Observation of Aerosol Spatio-Temporal Variations Over Ghana Using MODIS Aerosol Optical Depth

James Nimo, Allison Hughes, Azoda Koffi, Abraham Amankwah, Nana Ama Browne-Klutse, Alabi Omowumi

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UNIVERSITY OF GHANA

SCHOOL OF BASIC AND APPLIED SCIENCES
DEPARTMENT OF PHYSICS

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OUTLINE

- Problem Statement
- Purpose and goal of the Study
- Results
- Conclusion
- References

STATEMENT OF THE PROBLEM – INCREASED IN URBANIZATION

- Sub-Saharan Africa (SSA) is the world's fastest urbanizing region (United Nations, 2019)

Source: https://www.quora.com/Will-sub-Saharan-African-countries-ever-get-a-chance-to-be-developed

STATEMENT OF THE PROBLEM – INCREASED IN MOTORIZATION

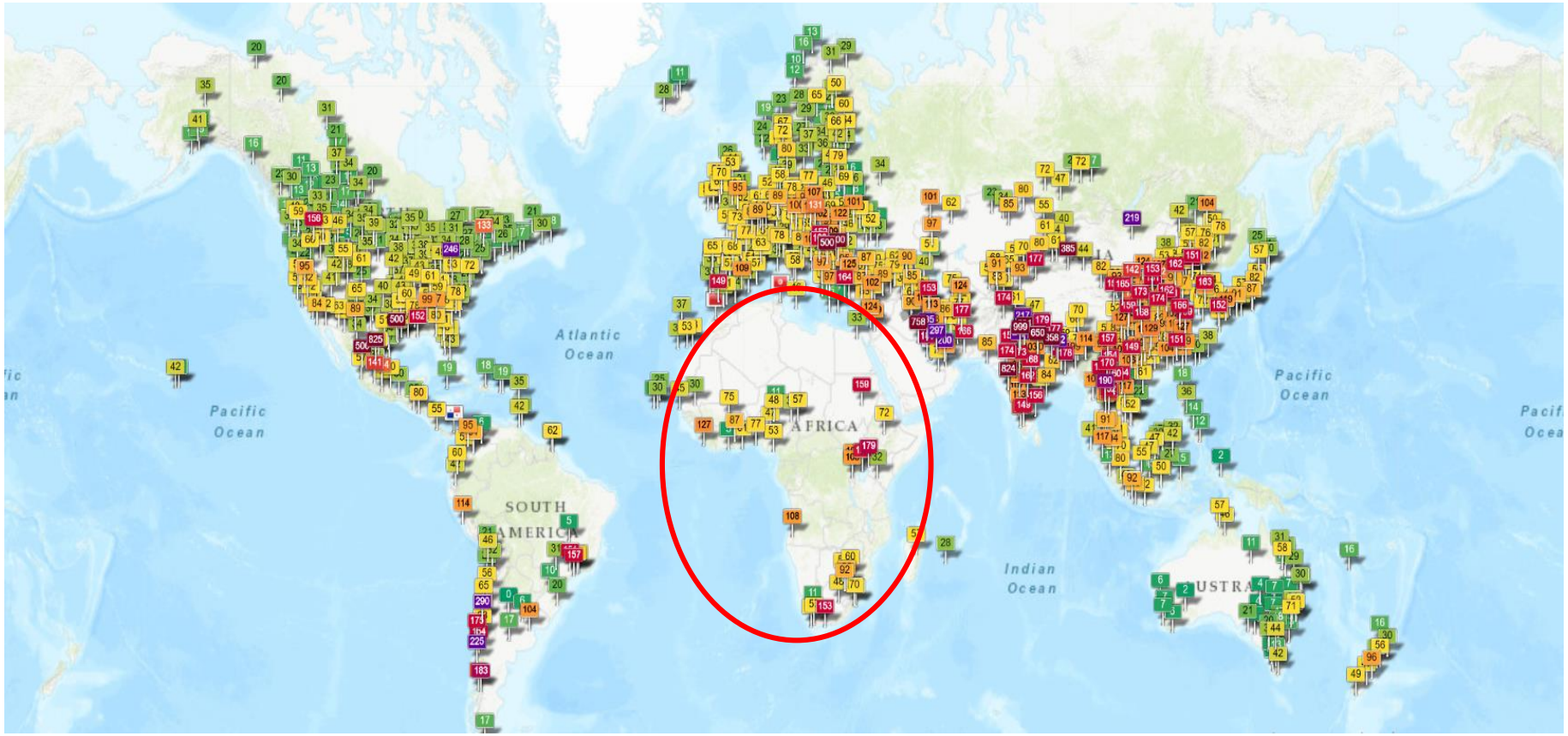
- Rapid increased in Motorization in most SSA's regions together with importation of more polluting vehicles

(Amegah and Agyei-Mensah, 2017; Marais et al., 2019).

Source: https://howwemadeitinafrica.com/urbanisation-in-sub-saharan-africa-city-master-plans/

STATEMENT OF THE PROBLEM – Scarcity of Ground Sensors

- Dearth of ground monitoring stations for air quality in Africa



Source:https://aqicn.org/map/world/

AVAILABILITY OF SATELLITE DERIVED DATA

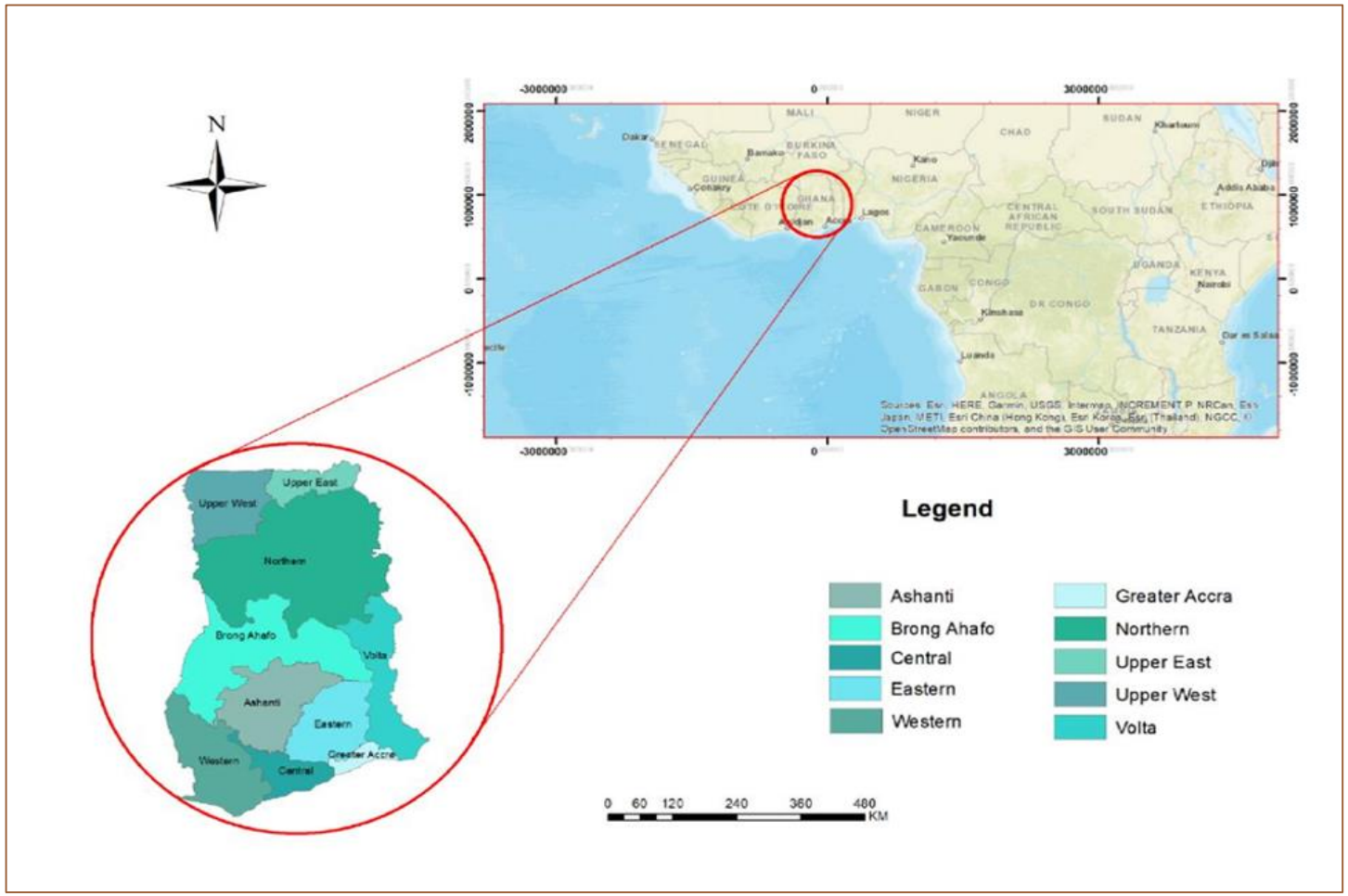
- The need to apply satellite derived data to monitor air quality

