Reconstruction of Weather Situations Involved in the AJ-2199 Ultralight Aircraft Incident on 7 January 2021

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Abstract

At 1635L (UTC+8) on 7 January 2021, the Pingtung County Fire Bureau received a report about a missing plane identified as a CTLS ultralight aircraft belonging to the Aero Jones Aero Club with the serial number AJ-2199. The aircraft departed from Runway 26 of Jiehao airfield in Gaoshu Township, Pingtung County at about 1420L (UTC+8) to perform orientation with a planned flight route. The study tries to focus on the mesoscale analysis of weather conditions (local circulation, wind speed, wind direction, relative humidity, rainfall rate, visibility, cloud patterns, etc.) embedded within the intense NE monsoon flow under the influence of mainland China high pressure system, especially mentioning the cloud initiation in the complex terrains over the western side of Mt. Peitawu, located at the south edge of the Central Mountain Range. Furthermore, the mesonet station array in spacing of 6~18km on 07 January 2021 offered the primary and reliable data set, including the hourly data of five CWB weather stations plus the METAR data of Pingtung AFB.

The preliminary findings illustrated that the leeside circulation with NNE surface wind of 15kts under influence of the mainland China high pressure system was the large-scale weather circumstance during this day. Also, the vertical cross section along 22.5°N between 105°E and 135°E elucidated a vertical circulation located in an upward-downward motion transverse zone near the longitude of 120.5°E, and an obvious vertical wind shear in the layer between surface and 700hPa was identified, designating an unstable and turbulent condition over the Pingtung area. Moreover, the southwesterly flow off the coastal line of Taiwan between 850hPa and 700hPa levels brought abundant moisture air inland over the south Taiwan area, and a weak inversion at 875hPa as well as an obvious inversion at 700hPa in Pingtung area.

Furthermore, visibility reduced from 4000m to 3200m before the takeoff with light rain as well as scattered clouds in altitude of 600ft (183m) and overcast in altitude of 1600ft (488m) at 1400L (UTC+8), based upon the METAR report at Pingtung AFB around 18km away from the mesonet array in the hillside. During the flight period between 1420L~1530L (UTC+8), it kept in light rain, mist, and bad visibility, and was covered by scattered low clouds. It preliminarily concludes that the persistent light rain and scattered low clouds over the complex hillside area might reduce the visibility sharply and increased the flight risk in visual flight rules (VFR). Also, the estimated vertical wind shear could reach 4.7 m/s/km in magnitude and 105deg in wind direction change, a quite significant wind shear for aircraft. Those weather conditions will threat the flight safety for light sport aircrafts (LSA). A schematically conceptual model depicting the weather situation and the rough terrain at that time was managed for better understanding of this ultralight aircraft crash case. Also, some recommendations are raised for airfield owners, aircraft companies and pilots in order to reduce the incident occurrence effectively.

Keywords: mesonet station array, visual flight rules, ultralight aircraft crash.

重建2021年1月7日AJ-2199輕航機失事事件的氣象環境與天氣分析

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1. Introduction

Light sport aircraft (LSA) is a new category of small, lightweight aircraft that is much easier to operate than the regular aircraft. The LSA category encompasses a wide variety of aircrafts, including two-seat ultralight-type designs and powered parachutes, antiques and classics, and the latest composite aircraft. In Taiwan, the Regulations for Ultralight Vehicle Management were announced by Ministry of Transportation and Communication (MOTC) on 22 March 2004.

From the economical, easy-to-operate and easy-to-maintain points of view, LSA may bring exciting possibilities to making flying easier, safer, and more enjoyable. Therefore, the outdoor activities of LSA are very popular with youth generations. However, the current ill-legal fly cases and fields need to be well managed by central and local governments on going.

