



Article Dual-Polarization Radar Observations of Deep Convection over Lake Victoria Basin in East Africa

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Abstract: Lake Victoria in East Africa supports the livelihood of thousands of fishermen and it is estimated that 3000–5000 human deaths occur per year over the lake. It is hypothesized that most of these fatalities are due to localized, severe winds produced by intense thunderstorms over the lake during the rainy season and larger scale, intense winds over the lake during the dry season. The intense winds produce a rough state of the lake (big wave heights) that cause fishing boats to capsize. In this region, weather radars have never been a primary tool for monitoring and nowcasting high impact weather. The Tanzania Meteorological Agency operates an S-band polarimetric radar in Mwanza, Tanzania, along the south shore of Lake Victoria. This radar collects high temporal and spatial resolution data that is now being used to detect and monitor the formation of deep convection over the lake and improve scientific understanding of storm dynamics and intensification. Nocturnal thunderstorms and convection initiation over the lake are well observed by the Mwanza radar and are strongly forced by lake and land breezes and gust fronts. Unexpected is the detection of clear air echo to ranges ≥ 100 km over the lake that makes it possible to observe low-level winds, gust fronts, and other convergence lines near the surface of the lake. The frequent observation of extensive clear air and low-level convergence lines opens up the opportunity to nowcast strong winds, convection initiation, and subsequent thunderstorm development and incorporate this information into a regional early warning system proposed for Lake Victoria Basin (LVB). Two weather events are presented illustrating distinctly different nocturnal convection initiation over the lake that evolve into intense morning thunderstorms. The evolution of these severe weather events was possible because of the Mwanza radar observations; satellite imagery alone was insufficient to provide prediction of storm initiation, growth, movement, and decay.

Keywords: Lake Victoria weather; thunderstorms; convergence lines

1. Introduction

The purpose of this paper is to provide the first radar observations obtained over Lake Victoria in East Africa. These radar observations are particularly important since they are from an area where deep intense thunderstorms are common, and they are responsible for the loss of many lives. Surprisingly, the data shows clear-air features over the lake that has great potential for developing severe storm and wind warnings. This initial data has only been minimally integrated with other observations such as lightning, satellite, and surface station. Also, methodologies for ground clutter removal, velocity dealiasing, and second trip echo removal, as well as hydrometeor classification [1] algorithms were not available for these first observations. Future papers will focus on integrating

radar with other data sets to better understand the diurnal forcing mechanisms and for development of severe storm warning procedures.

Lake Victoria is Africa's largest and the world's second largest freshwater lake, with an area of 69,000 km² spanning Tanzania, Uganda, and Kenya. It is a key resource for the people of East Africa supporting over 30 million people and has the largest freshwater fisheries, producing 700,000 to 800,000 metric tons of fish annually worth \$350–400 million USD. Fish exports contribute \$250 million USD to the regional economy each year. Furthermore, there is an important untapped potential to expand both the tourism and transportation industries across the lake to benefit communities who share this trans-national freshwater resource [2,3].

During the past decade a major concern is the high number of marine transport accidents associated with the transportation and fishing industries that result more than 3000–5000 deaths every year. Safety has become a priority issue for passengers and operators of ferries and fishing boats, influencing their use of water transport. Most of these accidents have been attributed to hazardous weather conditions and water currents in the lake [2–5]. There are unique weather dynamics that continuously threaten air and marine navigation over the lake and its basin. The region around the lake has the highest occurrence of hailstorms and thunderstorms in the East African Community [6]. These are associated with local circulation patterns arising from differential heating between land and water surfaces and their interactions with the large-scale (synoptic) circulation patterns [5].

Surveys of fishermen and lake transporters engaged in activities over the Lake Victoria Basin (LVB) indicated that the most important navigation hazards affecting their activities were convective storms (28.80%), strong winds (14.87%), and strong waves (13.29%) [3]. Considering only weather hazards, fishermen, and transportation operators listed strong winds (43.04%), and convective storms (32.59%) as the greatest hazards. The high frequency of lightning is a rough proxy for storm intensity because the lightning is often associated with strong vertical motion within deep tropical convection over land and surveys show this was also a strong concern of local operators.