- Availability of MODIS Terra and Aqua sensors across sub-Saharan Africa for air pollution assessment.

Source:https://aqicn.org/map/world/

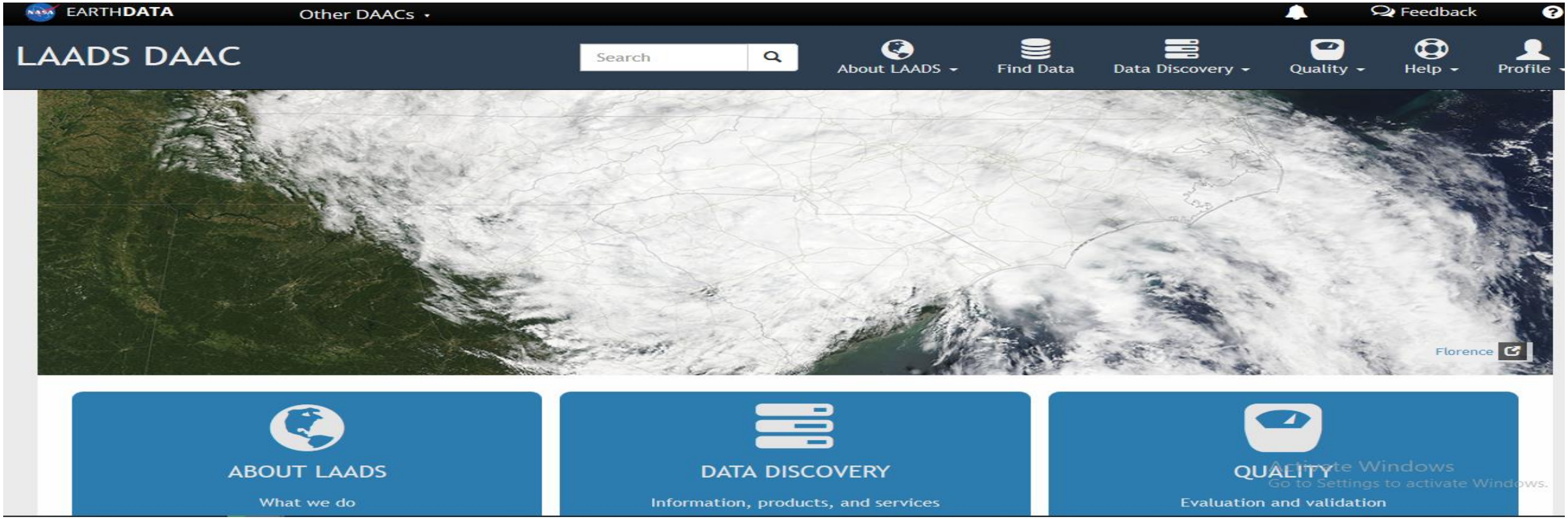
PURPOSE AND GOAL OF THE STUDY

- Use NASA MODIS level 2 10 km (combined dark target and deep blue algorithm) Aerosol Optical Depth (AOD) data on both Terra and Aqua satellites to assess the levels of aerosols over Ghana from 2013 to 2018.
- Evaluate the relationship between MODIS sensors and NASA Aerosol Robotic Network (AERONET) at 550 nm.
- Track the origins of aerosols over Ghana using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model.