According to the Civil Aviation Act approved by the Civil Aeronautics Administration (CAA), owners and operators of ultra-light vehicles shall be responsible for flight safety, keep the ultralight vehicles in serviceable condition, and perform a safe flight operation. Also, the operator of ultralight vehicles shall operate the vehicles by visual flight rules (VFR). The regulations of visual

meteorological conditions (VMC) for ultralight vehicles should reach the cloud ceiling of 1500ft and visibility of more than 5km. Also, the required take-off speed for CTLS (composite technology light sport) ultralight vehicles is about 85km/h, and the best cruising speed is between 130 ~ 140km/h. The flight altitudes are limited between 500~1000ft (Hsiao and Hsu, 2021).

Based upon the statistics of occurrence investigation on aviation of ultralight vehicles by Taiwan Transportation Safety Board (TTSB), there are eight closed investigation occurrences during the past six years (2016~2021) (TTSB, 2021). Only one of the eight cases is related to the weather factor. A powered paraglider (the PM1052 ultralight vehicle occurrence) took off from a softball field next to the Xiluo Bridge in Yunlin County at about 1720L on 14 September 2018. According to the witness, at that time, the wind direction was northwest, and the wind speed was about 6 to 8 mph. When reaching the altitude around 30-50 feet AGL, the vehicle started to swing abnormally six to seven times, and then the amplitude was getting bigger and bigger. Finally, the vehicle lost control and crashed in a farmland, about 300 meters away from the softball field nearby Xiluo Bridge, Yunlin County at 1720L that day. The summary of the investigation mentioned that it was probably caused by the operator's improper operation or gust wind which intensified the improper oscillation and resulted in the crash. The operator sustained fatal injury and the vehicle was damaged. The primary factors related to the other seven incidents are connected to the operator's improper control and the vehicle malfunction.

The only one ongoing investigation by TTSB, is AJ-2199 ultra-light vehicle occurrence on 7 January 2021. Officially, TTSB announced an AJ-2199 ultra-light vehicle occurrence initial report on 15 January 2021. The aircraft departed from Runway 26 of Jiehao airfield in Gaoshu Township, Pingtung County at about 1420L of 7 January 2012, and about ten minutes after takeoff, the ground personnel were unable to contact the vehicle personnel via radio and mobile phones. The search and rescue unit reported that the wreckage of the vehicle was trapped on the 70° steep slope in the mountainous area near of Sandimen Township, Pingtung County at about 2230L that day, and two persons on board sustained fatal injuries. The on-scene team performed wreckage inspections, site surveys and related evidence collections, and defined this incident as Category CFIT (controlled flight into or toward terrain). Further progress of the occurrence investigation was going on (TTSB, 2021). Also, Taiwan English News (Charlier, 2021) reported that video footage of the aircraft taking off showed that weather conditions were poor, with light rain, and poor visibility. The plane was seen disappearing into low cloud shortly after takeoff. And, residents of Saijia Village heard two explosions at around 1500L, and search and rescue personnel used this information to narrow the search. From the meteorological points of view, more detailed investigation needs to step forward in order to identify the realistic scenario through the multi-scale processes based upon the synoptic scale, remote sensing and mesoscale analyses.

The study tries to focus on:

1. Reconstruct the weather scenario of the accident from large-scale and meso-scale points of view;
2. Figure out the possible weather conditions which might threat the flight safety.

2. Data Resources and Methodology

2.1 Data Resources

By using the weather observation data, radar reflectivity maps, IR and VIS satellite imageries adopted from the Central Weather Bureau (CWB), and the Air Force Weather Wing of ROC as well as NCEP reanalysis data, this study focuses on the local circulation over the Pingtung Plain and the complex terrains in the southwest part of Taiwan. Also, it tries to delineate the characteristics of the flow pattern, visibility and relative humidity embedded within the local circulation, and the related weather conditions in the lower atmosphere.

2.2 Methodology

The primary approaches conducted in this study include the 3D large scale analysis, mesonet array analysis, and remote sensing analysis. Again, a conceptual model is planned to construct based on the available meteorological information.

