EYES IN THE SKY: AN AQUA-BASED CHARACTERIZATION OF THE SAHARAN AIR LAYER

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MODIS/VIIRS Science Team meeting
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ORTH AFRICA'S OMPLEX CLIMATE SYSTEM (1)

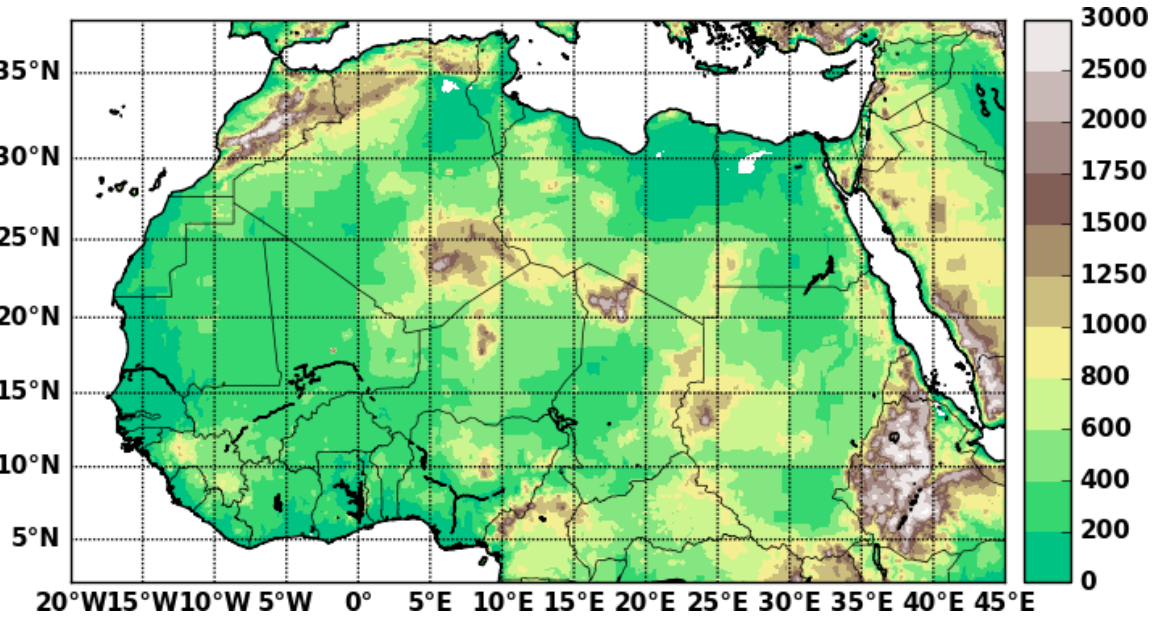
Vast piece of real estate

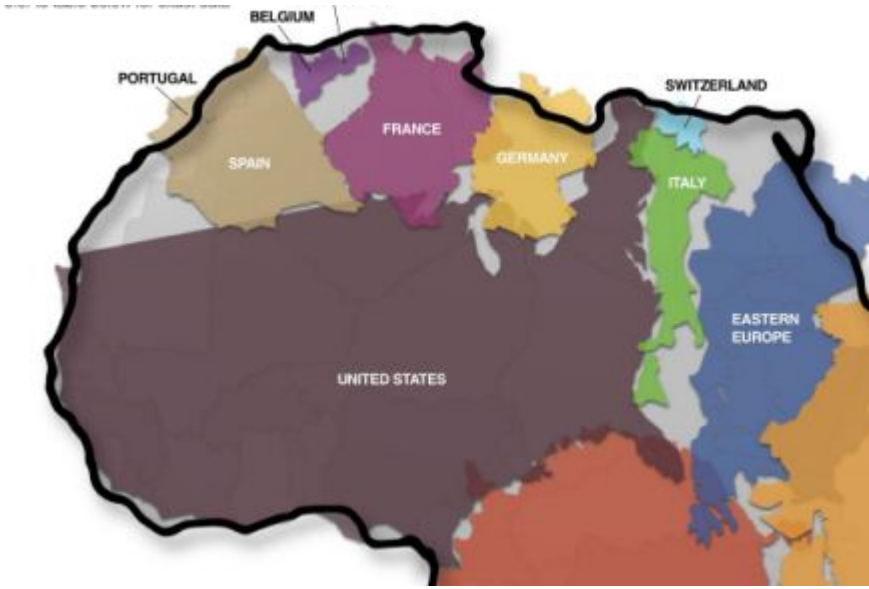
- Spans Equator to 39N, 20W to 50E

Diverse ecosystem

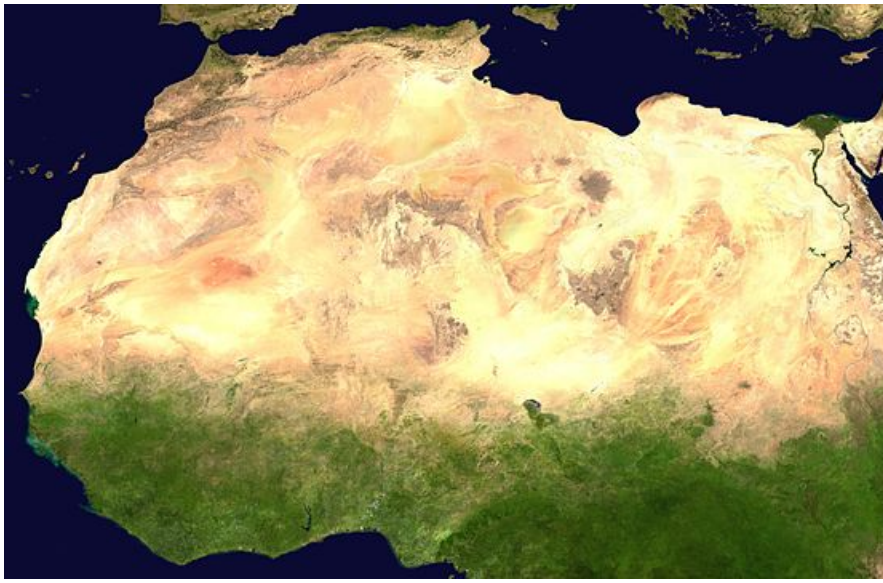
- Rainforests to savannas to Desert
- Sahara 9.4 million km^2 ~ US

Diverse topography (Sea-level to 3000m+)





Source: dailymail.co.uk



Messager et al. 2009

ORTH AFRICA'S
OMPLEX CLIMATE
SYSTEM (2)

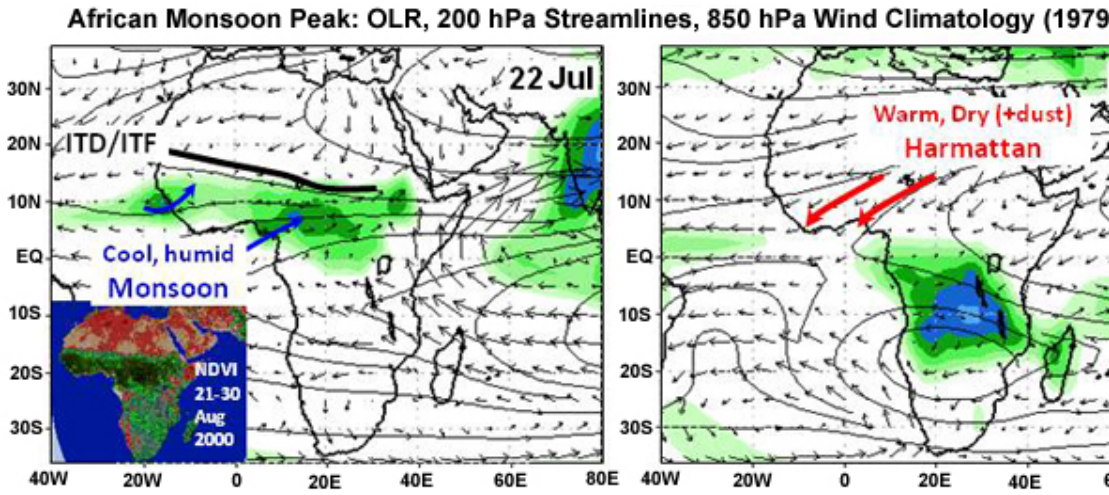
Monsoon (ITCZ)

Mid-latitude Systems

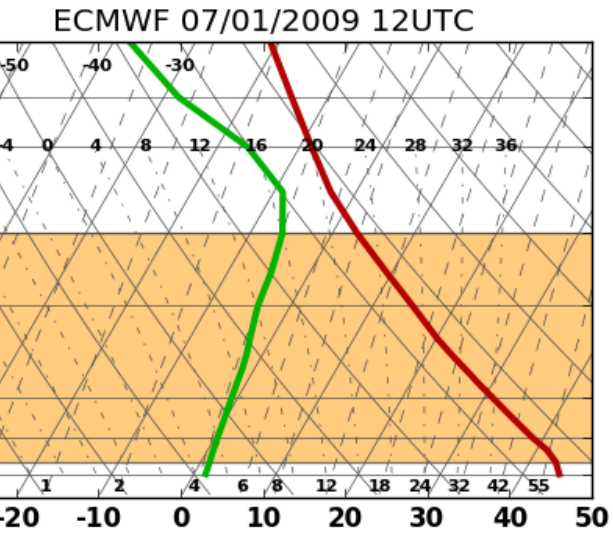
Strong Thermal Contrasts (AEJ)

