Lake Victoria HIGHWAY[1] Field Campaign Operations Plan

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1 Acronyms

3D-PAWS	3D-Printed Automatic Weather Station
ALAM	Asia Limited Area Model
AMDAR	Aircraft Meteorological Data Relay
AMMA	Africa Monsoon Multidisciplinary Analysis
API	Application Programming Interface
ARC	Advanced Radar Corporation
PLATFORM	Automatic Message Switching System Overall meteorological platform used by Météo Rwanda to receive, transmit and view meteorological data.
ATDNet	Arrival Time Difference Network
COSMO	Consortium for Small-scale Modeling
DFID	Department for International Development
EA	East Africa
ECMWF	European Centre for Medium-Range Weather Forecasts
EEC	Enterprise Electronics Corporation
ENTLN	Earth Networks Total Lightning Network
EOP	Enhanced Observation Periods
EWS	Early Warning System
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FOREST	Forecast, Observations and Research Evaluation and Survey Toolkit
FTP	File Transfer Protocol
GCRF	Global Challenge Research Fund
GLD360	Vaisala Global Lightning Dataset
GLOBE	Global Learning and Observations to Benefit the Environment
GTS	WMO Global Telecommunication System
HIGHWAY	HIGH impact Weather lAke sYstem
GEWEX	Global Energy and Water Exchanges
GPM	Global Precipitation Measurement
HyVIC	Hydroclimate project for Lake Victoria
HyCRISTAL	Integrating Hydro-Climate Science into policy decisions for climate-resilient Infrastructure and Livelihoods in east Africa
ISS-LIS	International Space Station- Lightning Imaging Sensor
KMD	Kenya Meteorological Department
LVB	Lake Victoria Basin
MODE-S	a secondary Surveillance Radar
MOYA	Methane Observations and Yearly Assessments field campaign
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
NERC	Natural Environment Research Council
NSF	National Science Foundation
NMHS	National Meteorological Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
NCAR	National Center for Atmospheric Research
MetOp	a series of three polar orbiting meteorological satellites operated by EUMETSAT
OSCAR	Observing Systems Capability Analysis and Review Tool
PRF	Pulse Repetition Frequency
PUMA	An African project to disseminate Météosat Second Generation satellite
SC	Steering Committee
Suomi NPP	Suomi National Polar-orbiting Partnership
SWIFT	Science for Weather Information and Forecasting Techniques
SYNERGIE	Operational forecasting tool used by Météo France displays modeling and observation fields
SWFDP	Severe Weather Forecast Demonstration Project

TAHMO	Trans-African HydroMeteorological Observatory
TMA	Tanzania Meteorological Agency
UK	United Kingdom
VCP	UK Voluntary Co-Operation Programme. This is the Met Office Unified Model run over Africa as a limited-area model
UKMO	United Kingdom Meteorology Office
UNMA	Uganda National Meteorological Authority
USAID	U.S. Agency for International Development
UTC	Coordinated Universal Time
WGNMR	Working Group on Nowcasting and Mesoscale Research
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting model
WWRP	World Weather Research Program
WWLLN	World Wide Lightning Location Network

2 Preface

This document is the Operations plan for a mini Field Campaign that will take place during selected periods from January to August 2019 to collect enhanced weather observations over the Lake Victoria Basin region in East Africa. The Lake Victoria HIGHWAY Field Campaign differs from more traditional field campaigns in that it focuses on the use of existing observational systems rather than deploying a number of temporary observation platforms, such as radars, research aircraft, profiling systems, and disdrometers for the duration of the campaign. In a typical field campaign, principal scientific investigators would have daily meetings to decide on when to conduct Intensive Observation Periods (IOP), the scientific objectives for those IOPs and where to deploy instrumentation and collect data for the IOP. For the Lake Victoria HIGHWAY Field Campaign, there are neither sufficient funds for a large array of mobile and temporary facilities nor is there support for the participation of large international, scientific research teams (as in AMMA, for example). However, limited supplemental funds are expected to be available that will support the additional deployment of temporary and permanent surface stations, additional expendables (balloons, helium, sondes) for more frequent radiosonde launches over duration of the HIGHWAY project, occasional dropsondes from a research aircraft, and deployment /operationalization of buoys on Lake Victoria[9]. These funds will also support archival of radar data, provision of radar spare parts, transmission of radar data to National Meteorological Hydrological Services (NMHSs) and training of meteorologists in processing and interpretation of radar data in East Africa.

2.1 History

In 2012, the WMO Executive Council requested the WMO Working Group on Nowcasting Research (WGNR) to prepare a plan for a field program to better understand the dynamics of Lake Victoria thunderstorms. In response, a scientific proposal developed by Wilson and Roberts in 2013 was submitted to the United States National Science Foundation (NSF) for funding and support for a major Field Program over Lake Victoria to collect high-resolution observations of the pre-storm and storm environment. In the proposal a significant number of temporary observational platforms were requested. This proposal was not funded because of the inability to identify matching funds from other international sources, a requirement of NSF. However, the scientific goals and hypotheses of the NSF proposal are relevant to the HIGHWAY Field Campaign. Thus, the scientific goals and hypotheses that were presented in the NSF proposal are provided here in Appendix A and not in the main document, as the primary purpose of this Operations Plan is to discuss the instrumentation

[9] As of 4 June 2018, the United Kingdom's Department for International Development (DFID) has awarded a Capital Expenditure (CAPEX) of 1MIL GBP for the HIGHWAY Field Campaign for collection of enhanced observations.

platforms, measurements, archival requirements, and enhanced observational periods of the Field Campaign. It is a highly desirable goal for the Field Campaign to be able to collect the necessary data that will help to address the science questions and hypotheses posed in Appendix A and posed by forecasters and managers at the NMHSs.

2.2 Data Sharing

Data sharing is very important for the Field Campaign. Only with data sharing will it be possible to build a set of severe weather case studies that can be used for scientific understanding, training of forecasters, verification of NWP forecasts, and development of products for a regional Early Warning System (EWS). Low bandwidth data, as from surface stations and radiosondes, will be readily accessible via the WMO Global Telecommunication System (GTS). However very high bandwidth data like radar digital data needs to be archived locally and dispersed to Highway participants by other means including File Transfer Protocol (FTP), Application Programming Interface (API) and exchange of hard disks. Only those observational data sets that the NMHSs are willing to share with all HIGHWAY participants will be considered as part of the Lake Victoria HIGHWAY Field Campaign data (see Section 3). A regional repository (such as a "cloud" storage service) is recommended for data archival and sharing of Field Campaign data, however the exact details for this data repository system has yet to be defined and approved by the HIGHWAY Steering Committee (SC). A successful Lake Victoria Field Campaign will involve reliable and routine collection, archival and acquisition of all available data within the vicinity of Lake Victoria Basin and an Operations Plan supported by all HIGHWAY participants.

3 The Lake Victoria HIGHWAY Field Campaign

3.1 Objective

The goal of the Lake Victoria Field Campaign is to develop scientific understanding of the processes leading to severe weather over the Lake Victoria Basin (LVB) in East Africa. There is significant loss of life on Lake Victoria (an estimated 3000-5000 deaths per year) because of boating accidents; many believed to be caused by strong winds and resulting waves. During the East African (EA) rainy season, an emphasis is on understanding the initiation and evolution of nocturnal thunderstorms that produce intense low-level winds that are a deadly hazard to the fishing and transportation industry on Lake Victoria. During the EA dry season intense synoptically-driven winds have been associated with numerous boating accidents and fatalities. The local and mesoscale atmospheric processes associated with these large scale winds over the Lake are not well understood. The ultimate purpose of the Field Campaign proposed here is to develop sufficient understanding of thunderstorm evolution and factors controlling storm severity to help local weather services improve nowcasting and warning capabilities that would lead to greater safety for Lake Victoria boating interests.

3.2 Project Motivation

The over-arching motivation of the HIGHWAY project is to improve the early warning of severe weather events in the LVB. Lake Victoria is shared by Tanzania, which owns 51% of its surface area, Uganda which owns 43% and Kenya which owns 6%. Although Kenya controls only a small part of Lake Victoria, its lake shore areas are heavily populated and a high proportion of the population is affected by weather events over the lake. Over the past few years, each of the countries that bound the lake have initiated national programs to provide early warnings of severe weather over the lake by issuing a special daily weather forecast (see Powell, 2016) . The ability to provide more frequent forecast and nowcast updates and timely warnings depends upon a number of factors that include:

- high spatial and temporal observations over and around the lake that can be accessed in real-time by forecasters at the NMHS,
- displays that integrate a variety of observations (satellite, radar, surface station, lightning data) and NWP model forecast fields
- forecaster conceptual models of the different scenarios that produce severe weather over the lake and criteria to use for issuing warnings
- and training on the use of the new and improved warning decision-making products

These factors are achievable from the additional data and observations collected during the Field Campaign.

3.3 Field Observation Period

The Mini-Field Campaign is designed to maximize the use of ***existing observations*** along with modest enhancement of the observations where possible, to improve scientific understanding of weather over LVB. Two Enhanced Observation Periods[10] (EOPs) are planned, the first during the rainy season (Mar-May 2019) for a three month period and the second during the dry season (Jun-Aug 2019) for a one month period centered during July and August. A third, smaller observing period of 3 days will occur from 27-29 January 2019, in association with the MOYA field campaign. The total duration of the field campaign will be dependent on the total amount of resources available.

[10] Not to be confused with an Intensive Observation Period as discussed for traditional Field Campaigns in Section 1.

3.4 Domain

The primary domain for the observational Field Campaign includes the lake region and the land extending 100-200 km outward from the lake. This designation is based on prior scientific proposals (Wilson and Roberts, 2013). Figure 1 shows the location of the domain, which includes the lake and extends to the crest of the mountains on the east and west sides of the lake. The surrounding terrain has a strong influence on diurnal storm formation with storms forming over the land during the day and over the lake at night. Additional local triggers for storm initiation are convergence of wind set up by anabatic and katabatic winds generated by the high terrain surrounding the lake as well as lake and land breezes generated by the lake and the large scale flow. Other convergence lines are generated by gust fronts and possible strong, horizontal temperature gradients within the lake.

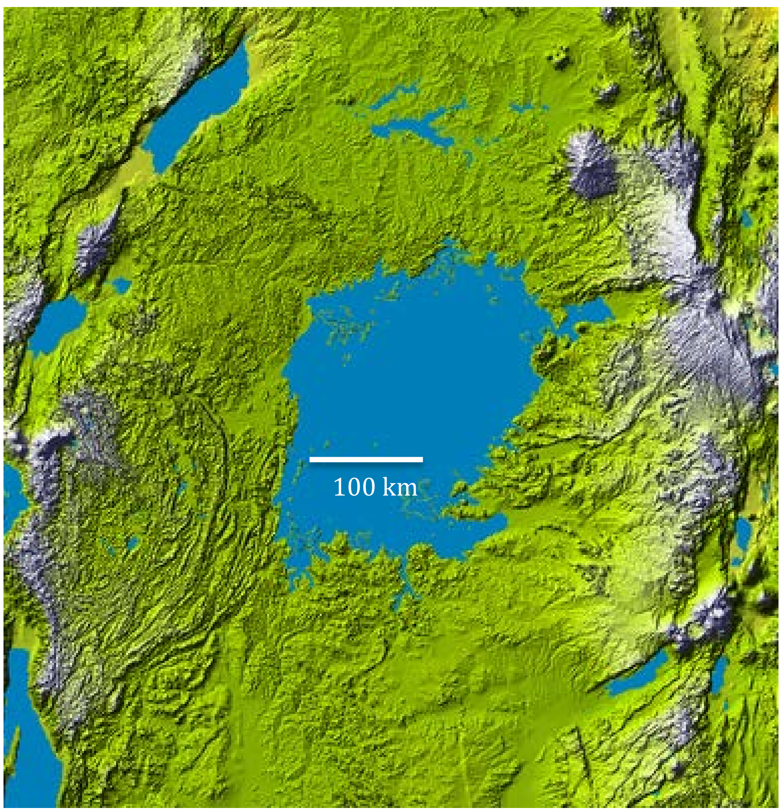

Figure 1. Terrain map and proposed domain for the Lake Victoria 2019 Field Campaign.

3.5 International Collaboration and Participating Institutions

The Field Campaign funding is sponsored by the UK Department for International Development (DFID), with oversight management provided by the WMO. The National Meteorological and Hydrological Services of Kenya, Tanzania, Uganda, and Rwanda, the

United Kingdom Meteorology Office (UKMO) and the National Center for Atmospheric Research (NCAR) of the United Sates will collaborate closely in the design and conduct of the mini Field Campaign.