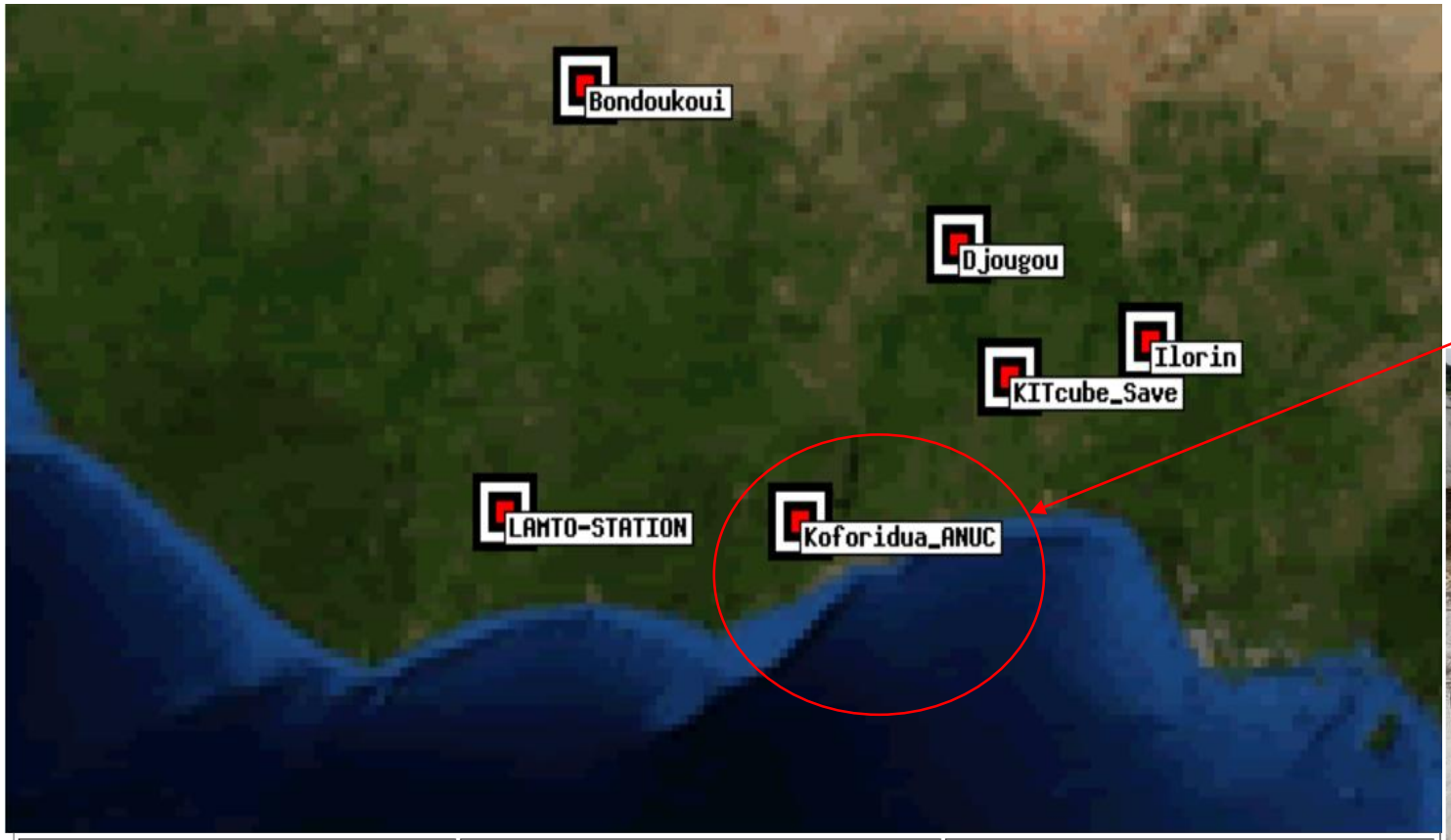
DATA SOURCE

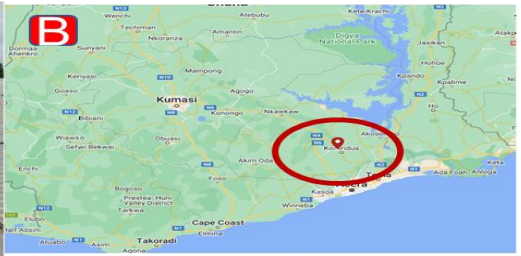
- The MODIS level 2 10 km collection 6.1 Terra and Aqua satellite sensor (10 am and 13 pm UTC) Aerosol Products was obtained from **https://ladsweb.modaps.eosdis.nasa.gov/**

