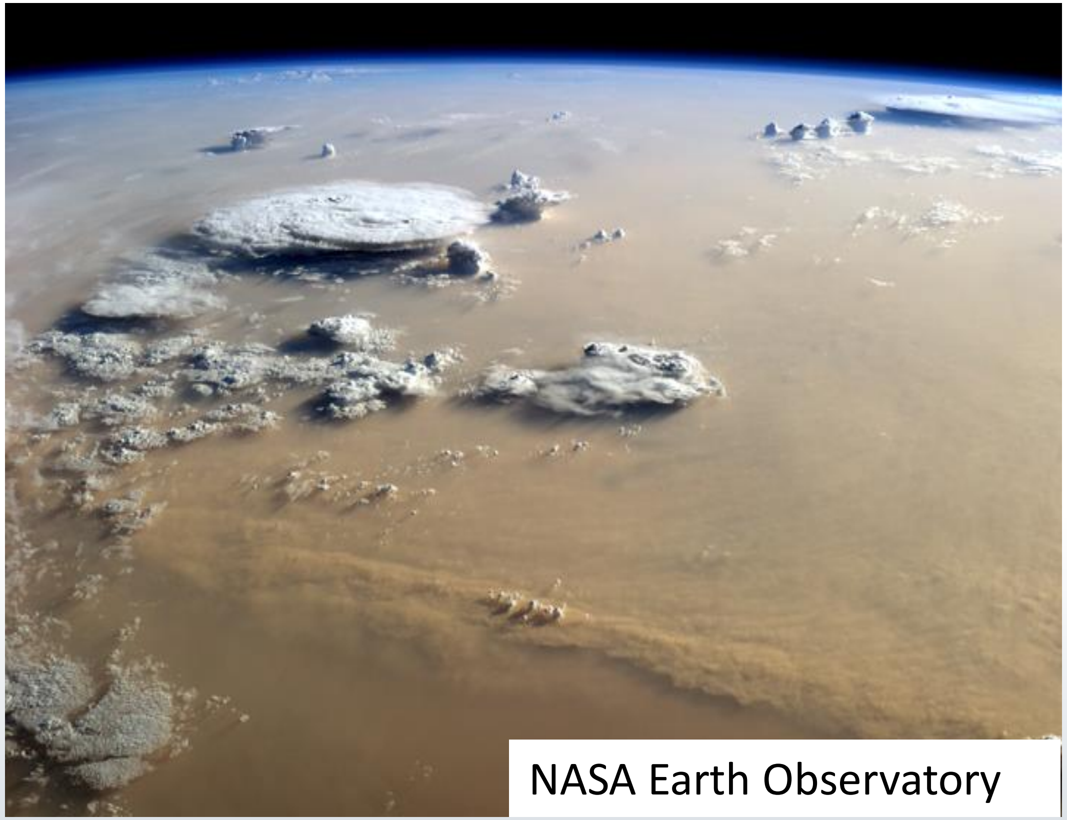
An IR Sounding-Based Analysis of the Saharan Air Layer in North Africa

10A.1


NASA Earth Observatory

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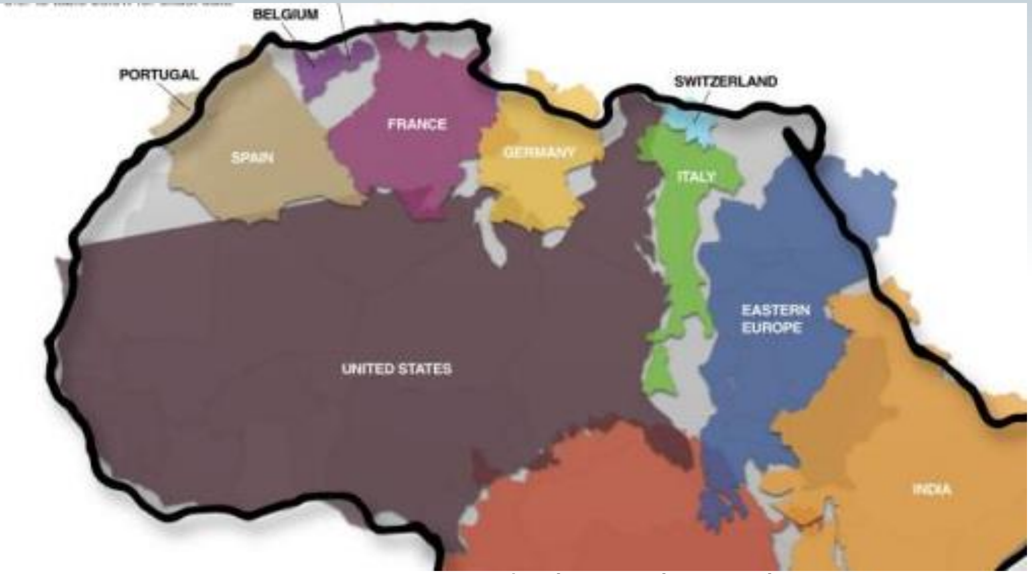
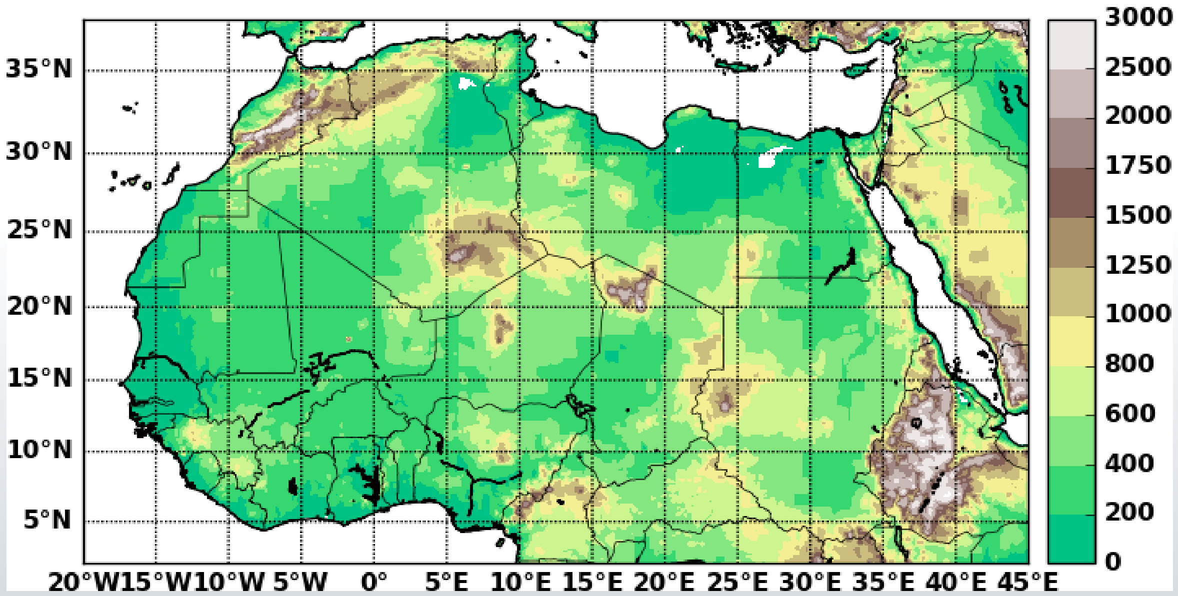
31st Conference on Climate Variability and Change (10 January 2018)

North Africa's Complex 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

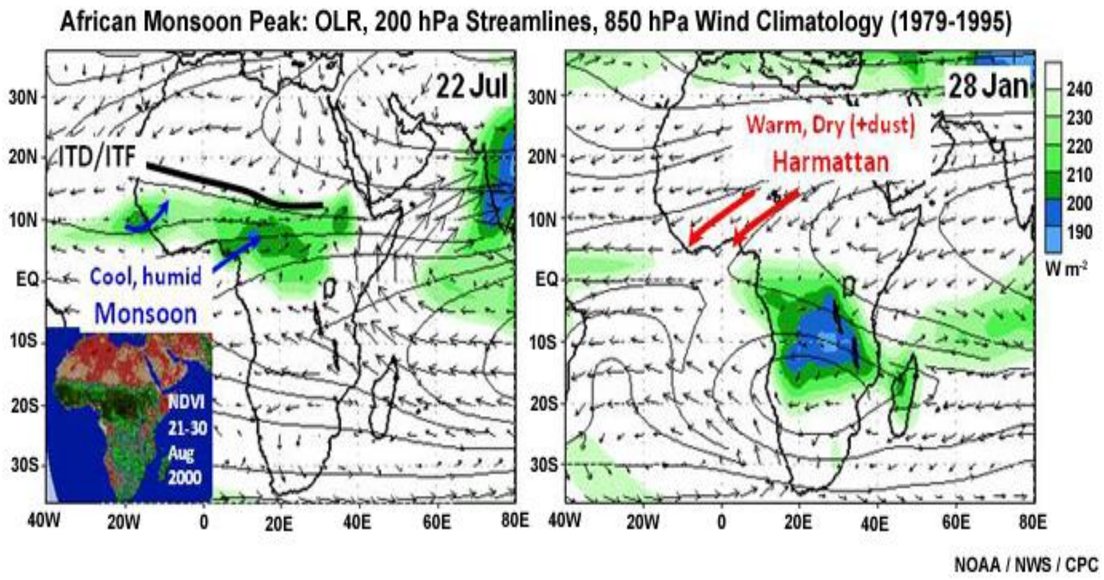


Messager et al. 2009

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)