Four other programs will be ongoing during the HIGHWAY Field Campaign: 1) the HyCRISTAL project (Marsham et a, 2015) sponsored by the United Kingdom's Natural Environment Research Council (NERC) and DFID, 2) GCRF's African Science for Weather Information and Forecasting Techniques (African-SWIFT) program, 3) the Methane Observations and Yearly Assessments (MOYA) project sponsored by the UK Natural Environment Research Council, and 4) the WWCP GEWEX Hydroclimate project for Lake Victoria (HyVIC). The HyCRISTAL project, which runs from July 2015 to July 2019 (and may be extended) is focused on climate change over East Africa, with a focus on the LVB. The SWIFT program is a large 4-year consortium that includes groups in Kenya working to develop a sustainable African weather forecasting and science capability (see https://africanswift.org).

Other partners include TAHMO, Kenya's AMDAR program, and the NCAR-USAID 3D-PAWS programs that are discussed later.

3.6 Expected Outcomes

The expected outcomes of the mini Field Campaign are

- increased scientific understanding of the initiation, evolution and intensity of severe weather phenomena hazardous to Lake Victoria fishermen and commercial ferries, and human populations residing along the shores of the lake,
- recommendations on new and improved nowcast products and their validation for Early Warning Systems that increase skill in predicting and warning of severe weather,
- forecaster training on radar interpretation, examination of severe weather cases and use of integrated digital data displays for nowcasting, and
- a unique opportunity for NMHS offices to gain regional wide understanding of the weather and modifying influences over LVB.

4 Overview of project observing systems

Observational platforms will only be considered to be part of the mini-field campaign if the data is shared with the Highway participants and the data is easily available. The data does not need to be available in real-time during the Field Campaign but ideally should be available in ***near real-time***. For some datasets, such as radar, there may be a larger delay in availability. Existing instrumentation expected to be available during the field campaign are shown in Fig. 2. As will be discussed below the status of many surface stations is unknown and potentially new surface stations may be added. By the time of the Field Campaign the

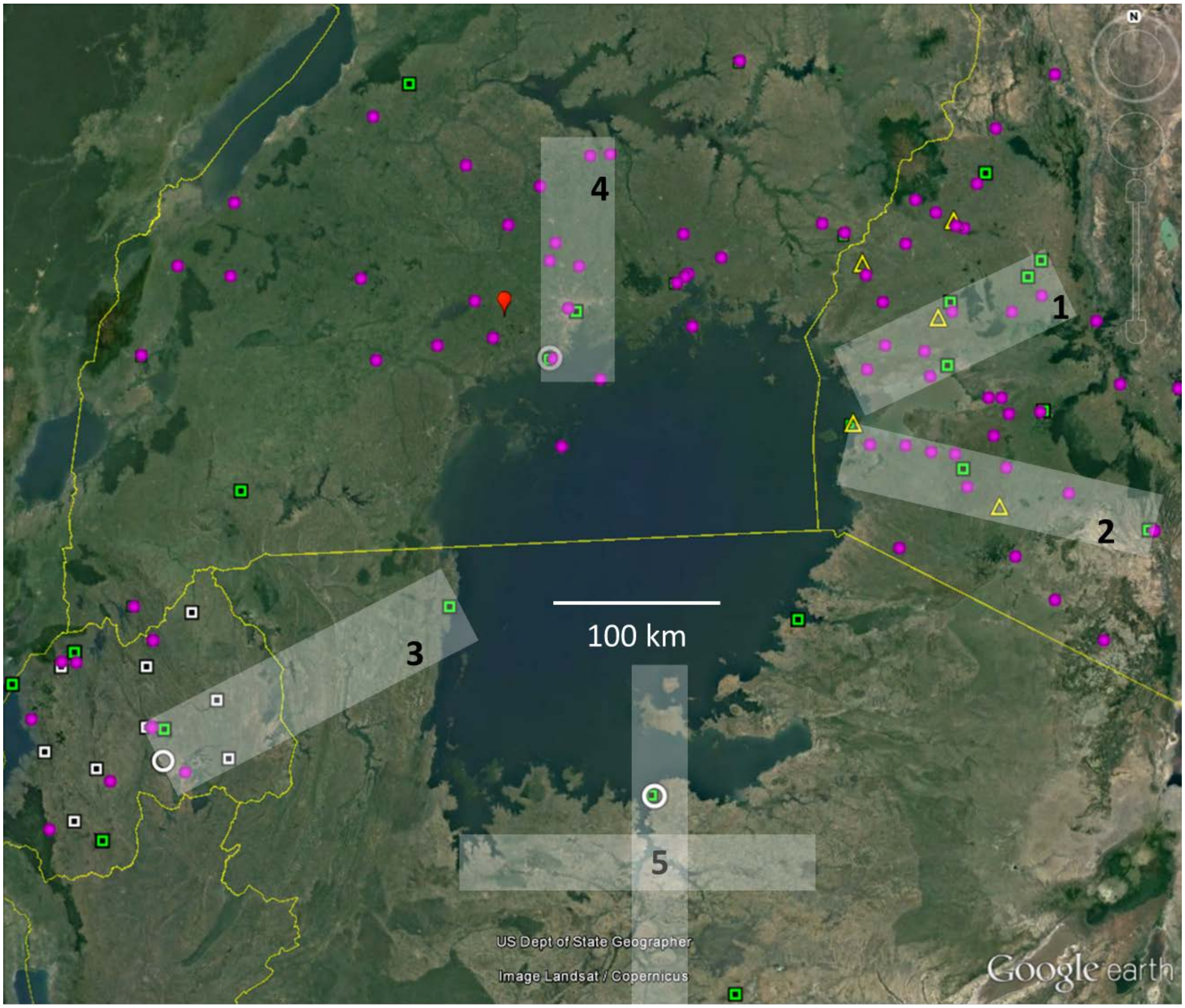

Figure 2. Map of existing surface weather stations within the domain of the field campaign. Weather stations reporting to GTS are green squares, TAHMO surface stations are purple dots, 3D-PAWS surface stations are yellow triangles and the white squares are Rwanda NHMS stations not listed as reporting to GTS. The open white circles are the Mwanza and Rwanda radars. The gray open circle is the Uganda radar that is being installed. The one occasional operational radiosonde (upper air) station is in Entebbe (orange balloon). The transparent white lines numbered 1 to 5 represent proposed lines of enhanced surface station coverage for studying boundary layer convergence lines and channeling.

potential exists for additional radiosonde sites, and GTS total precipitable water sites. Other data sets that will be available include satellite imagery and products from EUMETSAT, commercial lightning data, lake measurements collected by the Jubilee Hope hospital ship, instrumentation from Kenya's two fixed buoys and Kenya's AMDAR data collected from commercial aircraft on arrival and departure. These data are discussed in the following sections.

4.1 Surface weather stations

Surface weather stations during the Field Campaign will serve multiple purposes, as input to numerical models, verification of numerical models, monitoring weather conditions for NHMS forecasters, and monitoring boundary layer convergence lines for scientific understanding of triggering mechanisms for convective storm initiation and evolution. This latter need is a primary goal of the Field Campaign. There are three primary surface weather station networks that will be available during the Field Campaign. These are the TAHMO stations, 3D-PAWS, and the NMHS surface stations reporting to the GTS and viewable via the WMO OSCAR program. There may be a few additional stations from the HyCRISTAL campaign and other private networks. The TAHMO and 3D-PAWS stations are particularly important in that they record observations every 5 -15 min. The locations of the TAHMO and 3DPAWS stations are shown in Fig 2. Clearly TAHMO makes up a large majority of the stations.

Local wind phenomena such as gust fronts, land breezes, lake breezes, anabatic and katabatic flows associated with the surrounding higher terrain are believed to be the local triggering mechanisms that control storm evolution in the Lake Victoria Basin. At this time it is unknown how well radar and satellite can observe and track these local winds. Wind velocities from closely–spaced, frequently-observing surface weather stations could be very useful for this purpose. This could be accomplished from lines of surface stations with spacings of 10-20 km that are oriented perpendicular to the lake shoreline and extend from the lake to the mountain crests. Proposed examples of such lines of stations are shown in Fig 2. Figure 2 shows five proposed lines of surface stations. Two of the lines (lines 1 and 2) consist primarily of existing surface stations, but lines 3-5 require a number of new stations. New stations installed to fill out these lines for the Field Campaign data collection could then be redistributed after the campaign to locations desired by the NMHS's. The three surface station networks are described in further detail below.

4.1.1 National Meteorological Stations

All of the NMHSs have surface stations that measure, record and transmit state variable information to WMO's Global Telecommunications System (GTS). The GTS facilitates rapid collection, exchange, and distribution of observations for the World Weather Watch program. A repository of the surface station data is available via the WMO's Observing Systems Capability Analysis and Review Tool (OSCAR; https://oscar.wmo.int/surface//index.html#/). The surface stations located within the Field Campaign domain that are currently reporting to the GTS are shown in Fig. 2. A station will be useful for NWP purposes if it reports at least one of these variables:

temperature, dew point temperature or humidity, wind speed and direction, and rainfall. Stations that are most useful to deploy along the lines need to measure at minimum the wind direction, wind speed and temperature and record observations at least every 15 minutes.

Presently the quality of the data from the NMHS stations is unknown. The primary objectives of HIGWAY Activity 2.1 are to a) evaluate the quality of stations reporting through OSCAR, b) conduct a gap analysis of network station, c) recommend stations for upgrades and d) install new gap-filling stations. A priority of the Field Campaign is to conduct a data quality site survey, particularly for the lines of stations, prior to the start of the campaign. The possibility exists that new stations may be first located to fill gaps in proposed station lines in Fig. 2 and then after the field campaign be moved to locations that may be more useful for NMHS operations. The specific number of additional surface stations that may be installed in each country will be determined from the results of two workshops that will be held in Arusha Tanzania in August 2018.

Appendix B contains a list, for each country, of existing surface stations, their location, reporting frequency and variables measured.

4.1.2 3D-Printed Automatic Weather Stations (3D-PAWS)

In 2017, under USAID and U.S. National Science Foundation funding, fourteen 3D-PAWS stations have been sited at a variety of locations in Kenya. The majority of the stations (see Annex C for list) are located at schools participating in the international GLOBE program. GLOBE students and teachers are actively engaged to monitor and transmit the data and keep the instruments calibrated. One of the 3D-PAWS stations is located at KMD and the WMO has recommended that an inter-comparison be done of the 3D-PAWS with the existing KMD synoptic station and TAHMO station that are also co-located at KMD. For additional description of the 3D-PAWS stations see Appendix C.

For the Field Campaign, funding is available to install twelve additional 3D-PAWS stations in the LVB region. Preferred sites would be along the proposed station lines in Fig. 2 and at a couple of islands in the lake.

4.1.3 TAHMO Surface Stations

The Trans-African Hydro-Meteorological Observatory (TAHMO) program was initiated to install a dense network of hydro-meteorological monitoring stations in sub-Saharan Africa. TAHMO stations have been installed in Kenya, Uganda, Tanzania and Rwanda. The goal is to have one station located every 30 km. Some of the stations have been placed at schools and integrated in the educational program. Installation of several additional TAHMO stations are planned for 2018. The data from these stations are likely to be available to HIGHWAY participants during the mini Field Campaign free of charge. For additional description of the TAHMO stations see Appendix D.

4.2 Upper Air Stations

Several upper air stations have existed in the East African region in the past. Their locations are shown in Table 1. Currently, the Entebbe, Uganda upper air station launches radiosondes operationally. However these launches occur infrequently and not on any routine schedule. The Dagoretti Corner upper air station in Nairobi, Kenya also launches radiosondes operationally. The Global Climate Observing System (GCOS) monitoring shows that the site has been reporting on time and regularly from January 2018. However, there are no reports for May and June 2018 due to lack of radiosonde consumables. The Kenya Meteorological Department is in the process of procuring the radiosonde consumables, and the soundings may resume soon.

Some of the other upper air stations listed in Table 1 need to be resurrected for Field Campaign data collection and also for longer term operational needs.

Table 1. Locations of existing upper air (radiosonde) sites and frequency of observation measurements.

