Analysis on the Weather Circumstance Involved in the UH-60M Helicopter Incident on 2 January 2020

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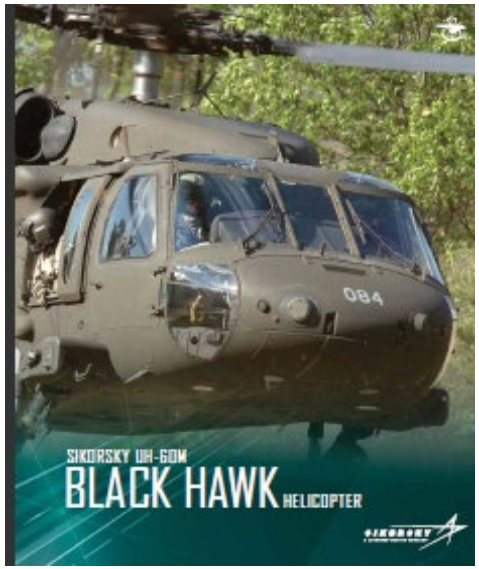


https://lockheedmartin.com/content/dam

UH-60M Black Hawk Helicopter of ROCAF Air Rescue Group 中國時報資料照片

A LEGACY OF PERFORMANCE

- **The UH-60M is more effective with its integrated digital cockpit, moving map display, enhanced GPS/INS system and fully coupled flight controls.**
- **The new advanced cockpit of the UH-60M helicopter reduces pilot workload and improves situational awareness.**
- **The advanced technology fitted on the UH-60M black hawk, including military GPS and inertial navigation system, should have been able to sound an alarm about any imminent terrain impact.**
- **This helicopter has four main rotor blades, and it can carry out missions day or night in all weather conditions.**

SIKORSKY UH-60M HELICOPTER BLACK HAWK
https://lockheedmartin.com/content/dam/lockheed-martin/rms/documents/black-hawk/sikorsky-UH60M-brochure.pdf

Helicopter Mountain Flying Tips

- **Warning # 07: A high reconnaissance should be flown at an altitude of 300 to 500 ft above the surface.**

  Look for: height barriers, obstacles, wind direction, area size, and area slope

- **Warning # 11: The effect produced by the heating of the sun can cause an inversion with drafts of air upwards on the side exposed to the sun and drafts of air downwards on the shaded side of the mountain.**

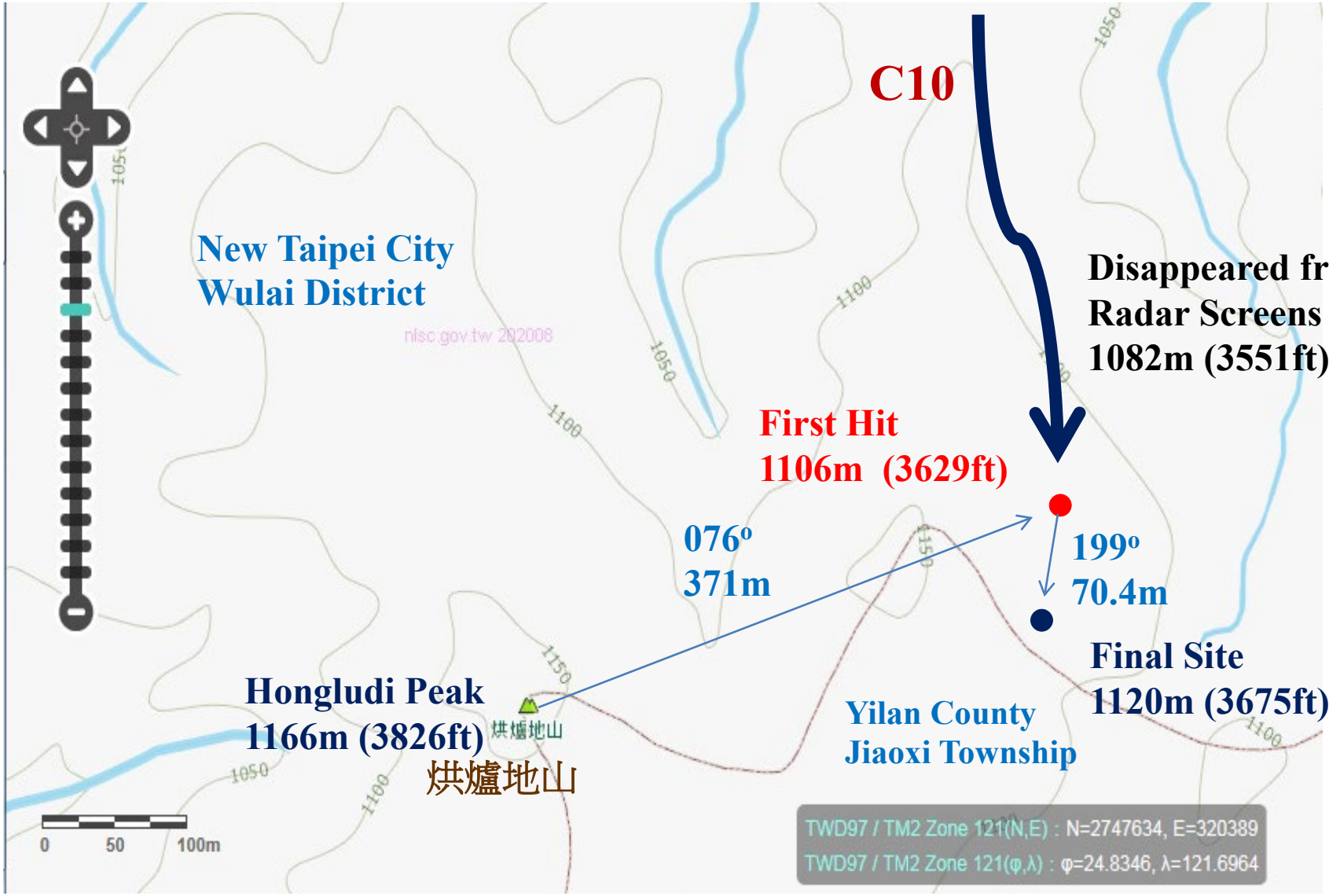
Helicopter mountain flying tips. 20 July, 2020 by Greek Helicopters