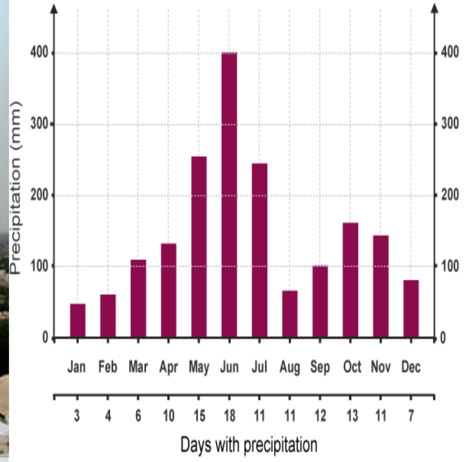
West African Monsoon



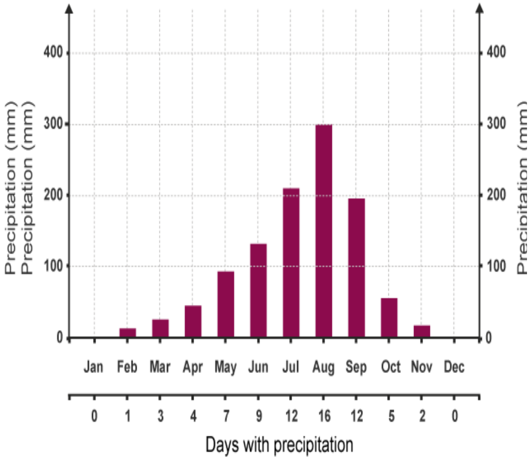
Dust Aerosols

Seasonal Precipitation

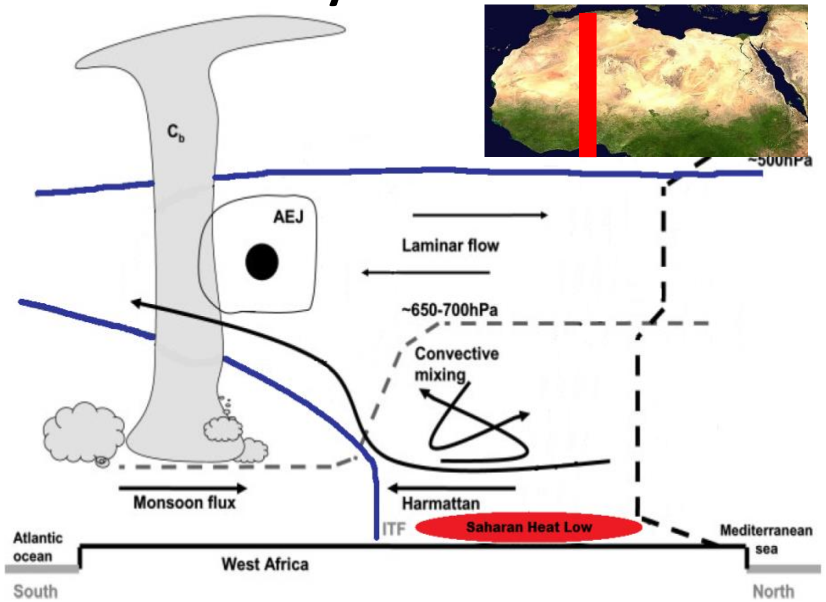
Abidjan, Ghana



Bamako, Mali



Climate System Overview



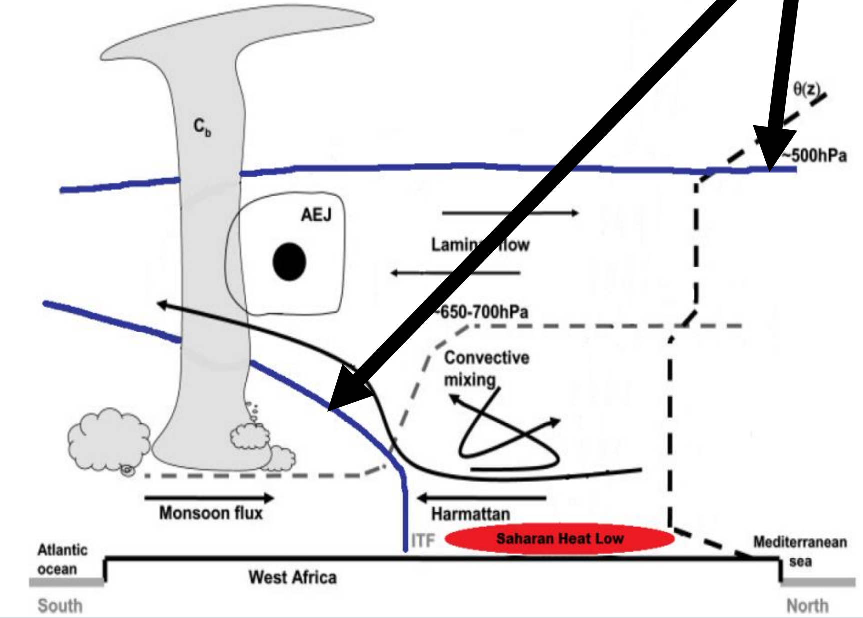
Saharan Air Layer

Well-mixed layer of warm, dry, and potentially dusty air of nearly constant water vapor mixing ratio generated by the intense surface heating and strong, dry convection in the Sahara Desert

M'bourou et al. 1997; Karyampudi et al. 1999

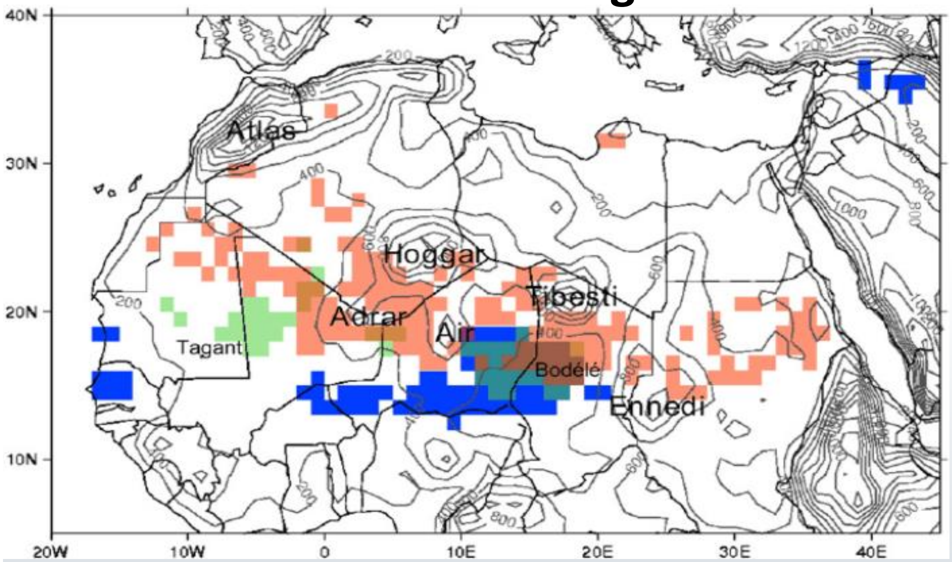
- Impacts to moist convection (Land and ocean)
  - Direct: Scatter solar radiation
  - Indirect: Act as cloud condensation nuclei
- Field campaigns: HS3, CLARINET, AEROROSE, AERONET, etc.

SAL within Climate System



(Messager et al. 2009)