Station Identifier	Latitude/ Longitude (deg)	Altitude (m)	Frequency of Observation	Transmission Location (GTS, NMHS, or other)
Entebbe, Uganda	0.30/ 32.20	1155	Infrequent	GTS?
Dagoretti Corner Nairobi, Kenya 63741	-1.3013/ 36.7597	1799	Once/day Operational	GTS, KMD
Garissa Kenya 63723	-0.458665/ 39.648956	147	00&12 UTC Not presently operational	GTS, KMD
Lodwar, Kenya 63612	3.118517/ 35.590299	502	00&12 UTC Not presently operational	GTS, KMD
Kigoma, Tanzania 63801	-4.8833/ 29.666	822	Twice/day	GTS. NHMS

			Not presently operational	
Tabora, Tanzania 63832	-5.0833/ 32.8333	1182	Twice/day Not presently operational	GTS, NHMS
Dar es Salaam, Tanzania 63894	-6.8666/ 39.2000	53	Twice/day Not presently operational	GTS, NHMS

4.3 Vertical Profiling Systems

4.3.1 AMDAR (MODE-S)

Kenya is in the initial stages of testing equipment that were installed on Kenya Airways plane(s). Currently we still do not have datasets but you can contact Kenya's AMDAR Focal Point Mr. Charles Mugah, cellphone +254 729 001060 email: cmugah7@gmail.com.

4.3.2 GPS-TPW Stations

In addition to conventional observations, it is expected that surface Global Position System (GPS)-Total Precipitable Water (TPW) stations[11] will be installed by the UKMO at 3-4 NMHS locations around the lake to provide continuous automatic reports of total precipitable water (TPW) throughout the atmosphere. These data will be available at least hourly and in real-time. The data will be used not only in forecast offices to help monitor day-to-day variations in the flow of moisture supplying moisture to thunderstorms that form over the lake, but also as an independent means of validating NWP analyses/forecasts and various satellite products being made available through the exercise.

4.4 Radars

During the Field Campaign the potential exists that three Doppler radars may be available to collect high resolution information on storm growth and intensification, storm-scale winds, thunderstorm outflows and wind shear over the lake and over land. Details on these radars are listed in Table 2.

[11] The UK DFID CAPEX funds are the source of funding for the GPS-TPW stations.

Table 2. Radar specifications for the Tanzania, Rwanda and Uganda radars.

Radar	Mwanza, Tanzania	Rwanda	Entebbe Airport, Uganda
Manufacturer	EEC	ARC	Vaisala
Latitude/Longitude	-2.4799/32.93	-2.158/30.113	00° 02' 16.9892" N 32° 26' 49.9080" E
Altitude			1180m
Wavelength (cm)	10	5.33	5
Beamwidth (deg)	1.0	1.0	1.0
Polarization	Dual	Dual	Dual
Transmit Power (KW)		250	250
Commercial Power/Generator	Yes/yes	Yes/yes	Yes/yes
Radar fields			
Horizontal Reflectivity (Zh)	yes	yes	Yes
Horizontal Doppler Velocity (Zhv)	yes	yes	Yes
Differential Reflectivity (ZDR)	yes	yes	yes
Specific Differential Phase (KDP)	yes	yes	yes
Correlation Coefficient (ρhv)	yes	yes	yes
Ground Clutter Removal	yes	yes	yes
Second Trip Dealiasing	yes	yes	yes
Velocity Dealiasing	yes	yes	yes
Hydrometeor classification	yes	yes	yes
HIGHWAY Scan Strategy			
Volume scan time and mode	6 min - surveillance	6min-survellance	4min-survellance
Low PRF (pulses sec^{-1})/range	500/240 km	160/250km	300/450 km
Low PRF elevation angles (deg)	0.2, 1.2	0.5, 1.5, 2.5, 3.5	-1, 0.5, 1
High PRF (pulses sec^{-1})/range	1000/150 km	200/100km	100/75 km
High PRF elevation angles	0.3, 1.0, 2.0, 3.0 4.0, 5.0, 7.0, 10.0, 15.0	0.5, 1.5, 2.5, 3.5, 4.5, 6.0, 8.0, 11.0°, 15.0, 22.0, 32.0	0.3, 1.0, 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0
Data Archive			
List of variables archived	All scans including above variables archived to disk	All scans including above variables	

4.4.1 Tanzania Radar

The TMA dual-polarization S-Band (10 cm) radar, manufactured by the EEC radar company, is located in Mwanza on the south shore of Lake Victoria and has been operational since 2015. It collects a suite of dual-polarization fields and also produces a hydrometeor classification field derived from a combination of the dual-polarization fields. The hydrometeor classification field is updated every 6 min, along with all of the other radar fields and provides useful information on the type of precipitation (rain, ice, graupel, hail) within the storms. This radar is able to cover the entire lake when running a low Pulse Repetition Frequency (PRF) scan although only the tops of tall storms are detected at farther ranges. At a higher PRF, the radar scans approximately half of the lake to the north of its location and collects full volumetric data within the storms. The archival process is presently being modified from storing only low elevation data for three months to storing all data indefinitely.

Figure 3 shows a low level scan at 0.07° collected by the Mwanza radar on 21 November 2017. A number of important features for nowcasting were observable over the water. Insects in the clear air were observed out to ~75 km range from the radar providing radar "clear air" echo signatures over the lake; these regions are indicated by the green and blue

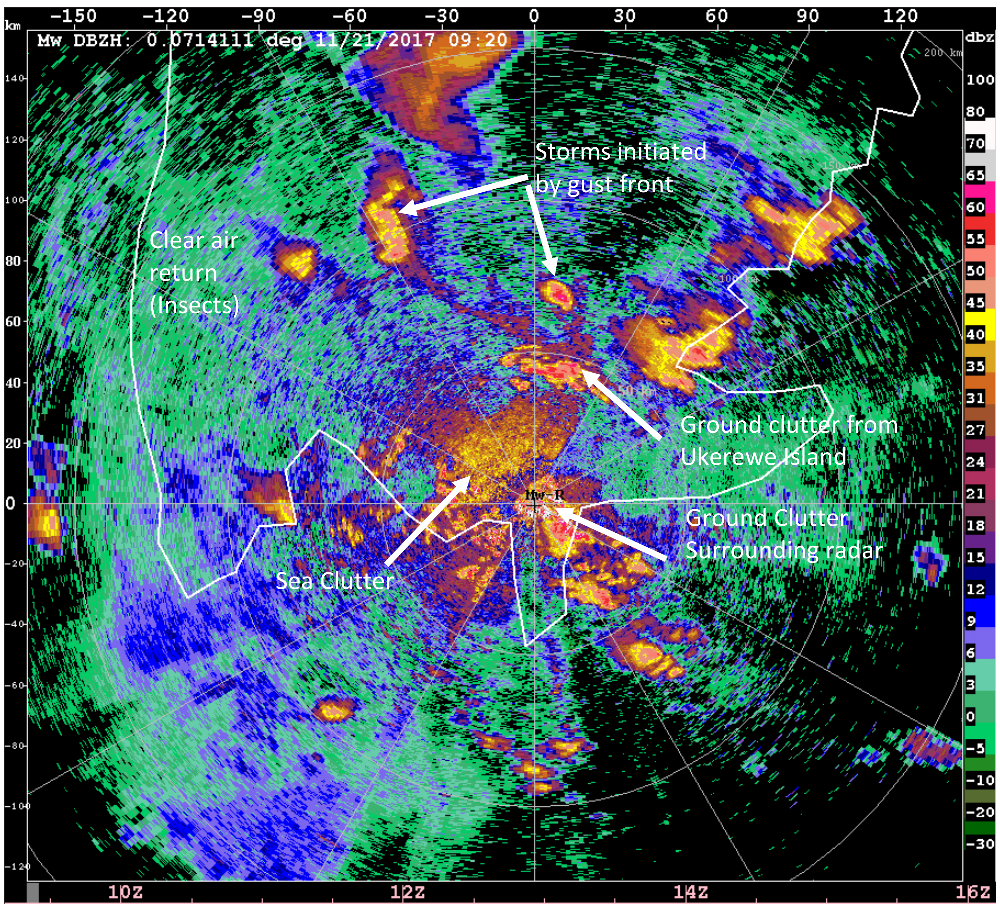

Figure 3. Mwanza radar reflectivity (dBZ) at 0.07 °elevation. The white polygon overlaid onto the image roughly marks the boundary between the land and Lake Victoria. The radar location in the image is located at (0, 0). Storm echoes are present over the lake and over the land. Strong ground clutter return is evident around the radar and associated with Ukerewe Island, the largest island in the lake. Sea clutter was also commonly observed. The radar clear air return (green/blue widespread echo) are the result of insect backscattering or Bragg scatter echo which results from strong moisture gradients in the atmosphere.

widespread echo. Gust fronts emanating from storms were observed frequently over the lake and observed to trigger new convection. The ability to detect gust fronts is of considerable importance in any early warning system, as gust fronts represent the leading edge of the thunderstorm downdrafts and outflows are likely a significant factor in generating increased wave heights on the lake.

4.4.2 Rwanda Radar

Rwanda radar is an ARC C250P C-band, dual Polarimetric Doppler weather radar located at Maranyundo hill (Bugesera Distict, Eastern Province) is located near Kigali at the latitude 02°09'29.07" S, longitude 30°06'44.43" E and the altitude 1616 m. This radar was installed to detect and monitor heavy rainfall in the area and the potential for wind shear over the Kigali International Airport and shall serve the new Bugesera International Airport in construction.

Every 6 minutes, the radar performs 11 azimuthal scans of 360° around a vertical axis with maximum range of 250 km. Figure 4 shows the radar reflectivity field at 1.5° elevation scan on 12 March 2018. A N-S line of convective storms 30-50 km east of the radar site.

With ARC C250P C-band dual polarimetric radar and the NCAR-developed Thunderstorm Identification and Tracking Analyses (TITAN) and Configurable Integrated Data Display (CIDD), hydrometeors in clouds and precipitation cells can be uniquely identified by the Polarimetric Hydrometeor Particle Identification algorithm (HPID) and the Radar Echo Classifier (REC). This algorithm detects erroneous reflectivity returns, such as ground clutter, anomalous propagation, sea clutter and man-made artifacts in radar measurements, allowing for this data to be removed for higher quality research. The radar gives quantitative precipitation estimates (QPE) over large areas with high spatial and temporal resolutions. It offers a tracking feature, as well as predictive motion, for identified storm cells. Storm cells are tracked from successive volume scans. Continuity of the cells between successive scans allows a cell to be tracked and the future position is determined and displayed in TITAN/CIDD displays. This facilitates accurate examination of the previous development and movement of a storm, as well as providing prognosticative guidance for its future impacts.

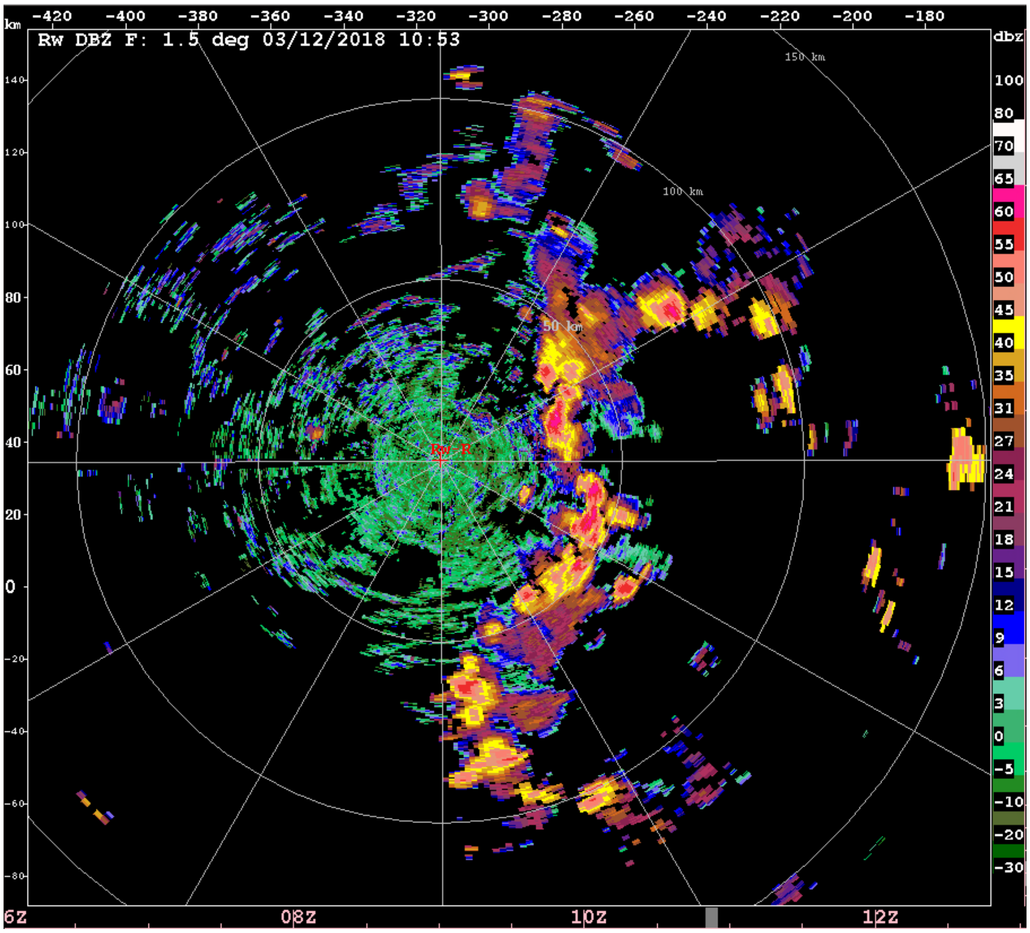

Figure 4. Radar reflectivity field from the Rwanda C-band radar located on Maranyundo hill (Bugesera Distict, Eastern Province) near Kigali International Airport. Range rings are in 50 km increments.