A great illustrated initiative 50 tip guide on helicopter mountain flying by Paolo Dal Pozzo, AW139 Pilot EASA CPL(H), developer of training programs and software.

https://greekhelicopters.gr/helos/helicopter-mountain-flying-tips/

The electronic tac map in the cockpit will turn to red while the barrier distance is under 500 ft.

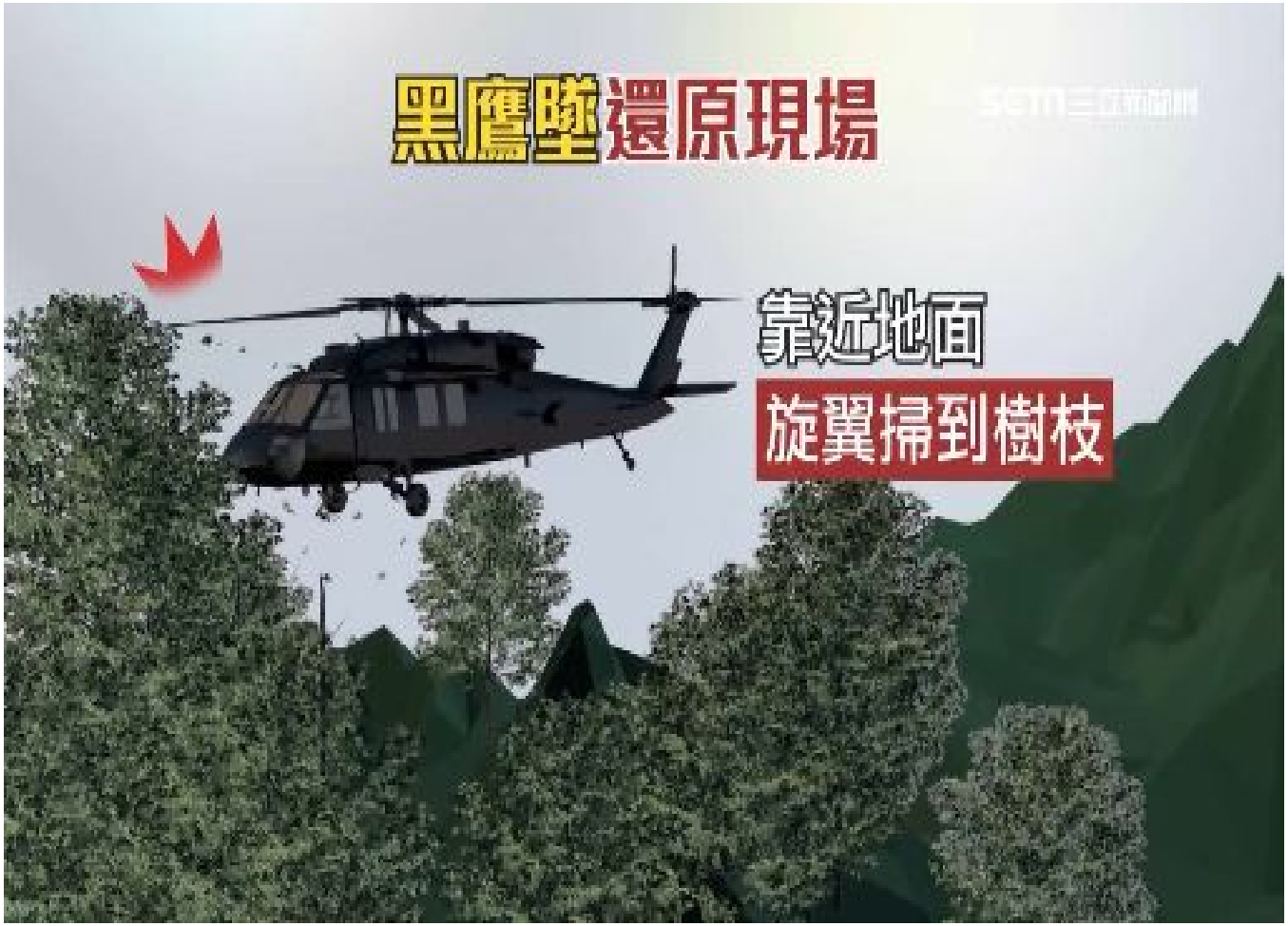
參考消息 http://www.news.cn/cankao/



渭水之丘

Fig. 14. The reconstruction map of crash site for ROCAF UH-60M helicopter on 2 January 2020. The peak of Hongludi ridge in altitude of 1166m (3826 ft) ASL is the landmark, and the bold black arrow is the flight track. (Made by T. H. Hor referring from MOI NLSC map and MND Preliminary Investigation Report of the UH-60M Incident on 15 February 2020)

The flight altitude of the UH-60M black hawk (No.933) was too low, and the main rotor blades hit the branches of trees on the hill before its crash at 0807:01.2TST on 02 Jan. 2020.



Disappeared from Radar Screens
1082m (3551ft)

First Hit
1106m (3629ft)

Final Site
1120m (3675ft)

Hongludi Peak
1166m (3826ft)

黑鷹失速驟降後旋翼撞擊樹枝。
黑鷹失事／報告出爐！2因素害墜地翻滾，機腹滑行70公尺。
三立新聞台記者葉為襄，2020/02/15

Length: 19.76 m and main rotor diameter: 16.36 m

Possible causes for helicopter crashes.

Table 1. (Referred from Hogan Injury, 2020)

Items	Causes	Remarks
1	Pilot error	Possible, Skip
2	Defective parts	Skip
3	Inefficient maintenance or repair	Skip
4	Weather conditions	Possible
5	On-Ground hazards	Possible
6	Excessive loads	Skip
7	Air traffic controller error	Skip
8	Pilot Inexperience	Possible, Skip

CRM: Cockpit Resource Mght. or Crew Resource Mght.

is a methodology in which the resources of equipment, procedures and people are collectively utilized as needed to safely complete every flying task. The individual components of CRM resources are communications, situational awareness, problem solving, decision making, and teamwork.