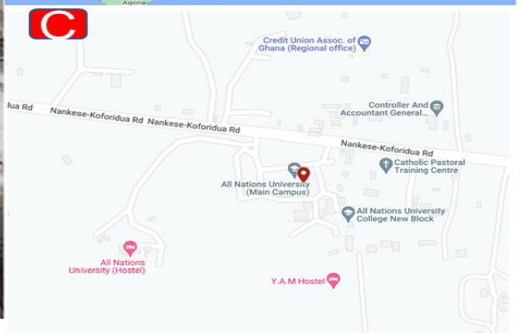


Source: https://ladsweb.modaps.eosdis.nasa.gov/

NASA AEROSOL ROBOTIC NETWORK (AERONET) GROUND MONITORING STATIONS





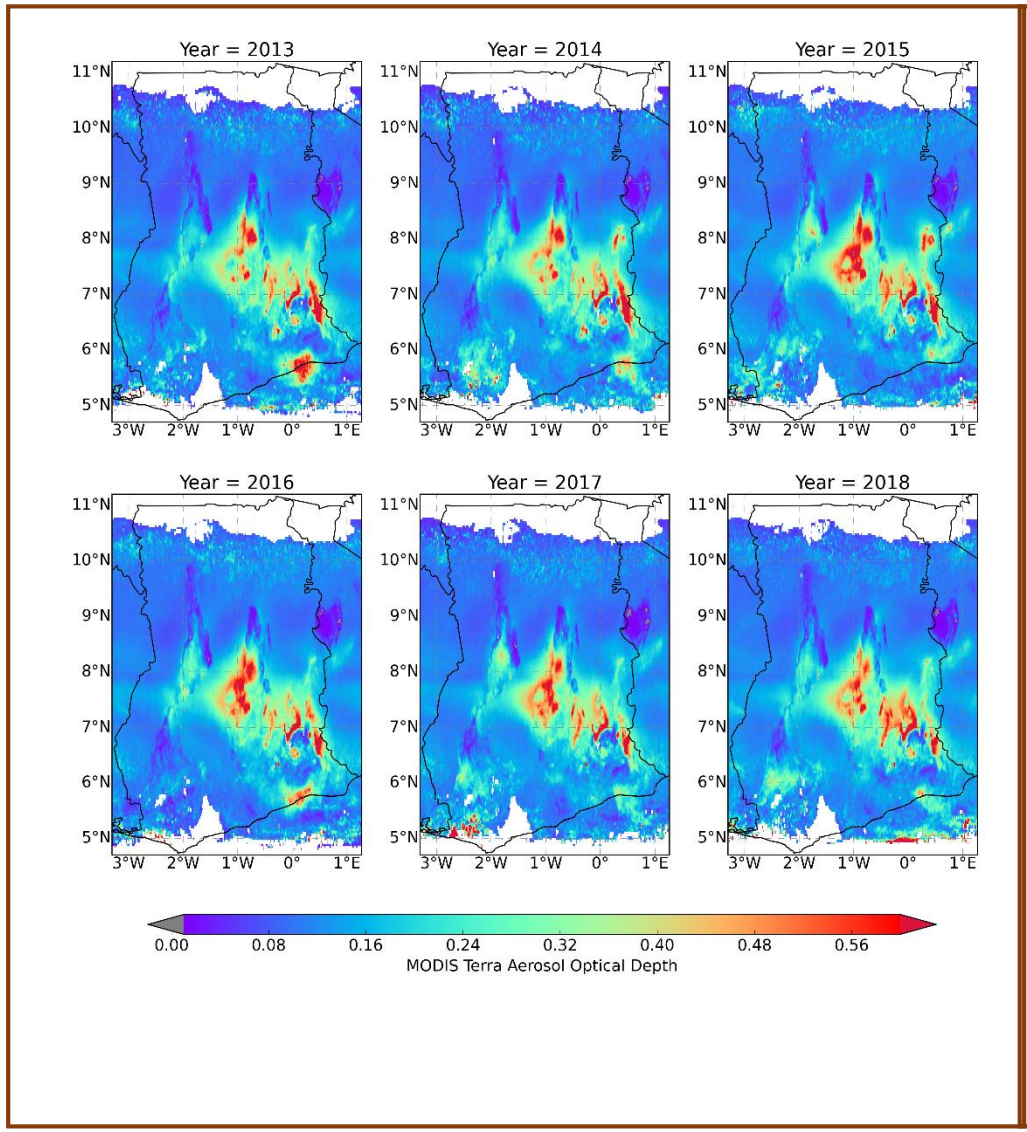


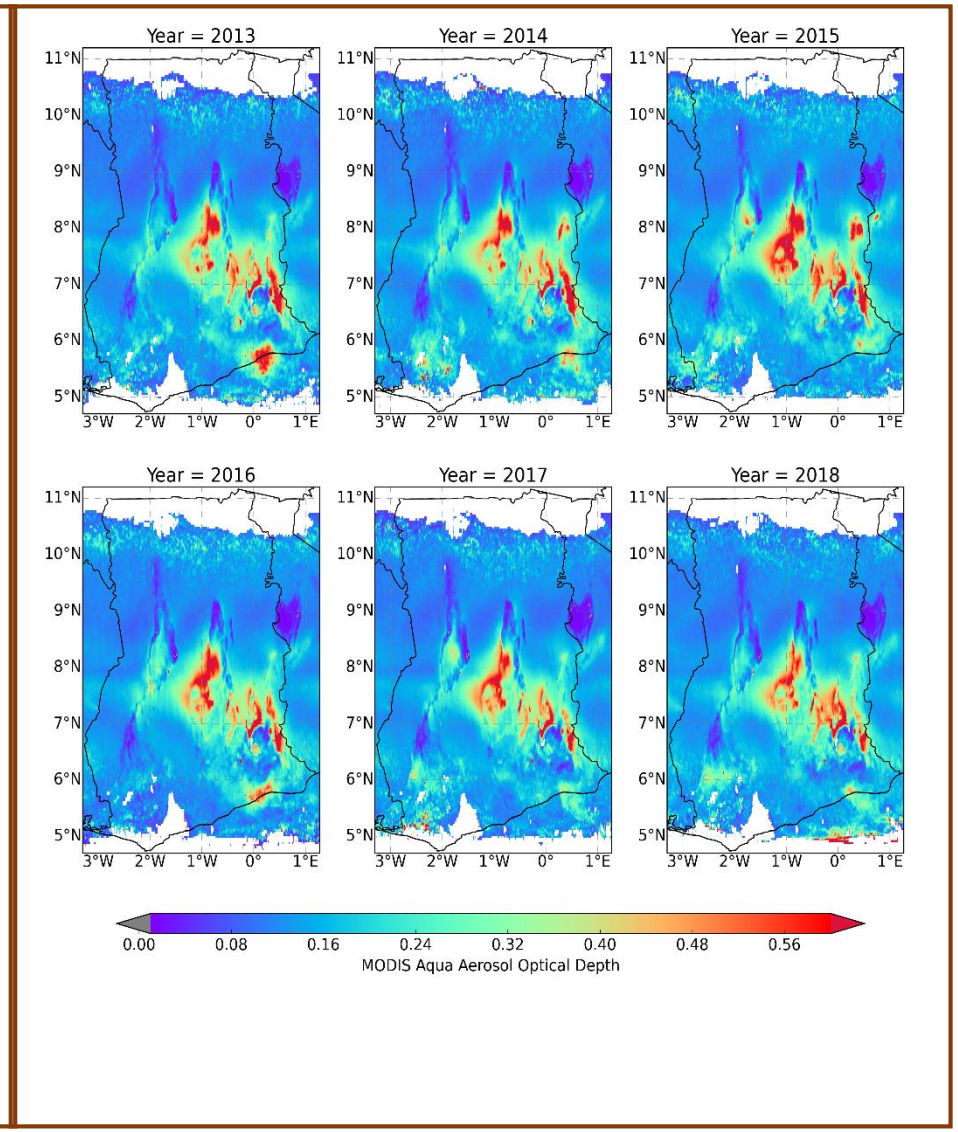
Bondoukoui (11.850N, 3.750W)	Djougou (9.760N, 1.599E)	Ilorin (8.484N, 4.675E)
KITcube_Save (8.001N, 2.428E)	Koforidua_ANUC (6.109N, 0.302W)	LAMTO-STATION (6.224N, 5.027W)

Source: aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_aod_v3

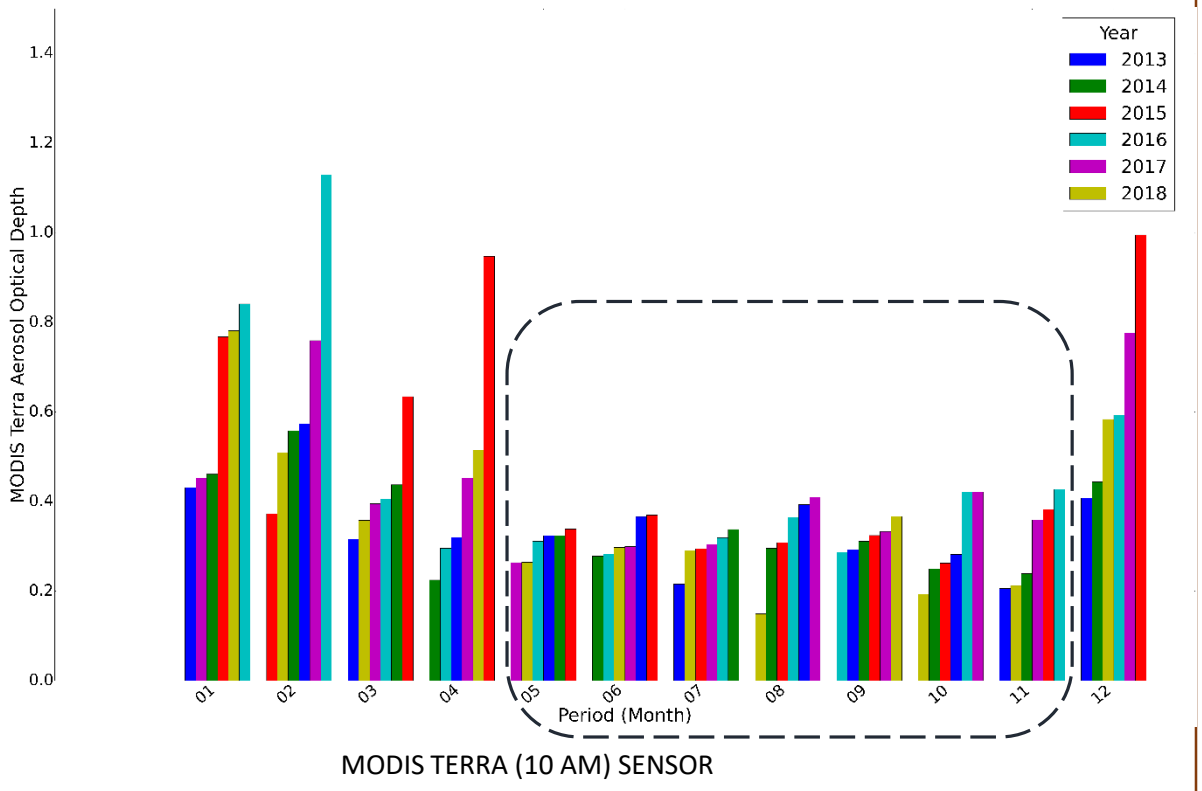
MODIS TERRA AND AQUA AOD MAPS FOR THE STUDY PERIOD

- There were available AOD retrieval over Ghana on a scale of 0.0 to 0.6 with peaks occurring in the middle and southern parts of Ghana.
- There were data void in some upper and southern regions of Ghana which can be due to cloud cover.