Aerosol-cloud interaction

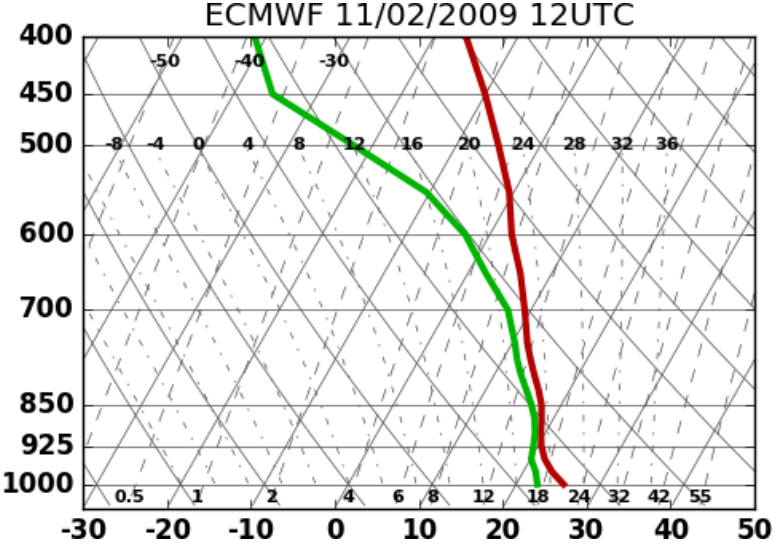
West African Monsoon



Sahara



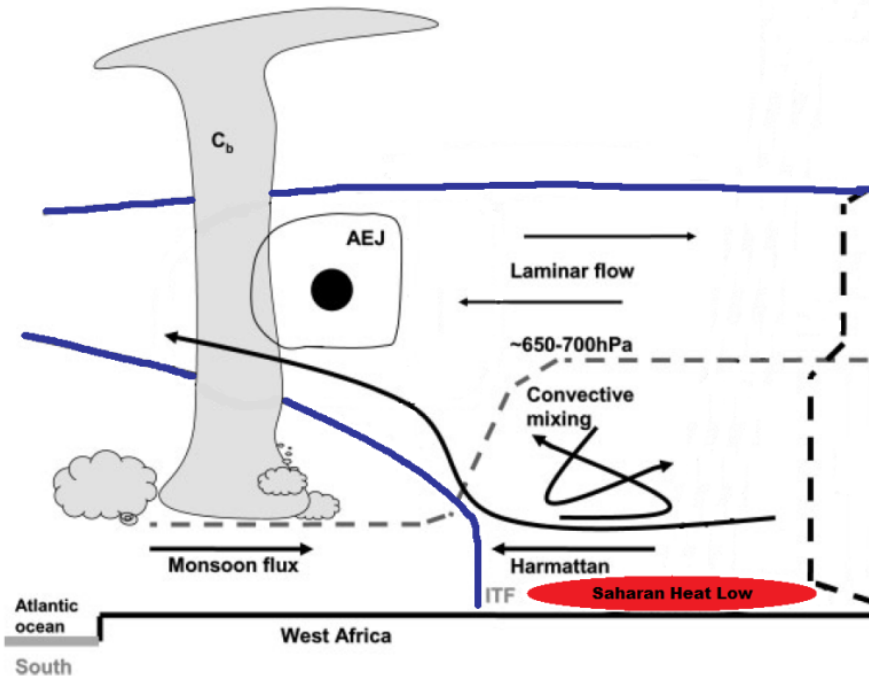
Guinea Coast



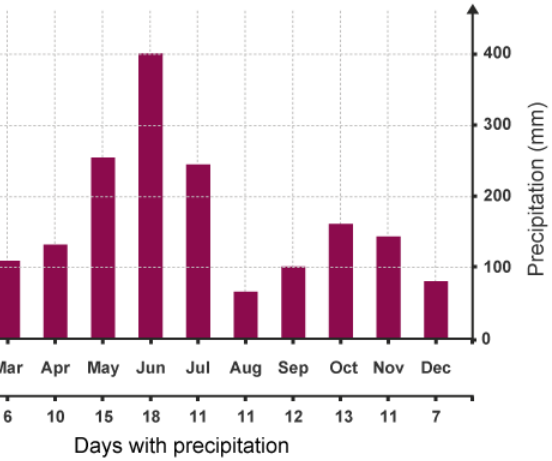
Thunderstorm in Burkina Fa

ORTH AFRICA'S OMPLEX CLIMATE SYSTEM (3)

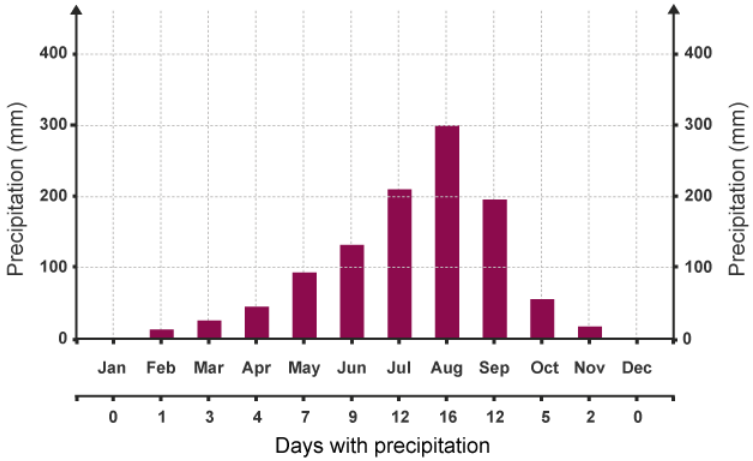
- Annual precipitation pattern characteristics
- Saharan heat low
- Saharan Air Layer (SAL) - next

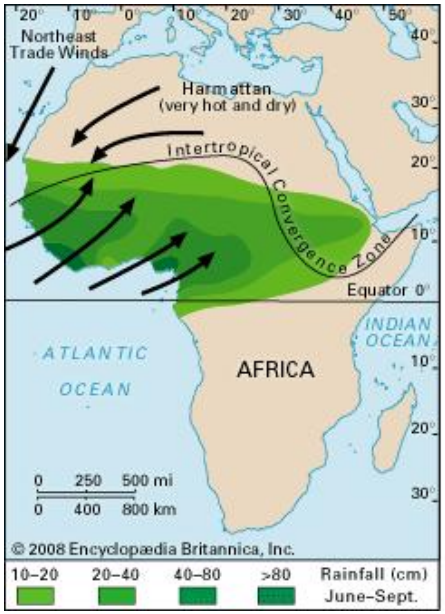


pidjan, Ghana



Bamako, Mali





AHARAN AIR LAYER (SAL)

Well-mixed layer of warm, dry, and dusty air of nearly constant 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

Influence far and wide-ranging (Spanning Africa to Americas)

Dust impact: Direct (solar rad), indirect (CCN)

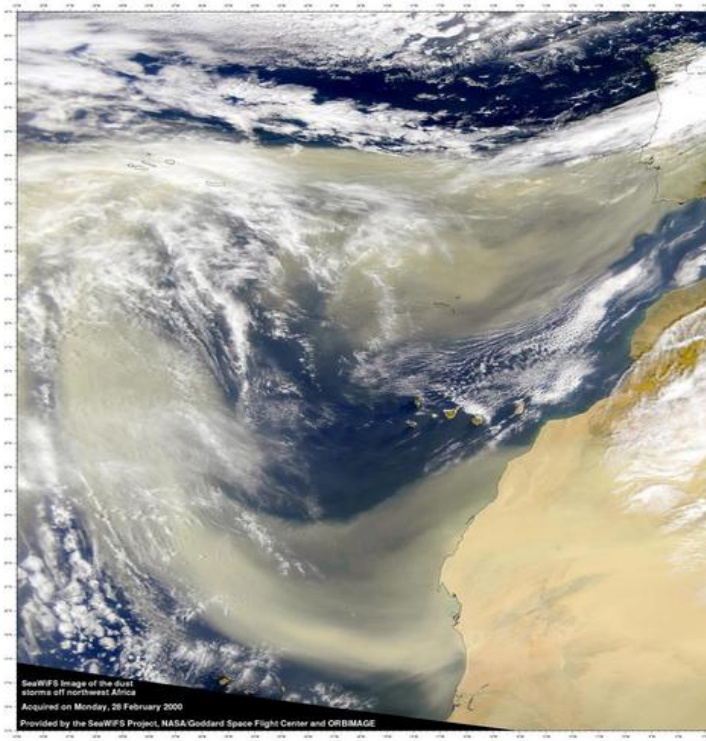


Image from SeaWIFS, NASA G

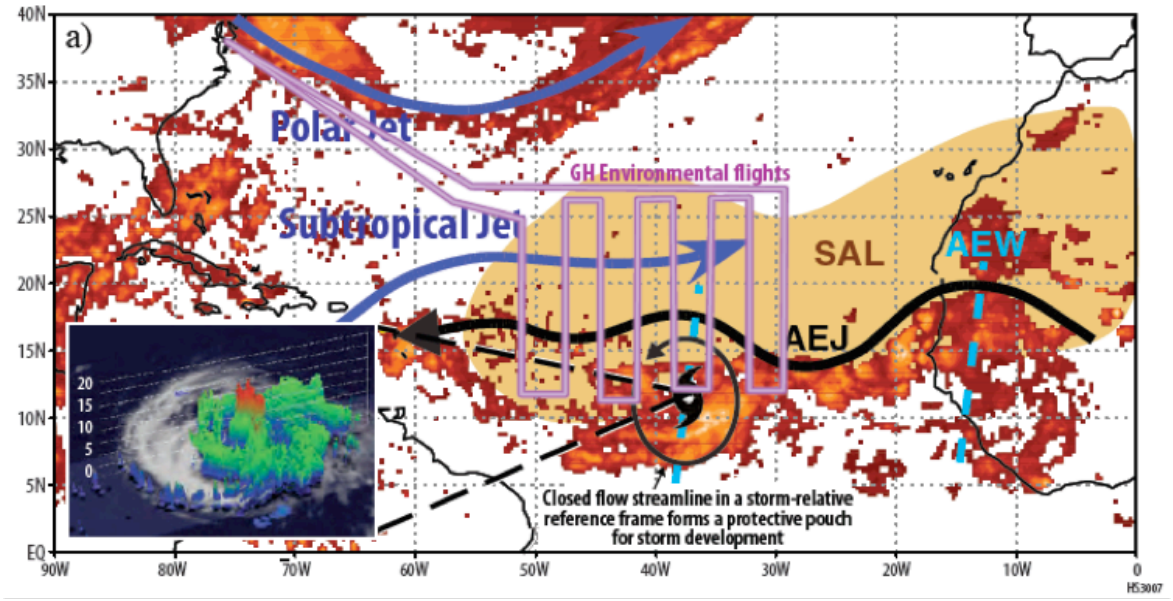
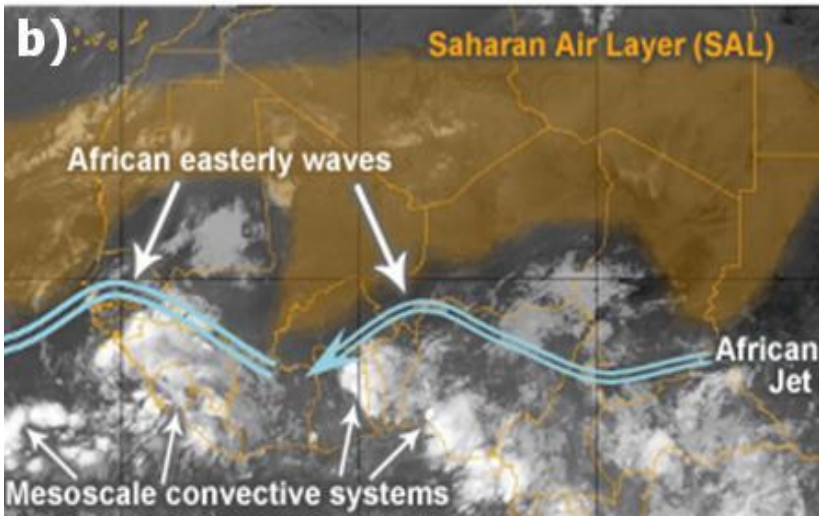