When the radar is operated in surveillance mode to collect full 360° scans, the radar data could be combined the Mwanza radar to produce a radar mosaic field covering a broader region of weather from the area south and west of the lake. Figure 5 shows the 150 km range rings for the Mwanza, Tanzania and the Kigali, Rwanda radars.

To support weather data analysis and training, Météo Rwanda proposes the integration of an additional five TITAN processing workstations, a Network Attached Storage (NAS) server with 50TB of disk space, and a 48-port network switch/router. This system will allow Météo Rwanda to archive weather radar data for the prior year and perform analysis using TITAN operational software. Météo Rwanda pushes radar data older than one year to an off-site (cloud based) storage for cost-optimized archive of data that is used less frequently.

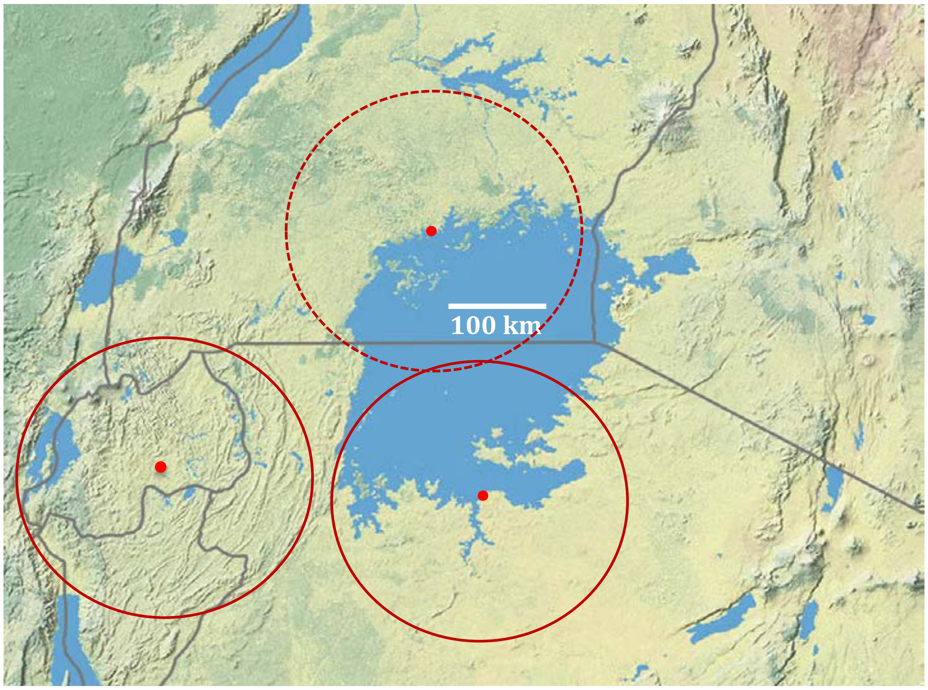

Figure 5. Coverage by the Mwanza and Rwanda radars in the Lake Victoria region. Range rings of 150 km are shown. Also shown is the Uganda radar coverage, once it becomes operational.

4.4.3 Uganda Radar

The UNMA dual-polarization C-Band (5 cm) radar manufactured by Vaisala is in the process of being installed at the Entebbe Airport, located on the north shore of Lake Victoria. It is expected that this radar will become operational by January 2019.

4.5 Radar Data Processing and Display

Most radar display systems are able to produce images of the radar fields. Image data can be transmitted very quickly to NMHS offices via low bandwidth communication lines. Digital gridded radar is necessary for case study analyses, integrated forecaster display systems, and assimilation of radar data into NWP models, and requires higher bandwidth transmissions. The radar data needs to be archived continuously during radar operations and distributed to PIs for case study analyses within one month of collection.

4.6 Satellite

The EUMETSAT MSG satellite provides the primary satellite imagery and nowcasting products for the Lake Victoria Basin. Nowcasting products of both the pre-storm environment and the individual storms will be available through the UK Met Office. Low earth-orbiting operational satellites such as the EUMETSAT MetOp, and NOAA Soumi NPP and NOAA 20 provide, at best, twice daily infrared and microwave soundings as well as sea surface temperatures for the lake. Precipitation data sets are available from NASA using data obtained from the NASA Global Precipitation Measurement (GPM) missions which use multiple satellites to obtain precipitation estimates.

4.7 Lightning

Multiple near real-time commercial lightning networks cover the HIGHWAY experiment domain having varying detection performance owing to the design, location and density of sensors in Africa. These include the Earth Networks Total Lightning Network (ENTLN), the World Wide Lightning Location Network (WWLLN) operated by the University of Washington in the U.S., the Vaisala Global Lightning Dataset (GLD360), and UK Met Office Lightning Arrival Time Difference Network (ATDNet). Preliminary studies indicate the performance (i.e., detection efficiency) of these networks vary across the Lake Victoria Basin with ENTLN best at detecting total lightning activity over the lake itself. The NASA Lightning Imaging Sensor on the International Space Station (ISS-LIS) provides near-uniform coverage across the entire basin and serves as an independent validation reference for the ground-based networks. Details of obtaining and sharing lightning data from these various sources for the Field Campaign is yet to be confirmed.

Figure 6 shows total lightning flashes from the ENTLN for a one hour period that is centered on the time of the 0920 November 17, 2017 this corresponds to the Mwanza radar reflectivity image shown in Fig 3. There is a good corresponds between the higher radar reflectivity values and the observed lightning flashes in Fig 6. Thunderstorm nowcasting tools will be investigated for combining radar and lightning data. In addition to the ENTLN lightning data the lightning product from the EUMETSAT Rapidly Developing Thunderstorm Product will be investigated to combine with the radar data. This satellite product is likely to be available from the UK Met Office.

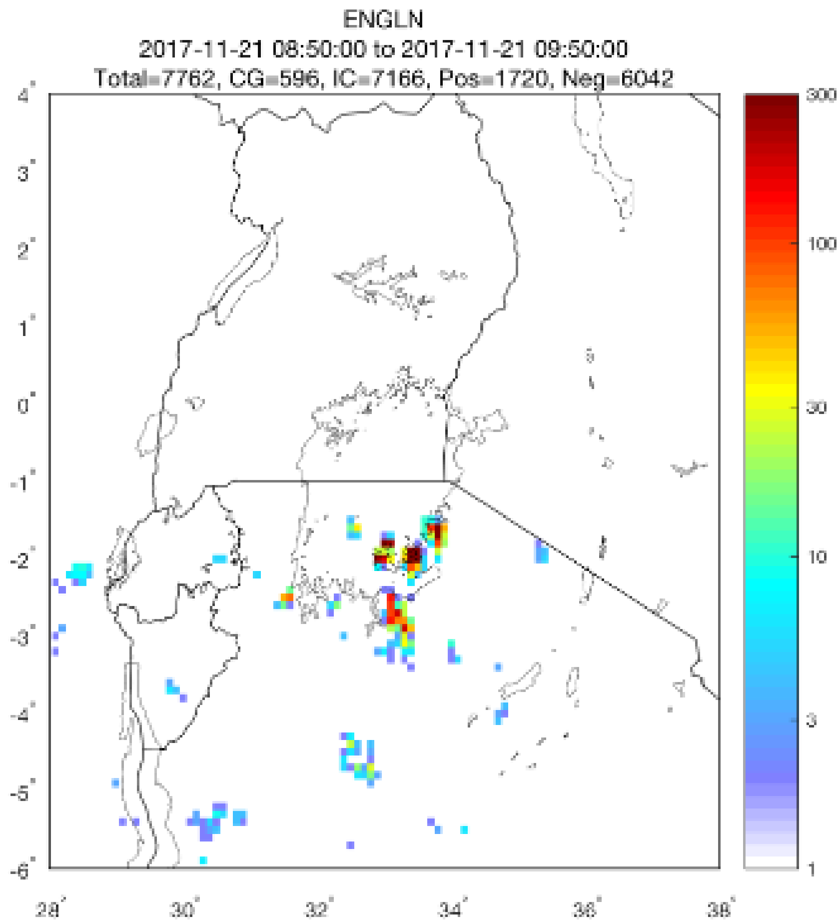

Figure 6. Earth Networks Total Lightning flashes for 21 November 2017 for the hour centered at 0920 UTC corresponding to the time of the Mwanza radar scan in Fig. 3. Positive colors are positive polarity flashes and negative colors (not shown) are negative polarity.

4.8 Water Measurements

4.8.1 Buoys

KMD plans to resurrect the two moored buoys which are situated in the Winam Gulf at Gingra and Rusinga Channel at Utajo. Additional buoys may potentially become available from the DFID 1 Mil GBP funds in support of the Field Campaign.

TMA has plans to purchase and install instrumented buoys on Lake Victoria that will transmit measurements to a server in real-time that will have the ability to store data for at least 2 years. The instrumented buoys will measure lake and meteorological parameters.

4.8.2 Instrumented Jubilee Hope Hospital Ship

As part of the HyCRISTAL and HYVIC field campaigns, water and near-surface atmospheric sensors have been installed on the Jubilee Hope ship and the Blue Bird passenger ship. The Jubilee Hope is owned by the Vine Trust (a British NGO) and is operated in cooperation with the Tanzanian Anglican Church. It provides health service to several islands in the southwestern corner of Lake Victoria. It recently changed the nature of the ship track. It now goes to one or two islands and spends two to five days and then goes back to its home port in Mwanza. The Jubilee has been taking measurements since August last year. The Blue Bird is a commercial 100+ passenger high-speed catamaran, which operates between Mwanza and Bukoba town. It takes slightly under 4 h for the transit. Blue Bird has had engine troubles and has not been operating since February 2018, but it is expected to start operating again in mid-June. Both ships measure the following: air temperature (~10 m), wind (~10 m), barometric pressure, relative humidity, rain rate, solar radiation (visible), and water temperature (on the Jubilee only). The paths of the Jubilee Hope and Blue Bird boats are shown in Fig. 7.

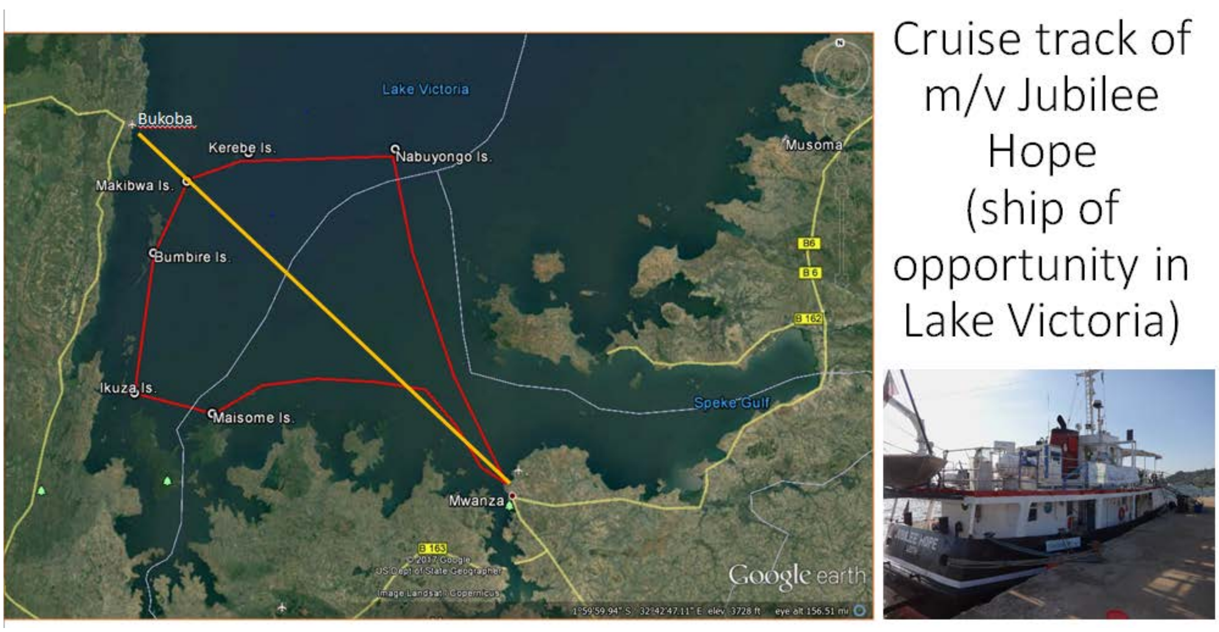

Figure 7. The red line shows the path of the Jubilee Hope ship and the orange line the path of the Blue Bird Ferry.