3. Synoptic Weather Analysis

The weather pattern in winter time during the Taiwan area is deeply influenced by the Siberian high pressure system and the related NE monsoon, bringing cold temperature, strong wind and abundant moisture due to the intense pressure gradient over ocean. The surface weather chart at 0800L (UTC+8) and 1400L (UTC+8) on 7 January 2021 mentioned that the southeastward movement of split high in intense pressure gradient was located at the south Mainland China and it brought strong NE monsoon over the Taiwan area. An obvious trough on the east side of the Central Mountain Range (CMR) and a ridge on the west side of CMR due to the high terrain effect (not shown). The composite mean surface vector wind distribution in synoptic scale at 1400L (UTC+8) on 07 January 2021 over the Northwest Pacific Ocean was shown in Fig. 1(a) analyzed by NOAA/ESRL (2020), and it told the strong NE monsoon between 15-18m/s was prevailing over the open ocean and Taiwan area. Also, the cross section (longitude by height) of omega wind (Pa/s) between 1000hPa ~ 500hPa at 1400L (UTC+8) on 7 January 2021 (shown in Fig. 1(b)) told that the vertical cross section along 22.5°N between 105°E and 135°E elucidated a vertical circulation located in an upward motion - downward motion transverse zone near the longitude of 120.5°E, designating an unstable condition over the Pingtung area.

Furthermore, the vertically atmospheric profile at 0800L (UTC+8) on 7 January 2021 shown in the skew T log P diagram at Pingtung weather station, located at a plain area on the west side of CMR, identified a weak inversion at 875hPa as well as an evident inversion at 700hPa with weak NNW to N wind in the lower troposphere between surface and 850hPa, obvious SW wind in 15kts at 850hPa and intense westerly wind in 30kts at 700hPa (Fig. 2(a)). There was possible potential for showers and scattered thunderstorms based upon the magnitudes of K index and Total index. However,

different situation occurred in the profile at Green Island weather station with the prevailing NE monsoon in 20~25kts in the lower atmosphere between surface and 850hPa induced by the mainland China high pressure system (Fig. 2(b)).

From the synoptic point of view, the Pingtung plain was under a transverse zone of vertical motions and an obvious vertical shear between surface and 700hPa, bringing a possibly turbulent situation. And it provided a favorable condition for the initiation of light rain and unstable circulation in the lower atmosphere there.

4. Remote Sensing Analysis - Satellite and Radar

Under the large-scale weather conditions of intense NE monsoon and terrain-induced trough on the east side of CRM on 7 January 2021, the visible satellite image illustrated that the shallow and overcast cloud layer with abundant moisture supply in the lower troposphere (above the 850 hPa level) propagated northeasterly toward the south Taiwan at 1420L (UTC+8) shown in Fig. 3(a). Radar image gave more precise information on the reflectivity distribution and the possible rainfall intensity over the same area. It showed evident rainfall phenomena over the north part of Pingtung County, including townships of Wutai, Gaoshu, Majia, Sandimen (shown in Fig. 3(b)). Basically, the composite reflectivity from long-term radar observations was a reliable tool to reconnaissance the initiation and development of low cloud over the open ocean and plain area usually. However, radar echoes couldn't identify the significant weather phenomena clearly over the Pingtung mountainous terrain due to radar beam blockage problem. Therefore, the further mesoscale analysis was necessary as followed.

5. Mesoscale Weather Analysis

5.1. Mesonet Array Mode

Mesonet array of six surface weather stations in spacing of 6~18km on 07 January 2021 was shown in Fig. 4. It includes hourly data collected by five local stations managed by CWB plus the METAR data of Pingtung AFB. Fig. 4 mentioned the locations of the Jiehao Airfield, AJ-2199 plane hit site and five CWB weather stations plus the Pingtung AFB. Notice the two eastern stations (Weiliaoshan, Ali) and the two western stations (Gaoshu, Sandimen) have different altitudes, and the vertical difference is more than 900m. Therefore, this restricted flight space has a characteristic landform in river valley, sharp slope and rugged terrain with outbound route altitude under 600ft and inbound route altitude of 800~1000ft. The five automated surface observing stations offered seven meteorological parameters every hour, including temperature, relative humidity, pressure, rainfall, wind direction, wind speed and sunshine hour. Moreover, the METAR and SPECI data collected by the Weather Center of Pingtung AFB delivered more weather data for the mesonet study in spatial and temporal scale, including the cloud category/altitude, visibility, and weather pattern. Even the weather station site at Pingtung AFB is around 18 km away from Sandimen station in the mesonet array, the METAR and SPECI data are the only reliable information for reconstruction of aviation meteorology on 7 January 2021.