Image from NASA HS3 Website



SO WHAT AM I RESEARCHING?

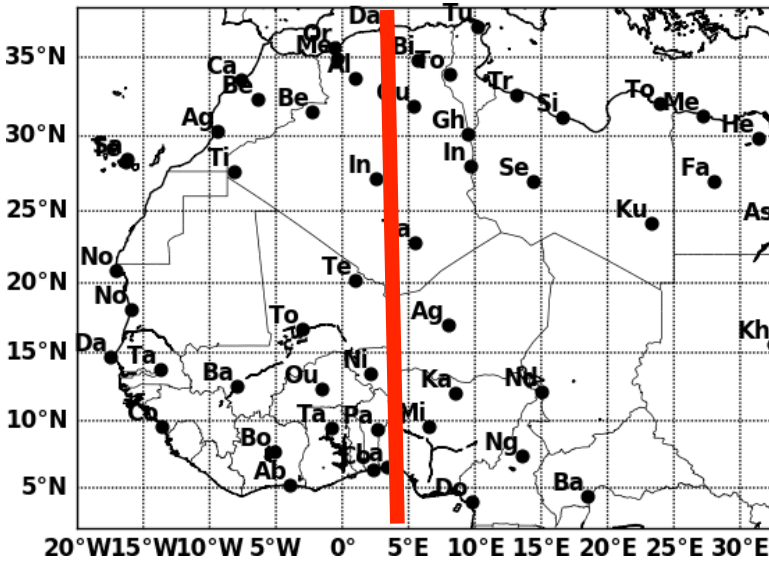
Hypothesis: NASA's Atmosphere Infrared Sounder (AIRS) can detect well-mixed layers (WML's) and SAL's

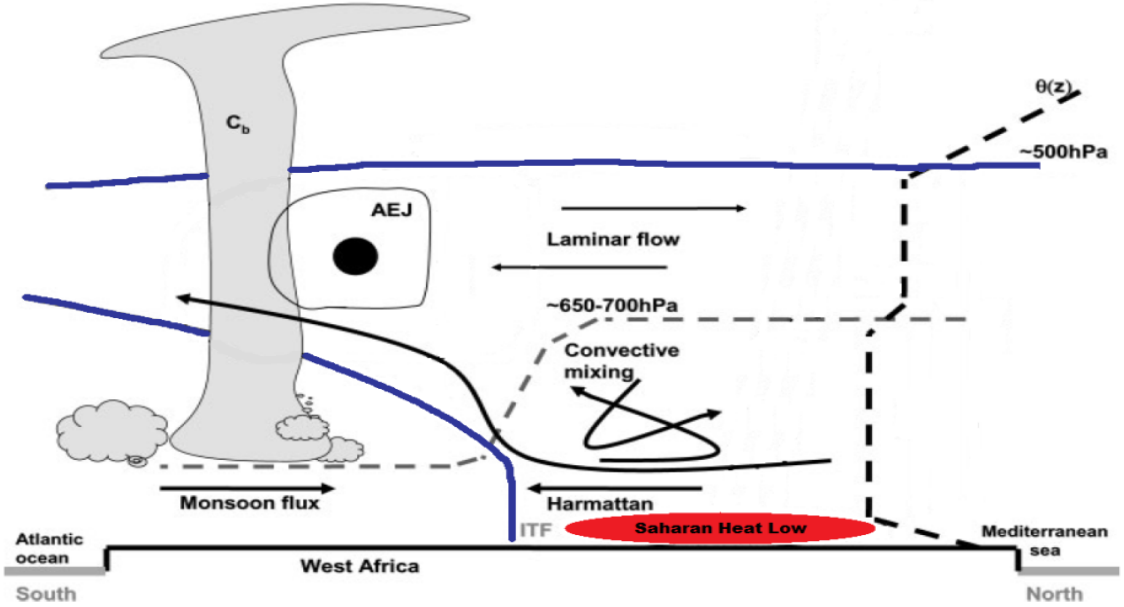
Gain: Detection of SAL's from space with regional coverage, consistent dataset quality

