJ instability)
- Mid-latitude systems
- Aerosol-cloud interactions
- Saharan heat low (SHL) and Saharan air layer (SAL)

West African Monsoon

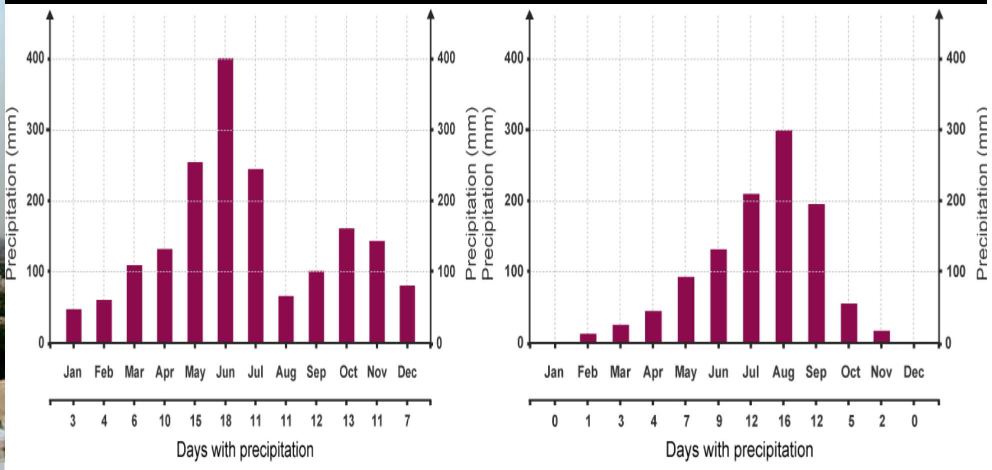


Dust Aerosols

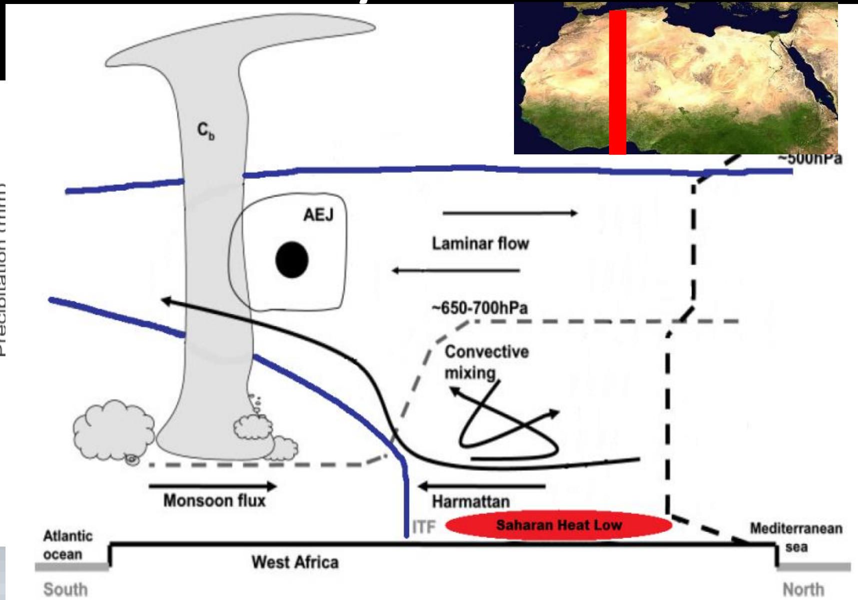
Seasonal Precipitation

Abidjan, Ghana

Bamako, Mali

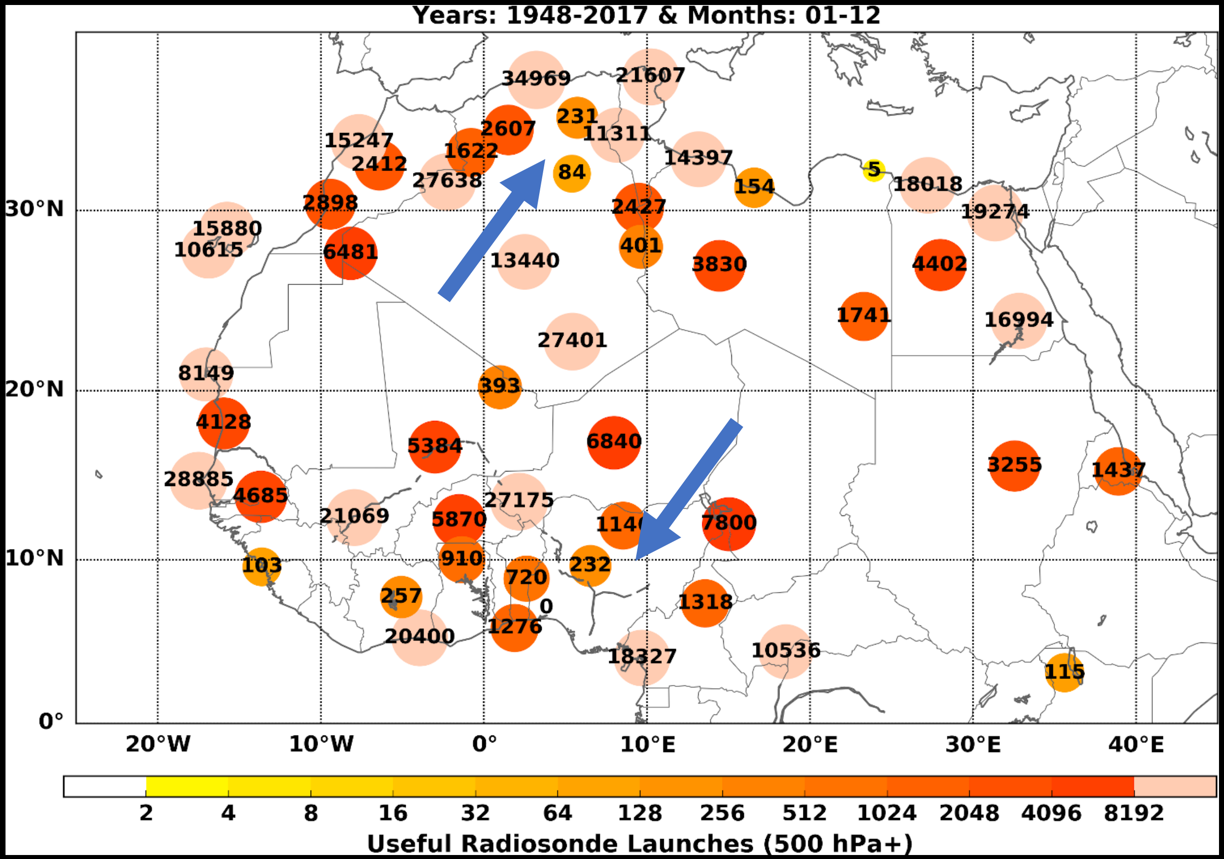


Climate System Overview

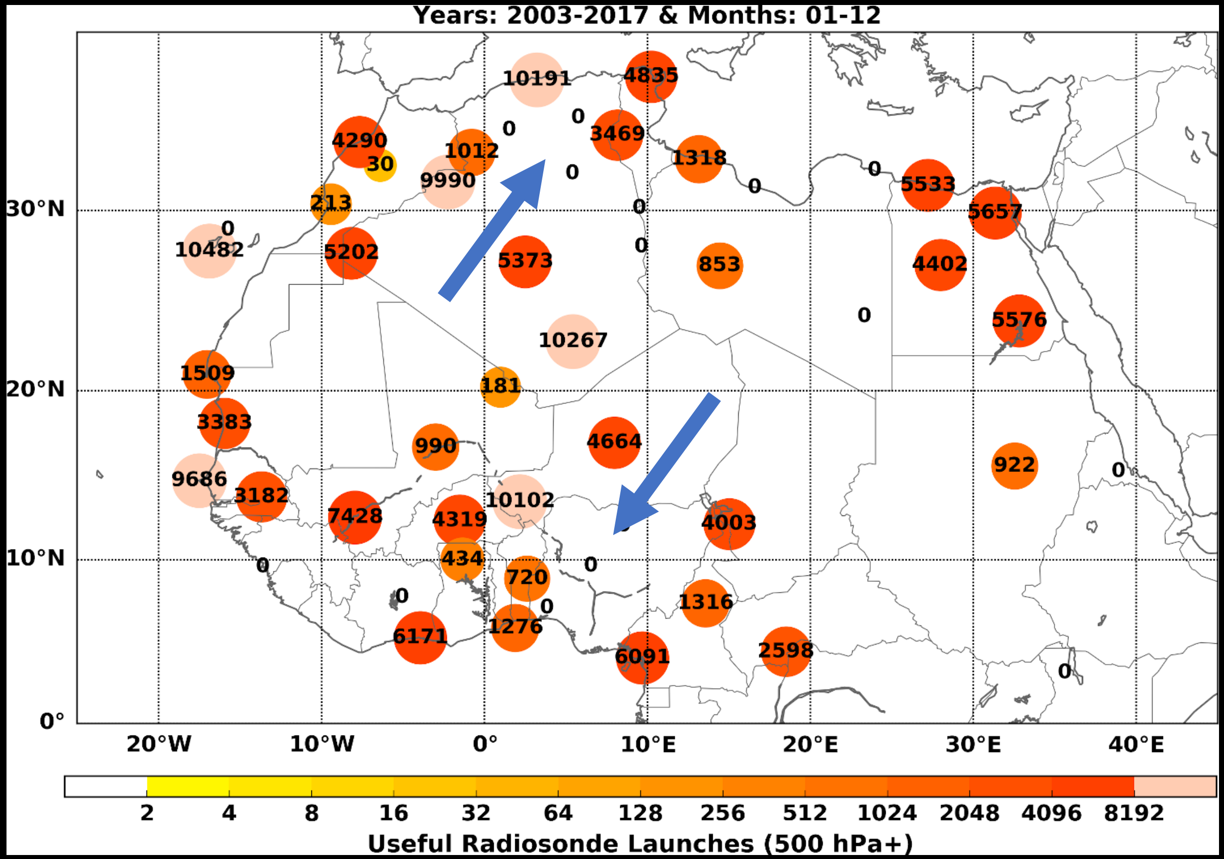


North African Rawinsonde Network (1): "Useful Launches"