Dust Source Regions



Dust source regions, Schepanski et al. (2012), Remote Sensing of Environment

Dust Transport in SAL

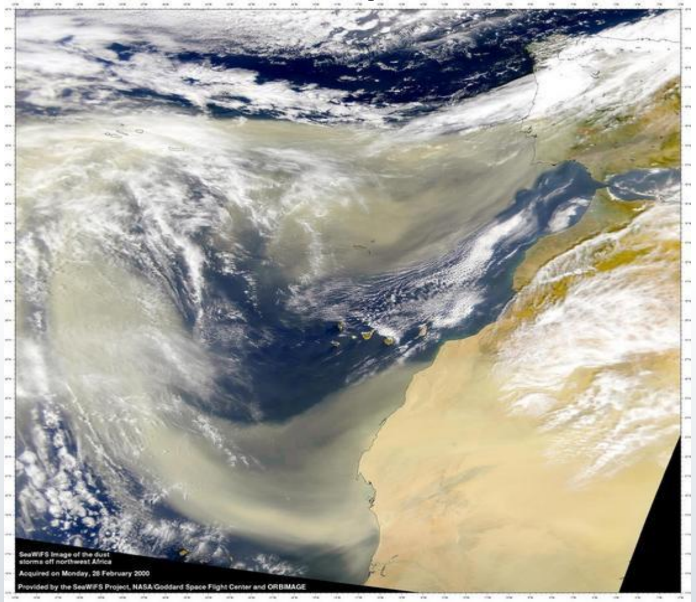


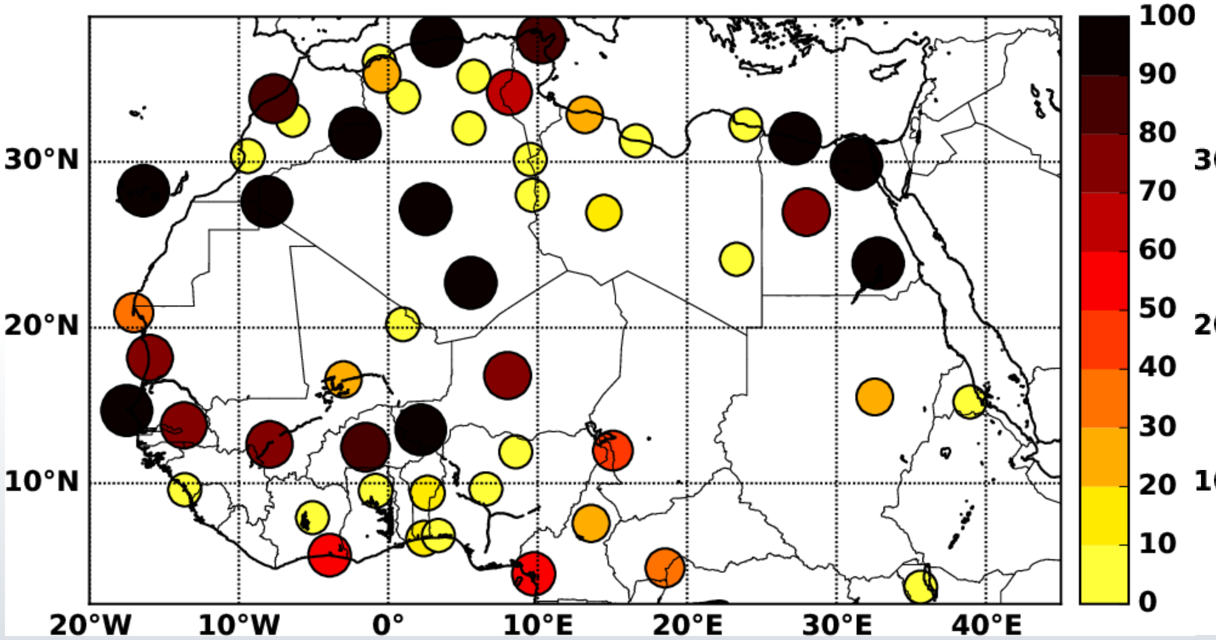
Image from SeaWIFS, NASA GSFC

So what I am researching?

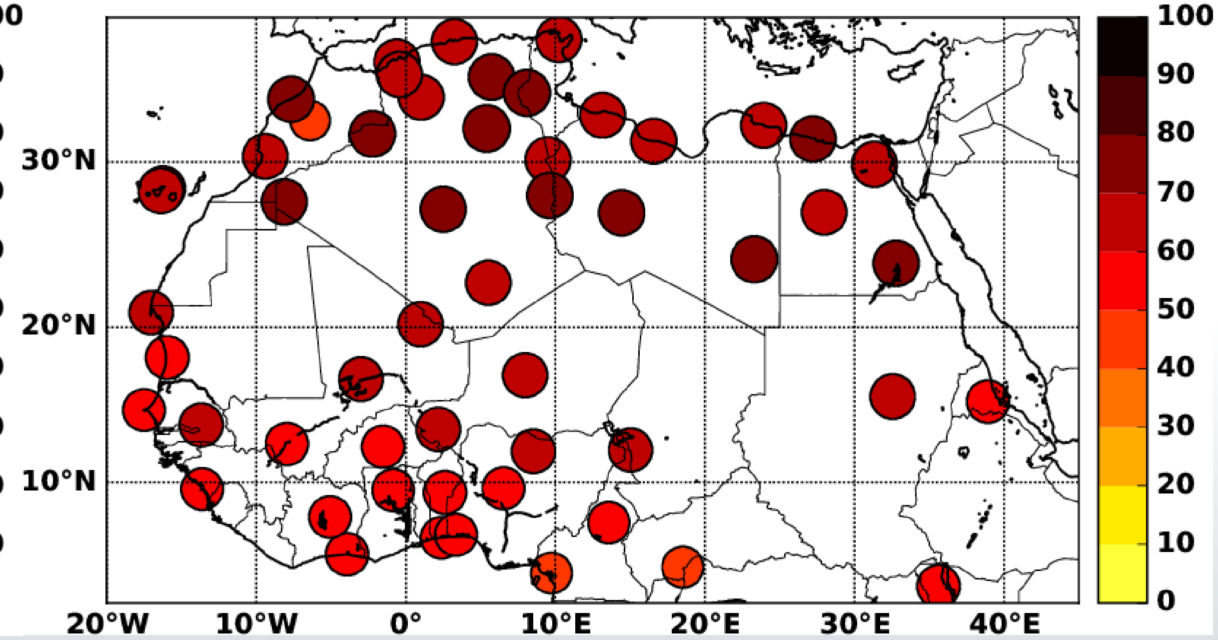
- **Hypothesis:** NASA's Atmosphere Infrared Sounder (AIRS) can detect well-mixed layers (WML's) and SAL's
- **Gain:** Detection of SAL's from space with regional coverage, consistent dataset quality

- 14.5 year period (09/2002-04/2016), 55 Stations. 1 time per day (AOD)
- Data: Rawinsonde (RAOB), ECMWF interim, MERRA-2, AIRS and AIRS+AMSU V6