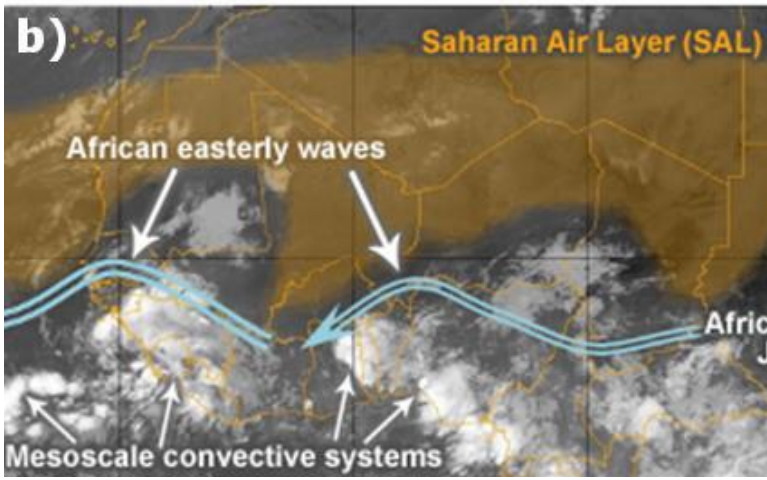
13 year period (2003-2015), 55 Stations

Data: L2 AIRS V6, L2 AIRS/AMSU V6, ECMWF-Interim, Rawinsondes

Rawinsonde Stations

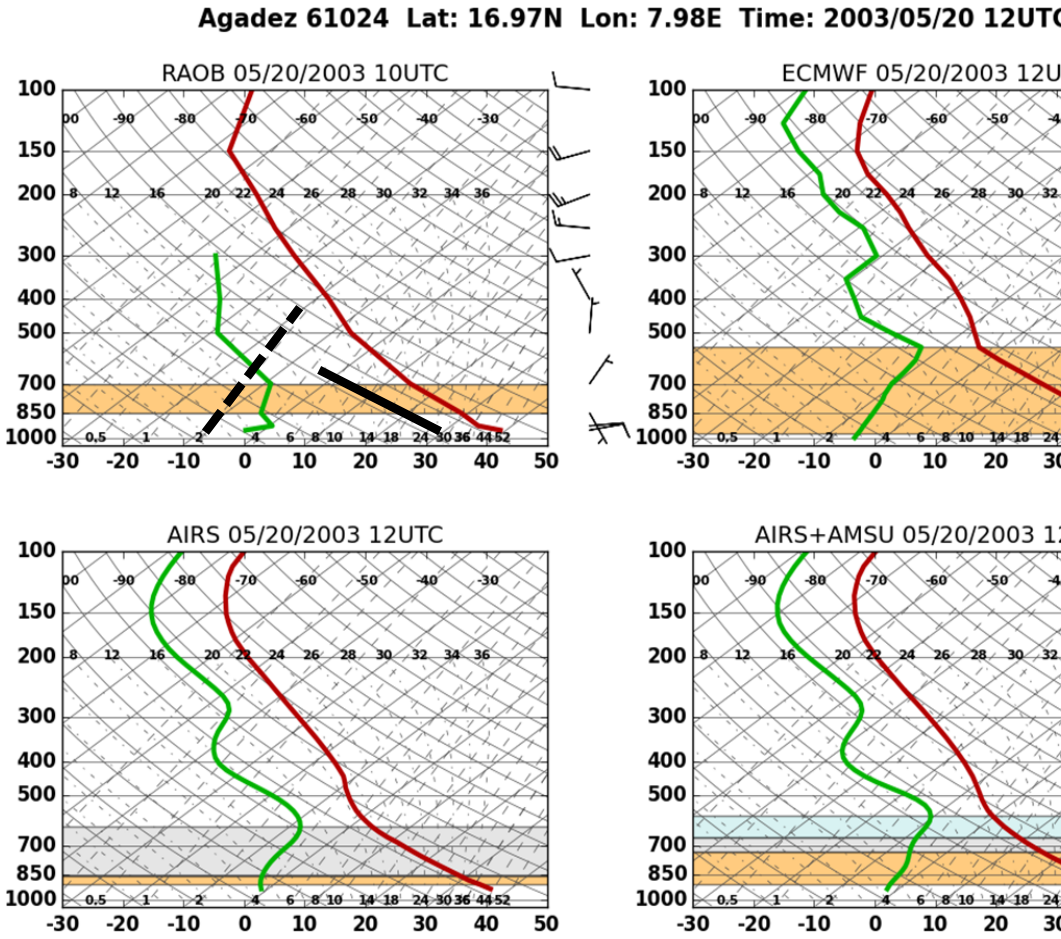




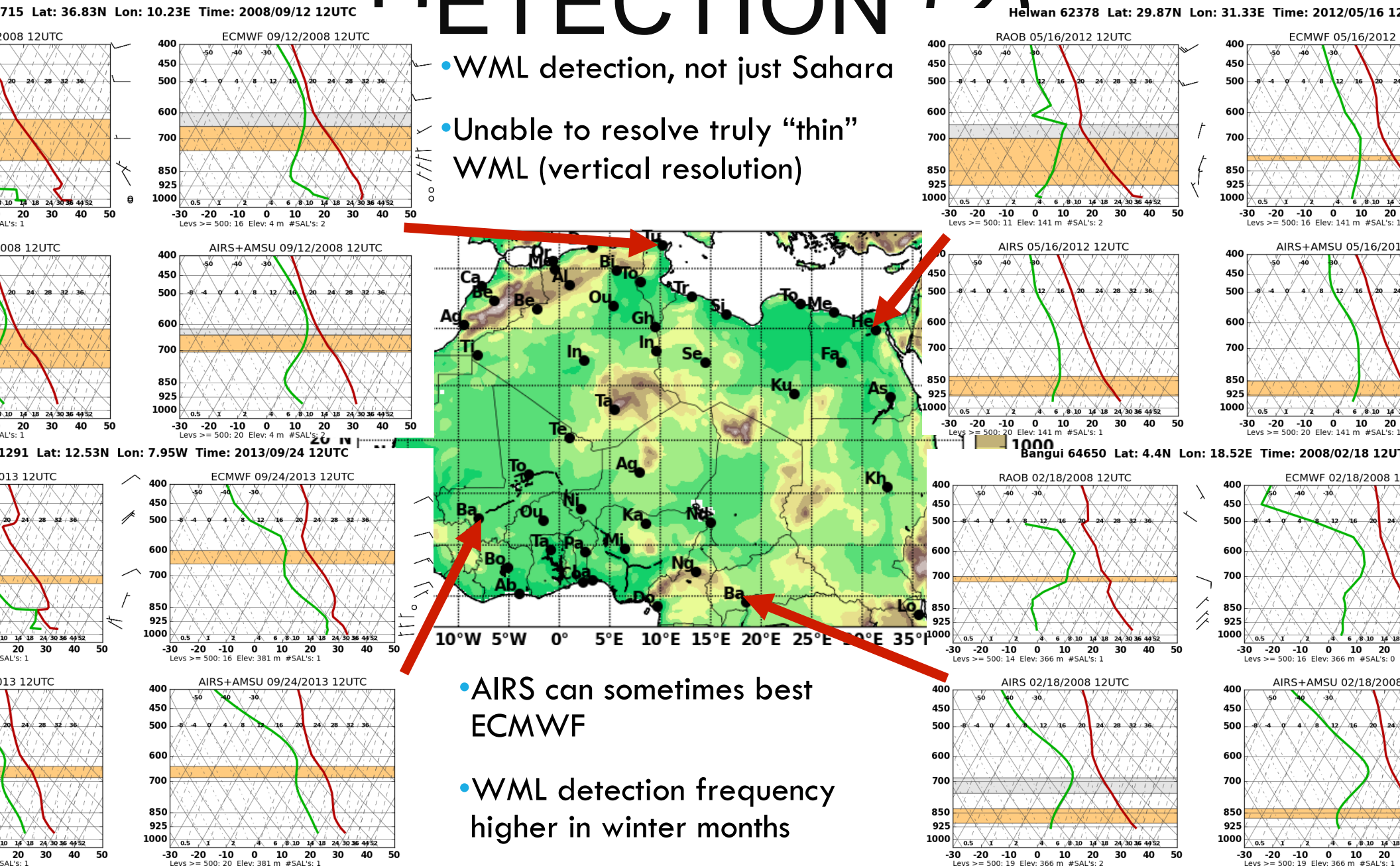


AIRS AND WELL-MIXED LAYER DETECTION ALGORITHM(1)

- Pressure: ≥ 500 hPa & Mixing ratio: ≤ 7 g kg^{-1}
- Log decrease in allowable constant mixing ratio deviation with height: (starting: 0.95 g kg^{-1} km^{-1})
- Two calculations (temps and mixing ratio):
  1. Bottom of layer (n_o) to current level (n)
  2. Level below (n-1) to current level (n)
- If 1 and 2: same layer; if 2 only: new layer; otherwise: no layer



AIRS AND WELL-MIXED LAYER DETECTION (2)



- WML detection, not just Sahara
- Unable to resolve truly "thin" WML (vertical resolution)
- AIRS can sometimes best ECMWF
- WML detection frequency higher in winter months

WELL-MIXED LAYER ANALYSIS (I DETECTION

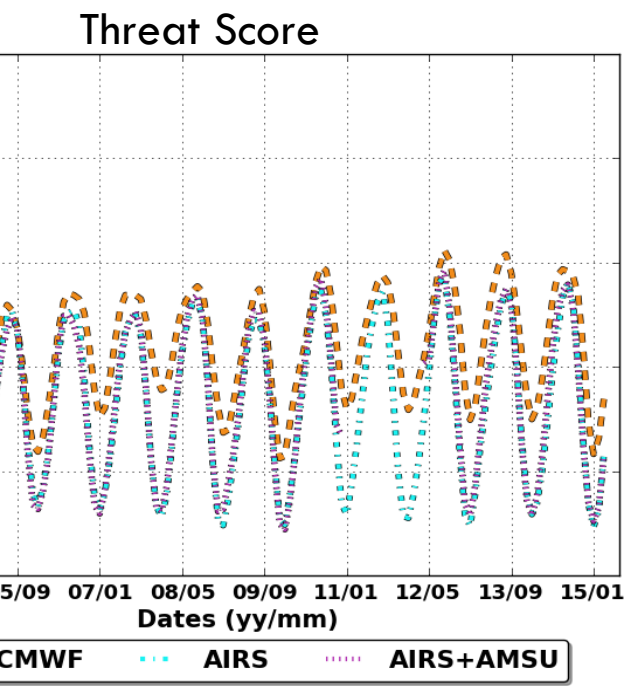
Statistics over all 55 Stations (2003-2015)

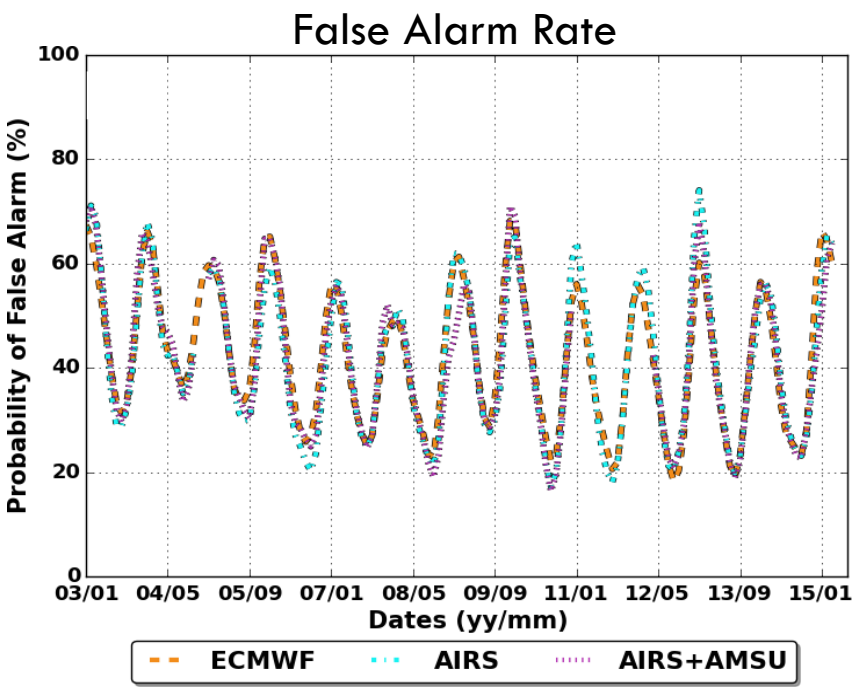
Strong seasonality (higher winter)

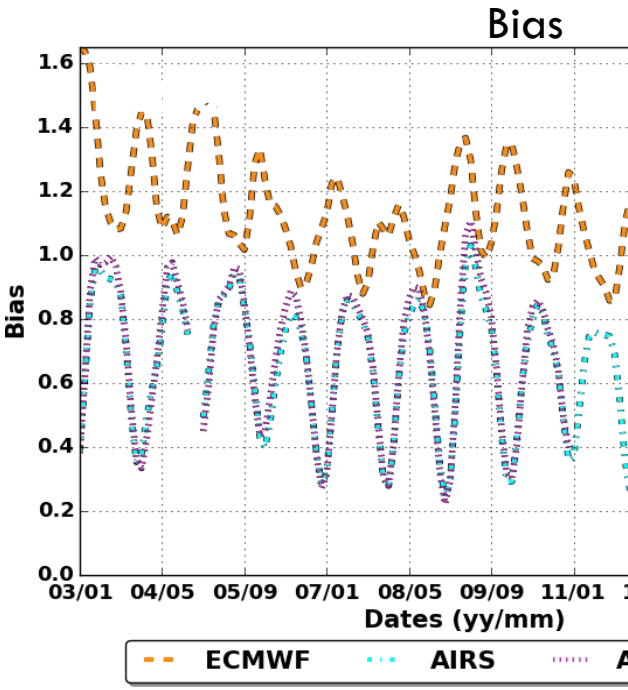
Threat Score (TS): 0.35 AIRS, 0.42 ECMWF. Highest Sahara, lowest coastal

FAR consistent between all data

- ECMWF over-biased (Mean 1.1)
- AIRS and AIRS+AMSU under-biased (0.6)
- Saharan detection rates: AIRS (60%), ECMWF
- Coastal detection rates: AIRS (20%), ECMWF