1948-2017

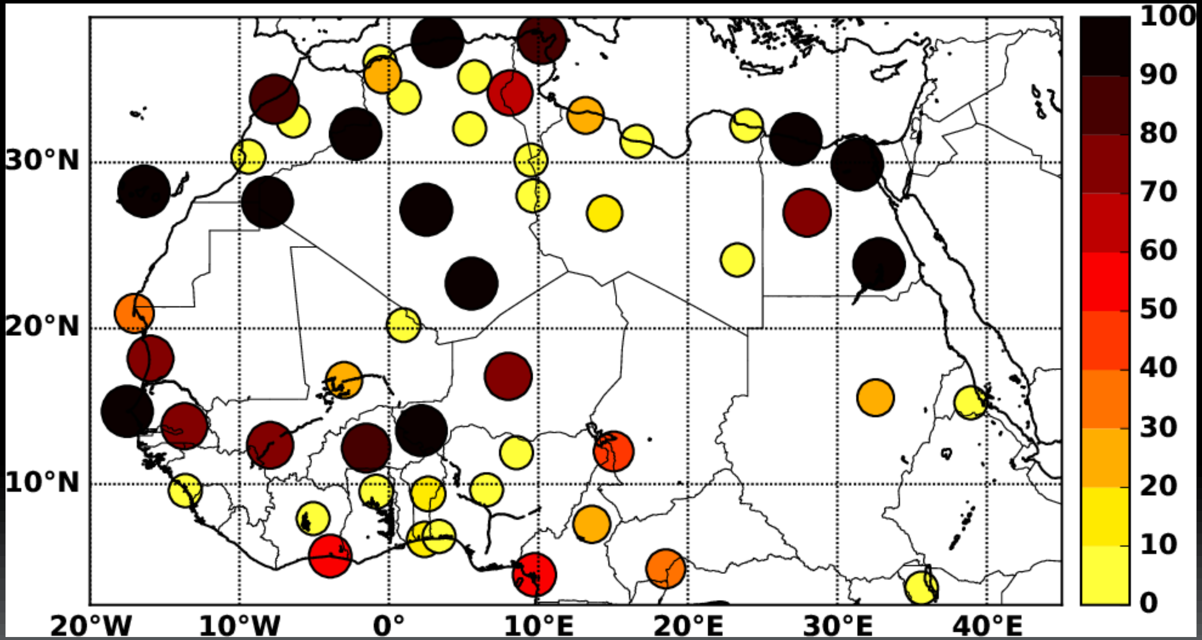


2003-2017

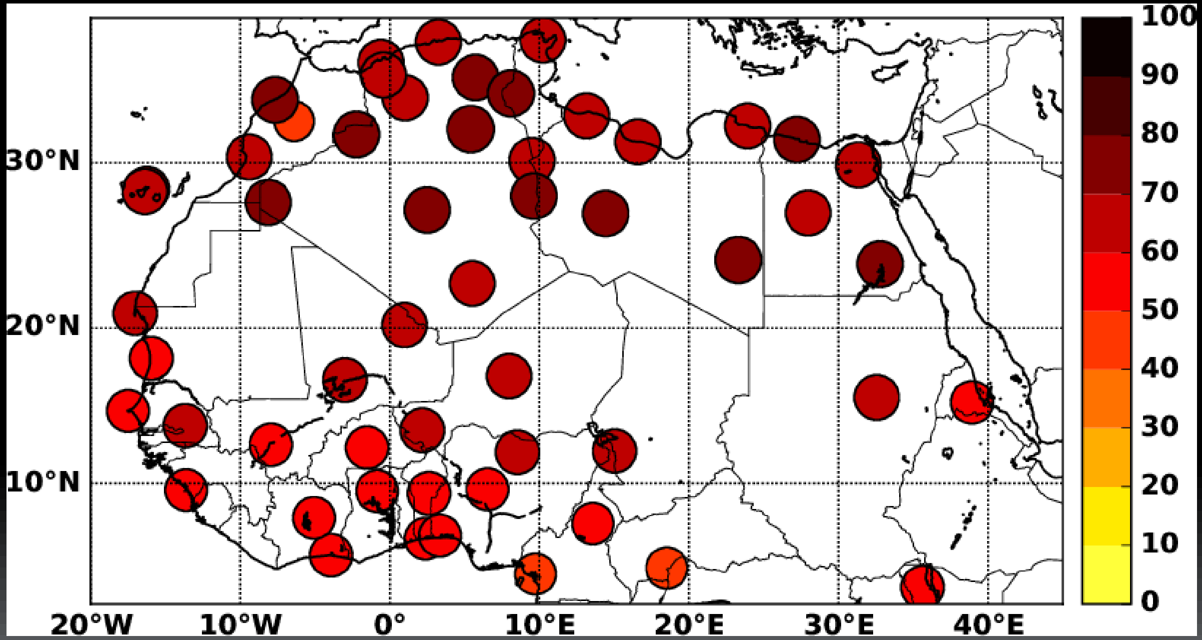


North African Rawinsonde Network (2): Limitations

Rawinsonde Launch Frequency (2003-2017)

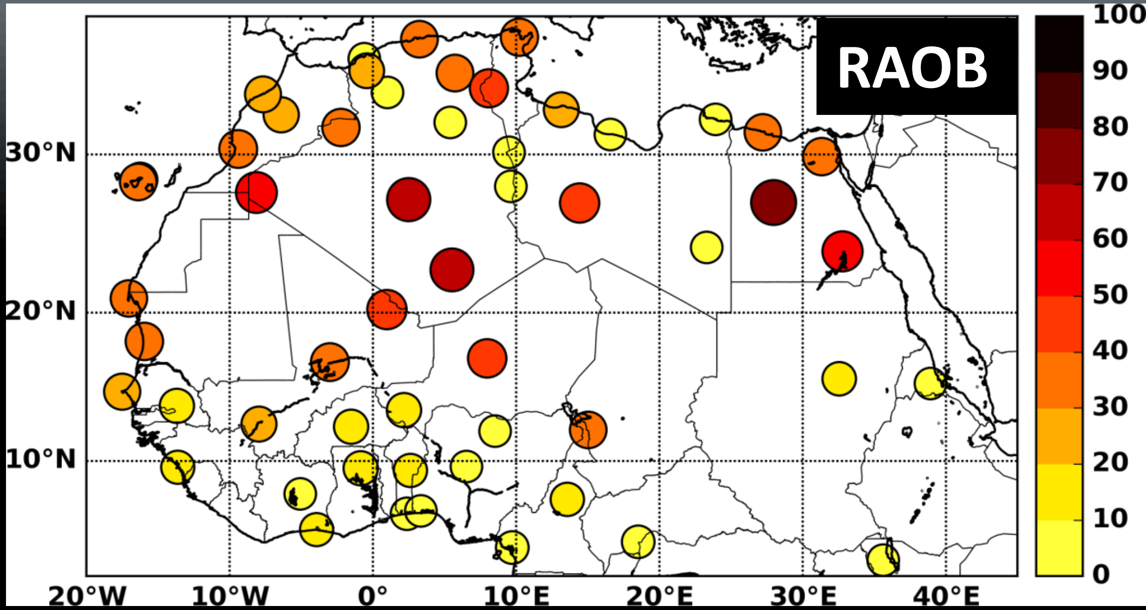


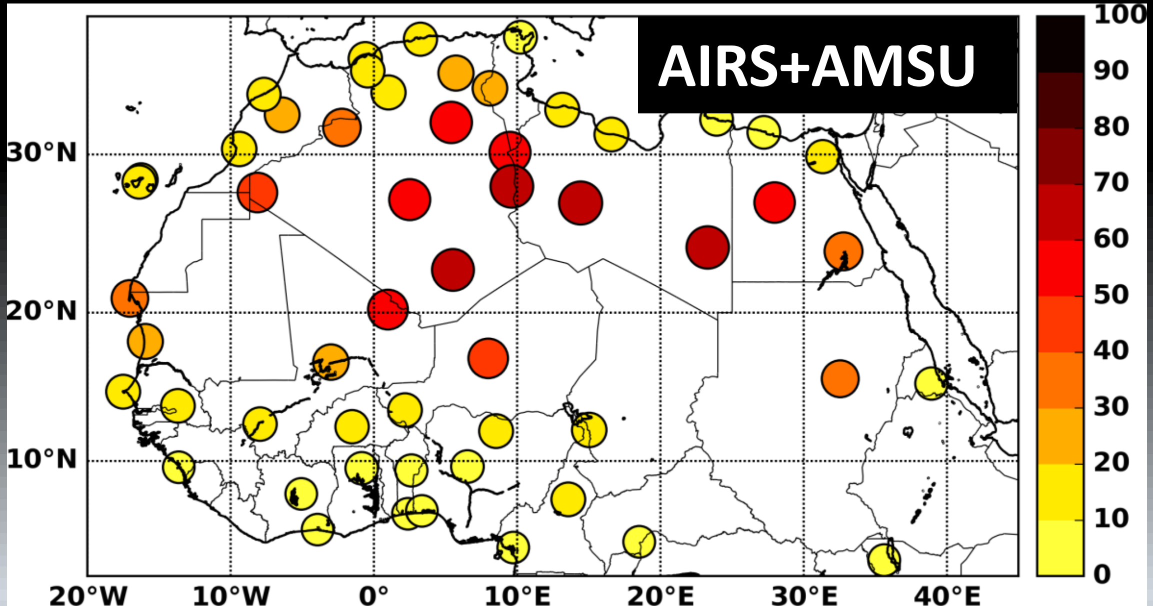
AIRS Data Frequency (2003-2017)

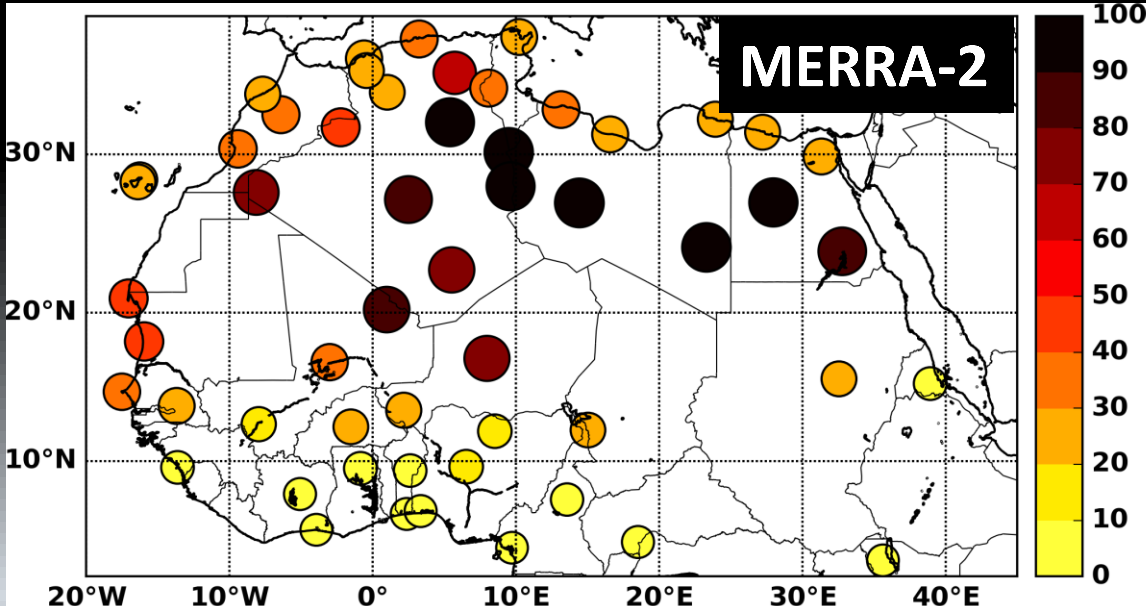


Last Time (AMS 2018)

- Highest in Sahara, lowest at Guinea Coast
- ECMWF & MERRA2 excessively frequent
- AIRS well-matched to rawinsondes
- Potent seasonal cycle (generally highest summer, lowest winter)
- Saharan-like, dry WML can be, but often not dusty (75^{th} = 0.37 ODU)
- **Limitation on conclusion:** Non-common vertical resolution