Before deployment of the Mwanza radar, it was very difficult to accurately forecast severe weather over Lake Victoria, as detailed observations over the entire depth of the atmosphere over LVB were not available and weather prediction models were unable to take into account the two-way interaction between the atmosphere and the water current. The attributes of the lake, located at the equator and with a variable shallow depth of 40–80 m, and data limitation in and around the Lake Victoria [7], coupled with the influence of complex topography on the local weather makes forecasting a difficult task. In addition, much of the severe weather is produced from deep, short-lived convection.

Due to the high number of human fatalities over the lake caused by high impact weather, the United Kingdom Department for International Development (DFID) and the World Meteorological Organization (WMO) WMO-DFID are sponsoring the high impact weather lake system (HIGHWAY) project that aims to improve regional early warning systems for the lake and increase resilience to extreme weather over LVB. Taking advantage of the existence of the dual polarization S-band radar in the region, two cases are examined here that demonstrate the importance of radar data for observation and forecast of deep convection over the lake and demonstrates how this data can be used to improve scientific understanding of deep convection initiation, dynamics, and evolution over LVB.

2. Radar Attributes

The TMA dual-polarization S-Band Doppler radar is located in Mwanza on the south shore of Lake Victoria (Figure 1) and has been operational since 2015. Attributes of this radar are given in Table 1. The radar transmits horizontally and vertically polarized waves and retrieves horizontal and vertical reflectivity (Z_H , Z_V) fields that are related to the power of backscattered electromagnetic waves and the diameter of the particles to the sixth power (D^6); for further polarimetric radar details see [6]. The suite of dual-polarization fields includes differential reflectivity (Z_{DR}), specific differential propagation phase (K_{DP}), and correlation coefficient (ρ_{HV}).



Figure 1. Lake Victoria Basin terrain map. The blue polygon shows the physical boundary between the lake and the surrounding terrain. Country boundaries are shown in black with the E-W line separating Uganda to the north from Tanzania to the south. Kenya is located on the eastern side of the lake. (a) Black circles represent the maximum radar range of the low pulse repetition frequency (PRF) and high PRF scans. The location of TMA's Mwanza radar is along the southern shore of the lake and is indicated by the red crosshair and text. (b) Radar reflectivity from a low PRF scan overlaid onto the terrain map, showing convective storms across the lake.

Radar Attributes	Details
Manufacturer	EEC
Latitude/Longitude	-2.4799/32.93
Altitude	1150 m
Wavelength (cm)	10
Beamwidth (deg)	1.0
Polarization	Dual
Transmit Power (KW)	850 kw
Commercial Power/Generator	Yes/Yes

Table 1. Radar specifications for the Mwanza, Tanzania radar.

The radar is located on a hill 136 m above the lake. Thus, the center of the beam at a 0.2° elevation angle will be 556 m above the lake at a range of 60 km. The lower half of the 1° beam width (-0.5°) at 60 km range will be 34 m above the lake; never getting any closer than 21 m above the lake at any range [8]. Thus, wind velocities and reflectivity at lake level will only be observed in the lower portion of the beam and the ability to observe near surface features will be dependent on radar range and the vertical distribution of reflectivity [9]. Scanning at elevation angles below 0.2° would increase the amount of sea clutter.

A specific radar surveillance scan sequence has been set up for the HIGHWAY project that includes two low pulse repetition frequency elevation scans (0.2 and 1.2) followed by nine high pulse repetition frequency (PRF) elevation scans (0.3, 1.0, 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, and 15.0) every 6 min to capture the rapidly evolving weather over the lake. This radar is able to scan the entire lake when running a low PRF (400 pulses s⁻¹) scan although only the tops of the tall storms are detected at further ranges. At a higher PRF (1000 pulses s⁻¹), the radar observes approximately half of the lake to the north of its location and collects full volumetric data within the storms.

Figure 2 shows an example of a high PRF, low-level reflectivity scan collected by the Mwanza radar on 21 November 2017. No ground clutter filtering was applied to the radar data collected in real-time. Thus, all radar data presented in this paper include ground clutter echoes. Ground clutter echoes are evident surrounding the radar and evident from the Ukerewe Island in the lake. Additional non-meteorological targets detected to the NW of the radar site in Figure 2 are caused by radar beam backscatter from the lake surface. This "sea clutter" echo is characterized by the large, stratiform-type echo in this region and the presence of this radar echo only in the lowest two elevation scans.