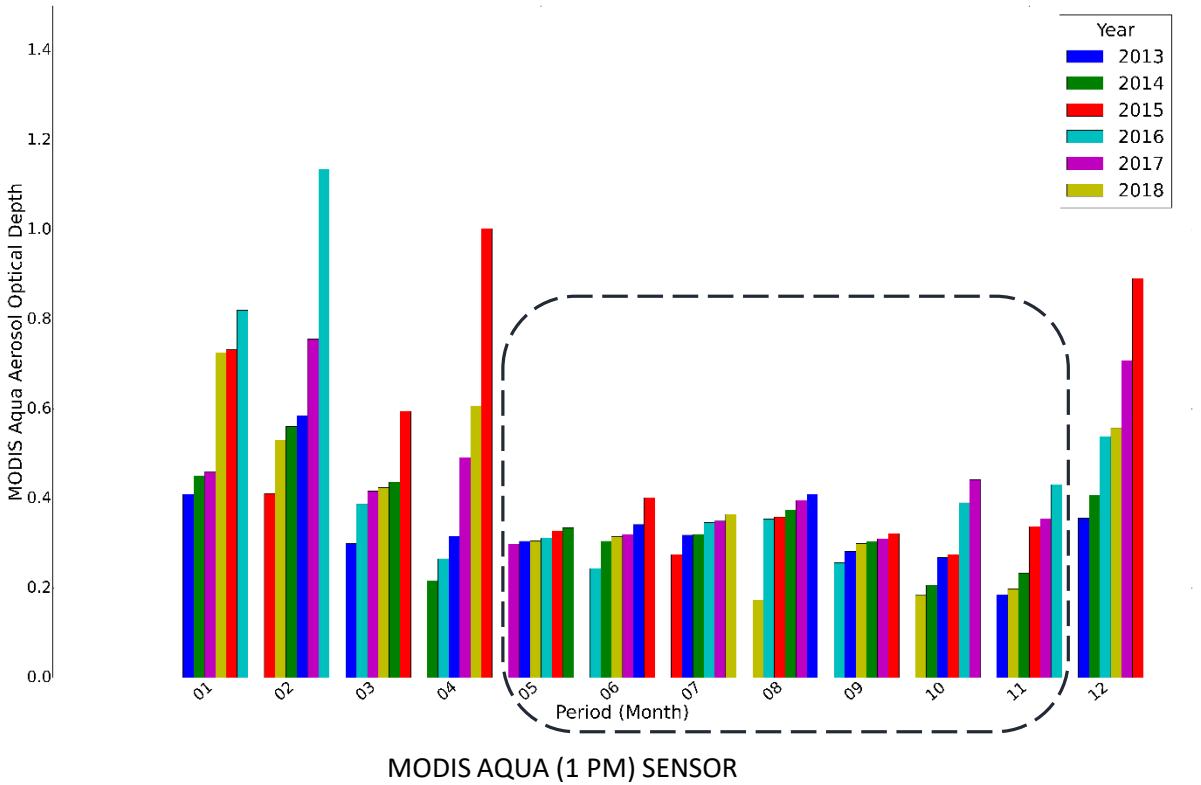




MODIS TERRA AND AQUA AOD MONTHLY BARPLOTS FOR THE STUDY PERIOD



MODIS TERRA (10 AM) SENSOR



MODIS AQUA (1 PM) SENSOR

- There was an increase in AOD during the dry season from December to February.
- Higher AOD was recorded in 2015 and 2016.
- Decrease in AOD was recorded during the wet season from May to November.
- Both Terra and Aqua sensors recorded different AOD episodes particularly in the wet season during study period.

MODIS TERRA AND AQUA RETRIEVED AOD ON 10 X10 KM SQUARE GRID

Date	Latitude	Longitude	Terra_AOD	combined_quality_flag	distance_to_monitor
2013-01-01 10:14:46	6.166451	-0.260562	0.525	3.0	7.835947
2013-01-01 10:14:47	6.077499	-0.281255	0.513	3.0	4.172318
2013-01-02 10:57:37	6.133971	-0.282803	0.616	3.0	3.484379
2013-01-02 10:57:39	6.045010	-0.301712	0.649	3.0	7.076559
2013-01-03 10:02:32	6.172440	-0.278241	0.560	3.0	7.492277
...	...	...	...	...	...
2018-12-26 10:08:55	6.093737	-0.298489	1.425	3.0	1.732042
2018-12-27 10:51:45	6.150736	-0.370066	1.350	3.0	8.835360
2018-12-27 10:51:45	6.130369	-0.238808	1.312	3.0	7.383072
2018-12-27 10:51:47	6.041246	-0.257306	1.538	3.0	8.978824
2018-12-28 09:56:40	6.097892	-0.263998	1.360	3.0	4.382180

397 rows × 5 columns

MODIS TERRA (10 AM) SENSOR

Date	Latitude	Longitude	Aqua_AOD	combined_quality_flag	distance_to_monitor
2013-01-02 13:57:46	6.098987	-0.270234	0.498	3.0	3.686523
2013-01-03 13:02:41	6.059364	-0.342876	0.920	3.0	7.113680
2013-01-03 13:02:43	6.147391	-0.361712	0.884	3.0	7.855523
2013-01-04 13:45:32	6.119722	-0.309876	0.589	3.0	1.471765
2013-01-06 13:33:17	6.058877	-0.302505	0.473	3.0	5.543223
...	...	...	...	...	...
2018-12-15 13:26:47	6.139249	-0.323575	0.489	3.0	4.110101
2018-12-24 13:20:41	6.073973	-0.282273	1.123	3.0	4.446655
2018-12-24 13:20:43	6.163544	-0.302193	1.132	3.0	6.031860
2018-12-25 14:03:34	6.115352	-0.322781	0.957	3.0	2.405102
2018-12-29 13:39:05	6.156115	-0.313807	1.188	3.0	5.371650