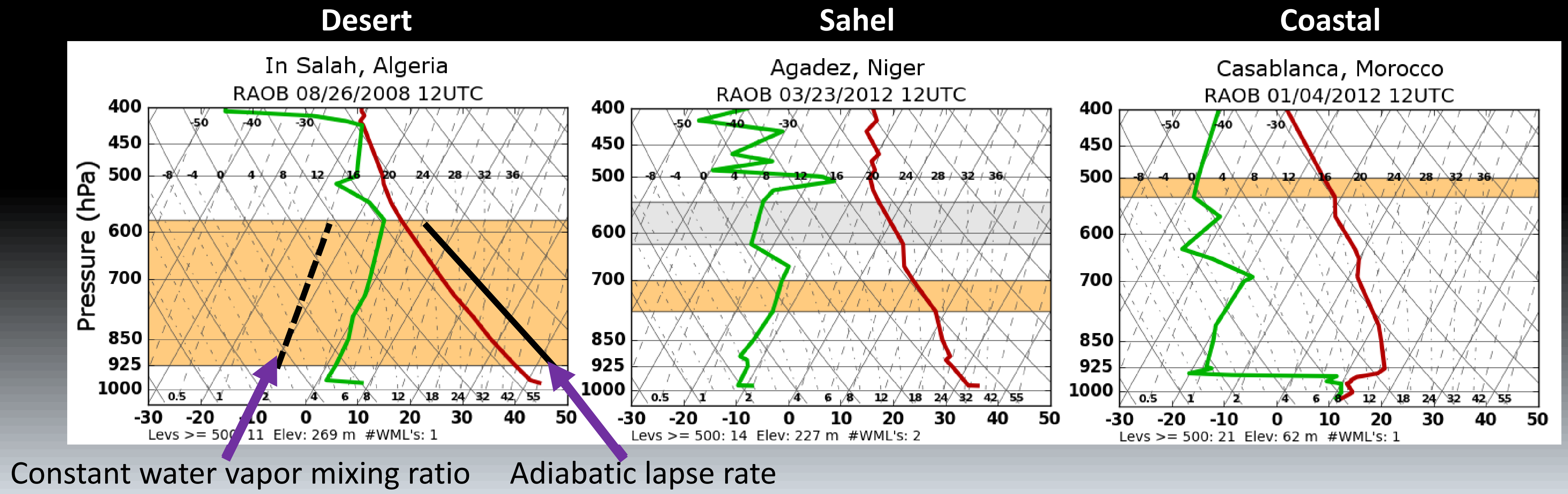
The follow-on act since AMS 2018

- Original: RAOB, AIRS, AIRS+AMSU, MERRA-2
- Added: JRA-55, ERA-I, ERA-5
- Refined the WML detection methodology
  - Biggest challenge: Mixing ratio lapse ratio (constant vs scaled)
  - Published: Nicholls and Mohr (2019) - JAO Tech
- Unlike 2018, all data evaluated at coarsest vertical resolution

- Presentation goals: Cross-platform assessment of WML-detection and WML-related properties at rawinsonde locations (Reanalysis & AIRS)
- Analysis Period: WAM season (May – Sept) 2003 - 2018

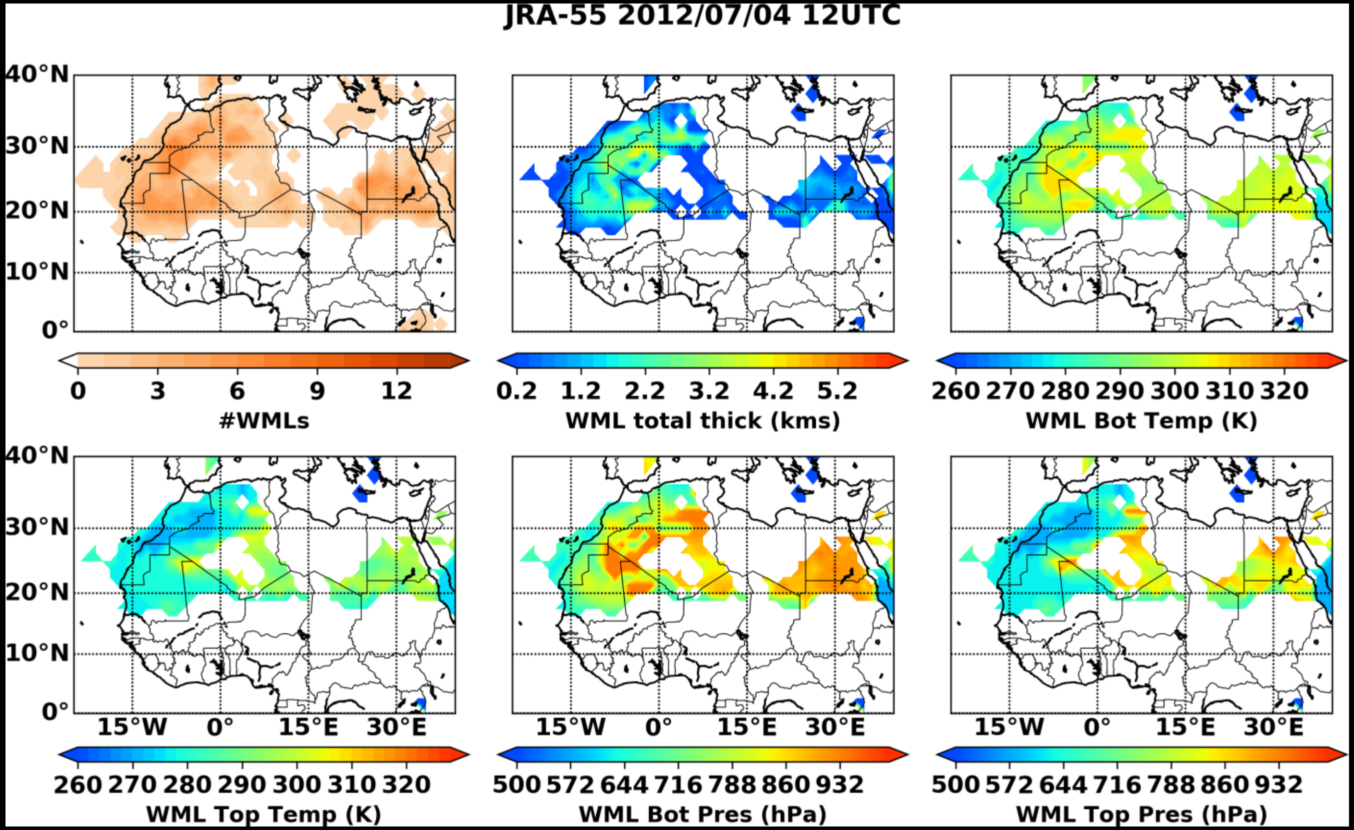
Saharan-like, Dry Well-mixed Layer Detection Algorithm

- Search for well-mixed layers (WMLs) that could be SAL (ideally not from monsoon-, subsidence-, or mid-latitude-based causes)
- Searches for nearly adiabatic temperature lapse rates with near constant water vapor mixing ratio (≤ 7 g/kg) (i.e., “Saharan-like”).
- Start surface through 500 hPa, **each color = new WML**
- Continuous WML if temperature and water vapor properties are roughly conserved, otherwise not a WML or a new WML



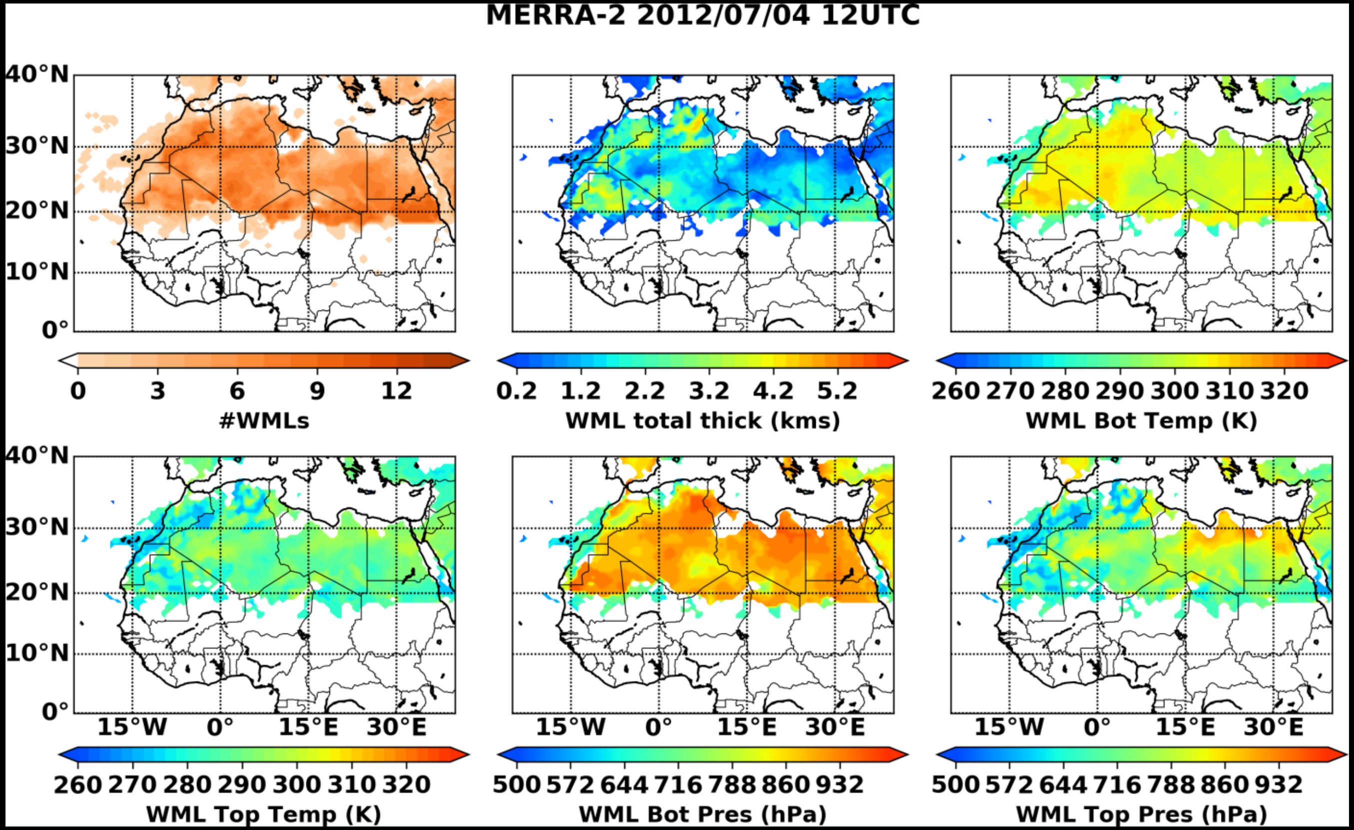
Dry, Well-Mixed Layer Properties (1): JRA-55

- Shown at native resolution
- 4 model products (JRA-55, MERRA-2, ERA-I, ERA-5)
- Simplified WML algorithm
- Spatial extent of WML insensitive to resolution (synoptic)
- Vertical WML extent sensitive (up to 2km!)
- While largely similar, how does each capture WMLs vs rawinsondes.