Weather Balloon (Rawinsonde) Frequency

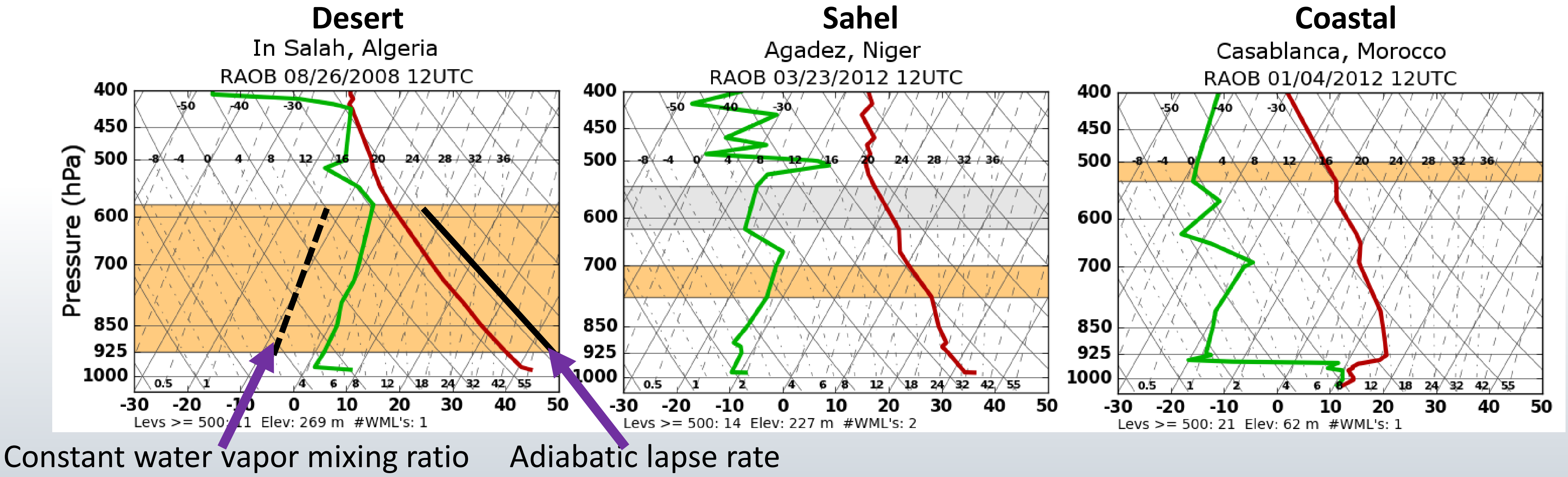


AIRS Data Frequency at Rawinsonde Stations



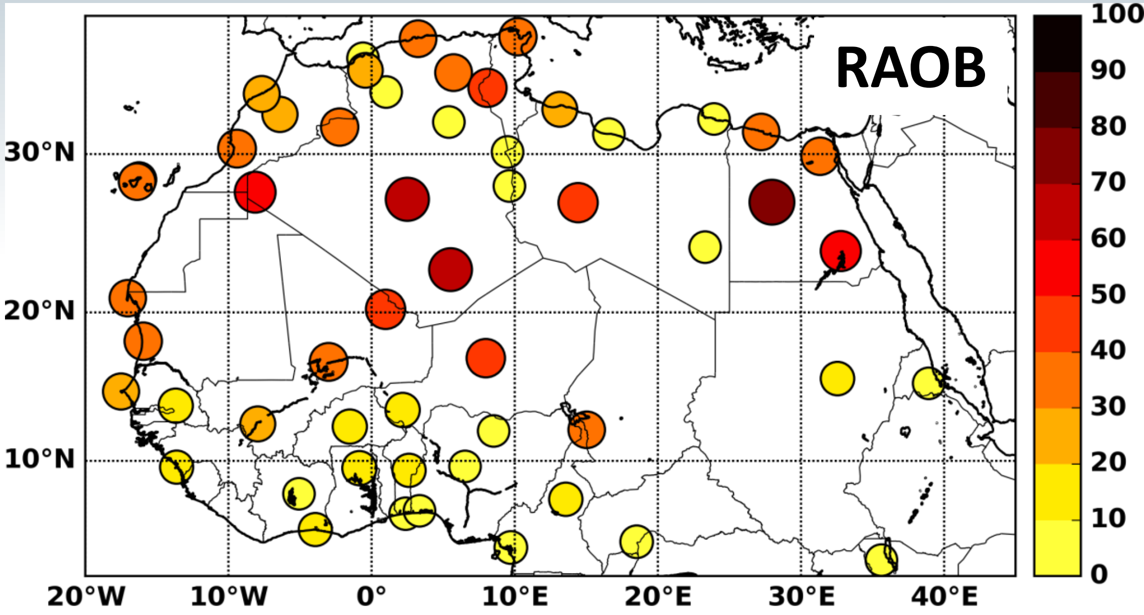
Well-mixed Layer Detection Algorithm

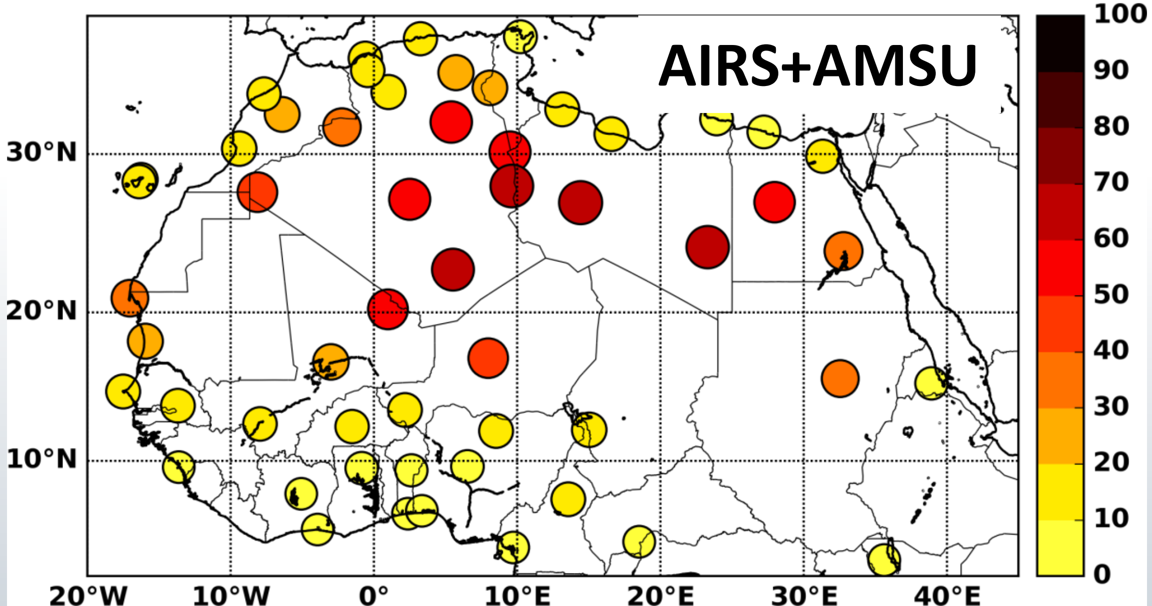
- Search for well-mixed layers (WMLs) that could be SALs
- Searches for nearly adiabatic temperature lapse rates with near constant water vapor mixing ratio (≤ 7 g/kg).
- Start surface through 500 hPa, **each color = new WML**
- Continuous WML if temperature and water vapor properties are roughly conserved, otherwise not a WML or a new WML

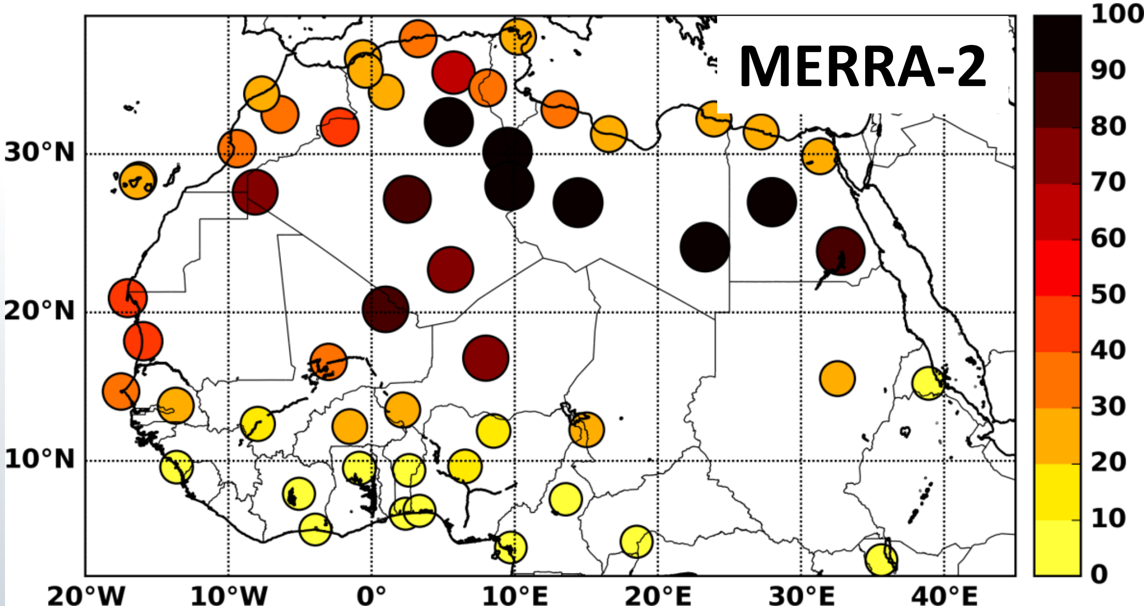


WML Frequency (All)

- Entire data period (2002-2016)
- Highest in Sahara, lowest at Guinea Coast
- ECMWF & MERRA2 excessively frequent
- AIRS well-matched to rawinsondes
- Potent seasonal cycle (generally highest summer, lowest winter)







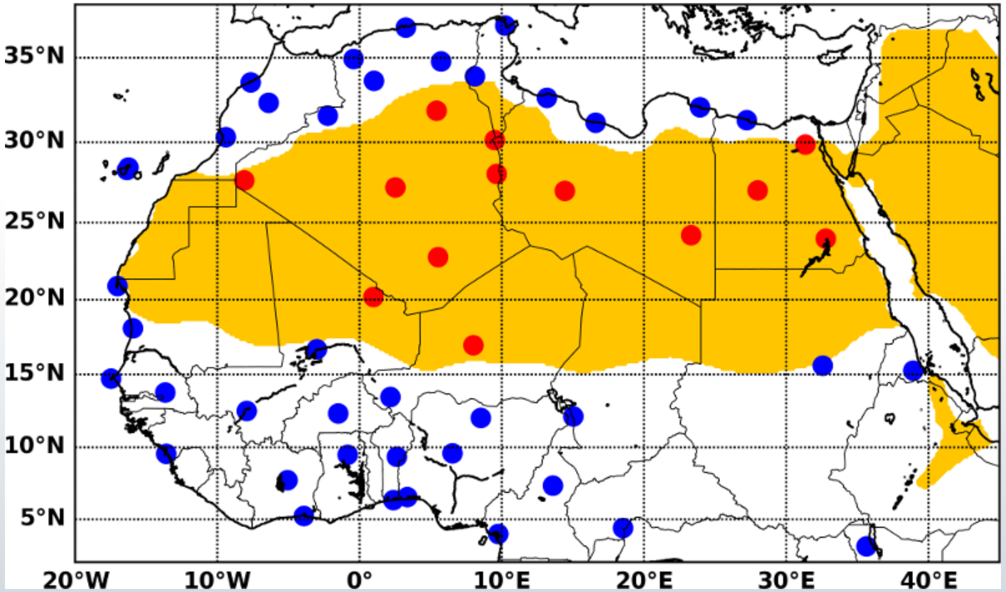
Categorizing SALs from WMLs with HySPLIT (1)

- Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)
- ECMWF Interim Analysis-based, 120 hours (5-day) backwards trajectories
- MERRA-2-based analysis in progress!!
- Track parcels every 200 m in WML

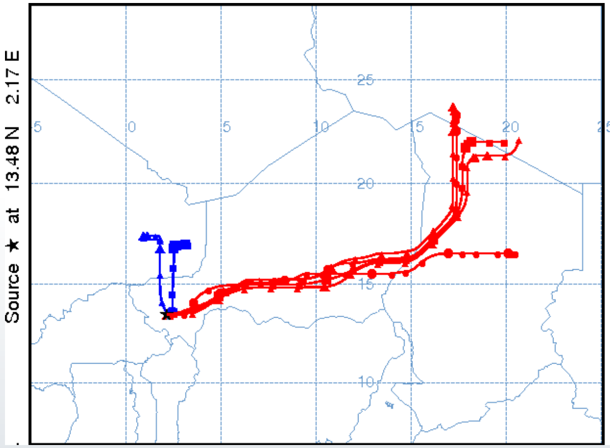
SAL Classification Rules

- 1) Individual trajectory is Saharan:
    - - 2 consecutive days in Sahara
    - - 24 hours in Sahara within 72 hours of detection
- 2) WML is SAL: >50% trajectories are Saharan