271 rows × 5 columns

MODIS AQUA (1 PM) SENSOR

ESTIMATION OF NASA AERONET AOD AT 550nm

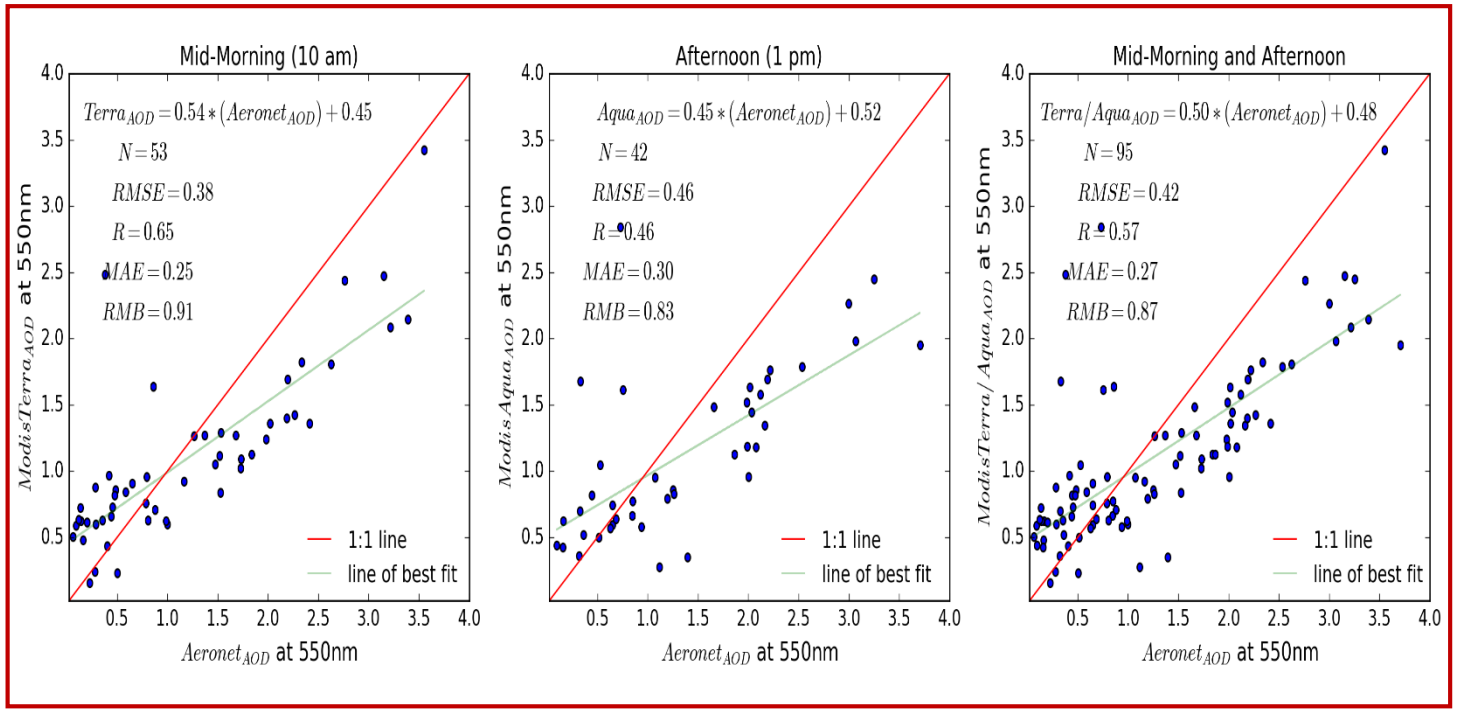
$$Angstrom\ \ Exponent\ (\alpha) = \quad \tau_{\lambda o}\left(\frac{\lambda}{\lambda_o}\right)^{-\alpha} \quad = \quad -\left[\frac{\log\left(\frac{\tau_1}{\tau_2}\right)}{\log\left(\frac{\lambda_1}{\lambda_2}\right)}\right] \qquad \text{(A)}$$

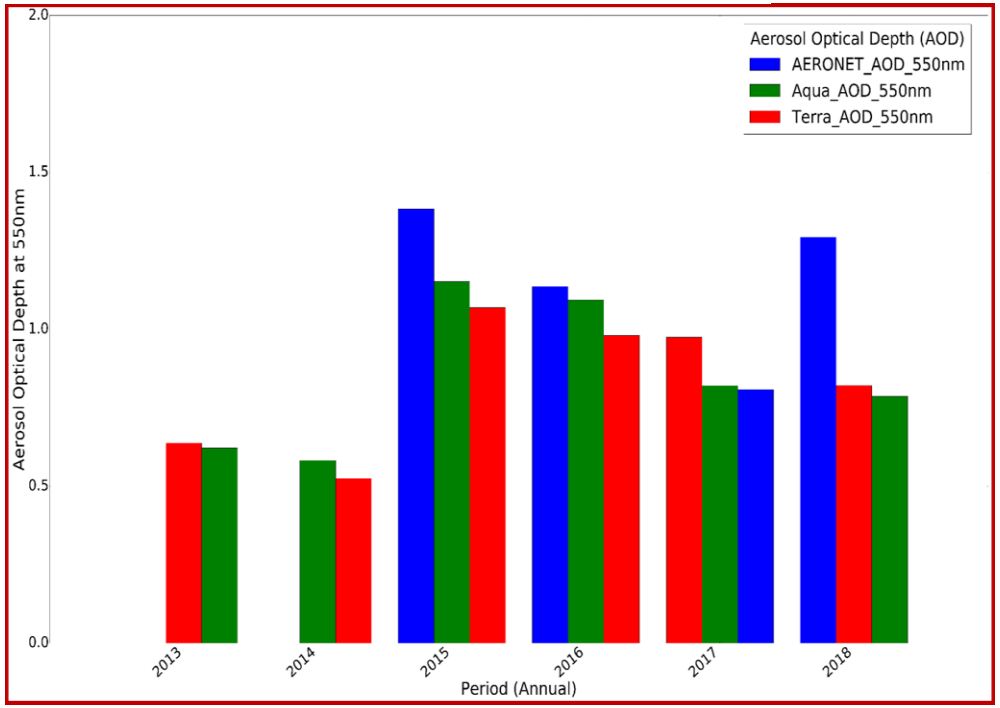
$$Estimated\ \text{Aeronet AOD at 550nm} = \quad -\left[\frac{\log\left(\frac{\tau_\alpha^{0.440nm}}{\tau_\alpha^{0.870nm}}\right)}{\log\left(\frac{0.440}{0.870}\right)}\right] \qquad \text{(B)}$$

- Where $\tau_\alpha^{0.440nm}$ and $\tau_\alpha^{0.870nm}$ are the AERONET derived τ_α at 0.440nm and 0.870nm respectively.

Q. Li et al., 2012; Gupta et al., 2018

CORRELATION and BARPLOTS BETWEEN MODIS TERRA, AQUA AND AERONET AOD AT 550nm





- Both MODIS Terra, Aqua and combined sensors underestimated the AOD with Relative Mean Bias (RMB) of 0.91, 0.83 and 0.87 respectively over Ghana.
- MODIS Terra agrees better with NASA AERONET stationed data followed by the combined (Terra/Aqua) and Aqua sensor dataset.

STATISTICS OF COMPARISON BETWEEN AERONET AND MODIS TERRA, AQUA AND COMBINED AOD FOR THE STUDY PERIOD

	Terra (10 am) AOD 10km	Aqua (1 pm) AOD 10km	Combined Terra/Aqua AOD
N	53	42	95
Slope	0.54	0.45	0.50
Intercept	0.45	0.52	0.48
MAE	0.25	0.30	0.27
R	0.65	0.46	0.57
RMSE	0.38	0.46	0.42
MBias	-0.11	-0.23	-0.16
RMB	0.91	0.83	0.87

EQUATIONS USED TO CALCULATE THE STATISTICAL METRICS

$$Mean\ bias\ (MBias) = \frac{1}{N}\sum(Modis\ AOD - AERONET\ AOD) \quad (C)$$

$$Root\ Mean\ Square\ Error\ (RMSE) = \sqrt{\frac{1}{N}\sum(Modis\ AOD - AERONET\ AOD)^2} \quad (D)$$

$$Mean\ Absolute\ Error\ (MAE) = \frac{1}{N}\sum|Modis\ AOD - AERONET\ AOD| \quad (E)$$