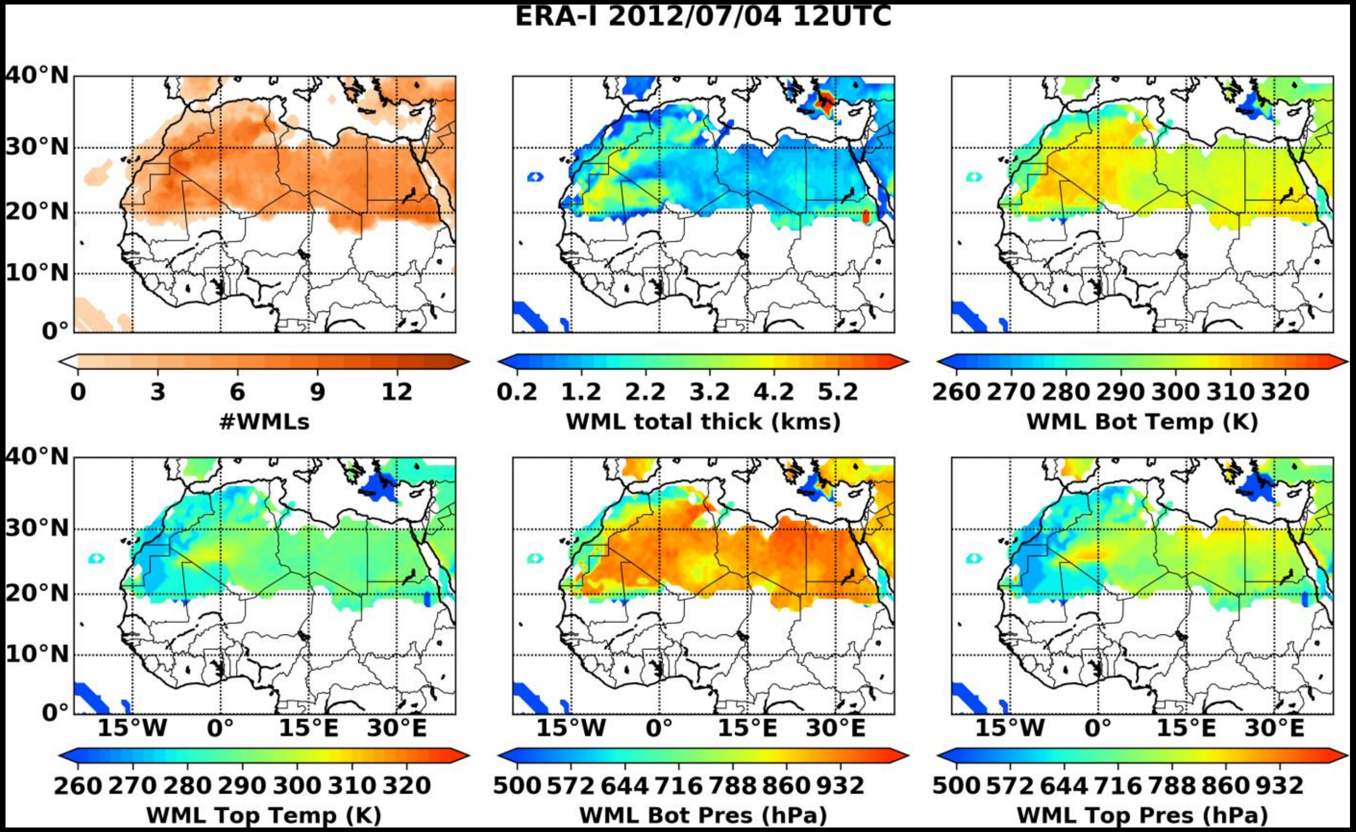
Dry, Well-Mixed Layer Properties (2): MERRA2

- Shown at native resolution
- 4 model products (JRA-55, MERRA-2, ERA-I, ERA-5)
- Simplified WML algorithm
- Spatial extent of WML insensitive to resolution (synoptic)
- Vertical WML extent sensitive (up to 2km!)
- While largely similar, how does each capture WMLs vs rawinsondes.



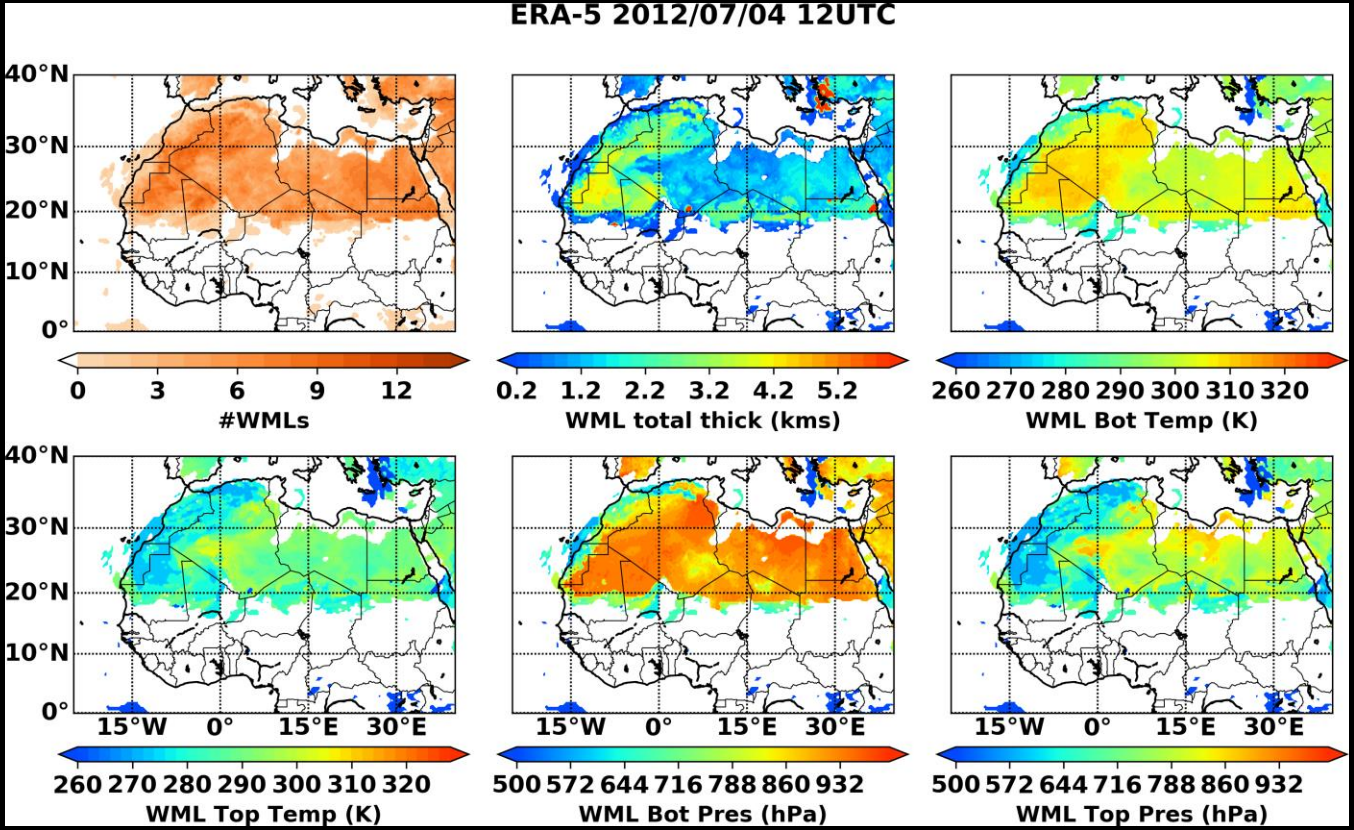
Dry, Well-Mixed Layer Properties (3): ERA-I

- Shown at native resolution
- 4 model products (JRA-55, MERRA-2, ERA-I, ERA-5)
- Simplified WML algorithm
- Spatial extent of WML insensitive to resolution (synoptic)
- Vertical WML extent sensitive (up to 2km!)
- While largely similar, how does each capture WMLs vs rawinsondes.



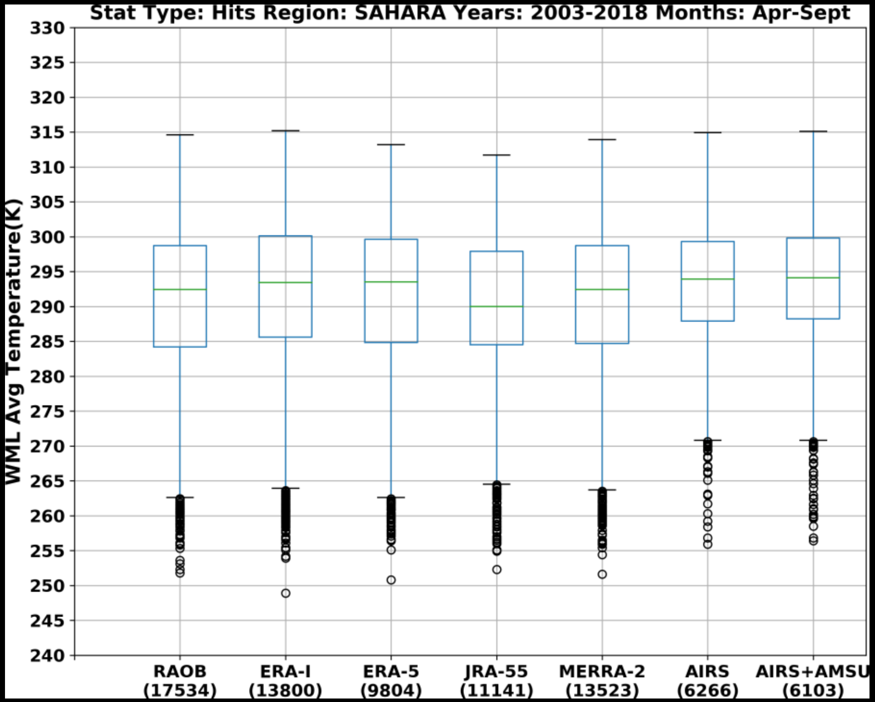
Dry, Well-Mixed Layer Properties (4): ERA-5

- Shown at native resolution
- 4 model products (JRA-55, MERRA-2, ERA-I, ERA-5)
- Simplified WML algorithm
- Spatial extent of WML insensitive to resolution (synoptic)
- Vertical WML extent sensitive (up to 2km!)
- While largely similar, how does each capture WMLs vs rawinsondes.