Figure 2. Mwanza radar reflectivity (dBZ) at 0.07° elevation. The radar is located at x = 0, y = 0 km. The white polygon overlaid onto the image marks the boundary between Lake Victoria and the surrounding land. Storm echoes are present over the lake and over the land. Strong ground clutter return is evident around the radar and in association with Ukerewe Island, the largest island in the lake. Sea clutter is often observed. The radar clear air return, that is, the green and blue widespread echo (–5 to 10 dBZ) are the result of radar backscattering from insects and by Bragg scatter echo caused by strong moisture gradients in the atmosphere.

A number of important meteorological features were observed over the water. Several storms are evident over the lake with maximum reflectivity values ranging from 40–55 dBZ. Also observable in the radar scan is the extensive "clear air" echo evident over the lake as indicated by the green and blue color-coded echo regions (-5 to 10 dBZ). These clear air echo regions are composed of radar beam backscattering from insects [10,11]. Insects in the clear air were observed out to ~75 km range from the radar which is very surprising, as typically most insects are not generally observed much beyond the shoreline of most bodies of water [12]. As observed by [12], insect populations concentrate along the coasts and respond behaviorally to avoid being drifted out over the water where they deplete their fuel stores rapidly, fall to the sea surface, and die. The presence of insects at such far ranges over the water implies that a continuous population of insects are being advected over the water by the wind against their natural survival instincts. Thus, the detection of clear air echo to such considerable distances from shore, is not only surprising but very fortuitous for detection and monitoring of winds, gust fronts, and wind shear over the surface of the lake. The ability to detect gust fronts is of considerable importance in any regional early warning system designed for the lake, as gust fronts represent the leading edge of thunderstorm downdrafts and outflows that are likely a significant factor in generating increased wave heights on the lake. Strong winds and high wave heights are strong candidates for contributing to boating accidents and human fatalities on the lake.

3. Results

3.1. 18 December 2017

3.1.1. Evolving Weather

During the late evening on 17 December 2017 at 21:00 UTC (All times hereafter are in UTC, Add two hours to get Local Time), storms formed along the eastern coast of Lake Victoria in Kenya and grew into deep storms with the EUMETSAT Meteosat–11 satellite imagery showing cloud top infrared (IR) temperatures reaching >60 °C by 00:00. A four-hour gap in observations exist after 00:00. By 04:15 (Figure 3a), the IR imagery shows that storms have moved westward over the lake and new storms may be growing ahead of the existing storms as indicated by the –40 to –55 °C storm tops centered at x = -40, y = 80 km and x = 70, y = 70 km. The low PRF radar scan in Figure 3b shows that many storm echoes are present under the cold anvil cloud that extends over much of the lake, with one particularly large cluster of storm cells directly aligned with the coldest cloud tops of –75 °C at x = 30, y = 125 km in Figure 3a. It can also be seen in Figure 3b that the clear air return is quite good, extending out to 150 km range from the radar during this early morning period.

Thirty minutes later, as the first wave of storms dissipate, new widespread cellular convection initiation occurs (Figure 4a). Over time, the individual storm cells produce downdrafts and gust fronts (Figure 4b); the gust fronts are more evident from animation of the reflectivity images. New storms initiate from gust front merged storms into an organized line of storms. This organized line of storms or collisions and storm mergers occur from 05:00 to 05:30 (Figure 4c). Intersecting gust fronts consolidate the outflow into an elongated line of convergence clearly evident in the radial velocity field (not shown) and transforms the individual storms into a squall line which likely created hazardous weather for the fishermen on the lake.



Figure 3. IR satellite imagery and Mwanza radar reflectivity on 18 December 2017. (**a**) IR cloud top temperatures at 04:15 with combined gray-color scale bar (in °C) located on the left-hand side of the figure. Warm temperatures are in gray shades; sub-freezing temperatures are color-coded. (**b**) Low PRF radar reflectivity field at 04:11 with color scale bar (in dBZ) located on the right-hand side of the figure. The outer boundary of the lake is the black polyline in (**a**) and white polyline in (**b**). Country boundaries are shown in white (**a**) and yellow (**b**) High reflectivity echo over land areas are ground clutter.



Figure 4. Radar reflectivity images from 18 December 2017 at (**a**) 04:28, (**b**) 05:00, (**c**) 05:31, and (**d**) 06:03. White polylines represent the south shores of the lake. Closed white polylines are islands in the lake. The high reflectivity echo over these islands and along the shoreline are ground clutter.