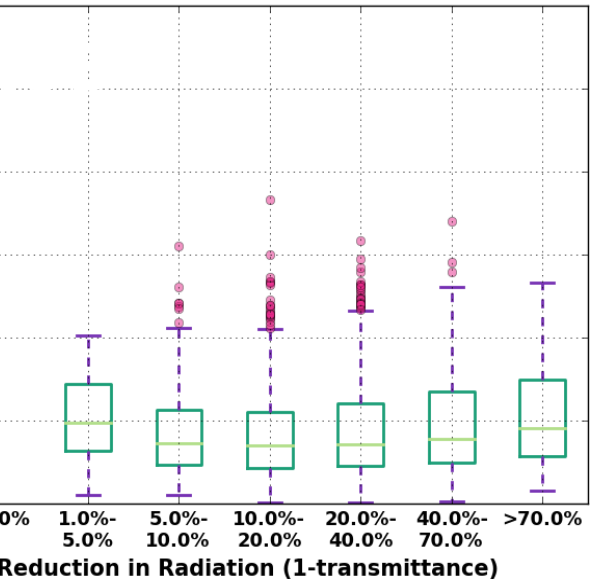


WELL-MIXED LAYER ANALYSIS (Z THICKNESS

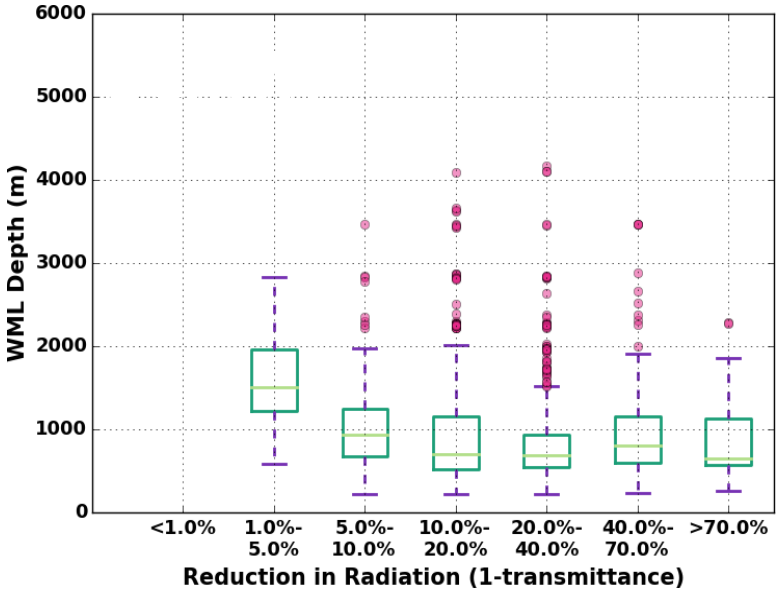
- WML Thickness (2003-2015)
- Aqua AOD-based bins
- WML thickness: < 50 m to > 3000 m
- Thickness-Dust: limited dependence

- ECMWF: Capture depth variance, under-biased
- AIRS: More limited skill with depth variance, under-biased
- Detection threshold: 300 m

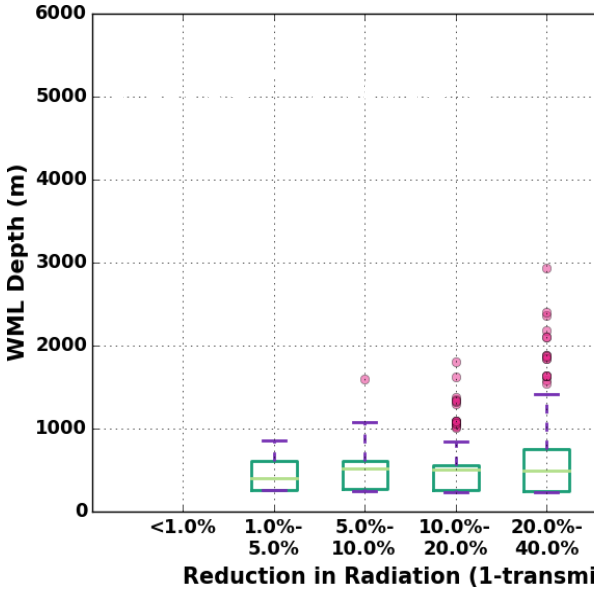
Radiosondes



ECMWF



AIRS+AMSU

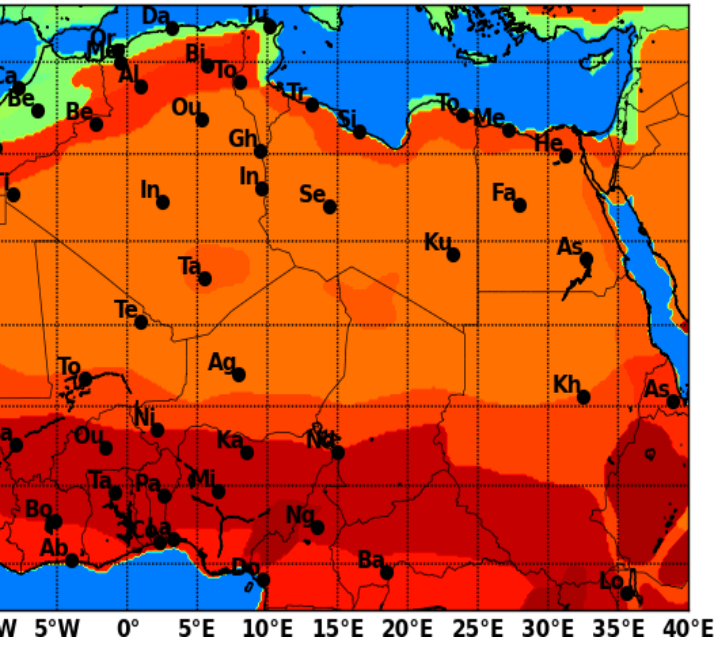


HYSPLIT

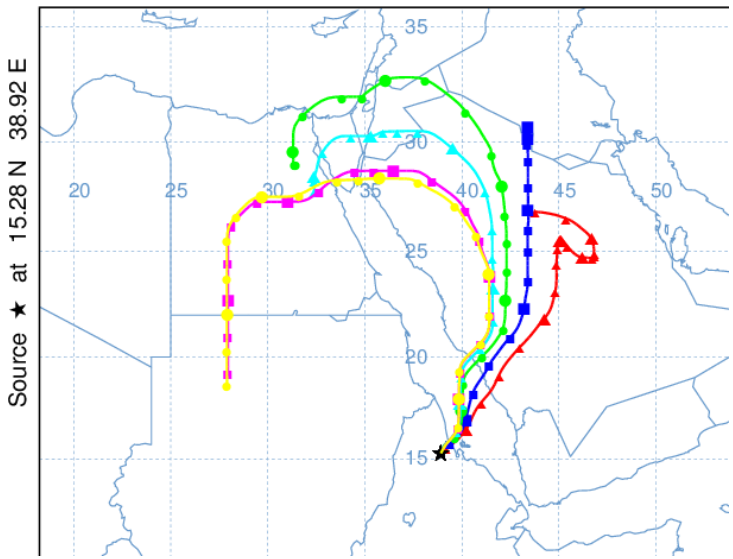
- Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)
  - NOAA Air Resources Laboratory (ARL)
- ECMWF Interim Analysis, 5-day backwards trajectories
- Track parcels every 200 m in WML

SAL Classification Rules

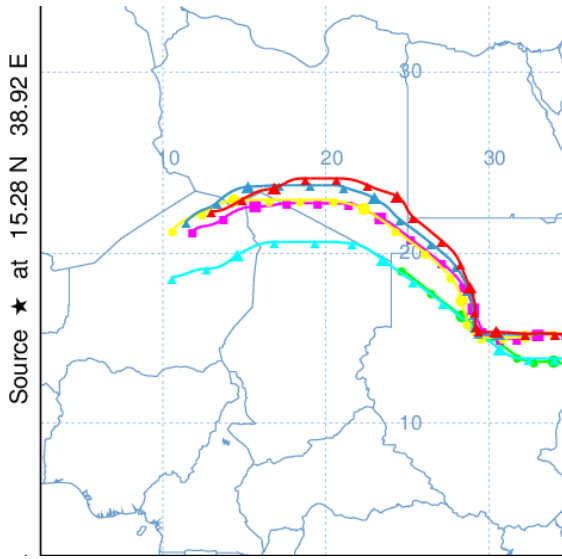
- 1) Trajectory is Saharan:
  - - 2 consecutive days in Sahara
  - - 24 hours in Sahara within 72 hours of dete
- 2) WML is SAL: >50% of all trajectories are Sah
- Examples (see below)