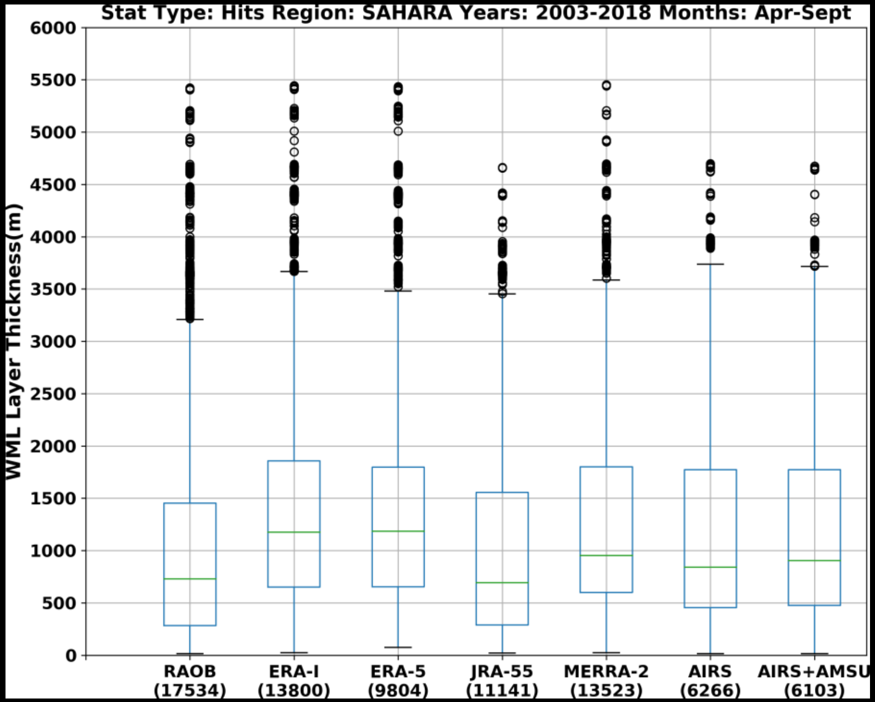


Dry, Well-Mixed Layer Analysis (1): Saharan

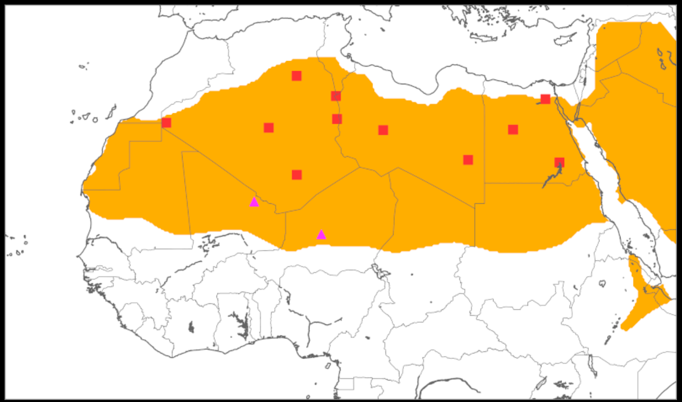
Temperature (K)



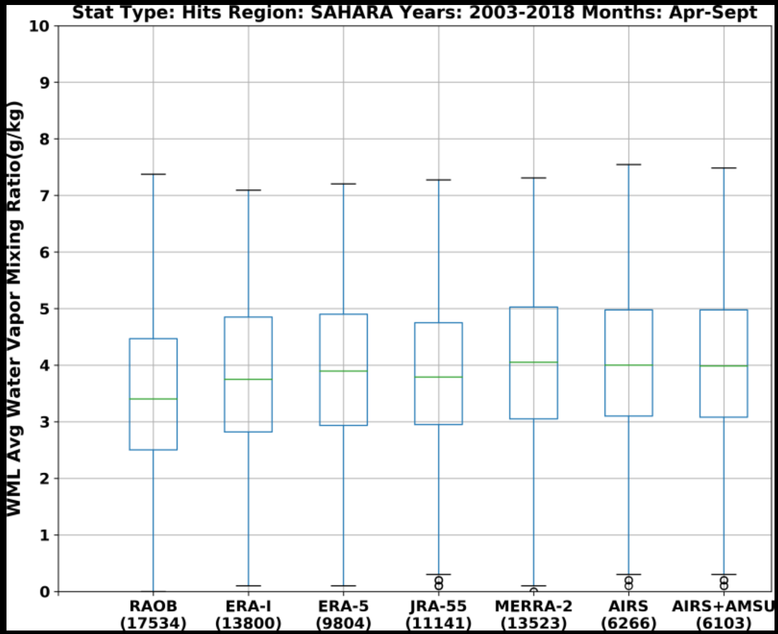
Layer Thickness (m)



Station Locations



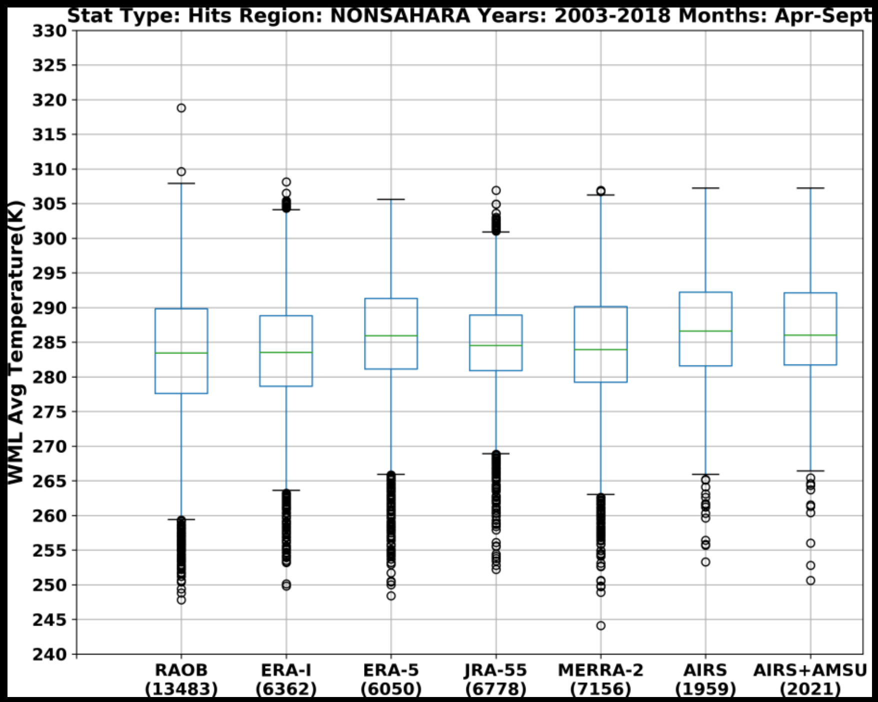
Water Vapor Mixing Ratio (g/kg)



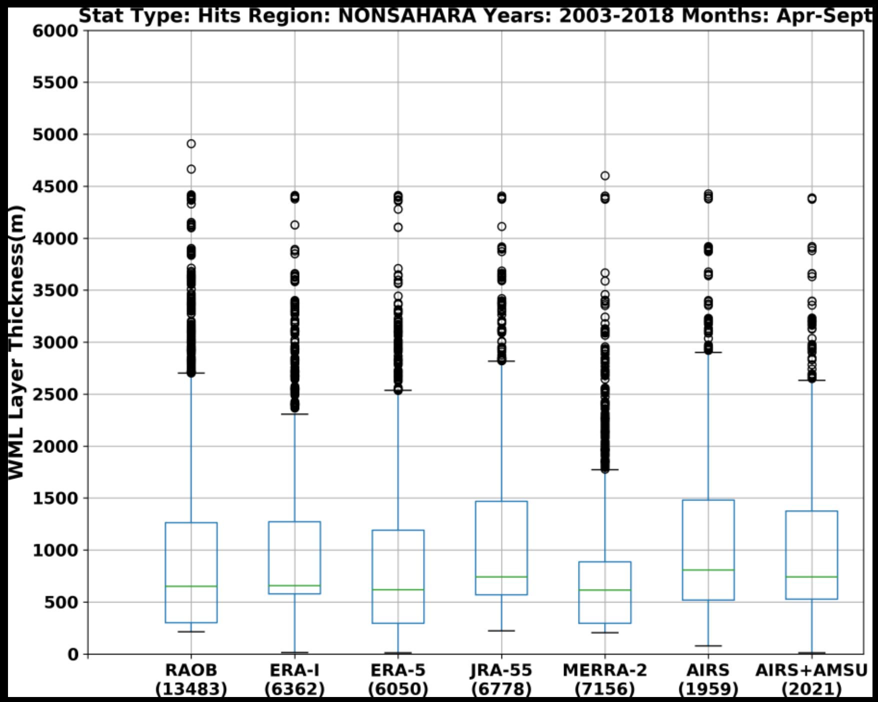
- Evaluate: 4 reanalysis, 2 AIRS products
- No winds evaluated because AIRS lacks it
- Similar environment (sensible heat) with deep PBLs (up to 5.5 km)
- IQR range of similar for Temp and Mix Ratio (Exc. JRA-55, 5K diff mean)
- Model resolution most notably improves temperatures, but can not reproduce a notably number of WMLs in RAOBs
- Despite assimilating AIRS radiances and RAOBs, ECMWF products favor thicker layers than AIRS.

Dry, Well-Mixed Layer Analysis (2): Non-Saharan

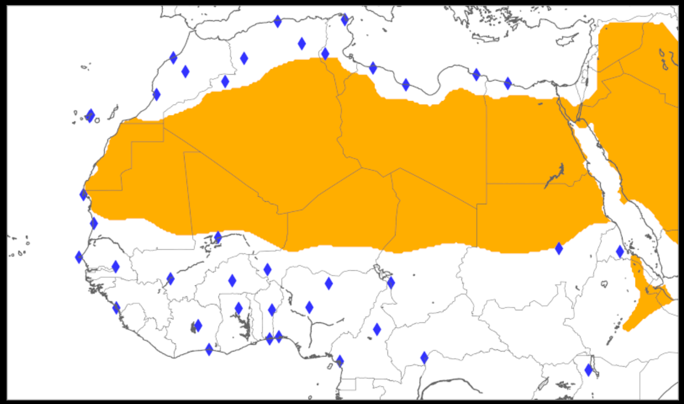
Temperature (K)



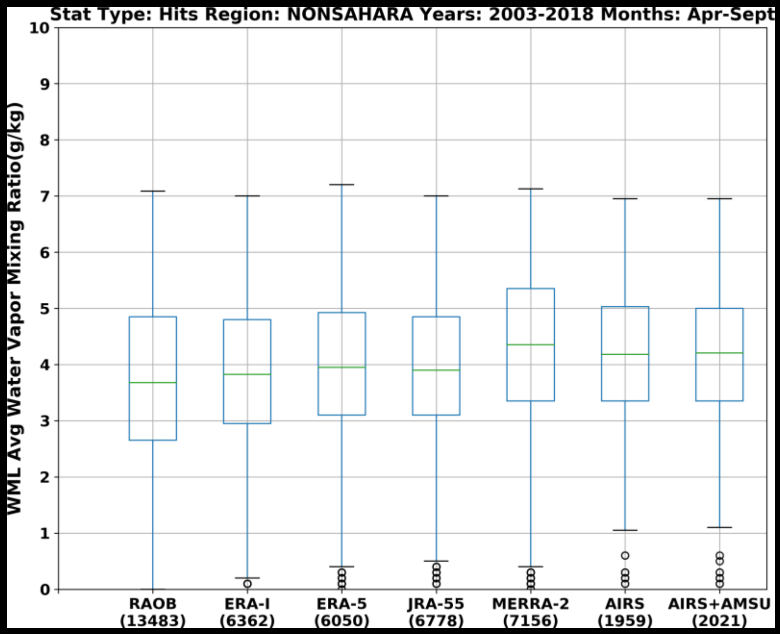
Layer Thickness (m)