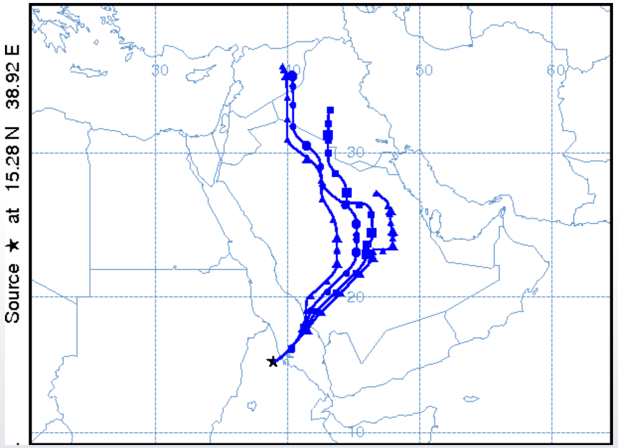
Saharan vs non-Saharan Locations



Niamey, Niger 9 June 2009



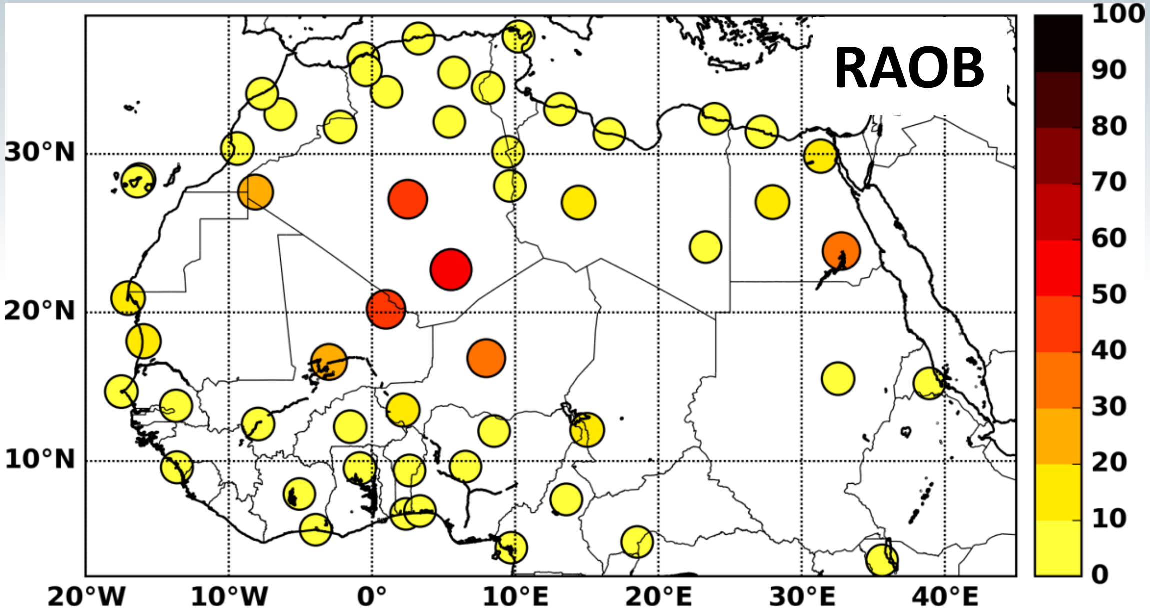
Asmara, Eritrea 9 June 2009

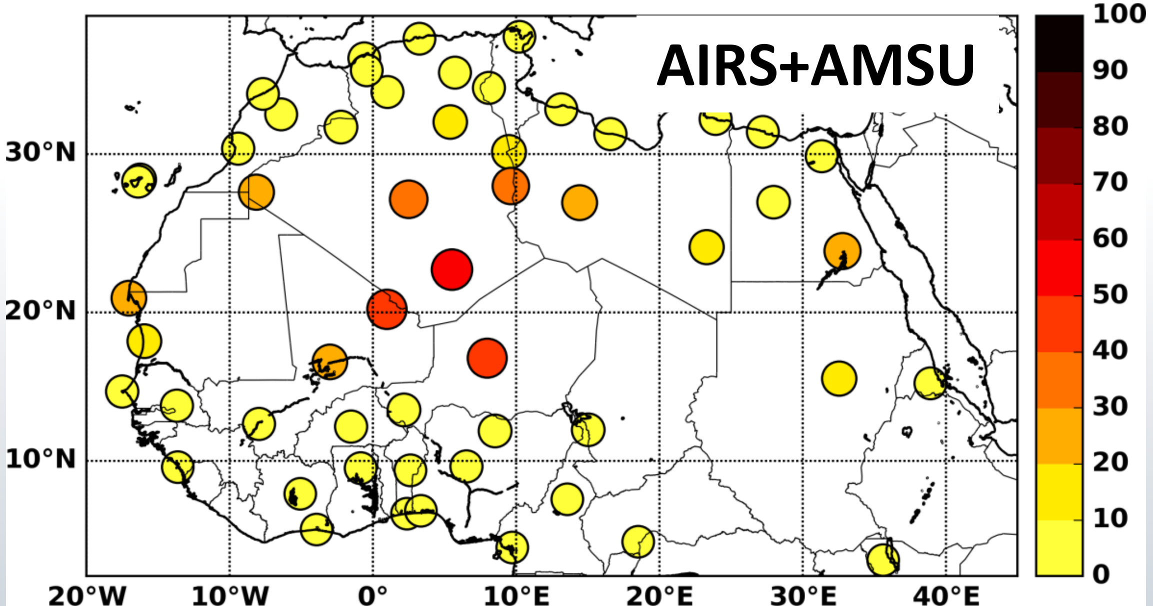


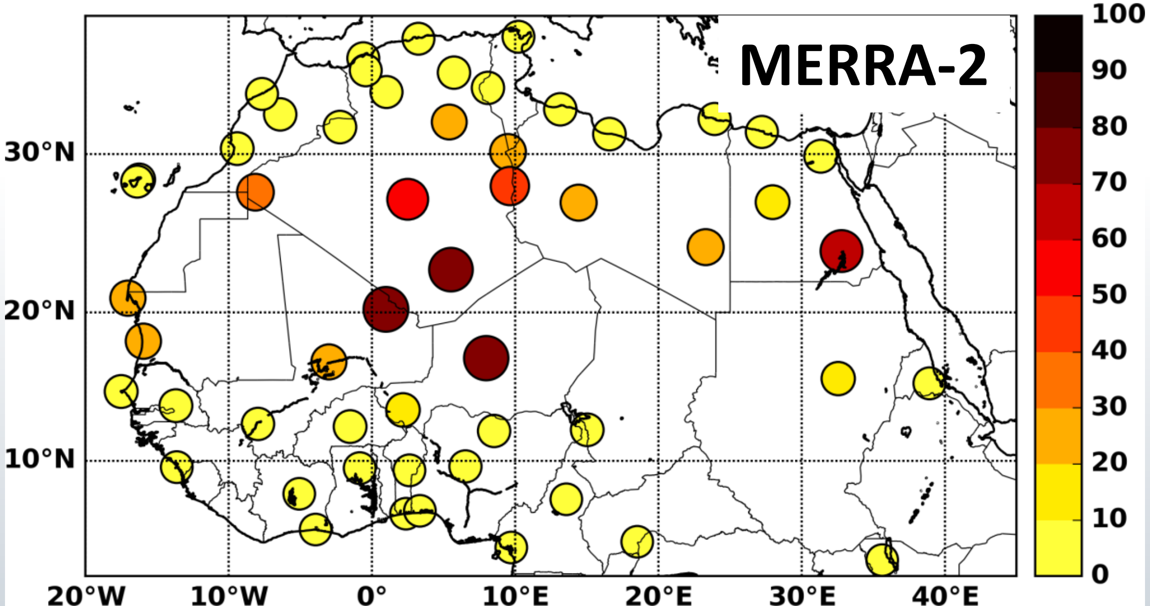
Saharan trajectories (red), non-Saharan trajectories (blue)

SAL Frequency (All)

- 09/2002 – 04-2006
- Plots show SAL frequency if WML detected
- Note: Not relative to total observations
- Higher in analysis, close match to obs
- Most detection in SAL, few otherwise
- Seasonality