3.1.2. Detailed Radar Observations

Over the next 30 min, the squall line and associated large-scale gust front quickly approach and pass over Ukerewe Island as they propagate to the W-SW (Figure 5a,b). The gust front is clearly evident as a long thin, wavy line of 25 dBZ intensity in Figure 5a at the leading edge of the storms. A higher reflectivity thin line (~40 dBZ) is also present in Figure 5a, most likely due to birds flying from the coastline of Mwanza towards the small islands due south of Ukerewe Island. While these flocks of birds have no role in the evolution of the weather over the lake, it is of interest to note the diversity of non-meteorological features over the lake. The more random pattern and shorter segments of high reflectivity thin lines to the east of the primary bird line may also be associated with birds feeding on insects and other prey over the lake (Figure 5b). Over the ensuing hour, several new storms with high reflectivity (>45 dBZ) are initiated by the gust front (Figure 5b–d), move onshore and then rain out and dissipate.



Figure 5. Radar reflectivity images from 18 December 2017 at (**a**) 06:03, (**b**) 06:30, (**c**) 06:56, and (**d**) 07:33. White polylines represent the south shores of the lake. Closed white polylines are islands in the lake. Gray shaded regions have been added to cover ground clutter echoes in order to highlight meteorological and biological features of interest.

Approximately ten hours later, long after the convection has died away and the sun starts to set, a very interesting phenomenon occurs. The radar observes the blooming of insects rising up from the ground and taking flight over the land and the lake. This "insect bloom" occurs just prior to and for several hours after sunset (Sunset in Tanzania on 18 December 2017 occurred at approximately 16:52 UTC or 18:52 LT). The insect bloom has been commonly observed over land world-wide [8] always near sunset, but not specifically over large bodies of water. The Mwanza radar detects this bloom in the form of an expansion in range of widespread, mostly stratiform-type echo in all radial directions from the radar, as can be seen in Figure 6b, near the start of the bloom and in Figure 6c during the bloom. Insects, which typically have elliptically-shaped bodies, with larger horizontal dimensions and smaller vertical extensions, are clearly detectable in the differential reflectivity field (ZDR) [13], with values that can range from 2–7 dB [13], with typical median values of 5–7 dB. The ZDR field in Figure 6d shows that the large expansion of radar echo extending 100 km from the radar at 17:01 is completely due to airborne insects, i.e., all the ZDR values that are not zero (gray) or negative (blue).



Figure 6. Reflectivity at 0.3° elevation on 18 December at (**a**) 16:03, (**b**) 16:30, and (**c**) 17:01, with corresponding colorscale bar (in dBZ) on the left-hand side. Range rings (gray) are in increments of 50 km. The southern shoreline of the lake is indicated by the continuous white polyline. The Z_{DR} field at 17:01 is shown in (**d**), with a corresponding colorscale bar (in dB) on the right-hand side. Regions of negative Z_{DR} values (blue speckling) are artifacts caused by ground targets and beam blockage. The high reflectivity echo over islands and along the shoreline are ground clutter.

3.2. 15-16 January 2019

3.2.1. Evolving Weather

During the late afternoon on 15 January, a boundary of unknown origin, potentially a land breeze, becomes apparent in the coastal waters on the south side of the lake (Figure 7a) as a distinct reflectivity thin line. The origin of the boundary was difficult to discern due to the sea clutter present between Mwanza and Ukerewe Island. The boundary propagates to the NW initiating the first set of storms by 23:08 (Figure 7b). These storms grow into two large thunderstorms (Figure 7c) with cloud top temperatures of -68 °C (see Figure 8a). The boundary is no longer detectable by the radar after 23:18, since the radar beam is above the boundary at that range (~80 km), it is evident that storms continue to be triggered as the boundary moves northwest (Figure 7d), until 02:25, when all storms move out of radar coverage.







From 02:30–04:00 all of the convective activity occurs outside the range of the radar. Examination of the IR satellite imagery during this period indicates that convection associated with boundary passage is still very prevalent and has reached the western side of the lake. The satellite imagery indicates additional storm development along the western coastal area (Figure 8c) the deepest portions of the storms remaining over the water. A very unique aspect of these storms is the back-building [14,15] which occurs on the eastern edges of the storms after 04:00. Close examination of Figure 8c shows a new short line of <-65 °C storms have developed on the eastern side (at x = -50 km, y = 150 km) of the middle storm. Based on animation of successive satellite imagery, the majority of the cloud tops move from the east to the west through the nighttime and early morning hours. The exception to this are the tallest and coldest cloud tops associated with the thunderstorms over Lake Victoria that move eastward as the storms back-build. After 04:00, the Mwanza radar is able to once again detect these storms as they move eastward back into radar detectable range.