5.2. Mesoscale Analysis

After integrating the observing data collected by CWB surface weather stations and Pingtung AFB weather station in spacing of 6~18km between 1300L ~ 1500L on 07 January 2021 (shown in Tab. 1), it delineated that before takeoff (1420L), the weather was getting worse with reduced visibility from 8000m at 1300L to 3200m at 1400L in accompanying with scattered cloud at 600ft (183m) and overcast at 1600ft (488m). Also, it became foggy due to light rain, and the hourly accumulated rainfall rate could reach 1.5mm at Shangdewun station (only for rainfall observation) within the mesonet array. After takeoff, the weather situation almost stayed the same, and the hourly accumulated rainfall rate at 1500L reached 1.5mm at Weiliaoshan, 1.0mm at Sandimen, Ali, and Majia stations. Just after 1510L, the visibility reversed from 3200m to 4000m, and then became 4800m at 1530L with scattered cloud at 600ft (183m) and overcast at 2500ft (762m).

Comparing with the radar reflectivity (dBz) and surface wind organized by the National Science and Technology Center for Disaster Reduction (NCDR) (shown in Fig. 5), the distribution of scattered rain spots was similar to that of surface observations, however, the surface data could convey more accurate rainfall rate information. Actually, it still remained light rain and resulted in bad visibility at the Pingtung AFB between 1400L ~ 1510L. If the weather scenario moved eastward from the Pingtung AFB (located in the middle of the Pingtung plain in 32m ASL) to the mesonet array (located in a rugged and hillside area between 100m~1040m ASL), the maximum rainfall rate at surface stations reached to 1.5mm, and the visibility should be getting worse there due to higher humidity (98%~99%) and almost calm wind (0.1m/s~1.5m/s). Right after 1530L, the scattered rain spots diminished, cloud would lift gradually, and then visibility was getting better.

5.3. Wind Shear Estimate

Wind shear is a difference in wind speed or direction over a relatively short distance in the atmosphere. Atmospheric wind shear is normally described as either vertical or horizontal wind shear. The estimated horizontal wind shear intensities calculated from the weather data of the mosonet array on surface between 1400L(UTC+8) to 1500L(UTC+8) on 7 January 2021 were from 0.8×10^{-2} m/s/km and 10.1×10^{-2} m/s/km with abrupt variability in wind direction, especially 10.1×10^{-2} m/s/km in shear magnitude and 53deg in wind direction change along the boundary of Sandimen(105m) - Majia(740m) at 1500L. The more serious feature was the estimated vertical wind shear based on the sounding data of Pingtung AFB at 0800L(UTC+8) on 7 January 2021. The magnitude of the vertical wind shear in the lower atmosphere could reach to 4.7m/s/km (2.5 knots at 1000hPa and 15 knots at 850hPa) and 105deg in wind direction change, both critical values to flight safety. Generally, vertical speed change greater than 4.9 knots (2.5 m/s) was qualified as significant wind shear for aircraft (WMO, 2020; Wikipedia, 2021).

In this 3D investigation based upon the radar imagery, CWB surface observing data, sounding data and METAR

data, it told that the weather situation became worse after 1300L in the hillside mesonet array, accompanying with light rain, scattered low cloud as well as bad visibility. The similar weather condition lasted about 2.5 hours until 1530L with improved visibility of 4800m and overcast at 2500ft (762m).