If one of the government passenger ferry boats start operating between Bukoba and Mwanza the HyCRISTAL program (i.e., Dr. Kamazima Lwiza) will install a similar set of instruments on that boat. At present, the UKMO is able to access the data every 7-10 days. Data may become accessible in near-real time via an iridium satellite. Examples of the types of measurements recorded are shown in Table 3 below. HyCRISTAL scientists are willing to share data according to HyCRISTAL's policy and MoU on ownership of the data and publications using the data.

Table 3. Observations collected by instruments on the Jubilee Hope hospital ship.

TOA5			Jubilee Hope Lake Vic Observations													
TIMESTAMP	UTC	lat	lat_dir	lon	lon_dir	alt	press_bar	airtemp	relhum	dewpt	wind_spd	ind_spd_k	ater_temp	rain_mm	SolarWatts	Speed Over Ground
TS																Knots
8/14/2017 12:32	93205.1	230.9698	S	3253.762	E	1137.6	1.0171	31.0	29.1	10.9	1.1	2.1	25.8007	0	906.1708	0
8/14/2017 12:34	93405.1	230.9693	S	3253.763	E	1136.5	1.0169	31.1	28.8	10.8	1.7	3.3	25.8559	0	912.1905	0
8/14/2017 12:36	93605.1	230.9697	S	3253.763	E	1135.2	1.0167	31.3	28.7	10.9	1.1	2.2	25.8846	0	925.7496	0
8/14/2017 12:38	93805.1	230.9703	S	3253.763	E	1135	1.0167	31.2	30.4	11.7	1.7	3.3	25.8907	0	953.9066	0
8/14/2017 12:40	94005.1	230.9703	S	3253.763	E	1138.9	1.0171	31.1	28.9	10.8	0.8	1.5	25.8958	0	287.7484	0
8/14/2017 12:42	94205.1	230.9691	S	3253.762	E	1133.2	1.0161	31.1	27.8	10.3	2.0	3.8	25.9120	0	225.1348	0
8/14/2017 12:44	94405.2	230.969	S	3253.763	E	1134.1	1.0162	31.0	28.3	10.4	1.2	2.4	25.9451	0	186.7783	0
8/14/2017 12:46	94605.2	230.9697	S	3253.763	E	1138.9	1.0169	31.0	28.3	10.4	1.0	1.9	25.9959	0	966.1218	0
8/14/2017 12:48	94805.2	230.9689	S	3253.764	E	1141.5	1.0171	31.2	28.4	10.7	2.0	3.9	26.0366	0	930.2808	0
8/14/2017 12:50	95005.2	230.9693	S	3253.763	E	1143.3	1.0174	31.2	27.5	10.2	1.4	2.8	26.0681	0	920.8155	0
8/14/2017 12:52	95205.2	230.9707	S	3253.763	E	1142.7	1.0174	31.6	28.0	10.8	0.6	1.2	26.0452	0	941.4506	0
8/14/2017 12:54	95405.2	230.9697	S	3253.763	E	1138.9	1.0167	31.0	27.8	10.2	1.6	3.2	26.0192	0	963.6120	0
8/14/2017 12:56	95605.2	230.9686	S	3253.763	E	1137.4	1.0166	31.0	28.3	10.4	0.9	1.7	26.0417	0	989.9594	0
8/14/2017 12:58	95805.2	230.9684	S	3253.763	E	1138	1.0166	31.3	27.8	10.4	0.4	0.7	26.0639	0	305.0335	0
8/14/2017 13:00	100005.2	230.9692	S	3253.763	E	1139.4	1.0167	31.5	26.5	9.9	2.9	5.7	26.0704	0	370.5351	0
8/14/2017 13:02	100205.2	230.9703	S	3253.763	E	1137.6	1.0164	31.3	26.7	9.8	3.0	5.8	26.0894	0	443.3543	0

4.9 Research Aircraft Measurements

The HIGHWAY project will collaborate with the MOYA[12] flight campaign in Uganda in January 2019 with the UK National Centre for Atmospheric Science (NCAS) providing hours for 3 flights. During these research aircraft flights an opportunity exists to get observations over the lake and examine the diurnal cycle of lake and land breezes. The flights will include the use of dropsondes across the lake to obtain vertical profiles of circulations. The HIGHWAY flight campaign has been tentatively confirmed with the MOYA team for the 27th, 28th, and 29th January 2019. While these dates are prior to the HIGHWAY Field Campaign they will provide scientifically interesting data.

4.10 HyCRISTAL Instrumentation

HyCRISTAL has deployed a network of automatic weather stations, rain gauges and hydrological flow sensors in Kampala, Uganda, to measure urban weather and flows (telemetered sites located within the Upper Lubigi catchment: 2 automatic weather stations;3 rain gauges; 2 surface water level sites; 1 groundwater level site). It has installed one eddy-covariance flux tower in Kericho, Kenya. As detailed insection 3.8, HyCRISTAL has deployed sensors on a hospital ship and similar sensors are planned for the Mwanza-Bukoba ferry.

[12] For more information about MOYA see http://homepages.see.leeds.ac.uk/~earjrmc/MOYA/MOYA/index.html

5 Forecasting and NWP models

5.1 Forecaster Displays

5.1.1 UKMO FOREST Display

Under the assumption that Field Campaign data will be available via a cloud-based storage, a visualization tool is under development by UKMO for the project partners. This web-based tool will enable viewing of NWP output, nowcasts, observations in a visualization platform called FOREST – Forecast, Observations and Research Evaluation and Survey Toolkit. Through the FOREST web interface, forecasters and scientists will be able to view observational data at point locations when available and use these observations to evaluate NWP models and near-real time nowcasting information.

5.1.2 NCAR CIDD display

NCAR's Cartesian Integrated Data Display (CIDD) will be installed at TMA's Dar es Salaam Central Forecast Office (CFO) for viewing selected gridded radar fields transmitted from the Mwanza radar site during the Field Campaign. This installation is completely dependent on the upgrade of the bandwidth between Mwanza and the CFO to sufficient capacity for transmission of gridded (not image) data. Forecasters will be trained on the use of this display and on interpretation of radar fields. A workstation will need to be identified at TMA where this software can be run and the display is easily available to the forecasters.

5.2 Identification of Case Study Days

An ongoing effort during the Field Campaign will be the identification and selection of high impact weather/severe weather days that can be used for building the case studies needed to fulfill objectives under HIGHWWAY Outputs 1-4. The NMHSs are asked to prepare a continually updated list of days when severe weather occurred over the lake and when NMHSs have forecast severe weather outlooks (Special Forecasts) for the day.

The Severe Weather Desk at TMA will work with the TMA Lake Zone Manager and extension Officer to monitor severe weather events and characterize the associated synoptic features. A report of the event will be prepared and provided to the Local Focal Points and Principal Investigators.

The Numerical Weather Prediction (NWP) / Severe Weather Forecasting Demonstration Project (SWFDP) at KMD will work with the County Director of Meteorological Services (CDMS) in Siaya County together with CDMS in the Counties bordering Lake Victoria to monitor severe weather events and characterize the associated synoptic features. A report of the event will be prepared and provided to the Local Focal Points and Principal Investigators.

The UNMA identifies severe weather over Lake Victoria using the following tools: 1) satellite, 2) Earth Networks storm tracker, and 3) models including NWP. The elements examined for severe weather are winds, precipitation, visibility and lightning/thunder. Visibility is determined by viewable objects at specific distances. Currently these measures categorized as low, moderate or high but may be changed in the future to very good, moderate and poor. Winds are categorized as strong, moderate or light. Precipitation is categorized as heavy, moderate or light. These categories are used based on thresholds set by UNMA. The corresponding geographical locations of severe weather conditions are described as widespread, isolated or a few areas.

5.3 NWP models and Special Modeling efforts

Table 4 provides a list of the NWP models that run locally by each NMHS. Also listed are NWP models run elsewhere with model output fields available for use by the forecasters. See Acronym list at the start of this document for definitions of these model acronyms.

Table 4. List of NWP models used by forecasters at each NMHS.

	Kenya	Uganda	Tanzania	Rwanda
Models run locally	10 km WRF	10 km WRF Models (plan to have 5km resolution)	WRF, WAVE WATCH 3, COSMO, WRF with data assimilation,	
Model output received from other countries	7 km COSMO; **UK** East Africa VCP 4 km resolution	**Météo France** - SYNERGIE System Models; **NOAA**-Climate Prediction Centre Models; **NCEP** – Global Forecasting System (GFS) Models for Africa; **UK** – ALAM; **UK** East Africa VCP 4 km resolution; **ECMWF** models; COLA GFS models	ECMWF, ALAM Ensemble Prediction Systems, Center for Ocean Land and Atmosphere; **UK** East Africa VCP 4 km resolution	MSG PUMA, SYNERGIE, AMSS Platform, NOAA East Africa Products, ECMWF Products, UK East Africa VCP 4 km resolution, and UKMO Products.

As part of the HIGHWAY project, the UKMO is running a regional convection permitting configuration of the Unified Model called RA1-T. This will be run at 4.4 km horizontal resolution over the whole Tropical African domain, including the Lake Victoria basin region. In comparison to the VCP East Africa model, RA1-T is a more recent version, and therefore an improvement on the model currently used in East African NMHSs. Another advantage of the RA1-T is that it is being run out to T+5 days, as opposed to T+2 days for the East Africa model. Model forecasts are initialized at 00 UTC and 12 UTC, and are usually available to view between 9-12 hours after initialization. The model output will be available through the FOREST portal in November 2018, but at the moment, forecasts can be viewed at the following URL: http://gws-access.ceda.ac.uk/public/mo_forecasts/restricted/TropAfrica/mo_f_tafr_dtime.html
Username: TAfrica
Password: TAfrica_4p4

5.4 Forecaster Participation in African-SWIFT

The GCRF African SWIFT project plans to conduct a forecasting testbed for a two-week period during the HIGHWAY field campaign. The dates for this testbed are not yet fixed, but are likely to be two weeks in April. The event will be held at KMD in Nairobi. KMD are a funded partner in SWIFT and have good facilities to host a larger group of scientists. We may also include regular teleconferences with other participating forecasting centers.

Testbeds are recognized as a key tool to improve weather predictions worldwide, in particular to pull-through research to operations; to critically evaluate NWP and other tools; and to stimulate new research directions (Ralph et al. 2013). The SWIFT-HIGHWAY testbed will consist of intensive, real-time forecasting activities at which weather forecasters from different institutions come together with researchers to perform operational forecasting. It is also intended to bring representatives of stakeholder groups into this testbed event, in order to explore and enhance the delivery of impact based forecasts. The focus will be on the Nowcasting to Synoptic timescales. Dedicated model and observational products will be made available. Access to the HIGHWAY field campaign observations in real time will significantly enhance the value and potential outcomes of the testbed. This testbed will be preceded by a forecaster training event, probably in West Africa late in 2018, to be conducted in collaboration with SWFDP (Severe Weather Forecast Demonstration Project). It will be followed by a later event at which a small group of participants from the researcher and forecaster communities come together to document conclusions from the testbed.

6 Education and Outreach

Depending on available funding, forecaster training will be conducted using the mini Field Campaign data sets for scientific understanding of storm evolution and severe weather. The Field Campaign data will also be used to educate forecasters on predictors of severe weather and to determine if these predictors can be included in EWS nowcast products. The participation of African scientists, engineers and students in this field program and in subsequent analyses of case studies is a critical activity that will help to foster a new generation of scientists and engineers in Africa who will learn to support the basic infrastructure, maintain meteorological instrumentation, conduct future scientific experiments and develop thunderstorm nowcasting/forecasting capabilities. Table 5 indicates potential professor and student involvement in the mini Field Campaign and subsequent data analysis.

Table 5. Potential collaborations between each NMHS and universities on Field Campaign data collection and case study analyses.