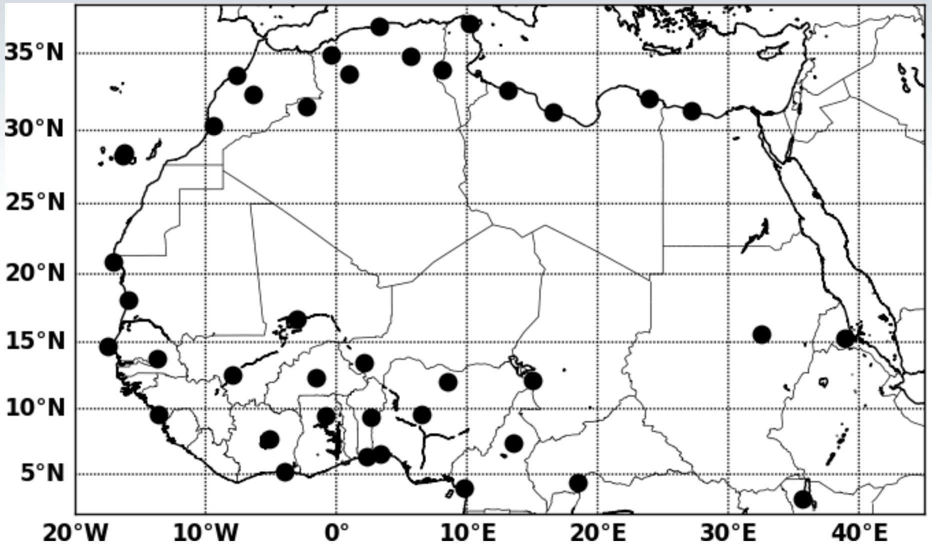




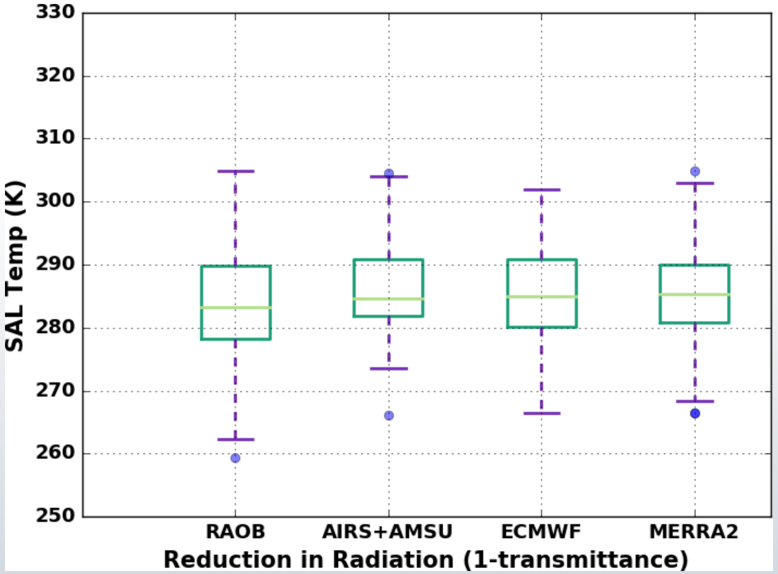
Saharan Air Layer analysis (1): Non-Saharan

- SAL Properties
    - Slight warm bias, all data sources
    - Moist bias AIRS+AMSU
    - Thickness variance underrepresented (Esp. MERRA2)
    - 300 m detection threshold

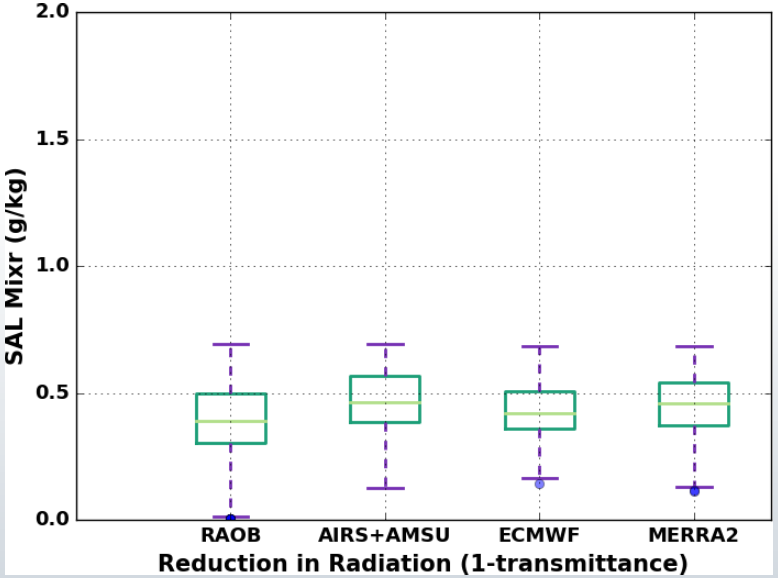
Non-Saharan Station Locations



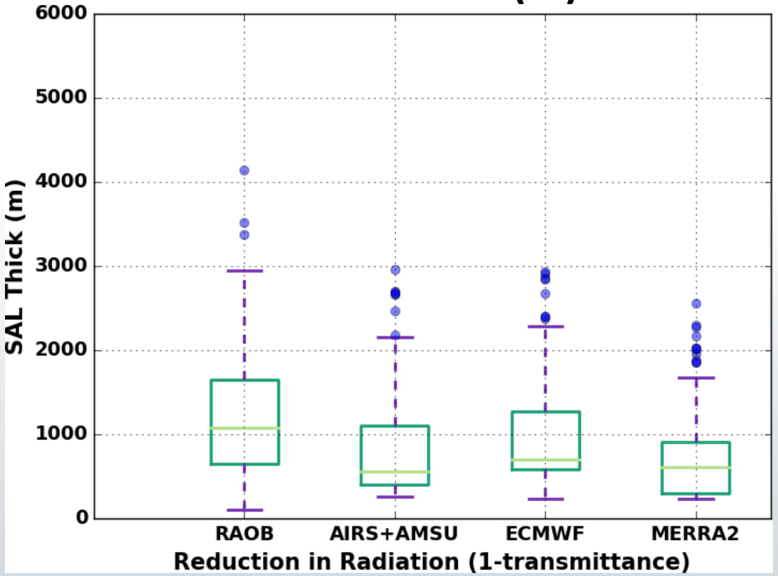
SAL Temperature (K)



SAL Mixing Ratio (g/kg)



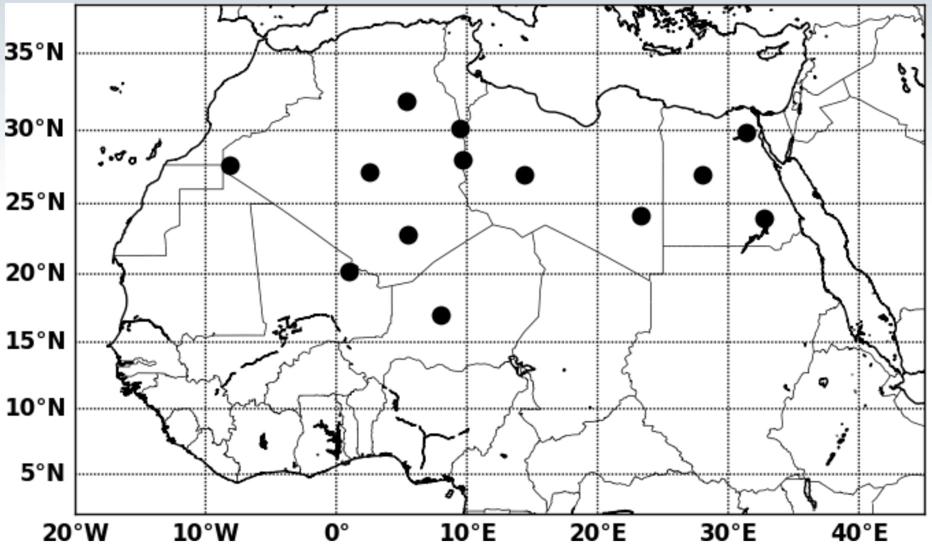
SAL Thickness (m)



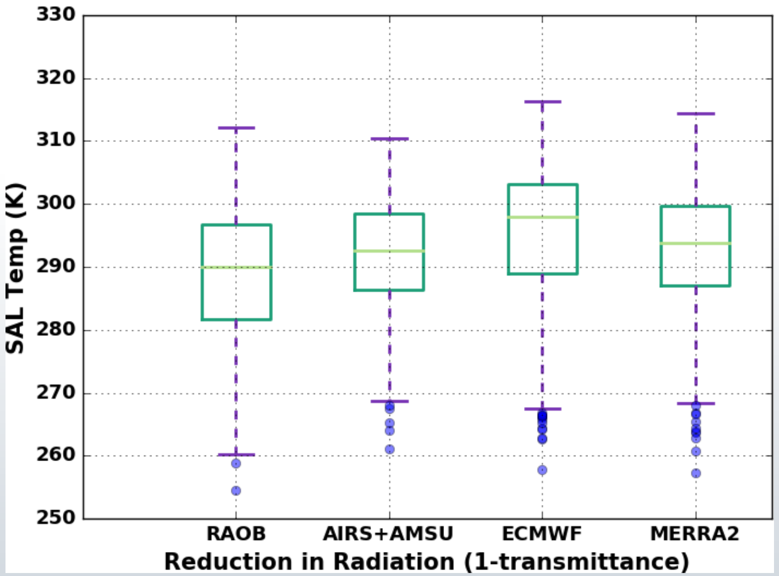
Saharan Air Layer analysis (2): Saharan

- SAL Properties
  - SAL's warmer, drier, thicker than non-Sahara
  - Distinct warm bias (Esp. ECMWF)
  - Slight moist bias
  - Thickness range decently represented
    - IQR too small in AIRS
    - Model Analysis SAL thickness (Esp. ECMWF)

Saharan Station Locations



SAL Temperature (K)