(https://upperlimitaviation.edu/crew-resource-management-makes-flying-safer/)

Study Goals

1. **Describe the characteristics of the local circulation embedded within the NE monsoon and land/sea breeze through the multi-scale processes.**

2. **Realize the possible causes of the Black Hawk helicopter occurrence from the perspective of weather conditions and on-ground hazards.**

Preliminary Investigation Report by ROCAF

- **Citing a report of the preliminary investigation on 15 Feb. 2020, the Air Force said it has ruled out mechanical failure as the main cause of the crash, after Sikorsky Aircraft last week provided a comprehensive analysis of the two data recorders retrieved from the wreckage.**
- **It said that preliminary findings have so far shown that the cause of the crash was most likely related to human factor and weather.**
- **According to the Air Force, the pilot tried to pull up for visibility as he flew into a huge layer of cloud that formed suddenly in the area.**

Black Hawk crash likely due to human factor, weather: report
Focus Taiwan, CNA English News, 02/15/2020
https://focustaiwan.tw/politics/202002150004

- A huge thud, what sounded like rotors clipping a tree, was heard a few seconds after 8:07 a.m., before the chopper's Cockpit Voice Recorder (CVR) stopped recording, it said.
- At the time of the crash, the UH-60M was at 3,551 meters above sea level and 87 meters from the ground.
- The Air Force said the aircraft had been trying to evade a sudden cloud layer that formed between Pinglin and Yilan.
- Just 12 seconds before impact, the co-pilot was heard in the CVR calling twice for the pilot to watch out for altitude, the Air Force said.