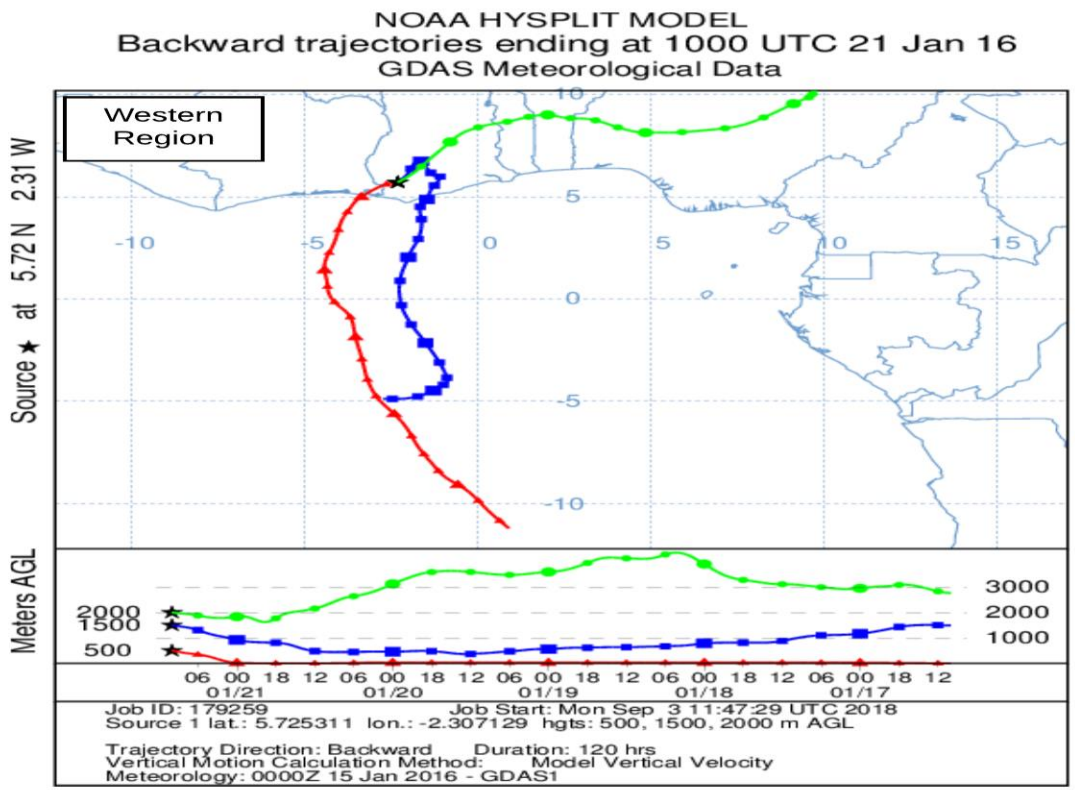
$$R = \sqrt{1 - \frac{\sum_{i=1}^{1}[(MODIS\ AOD)i - (AERONET\ AOD)i]^2}{\sum_{i=1}^{1}[(MODIS\ AOD)i - (\ \mu MODIS\ AOD)]^2}} \quad (F)$$

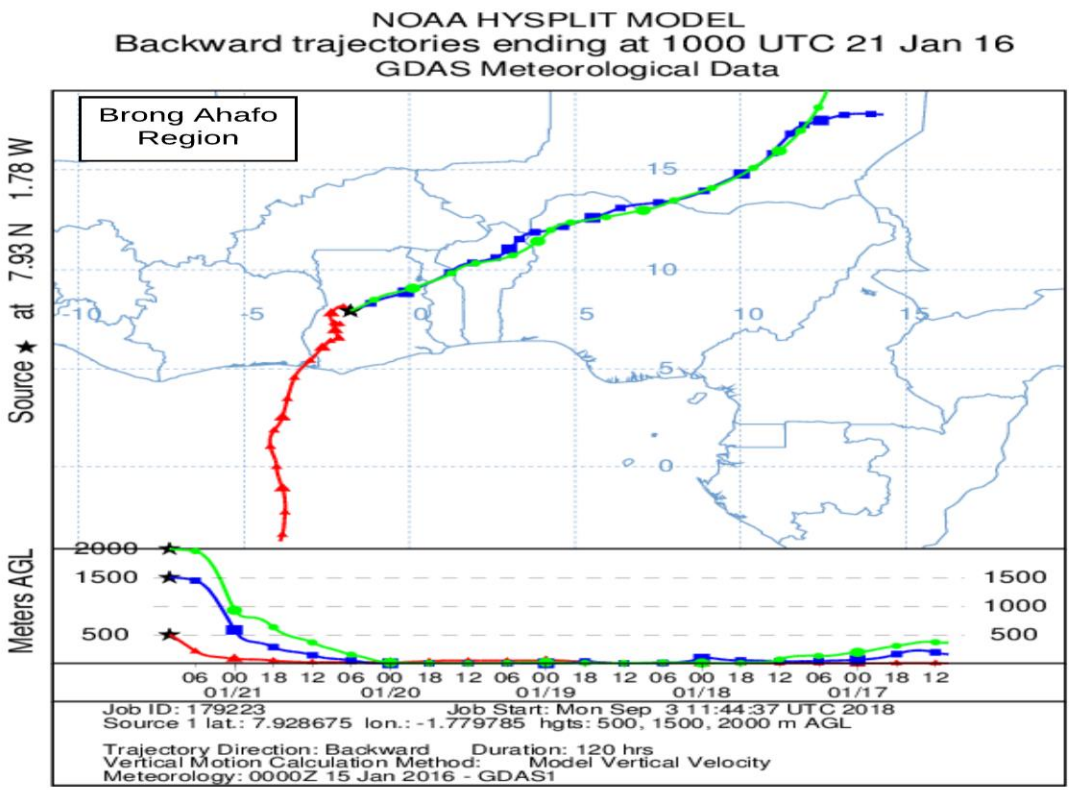
$$Relative\ Mean\ Bias\ (RMB) = \frac{\mu\ AOD\ of\ Modis\ data}{\mu\ AOD\ of\ NASA\ AERONET\ data} \quad (G)$$