Non-Saharan

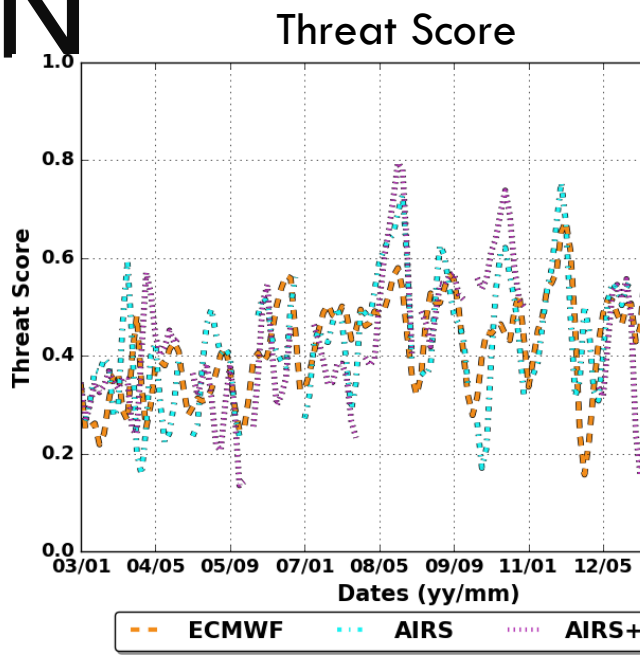


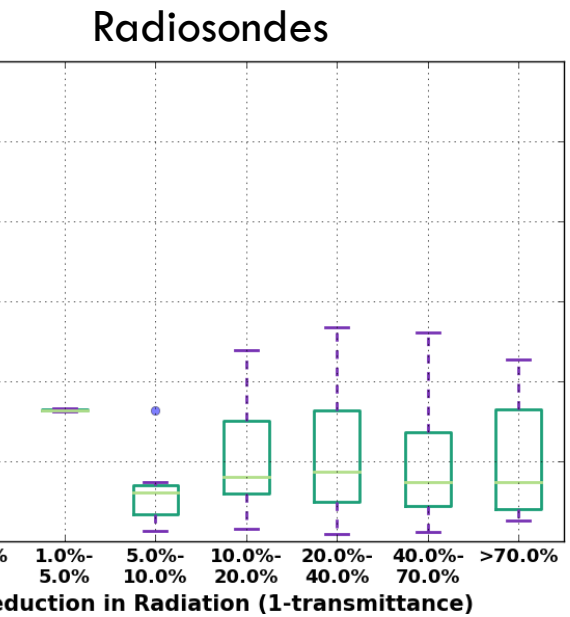
Saharan

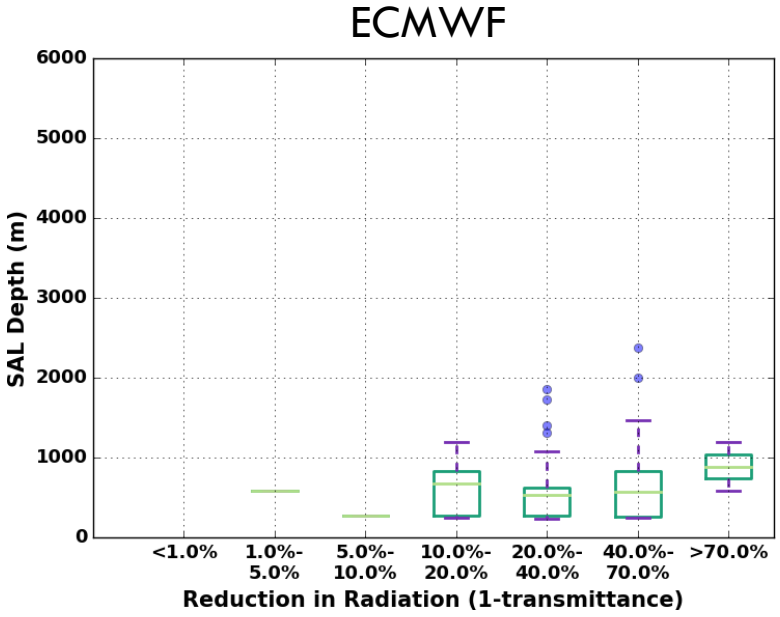


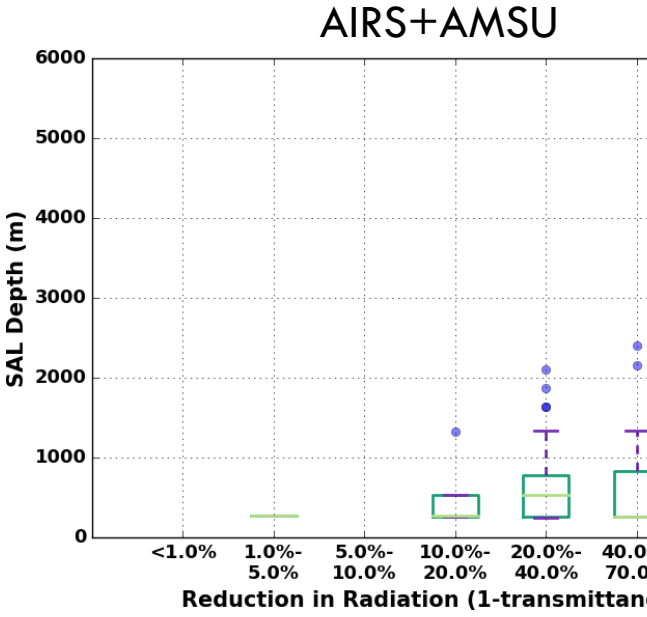
SAHARAN AIR LAYER ANALYSIS (NON-SAHARAN

- Threat score (see right): Avg 0.4;
  - General: AIRS > ECMWF, seasonal signal (dust extent)
- SAL thicknesses (bottom)
  - 300 m detection threshold
  - Limited dependence to dust (Aqua Deep Blue)
  - ECMWF & AIRS: Similar thickness variance and IQR ranges









AHARAN AIR LAYER ANALYSIS (4
SAHARAN

hreat score (see right): Avg 0.62;

General: AIRS > ECMWF, stronger seasonal signal

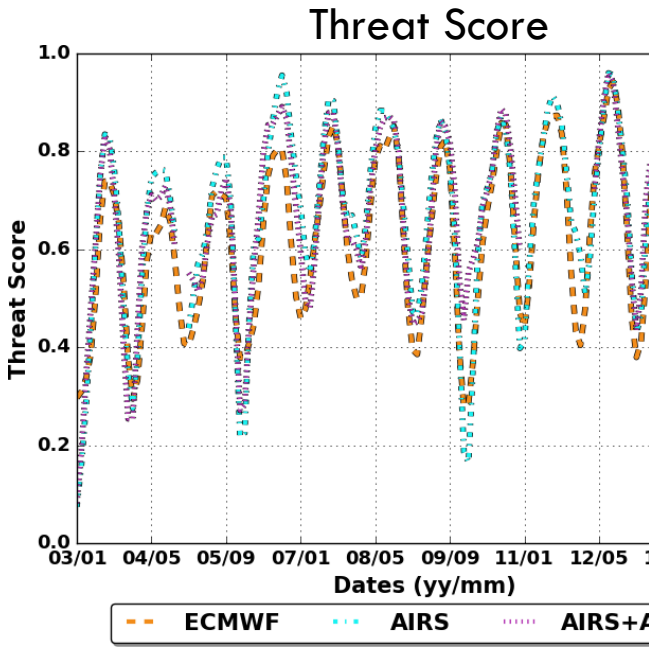
AL thicknesses (bottom)

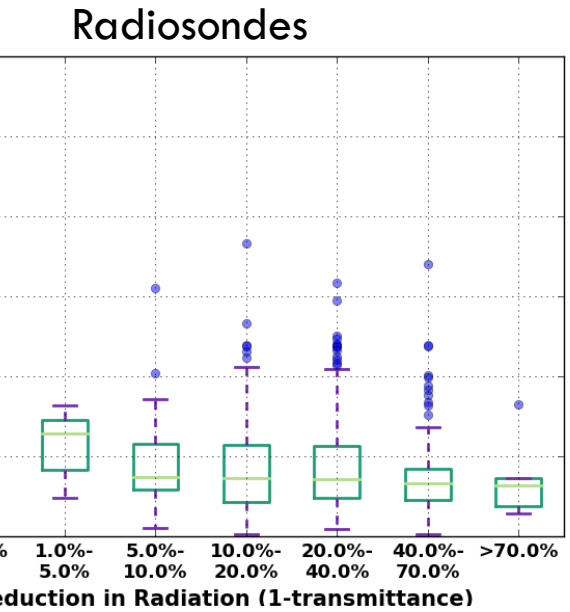
Same 300 m detection threshold as non-Saharan locations

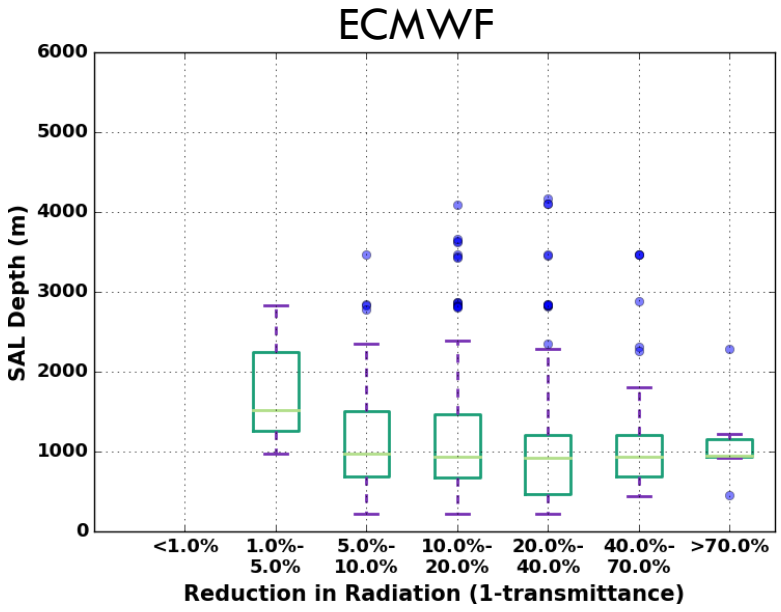
imited dependence to dust (Aqua Deep Blue)

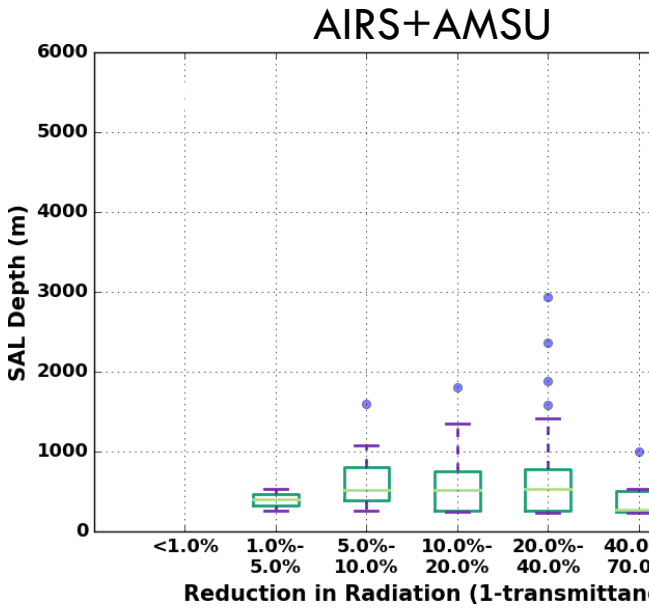
ECMWF: Better captures variance & IQR ranges than AIRS