Black Hawk crash likely due to human factor, weather: report
Focus Taiwan, CNA English News, 02/15/2020
https://focustaiwan.tw/politics/202002150004

Contents

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  Synoptic-scale and Mesonet
- **Remote Sensing Analysis:**
  Radar Network and Satellite Imageries
- **Flight Trajectory and On-Ground Hazards**
- **3-D Conceptual Model on Weather Pattern**
- **Discussions**
- **Conclusions**
- **References**

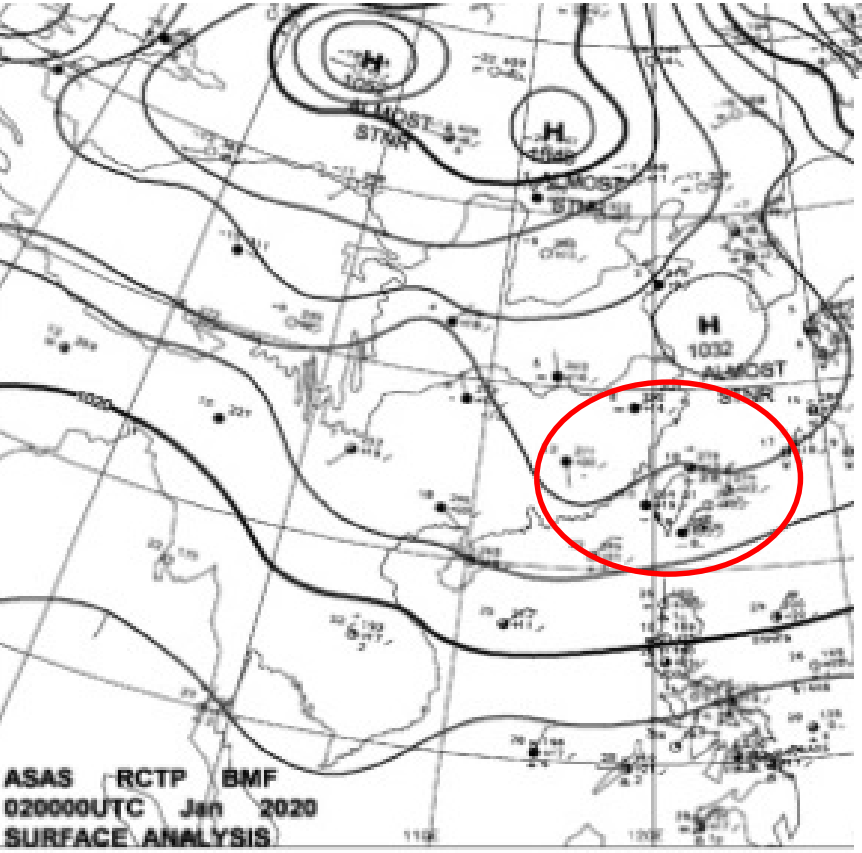
Weather Situation Analysis on 02 Jan. 2020

- **The surface weather map at 0000UTC on 2 January 2020 mentioned that the southeastward movement of split high in slight pressure gradient was located at the East China Sea and it brought weak NE monsoon over the north Taiwan area.**
- **The composite mean surface vector wind distribution in synoptic scale on 2 January 2020 over the Northwest Pacific Ocean showed the strong NE monsoon was prevailing over the open ocean with weak NE wind over the Taiwan area.**

- **Also, the composite mean relative humidity in 1000hPa level on 2 January 2020, supported the finding, an abundant moisture distribution (RH>80%) over the Taiwan area.**
- **Again, the composite mean omega distribution in 1000hPa level illuminated the slight vertical motion in the vicinity of Taiwan, a feasible condition for local circulation and cloud over the Taiwan area.**
- **The local weather pattern in the early morning over the Yi-lan Plain was affected by the combination of prevailing weak NE wind and land breeze, and resulted in cloud initiatives.**