6. Discussions and Conclusions

On 15 February 2021, TTSB announced an AJ-2199 ultra-light vehicle occurrence initial report, pointing out that the aircraft departed from Jiehao airfield at about 1420L of 7 January 2012 (TTSB, 2021). Taiwan English News (Charlier, 2021) mentioned that residents of Saijia Village heard two explosions at around 1500L. Based upon the above statements, the estimated AJ-2199 flight time interval from takeoff to collision was taken from 1420L to 1500L.

The study tries to focus on to reconstruct the weather scenario of the accident from large-scale and meso-scale points of view, and figure out the possible weather conditions which might threat the flight safety.

The mesonet array of five CWB weather stations and a Pingtung SFB station in spacing of 6~18km on 07 January 2021 offered more detailed and reliable data to realize the scenario. Before the takeoff (1420L), visibility reduced to 3200m with light rain and haze as well as scattered clouds in altitude of 600ft (183m) and overcast at 1600ft (488m). During the estimated flight period between 1420L ~ 1500L, it remained light rain and bad visibility covering by scattered low clouds. A schematically conceptual model to depict the entire weather conditions and related topography in the layer of surface and 1.5km in altitude is well prepared in order to figure out the key points in the flight incident. Another case study for the GE222 aircraft in 2014 also emphasizes its value (Hor et al., 2020).

According to Article 99-5 of Civil Aviation Act, the operator of the ultra-light vehicle shall operate the vehicle by visual flight rules (VFR), which govern the operation of aircraft in visual meteorological conditions (VMC). Also, take-offs and landings are not allowed under the limitations: the cloud ceiling at the airfield is lower than 1500ft (457m), and the ground visibility is lower than 5km (MOTC, 2021). Additionally, the outbound route altitude in the Jiehao airspace is lower than 600ft (183m), and inbound route altitude is between 800ft(244m) ~ 1000ft(305m). After integrating the observing data collected by CWB surface weather stations and Pingtung AFB weather station in spacing of 6~18km between 1300L ~ 1500L on 07 January 2021 (shown in Tab. 1), it delineated that before takeoff (1420L), the visibility at Pingtung AFB reduced to 3200m in accompanying with light rain, fog, scattered cloud at 600ft (183m) and overcast at 1600ft (488m). Also, the accumulated rainfall rate could reach 1.5mm at Shangdewun station within the hillside mesonet array. After takeoff, the weather situation almost kept the same until 1500L. Furthermore, video footage of the aircraft taking off (YouTube, 2021) showed that weather conditions were poor with light rain, and low visibility. The plane was seen disappearing into low cloud shortly after takeoff (Charlier, 2021). Just after 1510L, the visibility lifted to 4000m, and then became 4800m at 1530L. Therefore, during the AJ-2199 flight period between 1420L ~ 1500L, the weather condition over the rugged hillside area might be the worst, and the airfield owners, companies and pilots should pay attention on that bad situation in advance, and comply with the VFR made by MOTC strictly.

Besides, owners of Jiehao airfield have to manage a team to collect and organize weather data and make decision for daily flight activities. Also, how to enhance their own weather observation skills and high-tech instruments to avoid the local and harmful weathers in the future is necessary, especially for the meteorological parameters of visibility and cloud ceiling.

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Tab. 1 The mesonet array of weather stations in spacing of 6~18km between 1300 L(UTC+8) and 1500 L(UTC+8) on 07 January 2021. It includes hourly data collected by five CWB stations plus the METAR data of Pingtung AFB. (Referred from CWB and ROCAF Weather Wing)