NHMS	**University**	**Professor**	**Professor Email**	**Potential student involvement**[13]			
				Radio-sonde Release	Surface station maintenance	Research study	Other
KMD	University of Nairobi	Joseph Mutemi Nzau	jnmutemi@yahoo.co.uk	Yes	Yes	Yes	Data collection, processing, analysis
TMA	University of Dar es Salaam, Centre for Climate Change Studies	Prof. Pius Yanda	pyanda@gmail.com	Yes: Name to be provided	Yes: Name to be provided	Yes: Name to be provided	Yes: Name to be provided
TMA	Dar es Salaam Institute of Technology (DIT)	Dr. Joseph Matiko	jwmatiko@gmail.com jwmatiko@dit.ac.tz	Yes: Name to be provided	Yes: Name to be provided	Yes: Name to be provided	Yes: Name to be provided
UNMA	National Meteorologi	Mr. Ageet Simon					

[13] See end of Table 6 for list of students.

	cal Training School						

7 Contact information

A list of Field Campaign participants is provided in Table 6.

Table 6. List of HIGHWAY participants.

Name	Organization	Role	Email address
Frank Annor	TAHMO	TAHMO PI	annorfrank@tahmo.org
Alan Blyth	Univ. of Leeds	SWIFT Co-I	
Ladislaus Chang'a	TMA	HIGHWAY Focal Point	ladislaus.changa@meteo.go.tz
John Faragher	UKMO[14]	Project Manager	john.faragher@metoffice.gov.uk
Steven Goodman	NOAA NESDIS Retired	Lightning-Satellite Nowcast Products	SteveGman42@msn.com
Kathrin Hall	UKMO	Project Manager	kathrin.hall@metoffice.gov.uk
Andrew Hartley	UKMO	HIGHWAY & SWIFT Principal Investigator	andrew.hartley@metoffice.gov.uk
Paul Isabirye	UNMA	Director of Station Networks and Observations	paul_isabirye@yahoo.com
Benedicto Katole	TMA	Radar Engineer	Benedicto.katole@meteo.go.tz
James Kivuva	East African Commission		jkivuva@eachq.org
David Koros	KMD	NWP and Severe Weather	korosdav@gmail.com
Paul Kucera	NCAR[15]	3D-PAWS PI	pkucera@ucar.edu
Kamazima Lwiza	Stony Brook	HyCRISTAL Co-I/water measurements	Kamazima.lwiza@stonybrook.edu
Solomon Mangeni	UNMA	Director of Forecasting Services	Solomon.mangeni@unma.go.ug mangenis@hotmail.com
John Marsham	Univ. of Leeds	HyCRISTAL PI	J.Marsham@leeds.ac.uk
Karen McCourt	UKMO	HyCRISTALCo-I/water measurements	karen.mccourt@metoffice.gov.uk
Ezekiel Muigai	KMD	Forecaster	ezekielmuigai@gmail.com

[14] United Kingdom Meteorological Office

[15] National Center for Atmospheric Research

Joseph Mukola	KMD	Engineer/Technician	mukolajmmk@gmail.com
Joseph Mutemi	University of Nairobi	Engagement of University students	jnmutemi@yahoo.co.uk
John Mungai	UKMO		john.mungai@metoffice.gov.uk
Amos Christopher Ndoto	Lake Victoria Commission		Ndoto@lvbcom.org
Augustino Nduganda	TMA	Manager for TMA's Lake Zone	Augustino.nduganda@meteo.go.tz
Dominic Arodi Oginga	KMD	Observations	arodioginga@yahoo.com
Paul Oloo	KMD	HIGHWAY Focal Point	paul_oloo@yahoo.com oloo@meteo.go.ke
Douglas Parker	Univ. of Leeds	SWIFT Co-I	D.J.Parker@leeds.ac.uk
Ralph Petersen	U of Wisconsin CMSS	Satellite Nearcast Products	Ralph.Petersen@ssec.wisc.edu
Lars Peter Riishojgaard	WMO	Principal Investigator	lriishojgaard@wmo.int
Rita Roberts	NCAR	Principal Investigator	rroberts@ucar.edu
Fred Semazzi	NCSU	HyCRISTAL/HYVIC PI	semazzi@ncsu.edu
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James Wilson	NCAR	Principal Investigator	jwilson@ucar.edu
Fidele Maniraguha	Météo Rwanda	Radar Engineer	f.maniraguha@meteorwanda.gov.rw
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Musoni Didace	Météo Rwanda	Division Manager Observations	mmdidace@gmail.com d.musoni@meteorwanda.gov.rw
University students from each country			
Mr Anthony Musili Mwathi	University of Nairobi	PhD student	mmwanthi@gmail.com
Miss Victorine Jelagat	University of Nairobi	Masters student	jeshvick712@gmail.com

8 References

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9 Appendices

9.1 Appendix A: Scientific Background from a previous Lake Victoria Field Program proposed by Wilson and Roberts to the U.S. National Science Foundation

As stated in the Preface, a proposal was submitted by Wilson and Roberts for a major Lake Victoria Field Campaign to improve understanding of the initiation and evolution of life-threatening weather over the lake. This proposal included the collection of high resolution observations of the pre-storm and storm environment to understanding thunderstorm evolution and characteristics as well as the collection of observations to verify and improve satellite-based nowcasting algorithms and numerical model forecast prediction. The need for high resolution observations have also been cited and stressed in documents (reports and proposals) from North Carolina State University to the East African Community (EAC) and the Lake Victoria Basin Commission (LVBC) (Burleyson et al. 2012; Semazzi 2012; Semazzi et al. 2012).

The Wilson and Roberts proposal was submitted to the U.S. National Science Foundation and included 17 Co-Principal Investigators[16]. This proposal was **not** funded since NSF

[16] Michael Biggerstaff (University of Oklahoma), Lawrence Carey (University of Alabama, Huntsville), Belay Demoz (Howard University), Brian Golding (UK Met Office), Steven Goodman (NOAA), Yang Hong (University of Oklahoma), Kevin Knupp (University of Alabama, Huntsville), Karen Kosiba (Center for Severe Weather

required matching funds from other international sources that could not be obtained. However, the scientific questions and hypotheses from that proposal are repeated here since they are still relevant and can be partially addressed during the mini Field Campaign.

Present Meteorological Knowledge, Scientific Goals, Hypotheses and Required Observations

There are very few observational studies of convective storm evolution in the vicinity of Lake Victoria. Those that have been documented in the literature have been in association with hydrological investigations of water balance estimates and the impact of lake-level fluctuations on the riparian countries dependent on water from the Nile River. Flohn and Fraedrich (1966) were one of the first to discuss processes associated with heavy rainfall over Lake Victoria. They noted that rainfall over the lake was dramatically enhanced by a nocturnal lake-breeze circulation that produced convergence over the lake. They found that this convergence was enhanced by the thermal instability of the boundary layer over the lake that is caused by air temperatures above the lake being 3˚C cooler than the lake surface itself. Large and intense cumulonimbus clusters were observed to develop over the lake at night. Using infrared imagery (cloud top temperatures) from the Meteosat and surface station data, Ba and Nicholson (1998) documented the diurnal convective activity and the monthly and annual rainfall variability over the lake for a five year period from 1983-1988. They noted that several regional features have impact on the level of convective intensity and amount of rainfall in the area, including the position of the intertropical convergence zone (ITCZ), the presence of other convergence zones, the northeast and southeast trade winds, the complex topography and the influence of the Indian Ocean. Laing et al (2011) utilized Meteosat-7 data to examine convection initiation and propagation of MCS convection over Equatorial Africa. They found that a large fraction of the convection was triggered by heating of elevated terrain, sea/land breezes and lake breezes.

Using the TRMM Precipitation Rate radar data, Burleyson et al (2012) produced a ten-year climatology (1998-2007) of precipitation frequency. This climatology, which is shown in Fig. 3, indicates that daytime thunderstorms frequently occur around the lake but not over the lake. At night the reverse is the case with thunderstorms mostly over the lake and not over land. It is also seen that the frequency of precipitation begins first to increase on the far northeast side of the lake at around midnight local time and progresses west and south across the lake during the next 9 hours. A six-year satellite-based climatology of overshooting cloud top detections provided by Kristopher Bedka of CIMSS shows similar

Research), William McCaul (USRA), David Parsons (University of Oklahoma), Ralph A. Petersen (U. of Wisconsin), James Pinto (NCAR), Yvette Richardson (Pennsylvania State University), Tammy M. Weckwerth (NCAR), Earle Williams (Massachusetts Institute of Technology), Josh Wurman (Center for Severe Weather Research), Sandra Yuter (North Carolina State University) patterns in the location and frequency of deep convection[17]. The overshooting cloud top climatology also shows that Lake Tanganyika and Lake Malawi (see Fig 1), north-south oriented lakes located west and south of Lake Victoria, have distinct night time maxima of overshooting tops similar to Lake Victoria. Virts et al. (2013) used the World Wide Lightning Location Network to produce a worldwide hourly climatology of lightning frequency. Their Fig. 8 shows Lake Victoria, Lake Tanganyika and Lake Malawi all have nocturnal maximums of lightning. The climatology of the average number of thunderstorm days for Kampala, Uganda which is located on the north shore of Lake Victoria is 66 % per year increasing to between 73% and 80 % for the months of March, April and November. Most recently, Albrecht et al. (2016) produced high resolution (0.1 deg) global maps of lightning including the hot spots across Africa, the diurnal lightning activity for Lake Victoria, and the nocturnal maximum over Lake Victoria and other major lake bodies of East Central Africa using 15 years of TRMM (1997-2015) Lightning Imaging Sensor (LIS) data. A copy of the LIS instrument is currently on the International Space Station (ISS-LIS) and the data are publicly available.

While it is clear the Lake Victoria thunderstorms are frequent, deep storms that extend at least to the tropopause, have very frequent lightning and have been observed to produce waterspouts, there have been no observations that document convective storm initiation processes, the meteorological factors affecting the intensification of storms, and the strength of the surface winds produced by the thunderstorms that result in human fatalities. The field program will be specifically designed to understand these processes.

Scientific questions

Develop a thorough understanding of the initiation process of nocturnal thunderstorms over Lake Victoria, using remote and in situ observations with the purpose of developing reliable convective outlooks, nowcasts and warning systems.

a) Develop knowledge of factors governing the strength of thunderstorm downdrafts and outflows over Lake Victoria and resultant impact on wave height, using Doppler radar, radiosonde, and other remote sensing observations so that accurate nowcasts of low-level wind speed and direction can be produced.

b) Develop and evaluate relationships between observed hazardous weather conditions near the lake surface, such as severe winds, and features observable remotely in infra-red satellite images or lightning maps, such as variations in cloud top temperature or lightning frequency.

[17] http://www-angler.larc.nasa.gov/site/people/data/kbedka//OTclimatology_2005-2009_SEVIRI_Kenya_animation.gif

c) Evaluate and enhance the ability of ocean wave prediction models, applied to Lake Victoria, to reproduce observed relationships between hazardous wave conditions detected by instrumented boats and the forcing wind fields obtained from Doppler radar and *in situ* wind observations.

d) Collect observations to evaluate the capability of kilometer-scale Numerical Weather Prediction models to accurately model the interaction of synoptic scale atmospheric structure with the local topographic forcing, so as to predict the forcing that gives rise to severe convective weather over the Lake.

e) Collect and, where possible, deliver in real time observations needed to develop and evaluate data assimilation capabilities for kilometer-scale Numerical Prediction Models run over the Lake.

f) Collect and, where possible, deliver in real time observations to develop and evaluate relationships between outputs from Numerical Weather Prediction models run over the lake and the hazardous weather conditions that cause loss of life, especially wind speed and direction.

g) Collect reports of the occurrence of fatal and non-fatal accidents on Lake Victoria so as to relate them to observed hazardous weather conditions associated with nocturnal convection over the Lake.

h) Based on the knowledge gained from the field program develop thunderstorm nowcasting techniques for Lake Victoria that can be utilized by the weather services in Kenya, Uganda and Tanzania.

Scientific Hypotheses

i. Initiation of thunderstorms affecting Lake Victoria Basin

Hypothesis 1. The daytime thunderstorms surrounding Lake Victoria are initiated by lake breezes and/or anabatic flow along the slopes of the mountains.

Hypothesis 2. Nocturnal thunderstorms are initiated along the northeast coast by land breezes that are enhanced by downslope flow from the mountains to the east and outflows from local afternoon and evening thunderstorms. Variability in location is related to the strength, depth and density of individual downslope flows from individual mountain valleys.

Hypothesis 3. Nocturnal thunderstorms initiate over the lake as a result of a) land breezes moving over the relatively warm lake, b) wind convergence zones created by horizontal thermal boundaries or gradients in the lake or c) large scale wind confluence over the lake.

Hypothesis 4. The timing and/or location of "lake-initiated" nocturnal thunderstorms occurs when or where the near-surface air becomes 2-3˚C cooler than the lake surface temperature.

ii. Storm Intensification and severity

Hypothesis 5. Regardless of where the nocturnal storms initiate they reach their most intense stage with regards to updraft and downdraft strength over the lake as a result of the influx of relatively warm moist air into the updrafts.