Figure 8. Infrared satellite imagery of IR cloud top temperatures (°C) at four time periods on 15–16 January 2019. Color scale is on the right-hand side with warm temperatures in gray shades and color-coded sub-freezing temperatures. The lake is bounded by the black polyline. The country demarcations are denoted by the white lines. (a) 23:45 on 15 January, (b) 02:30 on 16 January, (c) 04:30 on 16 January, and (d) 06:30 on 16 January.

3.2.2. Radar Observations

Figure 9 shows the movement and evolution of the storms as they propagate toward Mwanza and the south shore of the lake. Similar to the case discussed in Section 3.1, a cluster of storm cells are evident (Figure 9a) that eventually organize into a full-fledged squall line with one large scale gust front located ahead of the strongest line of convection (Figure 9b–d). What differentiates this case from the one in Section 3.1 is the very large, trailing stratiform echo region located behind the line of intense convection. This storm system has a classic squall line structure commonly observed in many locales around the world and typically associated with severe weather. Considerable amounts of rainfall were produced by this squall line.



Figure 9. Radar reflectivity images of squall line evolution and propagation at 0.3° elevation scan on 16 January 2019 at four time periods. (**a**) 07:00, (**b**) 07:59, (**c**) 08:49, and (**d**) 09:57. The southern shore of the lake is indicated by the white continuous polyline. The high reflectivity echoes over islands and along the shoreline are ground clutter. The red cross is the location of the radar and the long thin echoes in advance of the squall pointing toward the radar are second trip echoes.

The dual-polarization fields provide useful information on the makeup of hydrometeors within the storms. Figure 10 shows the reflectivity and the Z_{DR} fields at the lowest two elevation angles. The convective cores of the storms had values of Z_{DR} ranging from 1–3 dB indicative of small to moderate sized raindrops and moderate to heavy rainfall. The stratiform region shows values of <0.5 dB that are typically associated with small drops and light rain. The regions of negative Z_{DR} values are highly suspect and can likely be attributed antenna polarization errors arising from cross coupling of the horizontal and vertical polarized signals [16].



Figure 10. Radar reflectivity (Z_H) and differential reflectivity (Z_{DR}) plots from the radar volume at 08:19 on 16 January2019. (**a**) Z_H at 0.3° elevation scan, (**b**) Z_{DR} at 0.3° elevation scan, (**c**) Z_H at 0.9° elevation scan, and (**d**) Z_{DR} at 0.9° elevation scan.

The Doppler winds associated with the squall line were quite strong, with a maximum core of radial wind speeds of 15–20 m s⁻¹ (red shades in Figure 11c,d) approaching the radar. These speeds are widespread and substantial enough to create high waves and whitecaps on the surface of the lake and potentially capsize small fishing boats and crafts. Reconstructed range-height (RHI) plots (vertical slices through the storms) are produced to examine the vertical attributes of the storms. See Figure 11a,c for the location of these RHIs. The reflectivity RHIs show the storms were relatively deep while they were located ~80 km out in range from the radar and propagating southeastward, with storm heights up to 7 and 8 km above ground level (AGL) (Figure 12a). However, as they approached the south coast, storm heights dropped to 4–6 km AGL (Figure 12c) while the storms rained out at the surface. The radial velocity RHIs show the very strong approaching flow (outflow) extends several km above ground, with 15 m s⁻¹ receding flow located above. At the interface of these two flows, Kelvin-Helmholtz (K-H) waves are evident [17].



Figure 11. Horizontal radar reflectivity and radial velocity plots on 16 January 2019 at 08:19 and 09:38. (a) reflectivity and (b) radial velocity at 08:19 and (c) reflectivity and (d) radial velocity at 09:38. Thin yellow line shows the location of the reconstructed RHIs shown in Figure 12. Reflectivity (radial velocity) color bar is on the left-hand (right-hand) side of the figure. Shades of yellow and red represent radial winds approaching the radar; shades of blue and green represent winds receding from the radar. The high reflectivity echo over islands and along the shoreline are ground clutter.