Time	Station	WD/WS	T/Td	RH	Rainfall	Cloud	Visibility
1400L	Pingtung AFB_32m	320°, 4m/s	16°C/15°C	94%	0.4mm	SCT006 OVC016	3200m
1400L	Gaoshu_103m	263°,1.5m/s	16.1°C	99%	0.0mm		
1400L	Weiliaoshan_1006m	67°, 0.5m/s	13.4°C	99%	0.0mm		
1400L	Ali_1040m	260°, 0.8m/s	13.0°C	99%	0.5mm		
1400L	Majia_740m	340°, 0.8m/s	14.1°C	99%	0.0mm		
1400L	Sandimen_105m	304°, 0.7m/s	17.0°C	98%	0.0mm		
1400L	Shangdewu_820m	-	-	-	1.5mm		
1430L	Pingtung AFB_32m	340°, 2m/s	16°C/15°C	94%	-RA BR	SCT006 OVC016	3200m
1500L	Pingtung AFB 32m	0°, 0m/s	16°C/15°C	94%	0.4mm	SCT006 OVC016	3200m
1500L	Gaoshu _103m	309°, 0.4m/s	16.3°C	99%	0.5mm		
1500L	Weiliaoshan 1006m	0°, 0.0m/s	13.2°C	99%	1.5mm		
1500L	Ali_1040m	0°, 0.1m/s	13.3°C	99%	1.0mm		
1500L	Majia_740m	0°, 0.0m/s	14.5°C	99%	1.0mm		
1500L	Sandimen _105m	307°, 0.6m/s	16.6°C/	98%	1.0mm		
1500L	Shangdewu _820m	-	-	-	1.0mm		
1510L	Pingtung AFB 32m	0°, 0m/s	16°C/15°C	94%	-RA BR	SCT006 OVC016	4000m

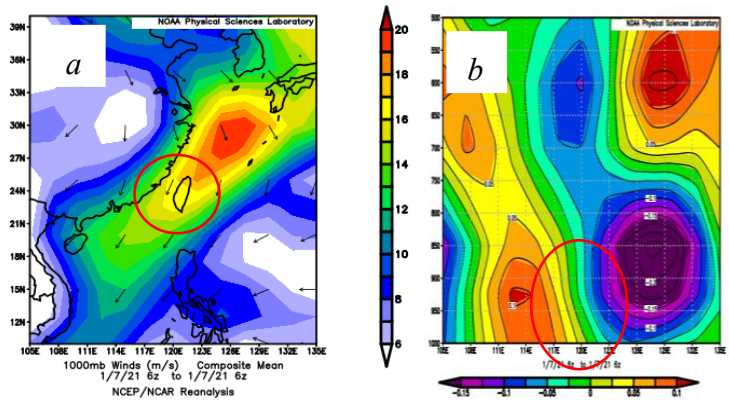

Fig. 1(a) Composite 1000 hPa-level vector winds (m/s) at 1400L (UTC+8) on 07 January 2021. (b) The cross section (longitude by height) of omega wind (Pa/s) between 1000hPa~500hPa at 1400L (UTC+8) on 07 Jan, 2021. The vertical profile of omega (Pa/s) is confined at latitude of 22.5°N between 105°E-135°E. (Resulted from NOAA/ESRL)

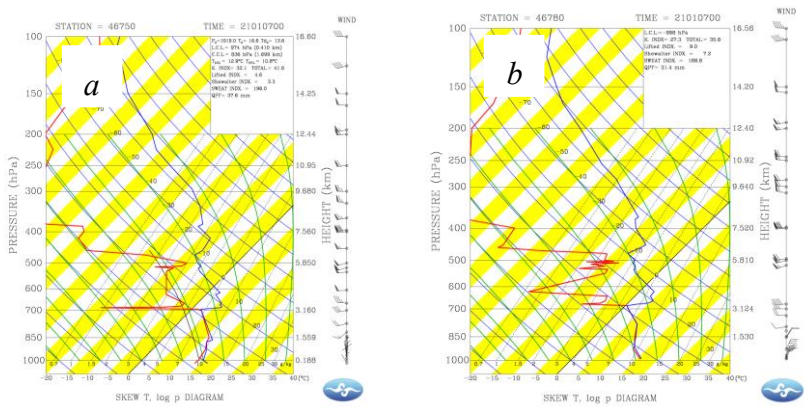

Fig. 2(a) The skew T log p diagram of Pingtung station at 0800 L (UTC+8) on 7 January 2021. The state of air in the lower atmosphere was under the conditional instability. (b) The same as (a) except for the Green Island station. (Referred from CWB)