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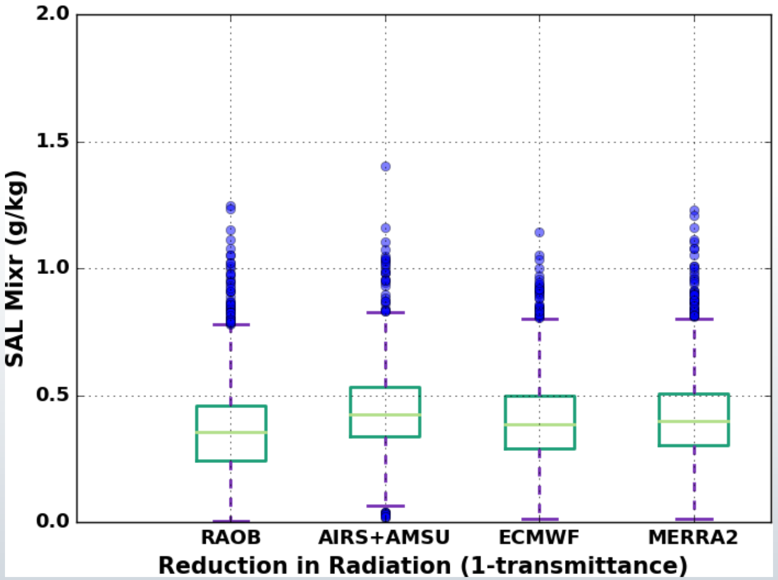
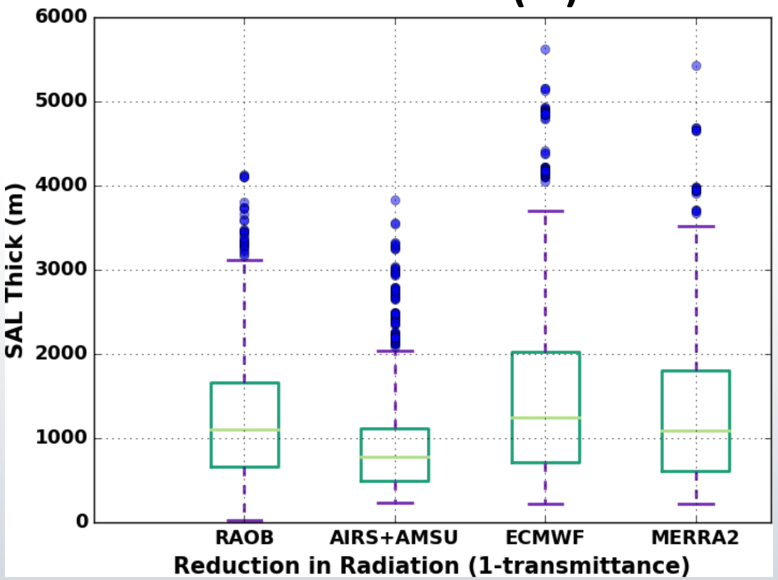
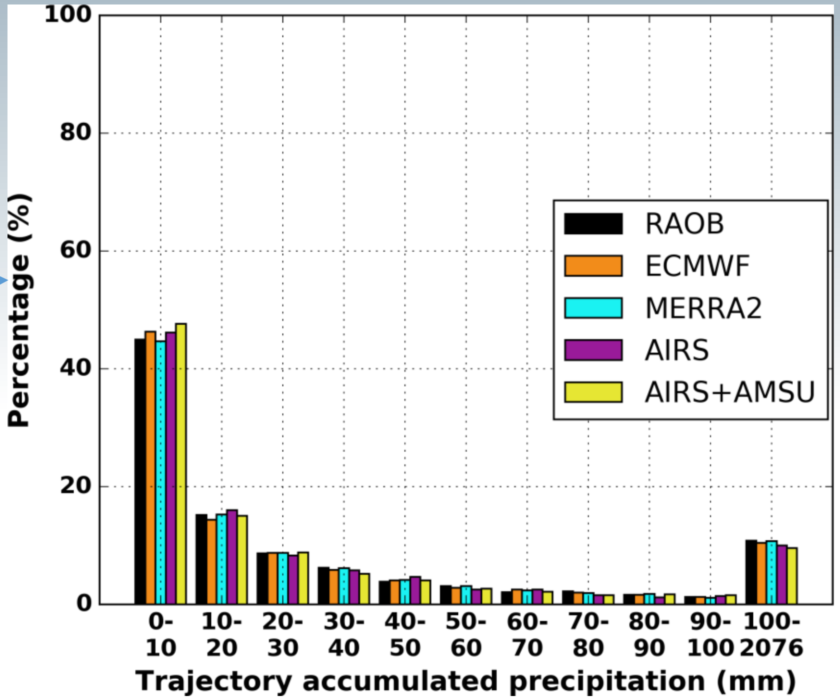


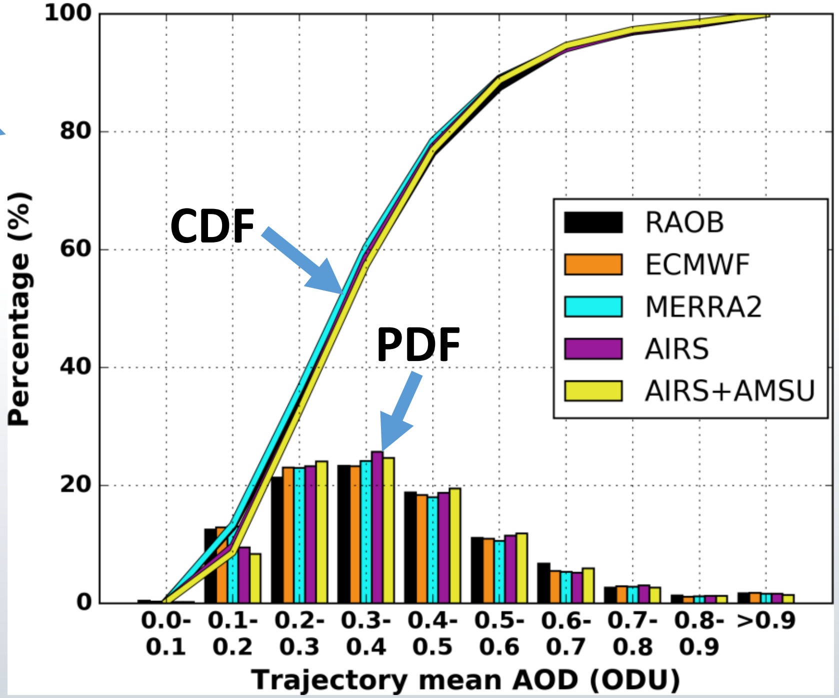
SAL Thickness (m)



Dust and Precip (1) – Non-Sahara

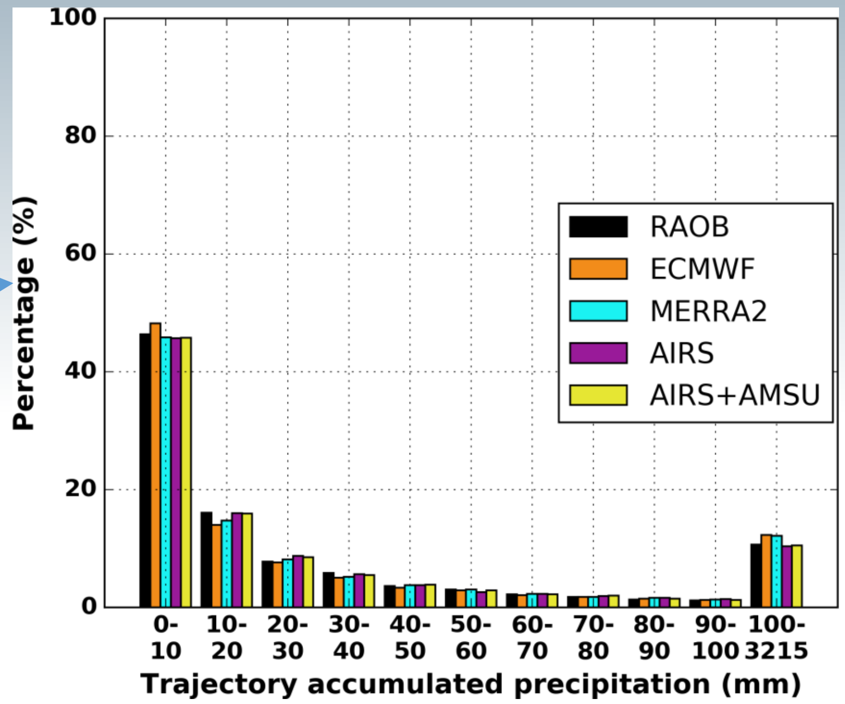
- 09/2002 – 04/2016 (42 Stations)
- Precipitation – PDF
  - Slight increase in mid-range precip (1-2%)
  - Decrease at tails (AEW tracks)
  - 8-12% of trajectories experience 100 mm +
  - Non-Sahara (right shift), Sahara (left shift)
- Aerosol Optical Depth (AOD) – PDF/CDF
  - Notable rightward shift in PDF/CDF
  - 0.37 ODU = 75th percentile AOD North Africa
  - 85% of values less than 0.5 AOD, 40% “dusty”