- Likely related to other data assimilated by ECMWF
- **Hypothesis:** Away from stations AIRS likely better (data consistency)



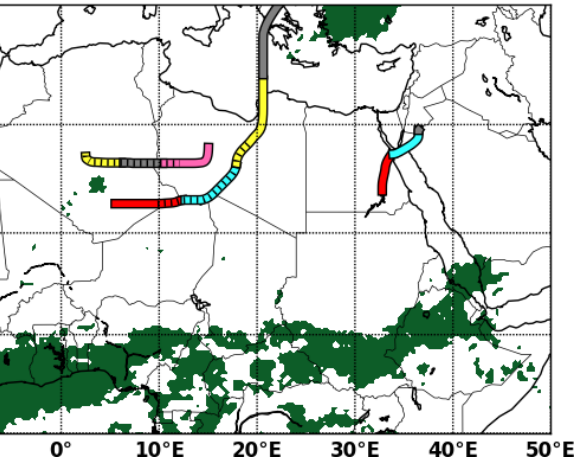




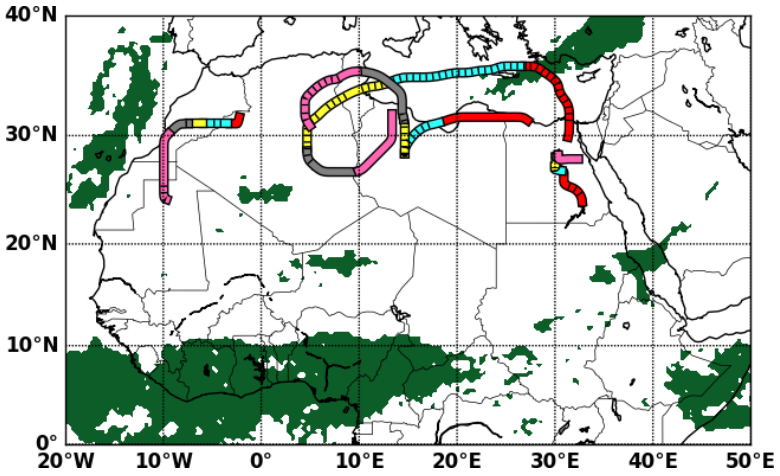


AL TRAJECTORIES VS AQUA AOD V TRMM 3B42 PRECIPITATION

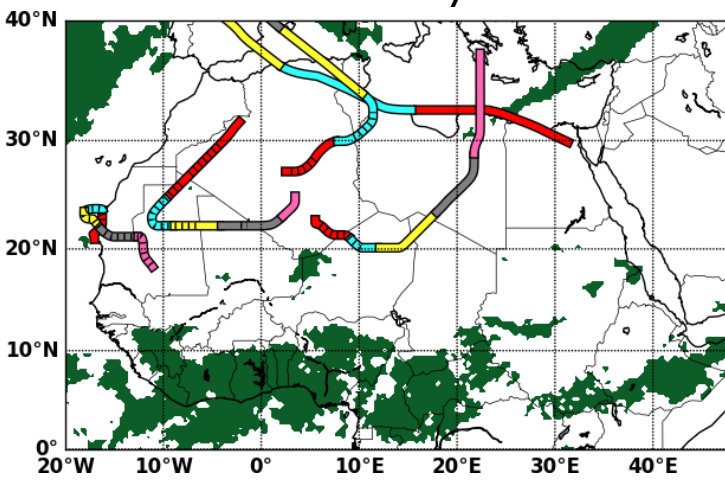
RAOB 11 July 2014



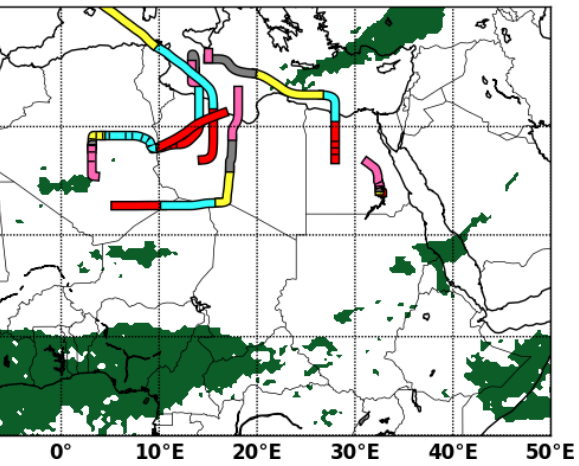
RAOB 12 July 2014



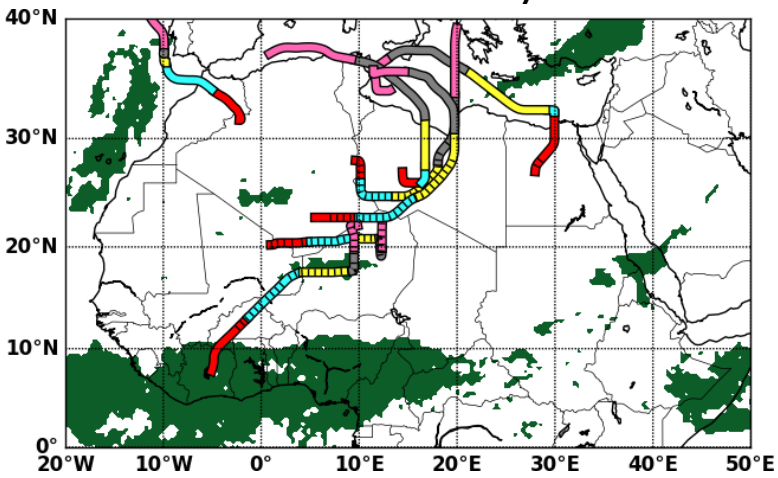
RAOB 13 July 2014



CMWF 12 July 2014



AIRS+AMSU 12 July 2014

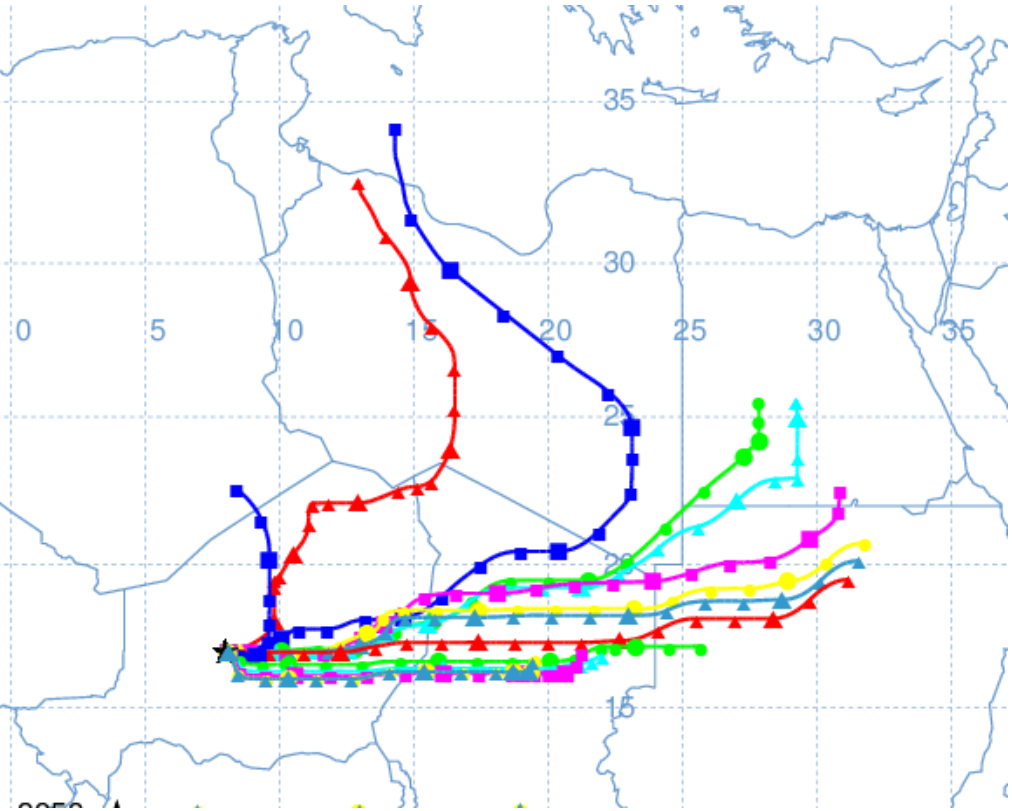


- What is shown:
  - Trajectories (24 hrs interval; colors, most recent)
  - TRMM 24-hr precipitation accumul (green)
  - Aerosol optical depth > 0.4 (hashe
- Differences between data sou
  - Detected SAL or SAL heights
- Trajectory origin points largel uncorrelated with precipitatio

SUMMARY

- Evaluated AIRS SAL detection potential given porous radiosonde netwo
  - 55 Stations, 13 years of data (2003-2015)
  - Detection of WML (constant Pot. T and mixing ratio), SAL (HYSPLIT)
- WML: All data under-biased, ECMWF performance slightly better (T.S. range of thicknesses)
- SAL detection at each station, 300 m detection threshold
  - Threat score: AIRS slightly higher (0.6 vs 0.58) than ECMWF
  - SAL Thickness: Detection rate over-bias, ECMWF better thickness
- SAL trajectory origin points not well-correlated with precip.
- AIRS results comparable or better than ECMWF at stations
  - AIRS likely better outside radius of radiosonde influence

Thanks for your time and attention!!!