Hypothesis 6. Nocturnal thunderstorms that produce the most intense downdrafts and outflows hazardous to the boating community are associated with preferred regions of the lake where strongest surface convergence and thermal gradients in the water routinely occur.

Hypothesis 7. The intensity of the thunderstorm downdrafts and subsequent surface winds are influenced by evaporational cooling as the precipitation falls through drier mid- and lower-level environmental air. Precipitation loading within these tropical storms may also play a major role in downdraft strength. The relative humidity profile is defined by the daily mesoscale or synoptic scale influences, thus the potential for strong outflows can likely be predicted with NWP assuming there are sufficient observations.

iii. Observations for initialization and verification of Numerical Weather Prediction models

Hypothesis 8. Current kilometer-scale Numerical Weather Prediction forecasts for Lake Victoria are unlikely to reliably predict the timing and location of hazardous nocturnal convection.

Hypothesis 9. Assimilation of additional observations into kilometer-scale Numerical Prediction Models will substantially improve the ability of the model outputs to distinguish reliably between hazardous and non-hazardous nocturnal convection over Lake Victoria.

Hypothesis 10. Enhancements to the domain and resolution (both vertical and horizontal) will likely enable improved predictions of hazardous surface weather conditions over Lake Victoria.

iv. Dynamics of thunderstorm outflows and wave height

Hypothesis 11. Interactions between strongly duration and fetch limited packets of lake-surface waves associated with individual thunderstorm downdrafts, can create highly dangerous cross seas that are not well represented by existing ocean wave models.

v. Development of thunderstorm nowcasting/warning capabilities and societal implications

Hypothesis 12. There is a close relationship between observable features of the wind and/or wave conditions over the Lake and the occurrence of serious accidents, whether fatal or not, to Lake users.

Hypothesis 13. There are signatures in the infra-red satellite images and/or the lightning frequency maps that are associated with the occurrence of current and/or future severe winds near the Lake surface.

Hypothesis 14. Kilometer-scale NWP forecast outputs contain signals that are associated with the occurrence of severe wind events near the Lake surface.

Hypothesis 15. Data collected from this field program on storm initiation and severity will provide the necessary information for development of a nowcasting system that provides advance notice of hazardous conditions over Lake Victoria.

Hypothesis 16. A nowcasting system that is able to provide warnings, of sufficient precision and accuracy for Lake users to change their behaviors, can be formulated from a combination of NWP, remotely sensed observations and in situ observations.

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9.2 Appendix B: NMHS Surface Station Information

Table B1. Uganda stations

Category Stations	Station Identifier	Latitude/ Longitude	Altitude (m/ ft)	Frequency of Reporting	List State Variables observed	List of instruments missing/need replacement	Data transmission location

Synoptic	Entebbe International Airport Met. Station, (Buku)	0°24'N 32°.27'E	1253.6 m / 3761ft	30 minute observation	T, T_d, T_w, RH, WS, WD, rain, SP, Max temp	Humidity slide rule, sunshine recorder; sunshine scale; anemometer; maximum thermometer; Hook gauge evaporimeter and evaporation pan; two metre cup anemometer**.**	GTS, Mobile phones, internet.
	Makerere University Met. Station (Kampala)	0°19'N 32°34'E	1333.3 m / 4000ft	Hourly Observation	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp	Humidity slide rule, sunshine scale; minimum thermometer; Hook gauge evaporimeter and evaporation pan; digital barometer and aneroid barometer; wind vane and anemometer	Mobile phones, internet,
	Jinja Met. Station	0°26'N 33° 12'E	1253.6 m / 3878ft	30 minute observation	T, T_d, T_w, RH, WS, WD, rain, SP, Min/Max temp, sunshine hours	Humidity slide rule; sunshine scale; grass minimum thermometer;	Mobile phones,
Agromet	Namulonge Agromet Station	0°32'N 32°35'E	1150m	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, Min/Max temp, sunshine hours, evaporation	Humidity slide rule, sunshine scale. grass minimum thermometer; evaporation pan	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every ten (10) days for decadal data.
	Kituza Agromet Station	0°16'N 32°36'E	1333.3 m / 4000ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Wind vane and anemometer; Hook gauge evaporimeter and evaporation pan, humidity slide rule; sunshine scale; minimum, thermometer;	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data

	Kamenyamiggo Agromet Station	0°18'S 31°40'E	1333.3 m / 4400ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Humidity slide rule, sunshine scale; dry bulb, wet bulb, maximum and minimum thermometers; Hook gauge evaporimeter and evaporation pan; wind vane and anemometer.	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data.
	Kawanda Agromet Station	0°25'N 32°32'E	1308 m/ 3924ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max	Humidity slide rule; sunshine scale; Hook gauge evaporimeter and evaporation pan; wind vane and anemometer.	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data.
	Kakira Sugar Works, Jinja District	0°30'N 33° 17'E	3900ft	9.00am	Max/min temp; sunshine hours; rain; RH, evaporation,		
	Kabanyoro University Farm. Luweero District	0°28'N 32°37'E	3900ft		AWS 2	All weather instruments	
Hydromet	Kiige Hydromet Station, Kamuli District	01°11'N 32°02'E	1060m	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Hook gauge evaporimeter and evaporation pan; Six's thermometer; measuring cylinder; anemometer; Humidity slide rule,; sunshine scale.	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data.

Kibanda Hydromet Station, Rakai District	0°52'S 31°22'E	3950ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Stevenson screen, Six's thermometer and maximum thermometer; Sunshine recorder; Hook gauge evaporimeter and evaporation pan; wind vane and anemometer; raingauge; Humidity slide rule; sunshine scale; Slots of sunshine recorder need to be adjusted.	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data.
Mubende Hydromet Station	0°35'N 31°22E	5095ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Piche evaporimeter; anemometer; Six's thermometer; Hook gauge evaporimeter and evaporation pan; humidity slide rule; sunshine scale.	Bring the data to Hqs. By public means every end of the month. Raise them by phone after every 10 days for decadal data.
Ntuusi Hydromet Station, Sembabule District	0°03'N 31°13'E	4250ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, sunshine hours, evaporation	Stevenson screen; Humidity slide rule; sunshine scale; Hook gauge evaporimeter and evaporation pan; humidity slide rule,; Six's thermometer/ maximum thermometer; wind vane and anemometer; raingauge; sunshine scale; Sunshine recorder;	Bring the data to Hqs. By public means every end of the month. Raise them by phone after every 10 days for decadal data.
Entebbe Hydromet Station at the Water Resources Management Department (WRMD)	0°.19'N 32°36'E	3770ft	9.00 am, 12.00 noon, and 3.00pm	T, T_d, T_w, RH, WS, WD, rain, SP, MIN/Max temp, evaporation	Minimum and maximum thermometers/ Six's thermometer; sunshine recorder; Hook gauge evaporimeter and evaporation pan; humidity slide rule; sunshine scale; hygrometer	Bring the data to Hqs. by public means every end of the month. Raise them by phone after every 10 days for decadal data.

Proposed AWS (04) at the four forecasting zones	Bugala, Kalangala Islands Buvuma, Buvuma Islands Namayingo District Kibanda, Rakai District				To be procured and installed during HIGHWAY Project Field Campaign

Table B2. Kenya stations

Station Identifier	Latitude/ Longitude (deg)	Altitude (m)	Frequency of Reporting	List State Variables (T, T_d, humidity, wind speed and direction, rainfall)	Data transmission location (GTS, NMHS, web site, or other?)
Kericho	-0.362802 / 35.273234	1981	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
Kakamega	0.27837 / 34.64642	1559	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
63709 Kisii	-0.682856 / 34.787827	1769	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
63708 Kisumu	-0.08613 / 34.73451	1153	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
Nakuru	-0.27102 / 36.10416	1902	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
Narok	-1.09467 / 35.86382	1891	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
Suba	-0.40282 / 34.14796	1162	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
63661 Kitale	1.002648 / 34.98588	1845	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS
63668 Eldoret Airport	0.4 / 35.2333	2079	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS

Eldoret	0.509757 / 35.30752	2139	METARS each hour, Synops every 3 hours	T, T_d, RH, WS, WD, rainfall	GTS

Table B3. Rwanda stations. Rwanda has a network of over 300 weather stations types combined (manual and AWSs). The following table shows the main agro synoptic stations across the country some of which are reporting to GTS.

Station Identifier	Latitude/ Longitude (deg)		Altitude (m)	Frequency of Reporting	List State Variables (T,T_d, humidity, wind speed and direction, rainfall)	Data transmission location (GTS, NMHS, web site, or other?)
Kigali	30.13	-1.97	1497	1hr	T, RH, WS, WD, SP, rain	GTS, NMHS
Kamembe	28.92	-2.47	1591	1hr	T, RH, WS, WD, SP, rain	GTS, NMHS
Gisenyi	29.25	-1.67	1554	1hr	T, RH, WS, WD, SP, rain	GTS, NMHS
Gikongoro	29.57	-2.48	1921	1hr	T, RH, WS, WD, SP, rain	NMHS
Kibungo	30.5	-2.15	1660	1hr	T, RH, WS, WD, SP, rain	NMHS
Byumba	30.05	-1.6	2235	1hr	T, RH, WS, WD, SP, rain	NMHS
Busogo	29.55	-1.58	2203	1hr	T, RH, WS, WD, SP, rain	NMHS
Ruhengeri	29.6	-1.5	1857	1hr	T, RH, WS, WD, SP, rain	GTS, NMHS
Gitega	30.03	-1.95	1525	1hr	T, RH, WS, WD, SP, rain	NMHS
Rubengera	29.42	-2.07	1590	1hr	T, RH, WS, WD, SP, rain	NMHS
Byimana	29.72	-2.18	1827	1hr	T, RH, WS, WD, SP, rain	NMHS
Kawangire	30.45	-1.81	1528	1hr	T, RH, WS, WD, SP, rain	NMHS
Nyagatare	30.33	-1.3	1381	1hr	T, RH, WS, WD, SP, rain	NMHS

Table B4. Tanzania stations

Station Identifier	Latitude/ Longitude (deg)	Altitude (m)	Frequency of Reporting	List State Variables (T, T_d, humidity, wind speed and direction, rainfall)	Data transmission location (GTS, NMHS, web site, or other?)
63729	-01°20' 031°49'	1144	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63733	-01°30' 033°48'	1147	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63756	-02°28' 032°55'	1140	½ hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63791	-03°25' 037°04'	891	½ hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63801	-04°53' 029°40'	822	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63832	-05°05' 032°50'	1182	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63844	-05°05' 039°04'	49	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS

63862	-06°10' 035°46'	1120	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63866	-06°50' 037°39'	526	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63870	-06°13' 039°13'	18	½ hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63894	-06°52' 039°12'	53	½ hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63887	-07°38' 035°46'	1428	Hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63932	-08°56' 033°28'	1758	3 hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63962	-10°40' 035°35'	1036	3 hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS
63971	-10°21' 040°11'	113	3 hourly	Rainfall, Temperature, Wind, Pressure, Relative humidity, Sunshine, Cloud,	GTS, NMHS

9.3 Appendix C: Description of 3D-Printed Automatic Weather Station (3D-PAWS)

The US National Weather Service (NWS) International Activities Office (IAO) in collaboration with NCAR and USAID established an initiative to develop and deploy low-cost weather instrumentation using new technologies that include 3D printers, Raspberry

Pi computing systems, and wireless communication. The motivation is to enhance environmental monitoring, enhance observations for applications such as early warning alert systems, and provide this technology to NMHSs in under-developed countries so they can build, deploy, and maintain their own surface observation network. Examples of the 3D-Printed Automatic Weather Station (3D-PAWS) are shown in Fig. C1.

The 3D-PAWS configuration consists of a 3-cup anemometer, wind vane, tipping bucket rain gauge, two temperature, relative humidity, and pressure sensors. The system is designed to be adapted and installed on a variety of frames using local materials readily available in the local country for a reasonable cost. Sensor operation, communication,

Figure C1. Photos of a 3D-PAWS setup. The left images shows the complete setup. The upper-right photos shows a close up view of the 3-cup anemometer (left) and wind vane (right). The bottom photos show images of the Raspberry Pi housing, radiation shield, and tipping bucket rain gauge.

and data archiving is done using a low-cost Raspberry Pi computer running a version of Debian Linux. The Raspberry Pi computer is housed in a water-proof housing unit mounted on the frame. The Power to the 3D-PAWS can be supplied using commercial power (5V is required as input) or through battery with solar power backup. Communications (data sent out) with the unit is accomplished with either a direct network connection, wireless, adapter, or cell-modem setup. One unique aspect of the 3D-PAWS design is that all the housing, connector, wire harnesses, are created using a 3D printer. There are about 120 components on the station that are 3D printed. The designs of the components are created using an open-source computer aided design (CAD) software. The goal of the project is to make these an open-source resource so other institutions and educational programs can use and adapt the designs to meet their needs for research, operations, and/or education and outreach. The list of 3D-PAWS stations that have been installed in Kenya are shown in Table C1.