Station Locations



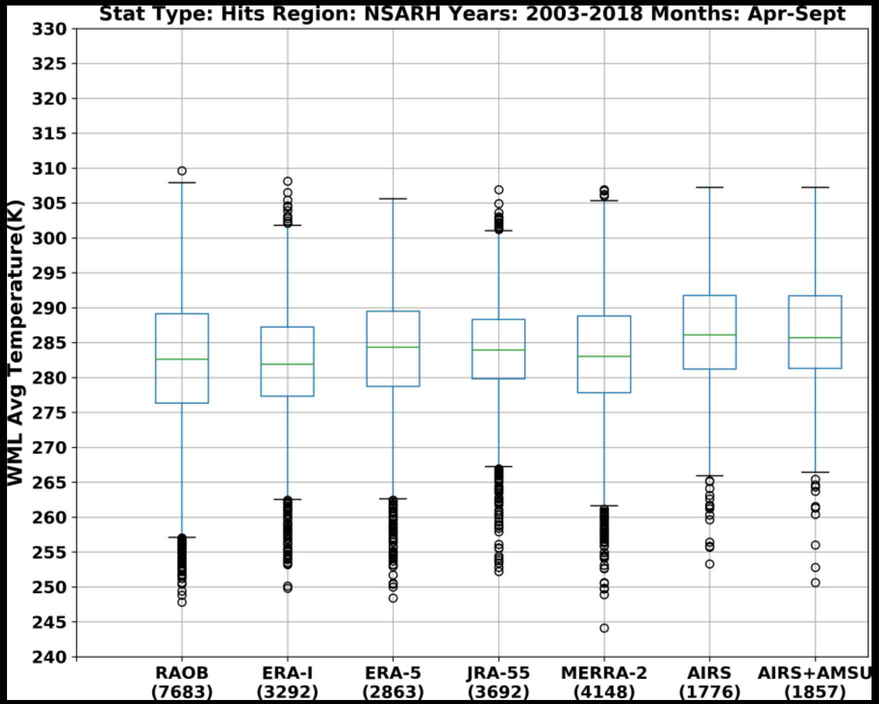
Water Vapor Mixing Ratio (g/kg)



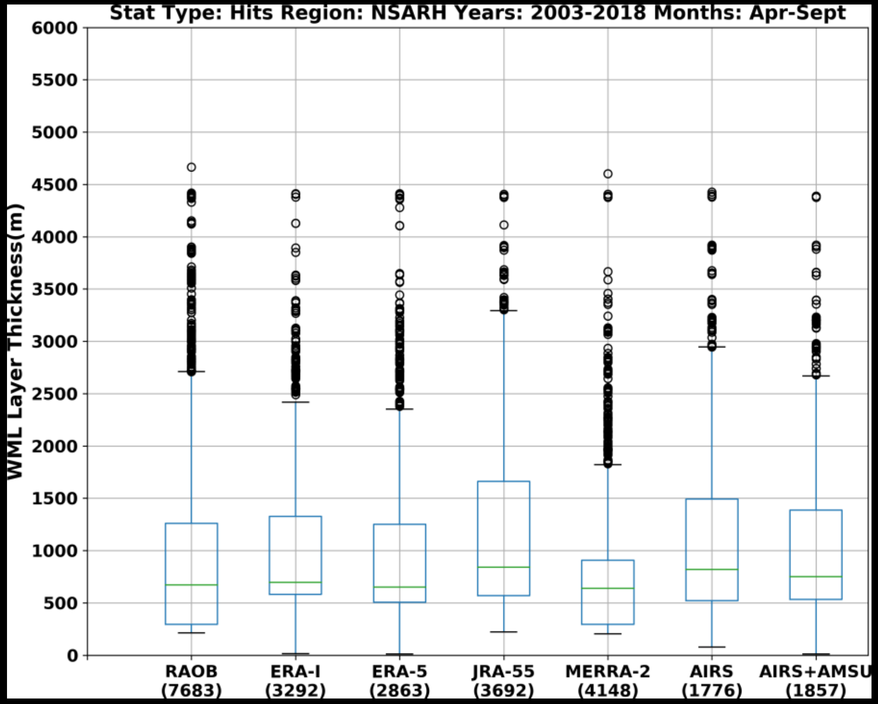
- Evaluate: 4 reanalysis, 2 AIRS products
- Non-Saharan WML profiles are cooler, moister and thinner than Saharan stations
- With exception of MERRA-2, all data and model products slightly favor thicker WMLs
- Significance decrease (up to 50% less) in WMLs matched by RAOBs
- Of what is matched, both temperature and mixing ratio deviate more from RAOBs
-

Dry, Well-Mixed Layer Analysis (3): N. Non-Saharan

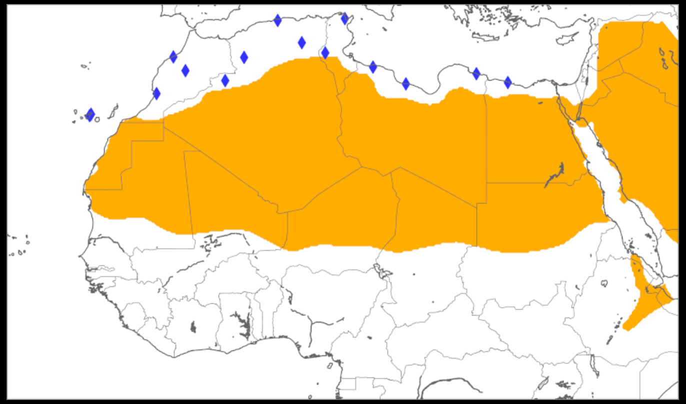
Temperature (K)



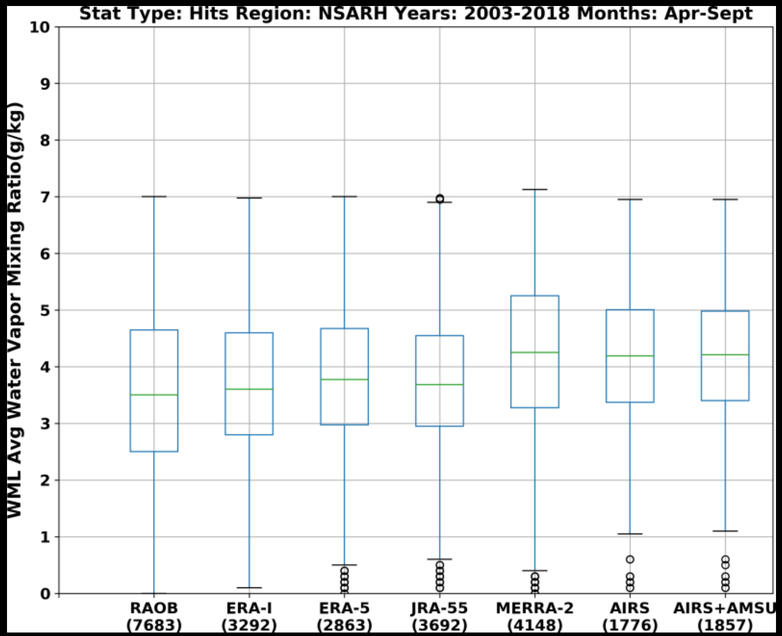
Layer Thickness (m)



Station Locations



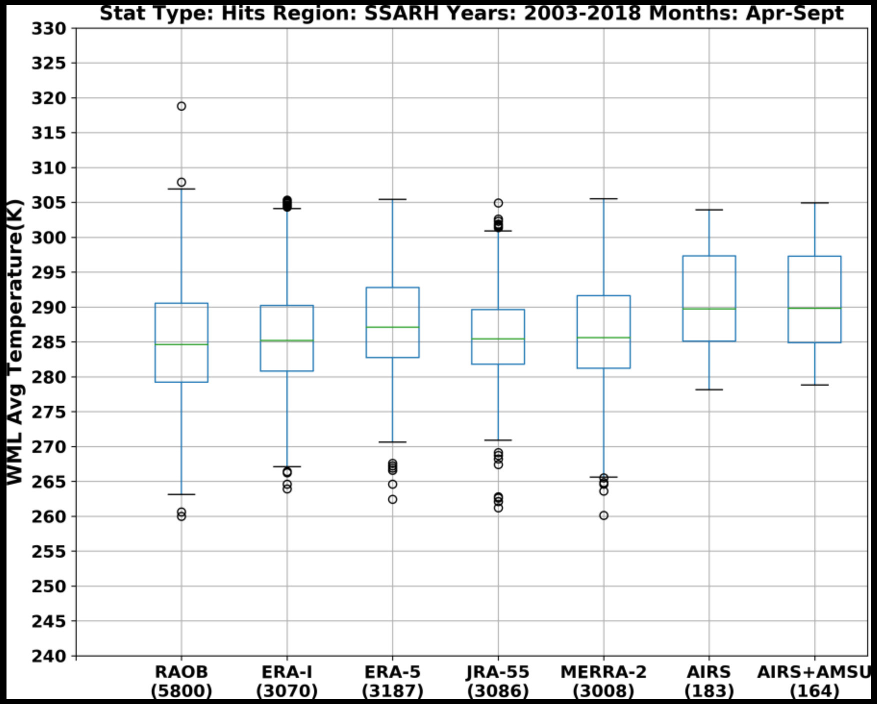
Water Vapor Mixing Ratio (g/kg)



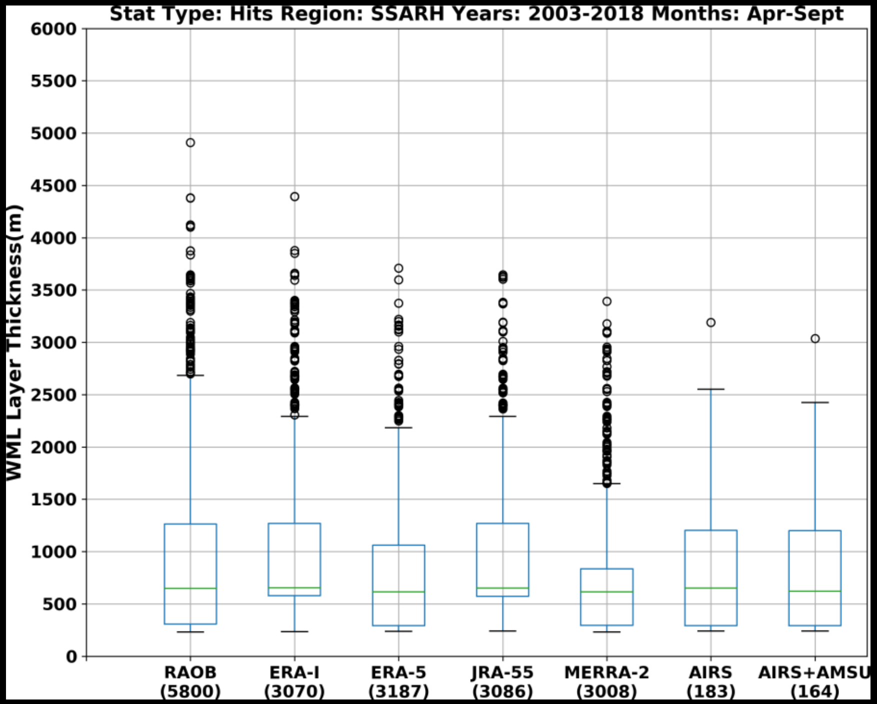
- Slightly warmer, drier shift matched by all data sources