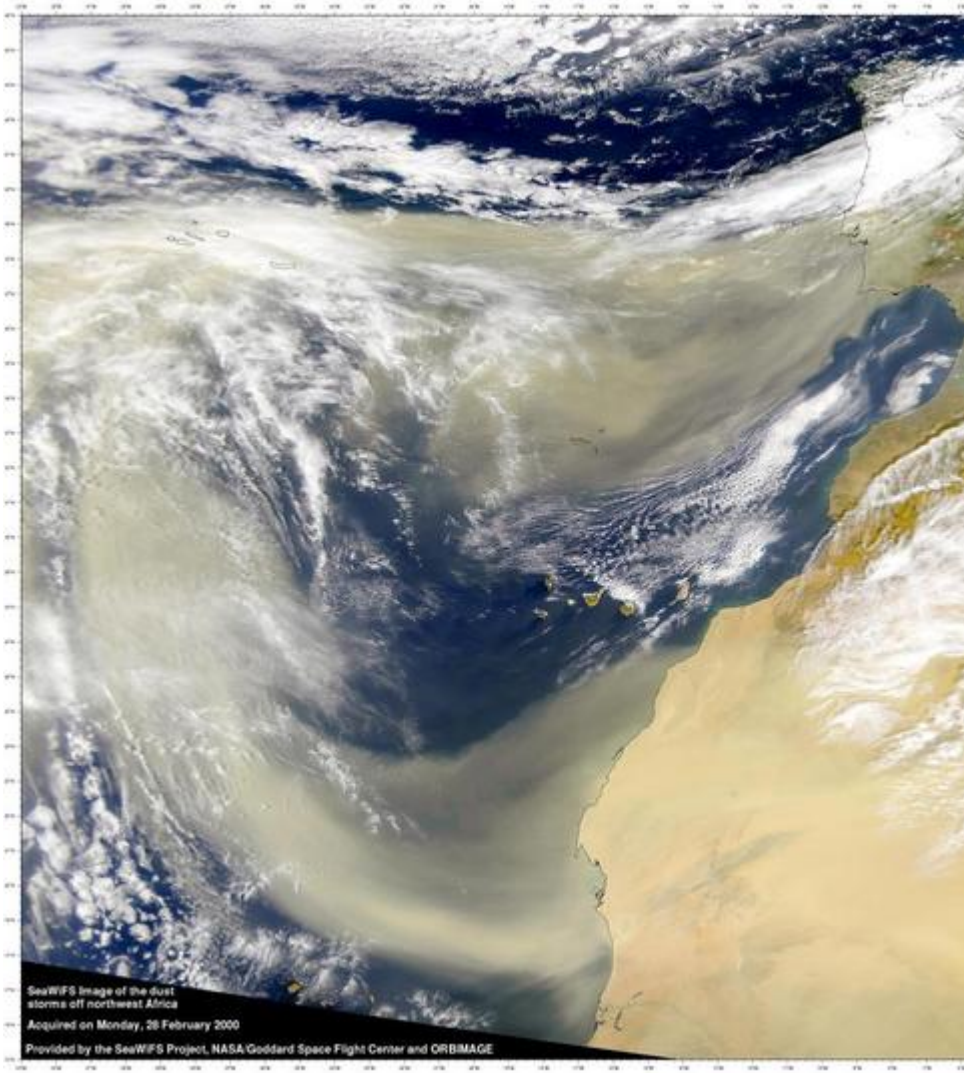


Image from SeaWIFS, NASA GSFC

TMOSPHERIC INFRARED SOUNDER (AIR VER. 6

Passive infrared sounder

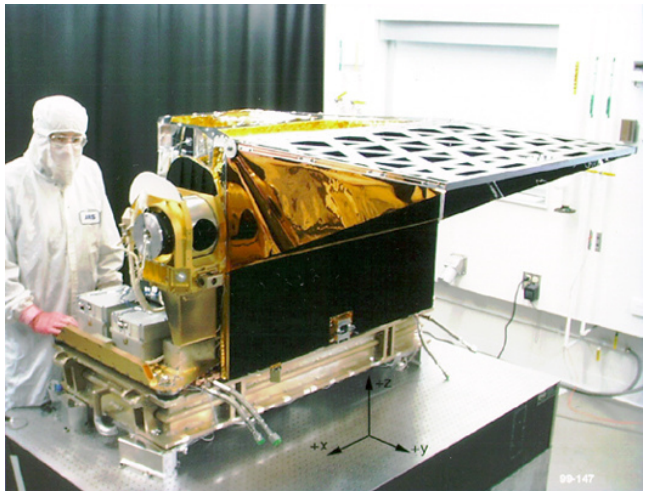
Resolution: 13.5 km at nadir, 41 km x 21.4 km at scan extremes

Operates in up to 90% cloudiness

Enhanced with Atmospheric Microwave Sounding Unit (AMSU data)

Global temperature and moisture data

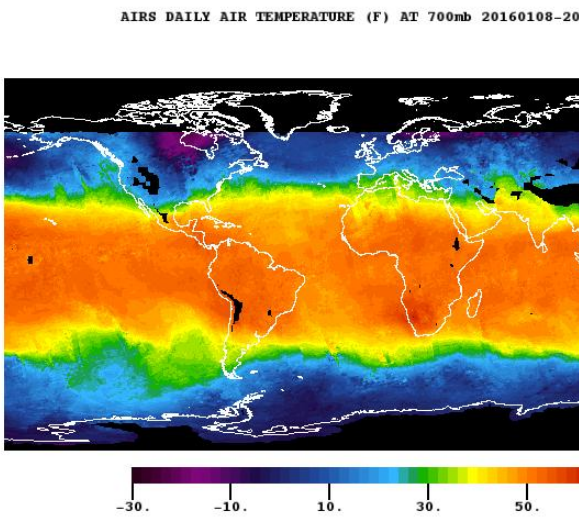
Focus: 100-level support product (25 levels ≥ 500 hPa)



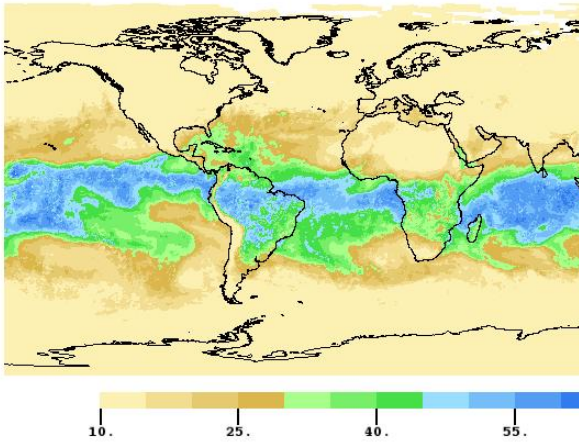
AIRS under construction

Images from AIRS JPL Webpage (http://airs.jpl.nasa.gov/)

700-hPa Temperature



Total Precipitable Water



AHARAN AIR LAYER (SAL) [2]

Dust sources

- Dry convection (Saharan thermals)
- Gravity currents (i.e., storm outflow) -- (Flamant et al. 2007)
- African easterly wave forcing (Karyampudi
- et al. 1999)
- Mid-latitude, upper level troughs -- Jankowiak and Tanre, 1992)

Impacts to moist convection (Land and ocean)

- Direct: Scatter solar radiation
  - Weaken: cools surface
- Indirect: Act as cloud condensation nuclei
  - Strengthen: Decrease condensate loads aloft

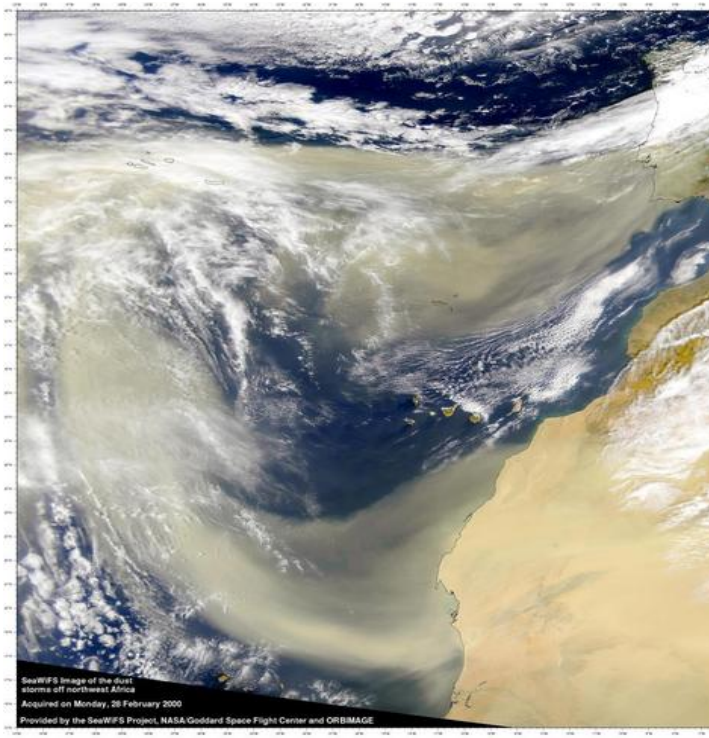
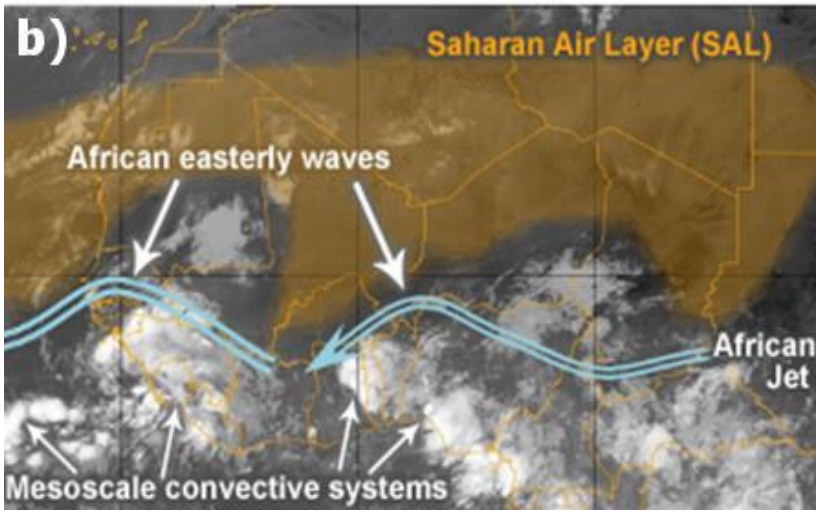



Image from SeaWIFS, NASA G