SFC Map at 0800TST, 2020/01/02

Composite Mean Surface Vector Winds in m/s 2020/01/02



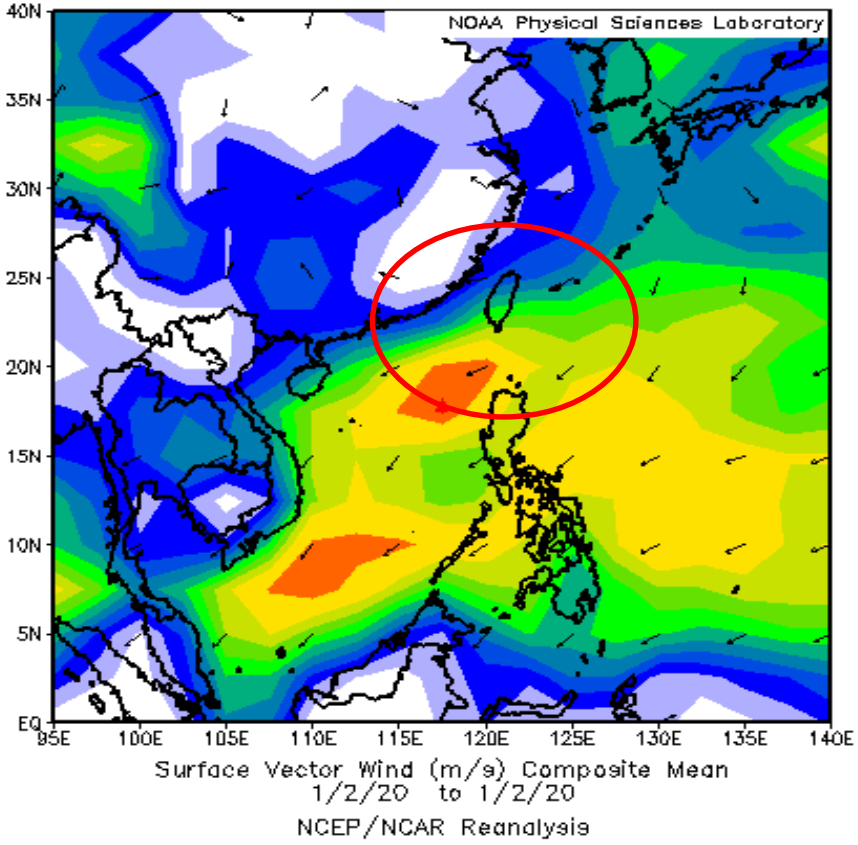
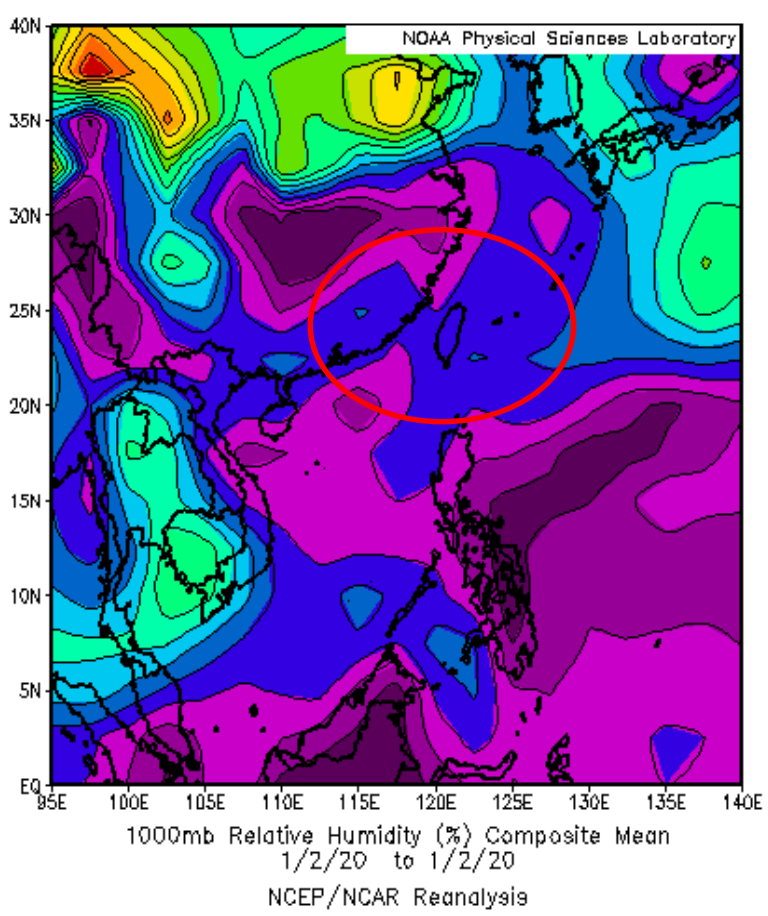