One last item of particular interest is the finger-like structures of the convective cells that comprised the squall line at 09:57 (Figure 9d) where the \geq 50 dBZ reflectivity cores are elongated backwards toward the stratiform region. While this aspect of storm structure has been observed occasionally with storms in other geographic regions, this is not a common pattern for squall lines and has been rarely documented in the literature. Examination of a squall line that showed similar convective patterns and was initiated by a solitary, leading edge gust front was conducted by [18]. They found that the solitary gust front induced internal gravity (IG) waves above the outflow which propagated backwards relative to the gust front and acted to modulate the convection and location of additional convection initiation at the intersection of the IG waves with the updraft portions of the K-H waves. In the case presented here, the radar radial velocities (Figure 12b) show that K-H waves were likely present as a result of the gust front, but undulating convection is not evident in the reflectivity RHI cross-section (Figure 12a) that would suggest the presence of IG waves. There is only the periodicity of cells evident in the horizontal reflectivity image (Figure 9d) perpendicular to the gust front that suggest IG waves may be present. Unfortunately, there were no upper air soundings collected during this period that could aid in understanding the evolution, structure, and persistence of this system. However, this case illustrates that mechanisms behind the initiation of storms and the factors affecting the changing direction of storm propagation are more complicated than expected and certainly provide challenges for prediction and warning of severe weather.



Figure 12. Reconstructed RHIs of reflectivity and radial velocity at two time periods on 16 January 2019. The horizontal location of these vertical slices are shown by the yellow lines in Figure 11. (**a**) reflectivity at 08:25, (**b**) radial velocity at 08:25, (**c**) reflectivity at 09:43, and (**d**) radial velocity at 09:43. The y-axes is height above ground level (km AGL) and the x-axes is range from the radar (in km), with the radar located at 0 km.

4. Discussion and Conclusions

In this study we have explored the contribution of S-Band dual polarization radar data for observation, evaluation, and movement of localized, large clusters of deep convection compared to traditional observation platforms that have existed in the region, including satellite observation. Two different cases were presented from 18 December 2017 and 15–16 January 2019. During the first case, formation and dissipation of short-lived, deep storm cells with clear formation of downdrafts and gust fronts are observed. A sequence of low-level radar reflectivity scans shows the intersection of gust fronts consolidate the outflow into an elongated line of convergence and transform the individual storms into a squall line. Later, new storms are initiated by this merged, larger scale gust front with the storms eventually organizing into a secondary line of storms over a short time period (less than 30 min) that no other observational platform in the region is able to capture this evolution. Also observed in this case is the diversity of non-meteorological features over the lake that can be observed by the radar. This includes the blooming of insects rising up from the ground and taking flight over the land and over the lake soon after the sunset; a unique radar feature.

In the second case presented from 15–16 January 2019 there is clear evidence of local features influencing the weather that forms over LVB and develops into the deep convection that is observed. Local circulation patterns arise from differential heating between the land and water surface that interact with large scale circulation patterns and produce a convergence line and vertical motions that produce two large thunderstorms with severe impact. Using both radar and satellite observations the

storms propagated to the west coast of Tanzania with new storms being triggered along the leading edge of the storms by the low-level gust front. Later storms back-build toward Mwanza and evolve into a classic squall line with a large trailing stratiform region. Significant rainfall and strong low-level 15–20 m s⁻¹ winds were observed over the surface of the lake associated with this squall line.

This work has been fundamental in the nascent scientific understanding of storm dynamics over the lake that previously has not been possible. This paper represents the first research on deep convection of the lake using radar observation. This work shows the importance of having a radar network around the lake in order to be able to track storms and severe weather events that originate from one side of the lake and propagate towards the other side. The Mwanza radar is critical for documenting areas of storm genesis, building climatologies of storm duration and movement under different weather regimes that can be incorporated into forecaster conceptual models of convective weather evolution, and for overall understanding of the atmospheric dynamics over the lake. This data will have a significant impact towards improving very short-range forecasts, nowcasts, and warnings of severe weather and hence has the potential to save lives of thousands of fishermen working in the lake.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "conceptualization, P.F.W, R.D.R. and J.W.W.; data curation, B.K.; writing—original draft preparation, P.F.W.; writing—review and editing, P.F.W, R.D.R. and J.W.W.; supervision, A.K.; funding acquisition, A.K.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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