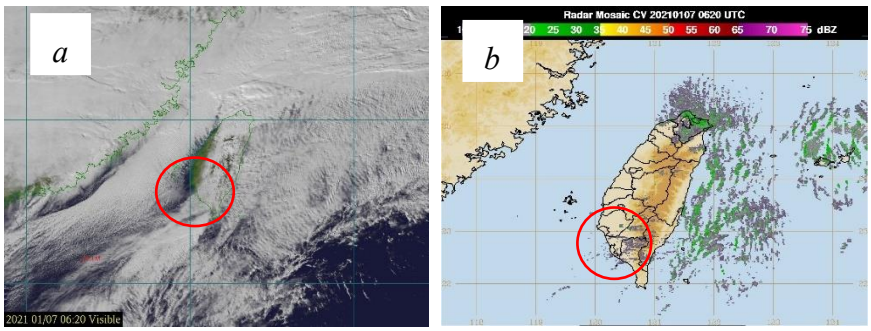

Fig. 3 (a) Himawari visible satellite image at 1420L (UTC+8) on 7 January 2021. The animation of images between 1400L to 1600L depicted the SW flows toward the south Taiwan area. (b) The same as (a) except for the radar reflectivity (dBz). The red circle covers the mesonet array mentioned in Fig. 4. (Referred from the CWB)

Fig. 4 The mesonet array of six weather stations in spacing of 6~18km on 07 January 2021. It includes hourly data collected by five CWB weather stations plus the METAR data of Pingtung AFB. The hit site of the ultralight AJ-2199 aircraft is located at 22.72959°N and 120.642942°E. (Referred from the CWB)

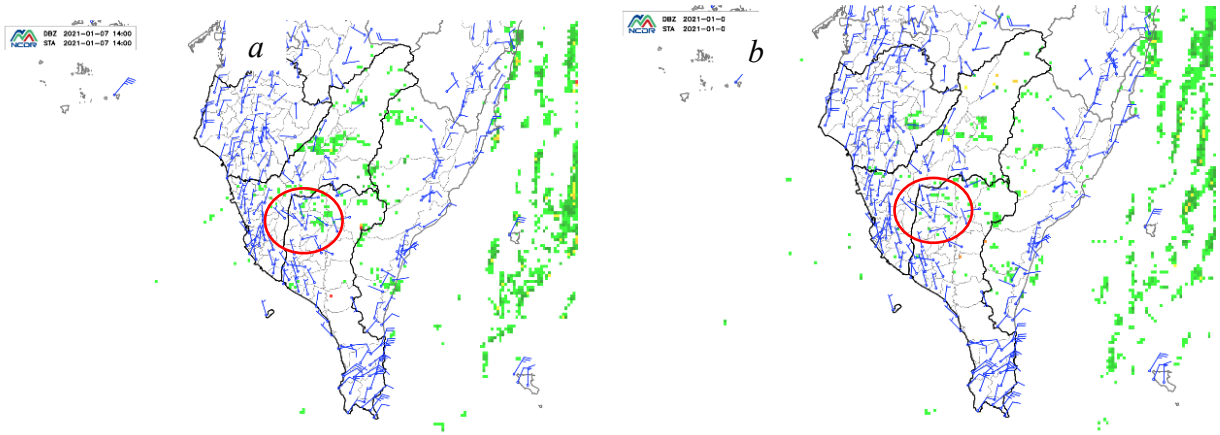

Fig. 5 (a) Radar reflectivity (dBz) and surface wind at 1400L (UTC+8) on 7 January 2021. (b) The same as (a) except radar reflectivity (dBz) at 1420L (UTC+8) on 7 January 2021. The red circle covers the mesonet array mentioned in Fig. 6. (Retrieved from NCDR).