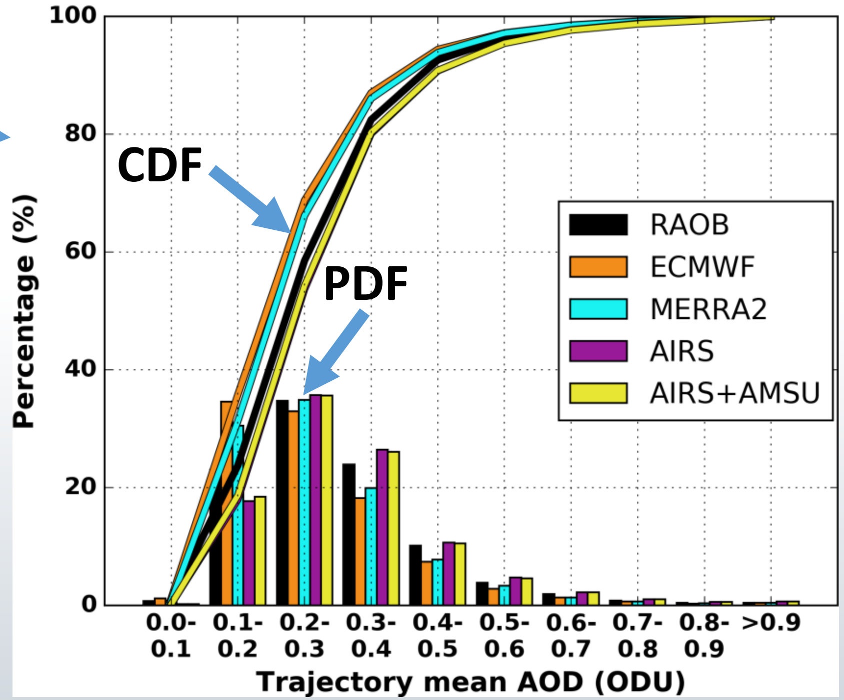




Dust and Precip (2) – Sahara

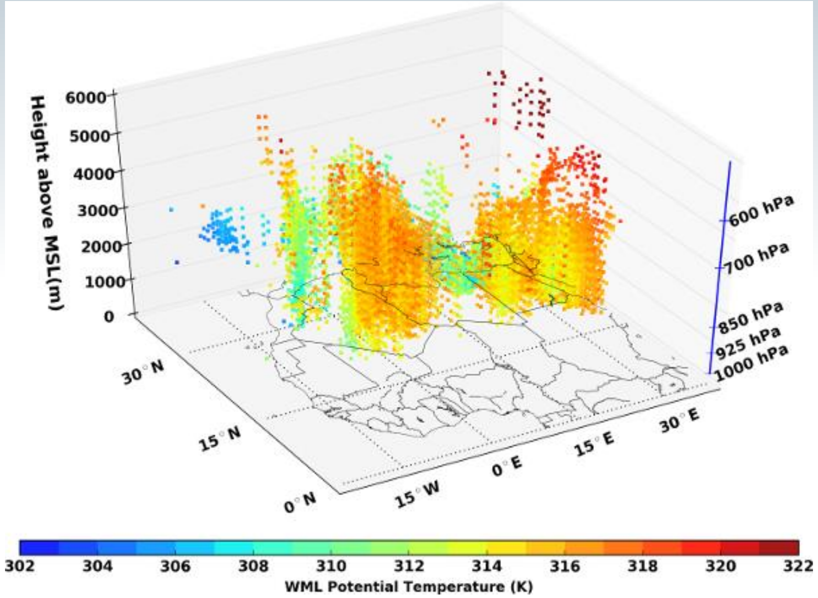
- 09/2002 – 04/2016 (13 Stations)
- Precipitation – PDF
  - Little to no change from all stations
  - Slight increase 100 mm + (up 1-3%)
- Aerosol Optical Depth (AOD) – PDF/CDF
  - Leftward shift of AOD values
  - 0.25 ODU = 75th percentile AOD North Africa
  - More than 95% of values below 0.5 AOD
  - Around 20% of trajectories "dusty"





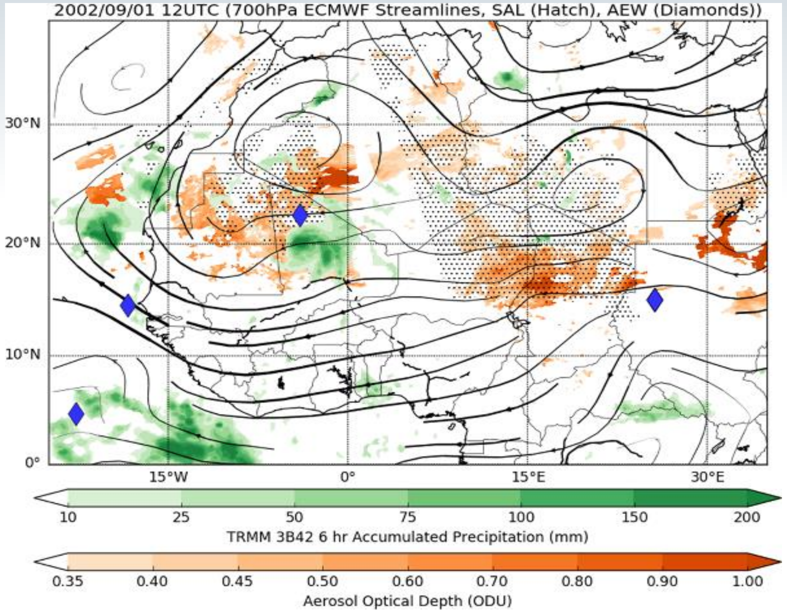
Additional Projects

Visualization of SAL from satellite/model data

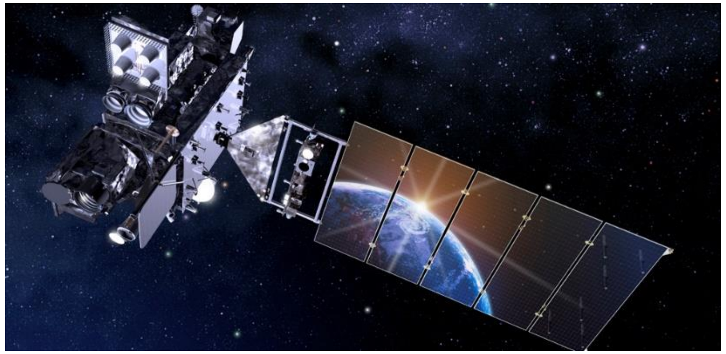


CrIS Profiles (JPSS & Soumi-NPP)

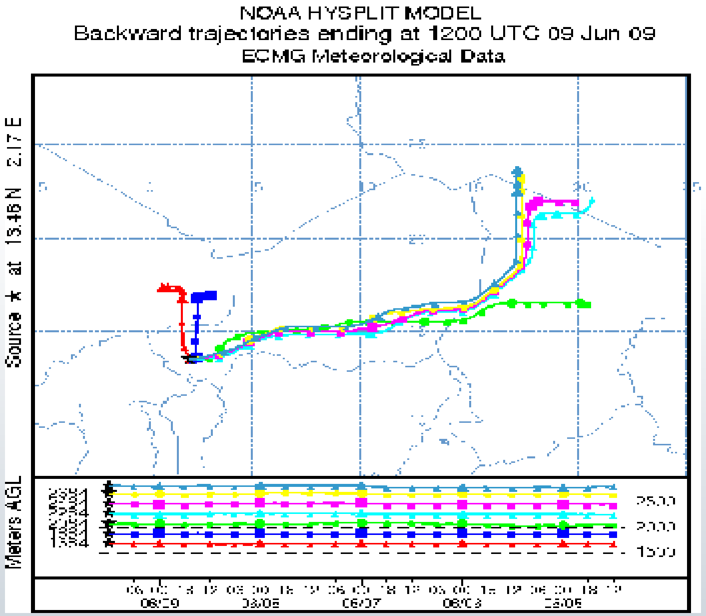
Daily climate system visualization



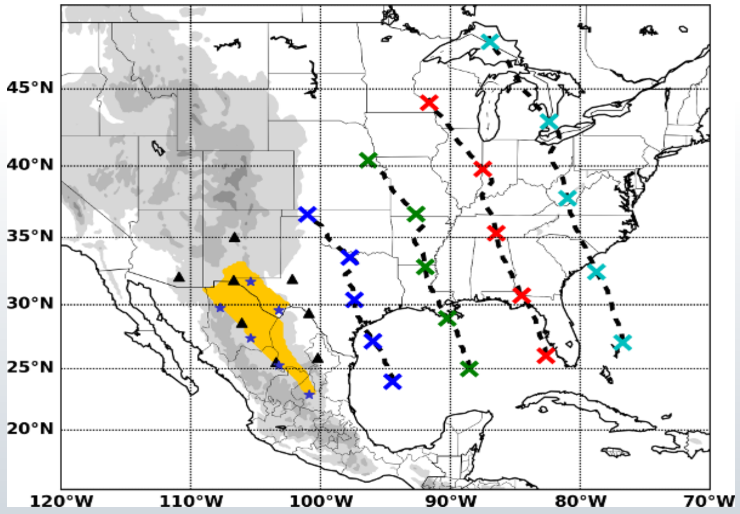
ABI Profiles & Aerosols (GOES)



MERRA-2 trajectories



Analysis of other low-latitude deserts



Cloud and Radiation Field Campaign

Summary

- Evaluated AIRS SAL detection potential given porous radiosonde network (2002–2016)
  - AIRS vs AIRS/AMSU WML detection rates within 5%
- WML: Potent seasonal cycle, best resolved by AIRS
- SAL Frequency: Well-matched to observations, WML to SAL conversion rates highest in Sahara (Max 26%)
- SAL Properties:
  - Distinct warm bias (esp. ECMWF)
  - Layer thickness well captured, but AIRS IQR too small
- SAL trajectories:
  - Precipitation: 43-47% (0-10 mm), 10-13% (100mm+)
  - Dusty air (> 0.30 ODU): Sahara – 20-22%, Non-Sahara – 40-55%
  - Caveat: AIRS likely to do better further from rawinsondes station, AIRS results lose little with loss of AMSU.

Austin, TX (undated)

Boston, MA (4 January 2018)

Thank you for your time!!!!

Questions!?!?

Contact: stephen.d.nicholls@nasa.gov

Work funded under NASA Science of Terra-Aqua Program: *NNH13ZDA001N-TERAQ*