Dry, Well-Mixed Layer Analysis (4): S. Non-Saharan

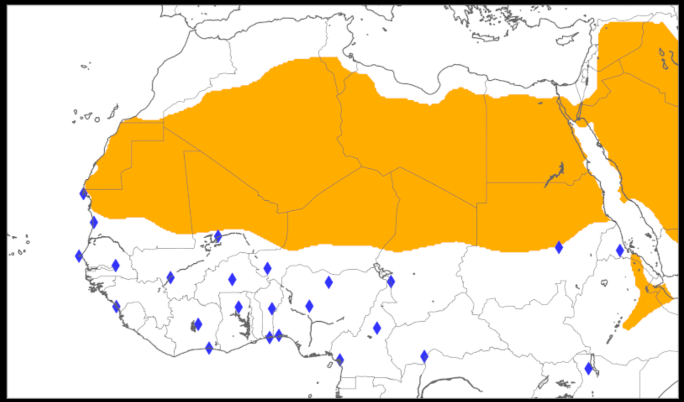
Temperature (K)



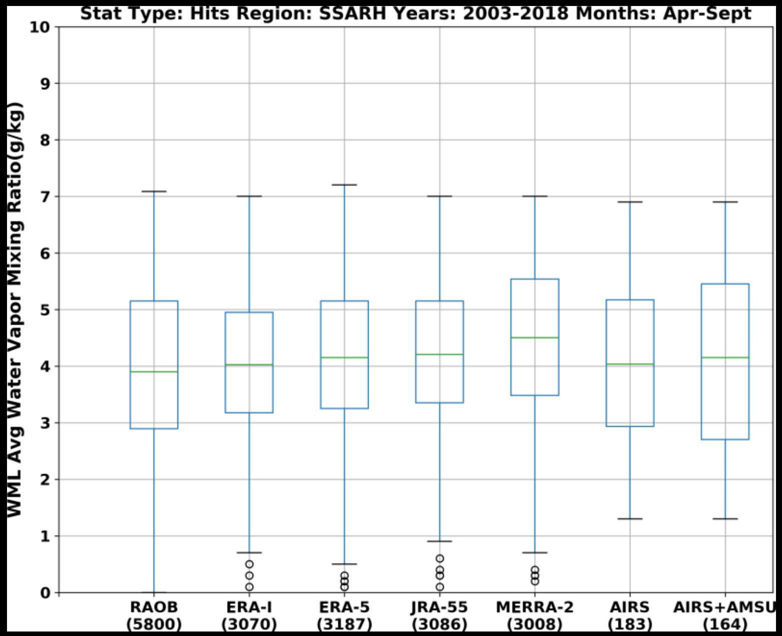
Layer Thickness (m)



Station Locations



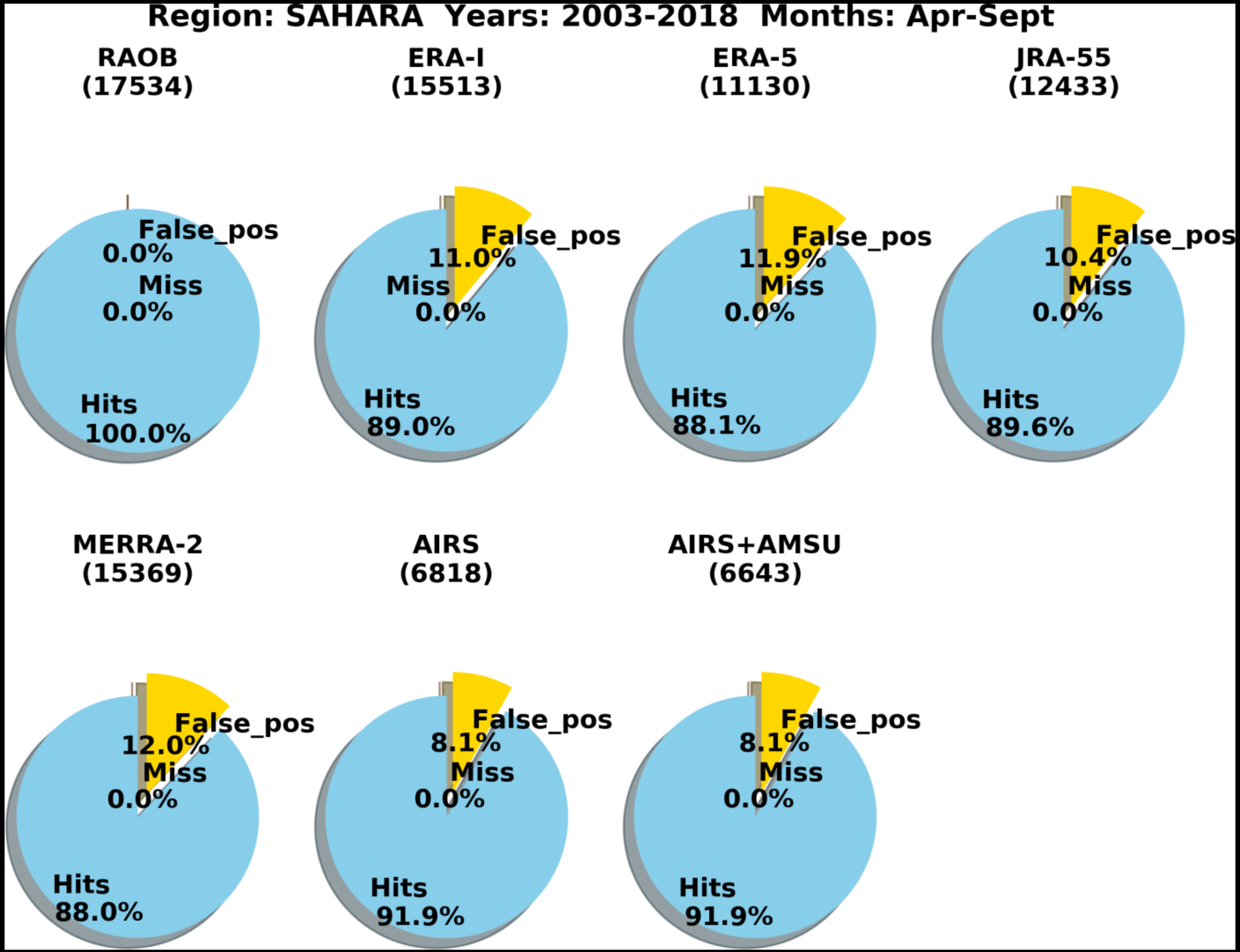
Water Vapor Mixing Ratio (g/kg)



- Slightly cooler, wetter shift matched by all data sources
- WML layers thinner than north of Sahara due to interference from WAM layer

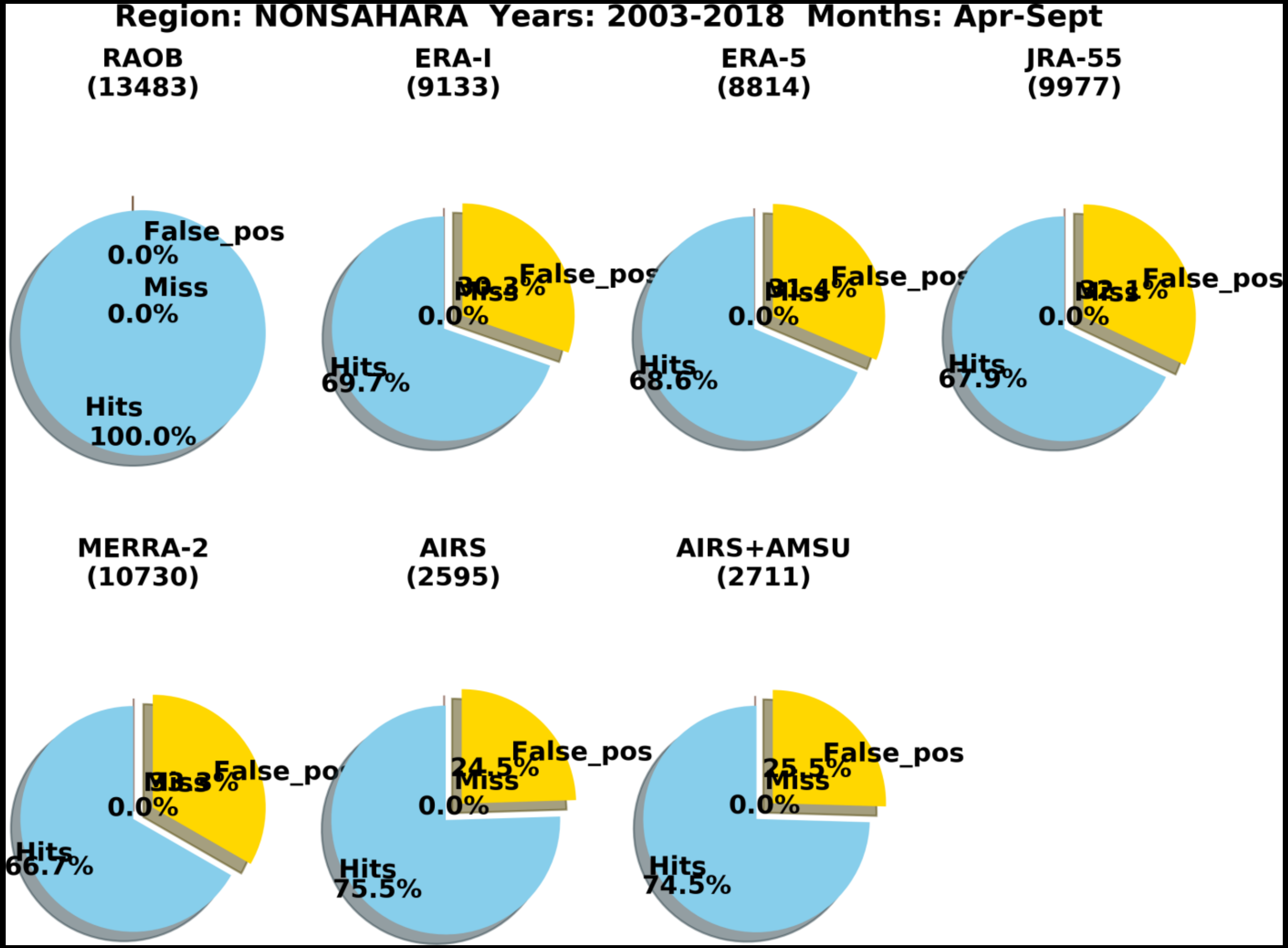
WML Detection Accuracy Analysis (1): Saharan

- Pie chart:
  - a) Hit = WML in RAOB and data source
  - B) False positive = WML in data, but not in RAOB
- AIRS-derived WMLs have up to 3.8% fewer false positives vs model analysis (ERA-5)
- However lower raw data resolution of AIRS leads to only a 30% of RAOB WMLs being detected
- All reanalysis products have similar WML detection statistics