Fig. 1 (a) The surface weather map at 0800TST (UTC+8) on 2 January 2020. (Referred from the Central Weather Bureau) (b) Composite mean surface vector winds (m/s) between EQ-40°N and 95°E-140°E on 02 January 2020. (Resulted from NOAA/ESRL)



Composite Mean RH in % at 1000hPa

Composite Mean Omega in Pa/s at 1000hPa

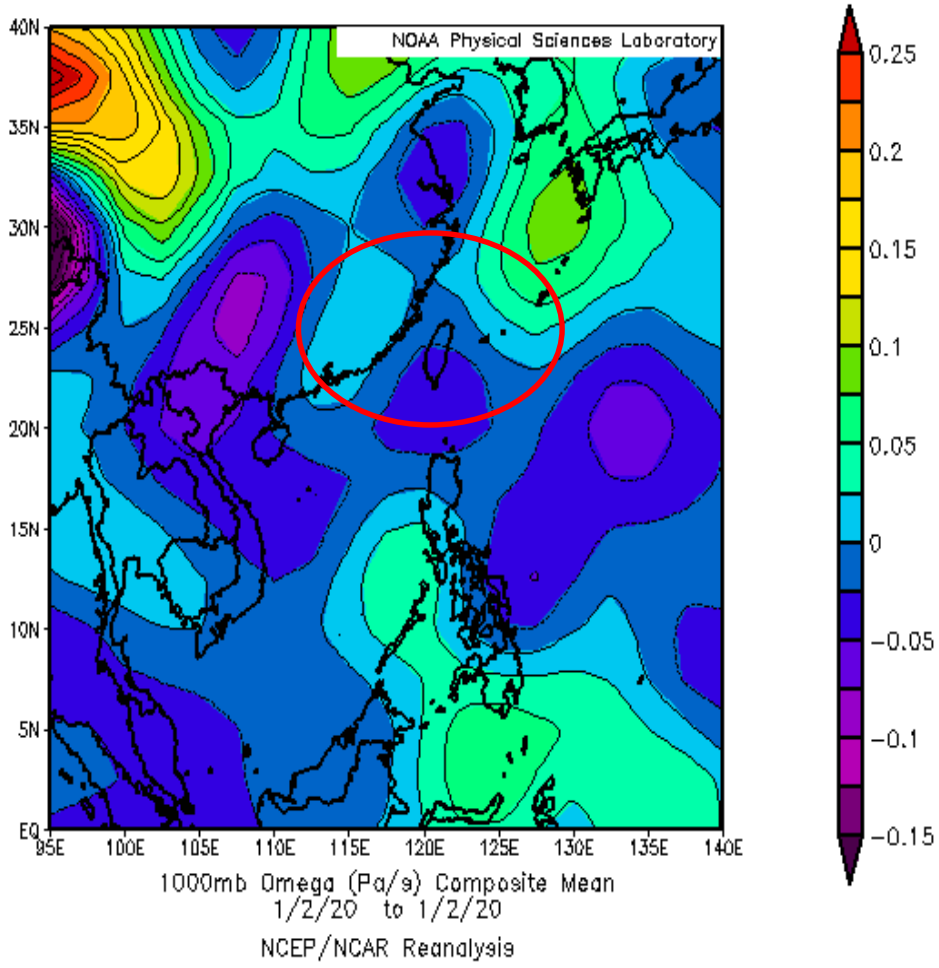
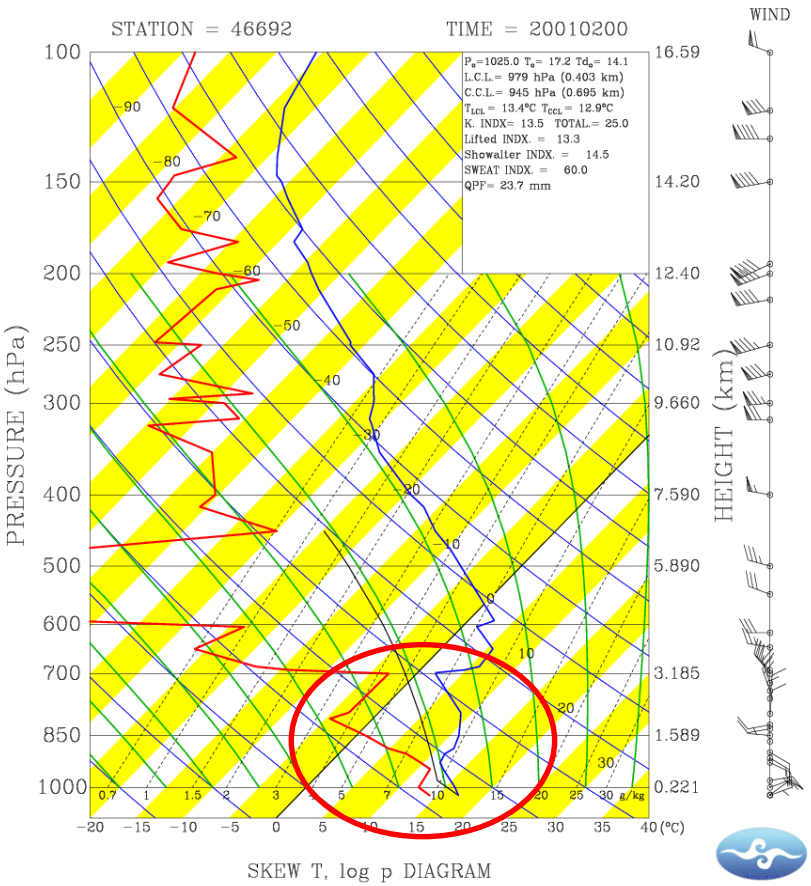
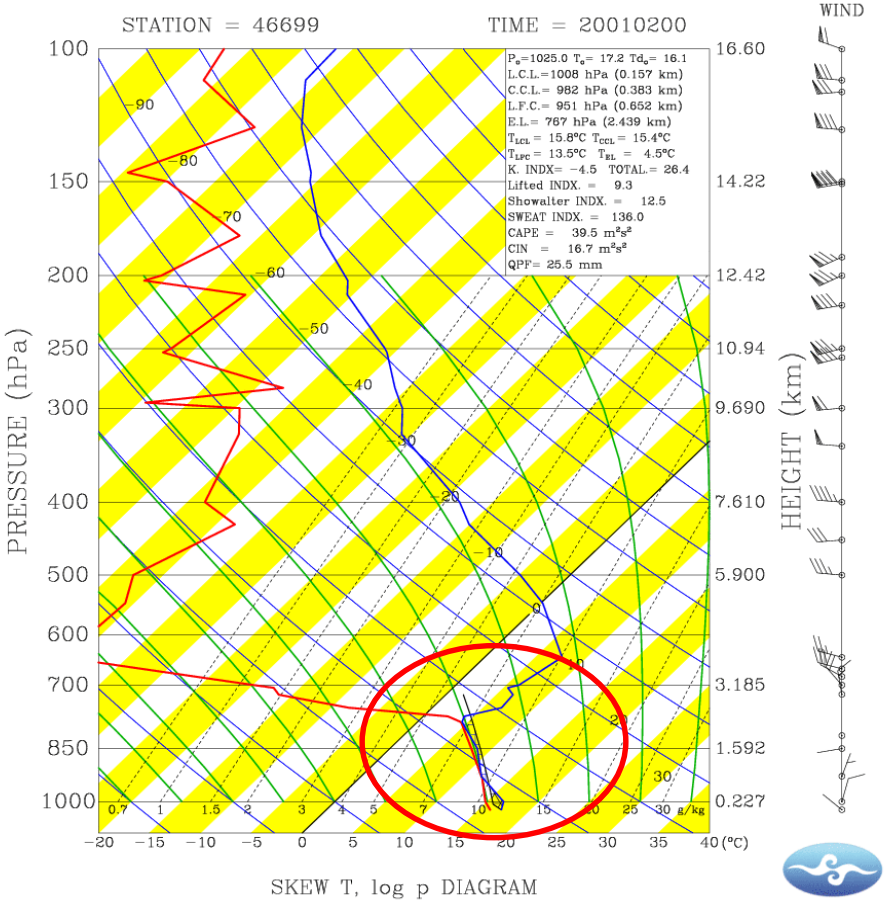


Fig. 2 Composite mean 1000 hPa-level relative humidity (%), and omega (Pa/s) between EQ-40°N and 95°E-140°E on 02 January 2020. (Resulted from NOAA/ESRL)