Table C1. Station information for the 3D Printer Automatic Stations (3D-PAWS) in Kenya.

Station Identifier	Latitude/ Longitude (deg)	Altitude (m)	Frequency of Reporting	List State Variables	Data transmission location (GTS, NMHS, web site, or other?)
Misemwa Primary School	0.7452/ 34.8061	1655	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Uasin Gishu Primary School	0.5176/ 35.2644	2086	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Bushalangala Secondary School	0.1878/ 34.6852	1527	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Thomas Mboya High School	-.3978/ 34.1644	1168	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Sirua Aulo High School	-0.912/ 34.9958	1991	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Magomano Girls High School	0.060714 / 36.5826	2488	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Naivasha Girls High School	-0.7376/ 36.4413	1940	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Kenya Met Department	-1.30172/ 36.7601	1750	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
Saint Mary's School	-1.2641/ 36.7802	1738	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/
RCMRD	-1.2214/ 36.893	1650	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/c ore-programs/3dpaws/
Moi Forces Academy	-1.2647/ 38.8731	1617	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/ core-programs/3dpaws/

SFS Integrated Primary School	1.3447/ 36.97995	1589	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/core-programs/3dpaws/
Mambrui Primary School	-3.12343/ 40.15971	3	15 min	T, RH, WS, WD, SP, rain	https://www.iepas.ucar.edu/core-programs/3dpaws/

9.4 Appendix D: Description of Trans African Hydro Meteorological Observatory (TAHMO) Surface Stations

The TAHMO project supports WMO Resolution 25, which adopts a stand of committing to broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data and products, in consonance with the requirements for WMO's scientific and technical programs. Allowing for free access to TAHMO monitoring data that is managed through the National Meteorological Agencies will also serve the public by beginning to close the existing hydro-meteorological data gaps in Africa and increasing the communication and application of this important information. The idea behind this initiative is to develop a dense network of hydro-meteorological monitoring stations in sub-Saharan Africa: one every 30 km. This entails the installation of 20,000 such stations. Stations are placed at schools and integrated in the educational program, adding richness to the curriculum and helping foster a new generation of scientists. . TAHMO Kenya will be involved in the HIGHWAY project and will focus on its' school2school component which offers a platform and training for students and teachers on the use of climate data and information for Science Technology Engineering and Mathematics education as well contribute as citizen scientists towards the collection, use of the data and the maintenance of the stations. TAHMO stations within the domain of the Field campaign are shown in Fig. 2 as well as their location and collection details in Table D1 below. Details on the existing and planned stations are provided in Table D1.

Table D1. TAHMO existing and planned surface stations

Station Identifier	Existing or Planned	Latitude/ Longitude (deg)	Altitude (m)	Frequency of Reporting	List State Variables	Data transmission location (GTS, NMHS, web site, or other?)
TA00019	Existing	-0.5241139, 34.2556472	1281	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00024	Existing	-1.0717306, 37.0455778	1520	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00025	Existing	-1.3018389, 36.7602	1798	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00027	Existing	0.0630611 ,37.656302 8	1607	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00028	Existing	0.0459861, 37.1428194	2016	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00029	Existing	-0.5008389, 36.5874972	2523	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00054	Existing	-0.2393417, 35.728897	2508	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00056	Existing	-0.7216559, 37.1455851	1376	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00057	Existing	-1.2530375, 36.8564253	1636	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00061	Existing	-0.3793746, 35.2507188	1968	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00064	Existing	0.7939077, 34.7053857	1721	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00065	Existing	0.2180637, 34.7684636	1566	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00066	Existing	-1.2654376, 36.6623375	1996	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00067	Existing	-1.7935253, 37.6211448	1184	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00073	Existing	-0.0717111, 36.9338194	1840	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00074	Existing	-0.5660801, 37.0744122	1722	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00076	Existing	-0.2843613, 34.9546417	1170	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00077	Existing	-0.3830663, 35.0684057	1765	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00078	Existing	-0.2001778, 36.3769356	2421	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00080	Existing	-1.0876139, 36.8184056	1767	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00108	Existing	-0.9919162, 37.5072973	1132	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00129	Existing	-3.390888, 37.717708	743	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00130	Existing	-3.4976, 38.585934	1158.2	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00131	Existing	-3.9603272, 39.7440763	15.4	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00132	Existing	-3.551352, 39.695029	165	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00133	Existing	-2.29839, 40.694046	5	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00134	Existing	-1.3075734, 36.8269703	1657	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00139	Existing	-1.1232833, 34.3979917	1393	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00140	Existing	0.131306, 35.607111	2568	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00145	Existing	0.2030556, 35.1166889	2.1	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00146	Existing	-0.148047, 34.622812	1141	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00147	Existing	0.449274, 34.282303	1276	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00155	Existing	-2.523037, 36.829437	1306	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00156	Existing	-1.701123, 38.068339	866	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00157	Existing	-2.656672, 38.107237	854	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00158	Existing	-1.184988, 38.001424	1369	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00166	Existing	-0.3195076, 37.6591392	1404	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00171	Existing	-0.00271, 34.596908	1532	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00172	Existing	0.353931, 37.58774	1110	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00173	Existing	-0.85481, 35.39565	2020	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00174	Existing	0.629802, 36.988102	1524	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00178	Existing	0.9529463, 34.9539819	1850	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00182	Existing	-1.22151, 36.89292	1273.3	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00183	Existing	-1.71137, 35.56528	1952	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00184	Existing	-1.46418, 35.28793	1605	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00185	Existing	-1.20328, 35.06718	1660	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00186	Existing	-0.54978, 38.2128	872	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00187	Existing	-0.31385, 38.21999	595	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00189	Existing	-0.79526, 37.66593	1080	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00190	Existing	-0.51664, 37.4562	1463	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00196	Existing	-0.551577, 37.2279373	1380	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00247	Existing	1.0983217, 36.7140148	1943	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00250	Existing	-0.7789404, 37.6767375	1067.6	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00258	Existing	-0.4465515, 37.4508975	1575.2	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00261	Existing	-3.0321434, 39.9588016	93	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00274	Existing	0.289569, 35.294804	2220	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00281	Existing	1.537267, 35.456667	959	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00283	Existing	-0.4038906, 36.9657273	1753	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00288	Existing	0.697685, 34.865316	754.58	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00306	Existing	-0.5820111, 34.6072611	1407	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00307	Existing	1.74755469 , 40.034483	257	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00316	Existing	0.289862, 34.371222	783.05	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00317	Existing	0.04044, 34.371716	772.71	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00320	Existing	-2.88283, 37.38735	1169.6	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00354	Existing	3.117623, 35.60461	400	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00355	Existing	3.50119, 35.847683	400	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00357	Existing	-4.46068, 39.48286	22.8	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00358	Existing	2.4942051, 39.5821546	415.5	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00359	Existing	1.015292, 39.4952226	263.9	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00360	Existing	-1.3795015, 38.0034942	1118.2	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00374	Existing	-0.0932099, 34.2603547	1270	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00377	Existing	0.40583, 37.1606	1816	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00378	Existing	-0.4052549, 37.1166527	1973	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00379	Existing	0.402296, 36.37726	2031.135	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00386	Existing	1.06117, 38.66609	289.4	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00387	Existing	0.8717, 34.5892	2350	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00388	Existing	-0.5048444, 34.9738574	1680	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00389	Existing	-0.6913096, 35.0366441	2044	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00394	Existing	-0.2882145, 35.0297404	1231	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00400	Existing	1.2733687, 35.0853832	2053	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00401	Existing	-0.5375802, 34.4601732	1218.676	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00402	Existing	0.7122493, 34.8182479	1946	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00412	Existing	-2.4105, 37.968	898.6	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00413	Existing	0.6202445, 34.520891	1509.11	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00414	Existing	-0.586642, 36.4930975	2432.497	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00416	Existing	-0.606799, 36.581097	2488	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00417	Existing	-0.2871222, 36.1699806	1936	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00418	Existing	-4.3118196, 39.3718956	243	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00419	Existing	-4.4062192, 39.4305531	55	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00420	Existing	-4.373488, 39.4409436	132	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00421	Existing	-4.4062421, 39.4305637	55	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00440	Existing	-0.2773667, 36.0746937	1891.618	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00441	Existing	-0.5993225, 34.7442225	1547.516	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00442	Existing	-0.7917716, 34.8047283	1819.267	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00444	Existing	-2.41999, 40.20436	13	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00448	Existing	-0.9325879, 37.677271	1133.211	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00450	Existing	-1.0947435, 35.8922797	1924792	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
Analat Secondary	Planned	-0.559865, 35.977673			T, T_d, WS, WD, rain	
SEKU	Planned	-1.306291, 37.756673			T, T_d, WS, WD, rain	
JKUAT	Planned	-1.091638, 37.008523			T, T_d, WS, WD, rain	
Garrisa University	Planned	-0.448870, 39.664181			T, T_d, WS, WD, rain	
TA00205	Existing	0.71285, 32.5133	1181	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00206	Existing	0.08902, 31.45796	1817	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00207	Existing	0.56302, 31.39055	1319	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00208	Existing	0.61717, 30.63842	1375	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00209	Existing	0.69355, 30.33222	1528	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00210	Existing	0.18919, 30.10059	962	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00211	Existing	-1.2542, 29.9919	1870	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00212	Existing	-0.60528, 30.67316	1425	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00214	Existing	-0.45427, 32.49455	1197	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00215	Existing	0.052465, 32.44069	1138	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00216	Existing	0.333542, 32.56863	1244	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00217	Existing	0.19692, 33.27136	1187	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00218	Existing	0.15583, 31.81268	1218	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00219	Existing	0.18395, 32.13239	1223	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00220	Existing	1.20684, 32.73557	1047	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00221	Existing	0.82875, 32.24802	1090	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00222	Existing	1.18624, 32.02033	1069	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00223	Existing	3.04679, 30.9135	1202	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00224	Existing	0.5715, 32.64165	1100	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00225	Existing	0.499446, 33.2634	1179	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00226	Existing	0.58487, 33.4567	1148	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00227	Existing	0.45047, 33.19557	1177	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00228	Existing	3.40472, 30.9596	1238	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00229	Existing	0.730337, 33.24717	1114	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00230	Existing	1.72469, 33.622	1123	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00231	Existing	0.6978, 34.17151	1177	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00232	Existing	2.72595, 31.39115	640	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00233	Existing	3.4535, 31.25125	970	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00234	Existing	2.29519, 32.92137	1096	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00423	Existing	0.0486111, 32.4725	1149	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00424	Existing	0.4834972, 33.2437194	1346	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00425	Existing	0.7569194, 34.0461694	1119	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00426	Existing	1.2102444, 32.4622806	1074	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00427	Existing	0.6106, 32.4752694	1223	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00428	Existing	0.4007722, 32.0373083	1224	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00445	Existing	-0.080571, 32.7333217	1157.757	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo

TA00446	Existing	1.498891, 31.4975346	1141.649	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00075	Existing	-2.2230288, 30.2378422	1352	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00326	Existing	-1.9562, 30.05773	1.524	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00395	Existing	-1.9558109, 30.057863	1522.51	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00399	Existing	-1.5543189, 29.550685	2203.229	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00429	Existing	-1.8807908, 29.3493637	1987	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00430	Existing	-1.45486, 30.09317	1831	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00431	Existing	-2.527662, 29.4166465	2386	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00432	Existing	-2.4924188, 28.8933834	1484	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00433	Existing	-1.562437, 29.636505	1628	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00434	Existing	-2.25891, 29.794155	1761	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00435	Existing	-1.9557757, 30.0578152	1538	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00436	Existing	-1.4545, 30.09326	1827	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00437	Existing	-2.5709521, 28.954602	1838	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00438	Existing	-1.9562, 30.05773	1740	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00439	Existing	-2.405129, 28.900336	1555	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00451	Existing	-1.9548202, 30.0566022	1271	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00154	Existing	-4.231122, 37.847762	877	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00269	Existing	-6.7657437, 39.2079037	91.9	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00270	Existing	-6.84239, 39.15676	96	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00271	Existing	-6.87985, 39.02493	173.8	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00272	Existing	-6.890039, 39.117927	139.8	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00273	Existing	-6.8091471, 39.2661084	9.8	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo
TA00422	Existing	-4.2112727, 37.885682	1387	Reporting 5min and upload 1 hour	T, T_d, WS, WD, rain	https://datahmo.org/login or api from national met agencies or tahmo