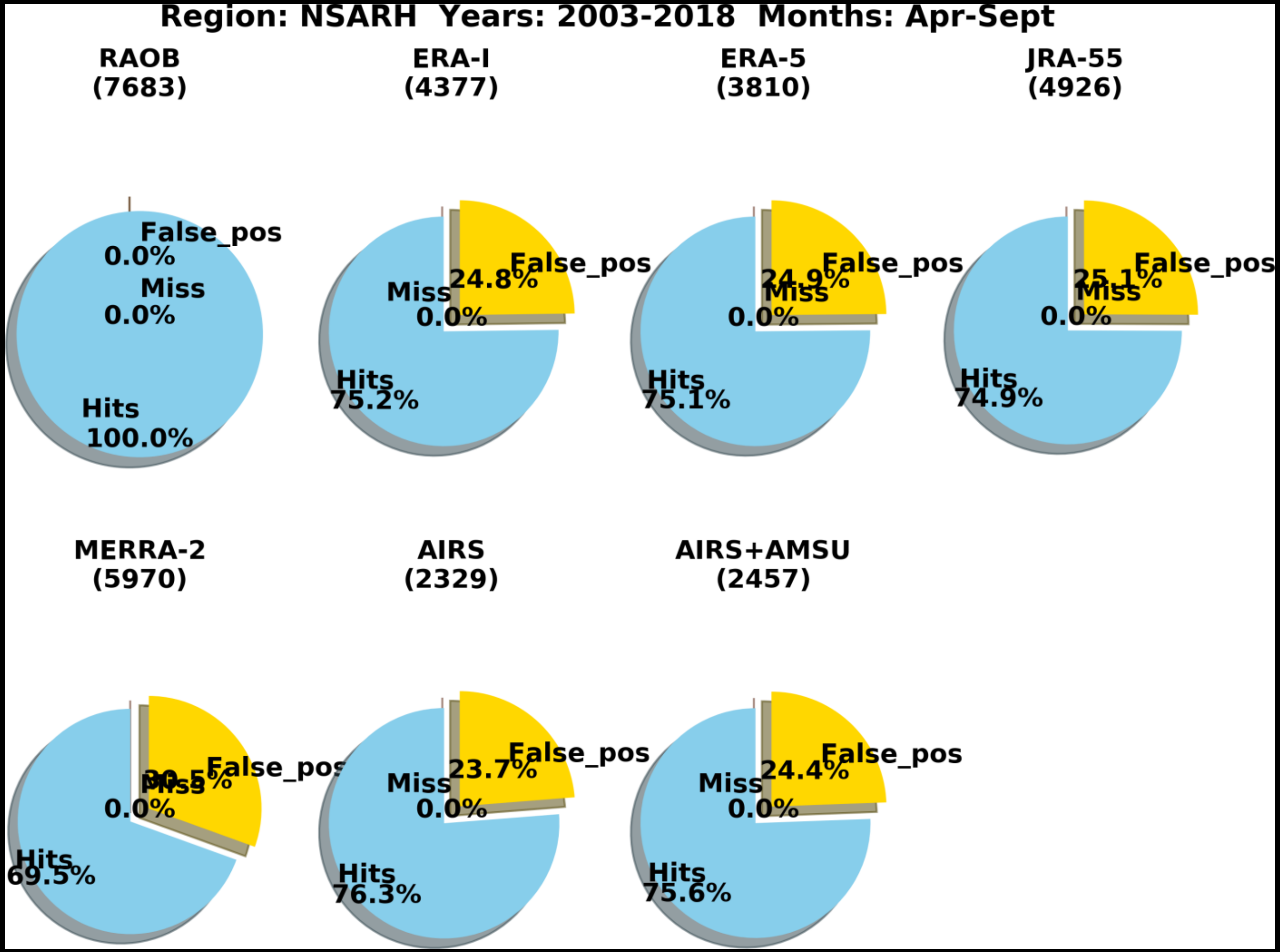
WML Detection Accuracy Analysis (2): Non-Saharan

- Pie chart:
  - a) Hit = WML in RAOB and data source
  - B) False positive = WML in data, but not in RAOB
- Sharp increase (up to 19.5%) in false positives: WMLs thinner
- Similar to Saharan locations, AIRS more accurate than reanalysis, but 75% fewer detections
- Models statistics exhibits similar WML detections statistical characteristics



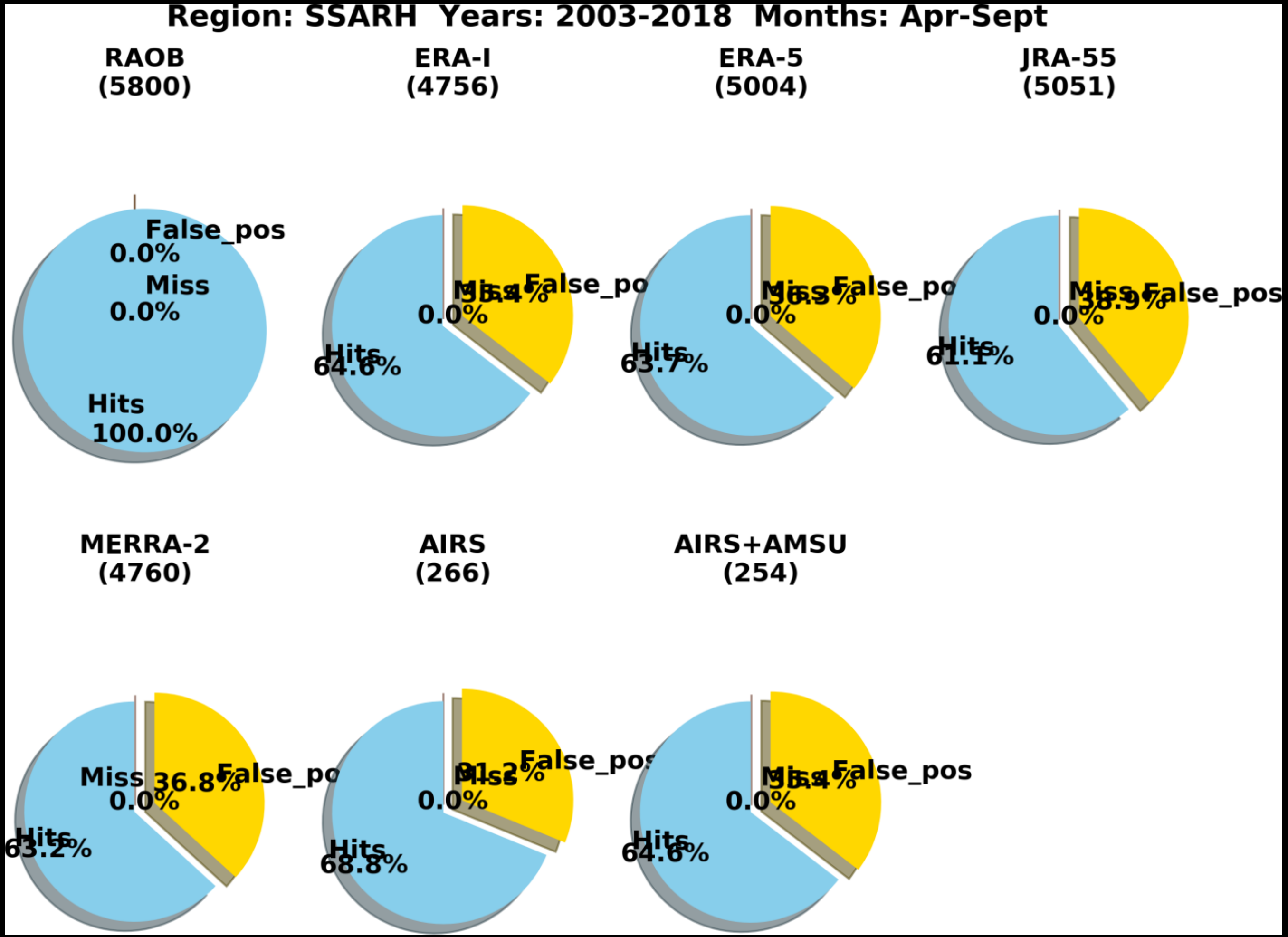
WML Detection Accuracy Analysis (3): N. Non-Saharan

- Pie chart:
  - a) Hit = WML in RAOB and data source
  - B) False positive = WML in data, but not in RAOB
- Slightly more accurate statistics than overall non-Saharan cases



WML Detection Accuracy Analysis (4): S. Non-Saharan

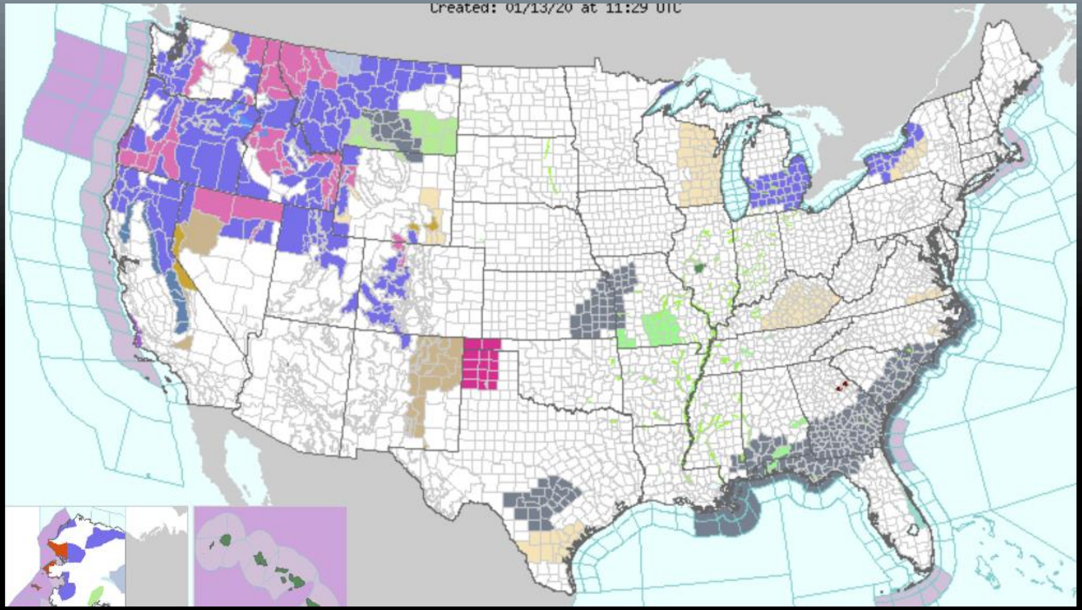
- Pie chart:
  - a) Hit = WML in RAOB and data source
  - B) False positive = WML in data, but not in RAOB
- Interference in monsoon layer challenges the models, but especially AIRS.
- AIRS profiles can not correct fast enough to resolve all, but the thickest WMLs



Summary

- Evaluated WML detection potential given porous radiosonde network (2003–2018)
- Revised WML detection algorithm and applied to RAOB, 4 reanalysis products (JRA-55, ERA-I, ERA-5, MERRA-2) and 2 AIRS products
- Regional WML data products show WML vertical is dependent upon model vertical resolution (up to 2 km difference)
- ROAB-matched WMLs from model reanalysis and AIRS roughly capture interquartile ranges (temp, mix ratio, thickness)
- Model reanalysis products are able to capture a similar number of WMLs are ROABs, but suffers from a higher false positive rate than AIRS products
- Greatest WML detection issues lie south of Sahara where Saharan-like WMLs are typically thinner and monsoon interference

Where is the snow?



Boston, MA (4 January 2018)

Thank you for your time!!!!

Any questions for me?

Contact: stephen.d.nicholls@nasa.gov