$where\ \ \mu = Population\ Mean$

BACKWARD TRAJECTORIES OF AEROSOLS OVER GHANA

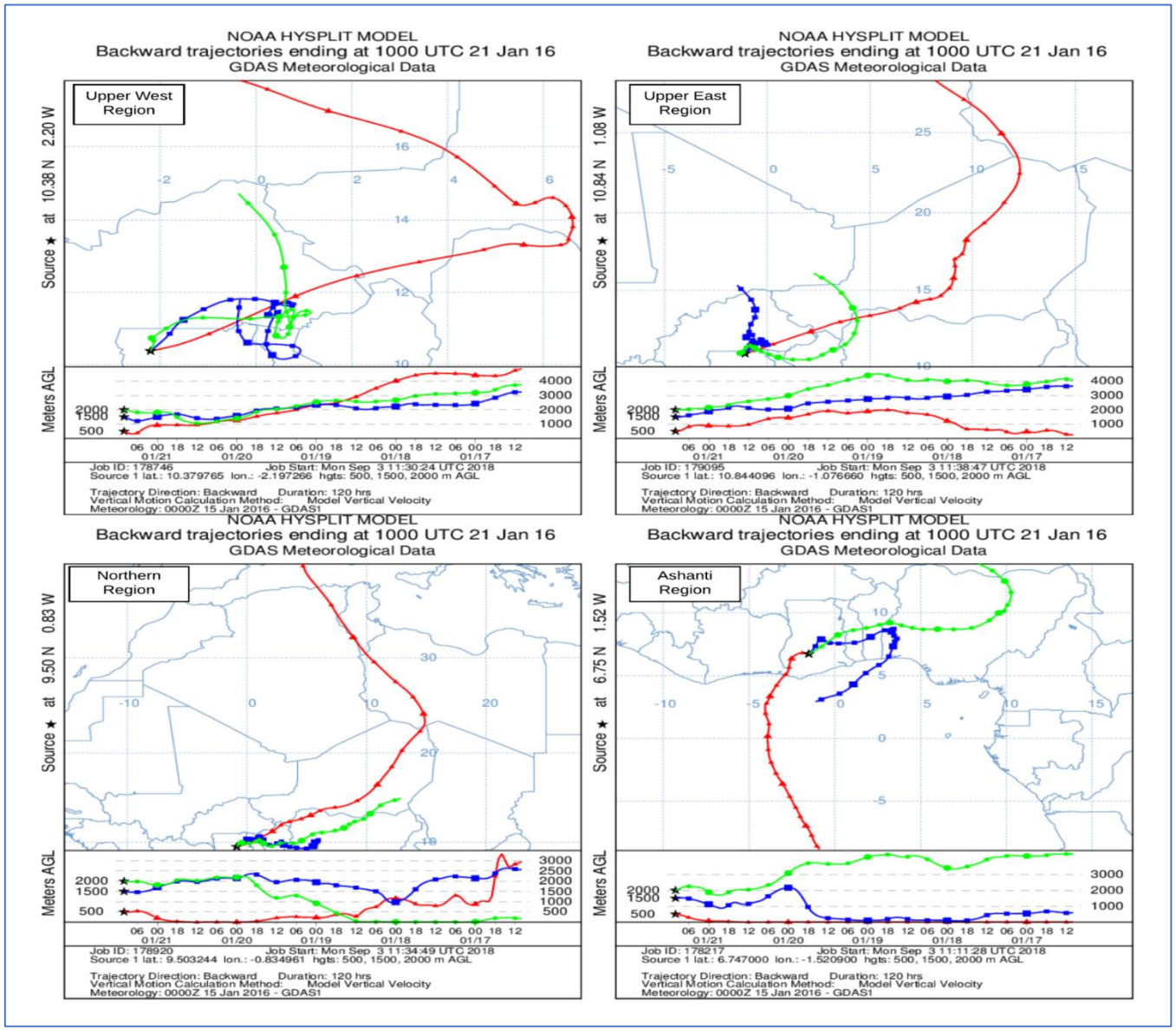
- The origin of aerosols over Ghana were traced on (21st of January, 2016 at 10:00 UTC) using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model





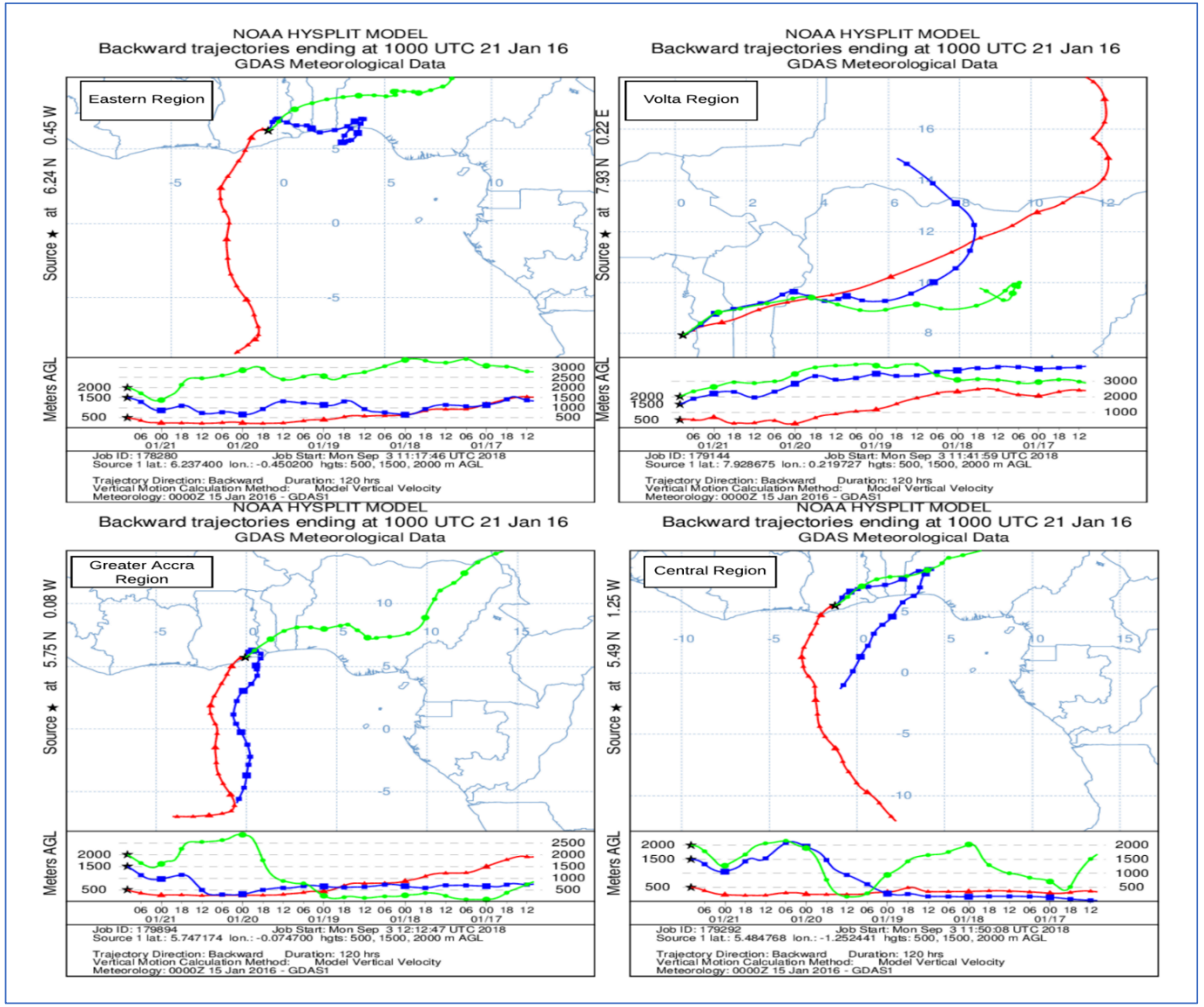
BACKWARD TRAJECTORIES OF AEROSOLS OVER GHANA

- Backward trajectories over Ashanti, Upper West, Upper East and Northern regions of Ghana.



BACKWARD TRAJECTORIES OF AEROSOLS OVER GHANA

- Backward trajectories over Eastern, Volta, Central and Greater Accra regions of Ghana.



CONCLUSION

- A decreasing trend of AOD was observed for both Terra and Aqua sensors during the study period. However, peaks of AOD occurred in the middle and southern parts of Ghana.
- MODIS Terra and Aqua sensors underestimated the AOD over Ghana.
- Different AOD episodes occurred for both Terra and Aqua sensors during the wet season as compared to the dry season.
- Origins of aerosols over Ghana during the peak of the dry season can be traced from the sea, Saharan desert, within and neighbouring countries.
- Above all, there is the need for collaboration for further research in terms of satellite sensor data correction over African regions.

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THANK YOU