RH > 85% & Omega (-) over the northern Taiwan





0800TST, Taipei
Dry air and inversion

0800TST, Hualian
Moist air and inversion

Fig. 3(a) The skew T, log p diagram of Taipei weather station at 0800TST (UTC+8) on 02 January 2020. (b) The same as (a) except at Hualian weather station. An evident inversion was identified at about the 780 hPa level. (Adopted from Central Weather Bureau)

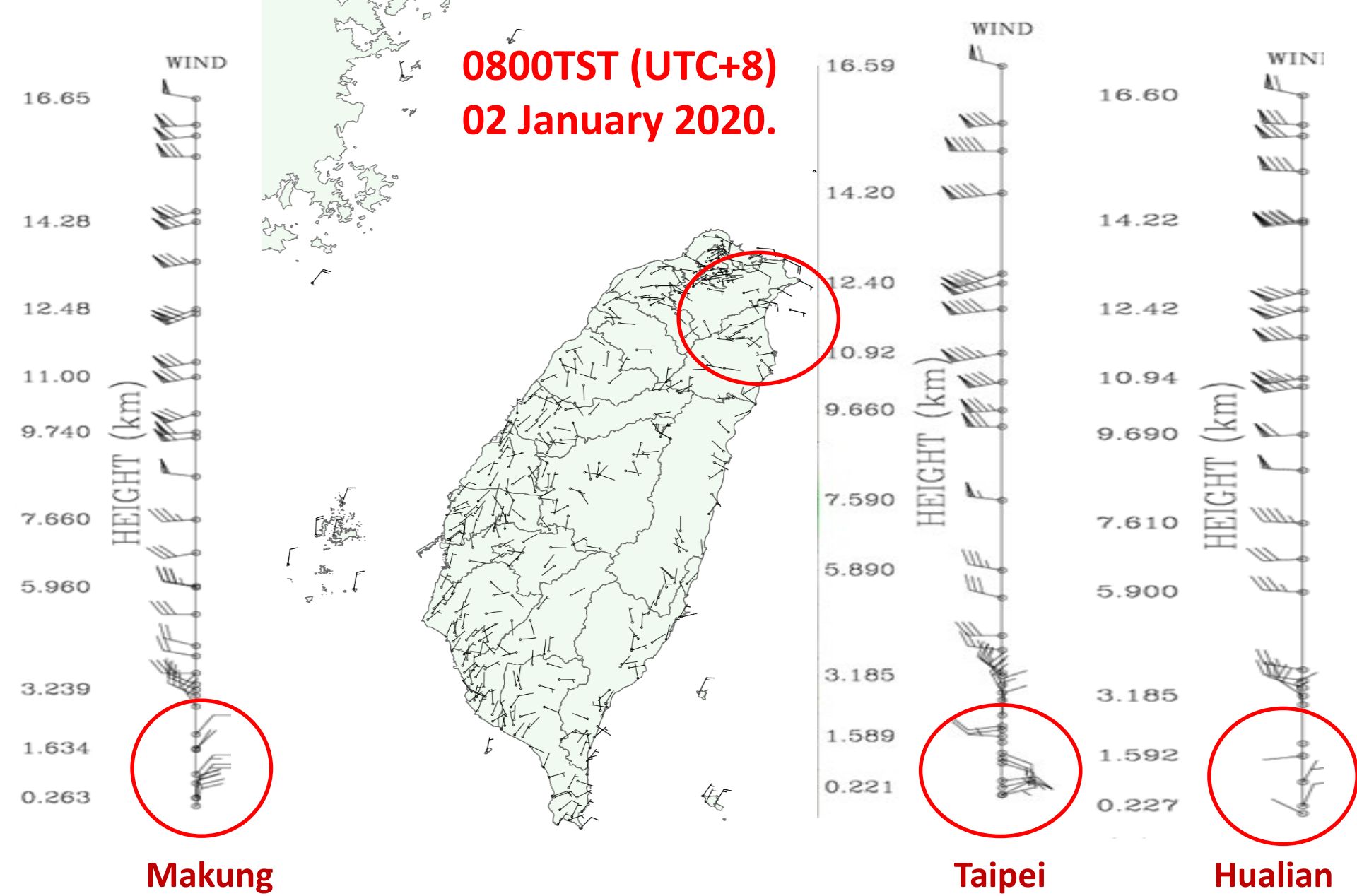


Fig.4 The surface wind map and vertical wind profiles (Makung, Taipei and Hualian) at 0800TST (UTC+8) on 2 January 2020.

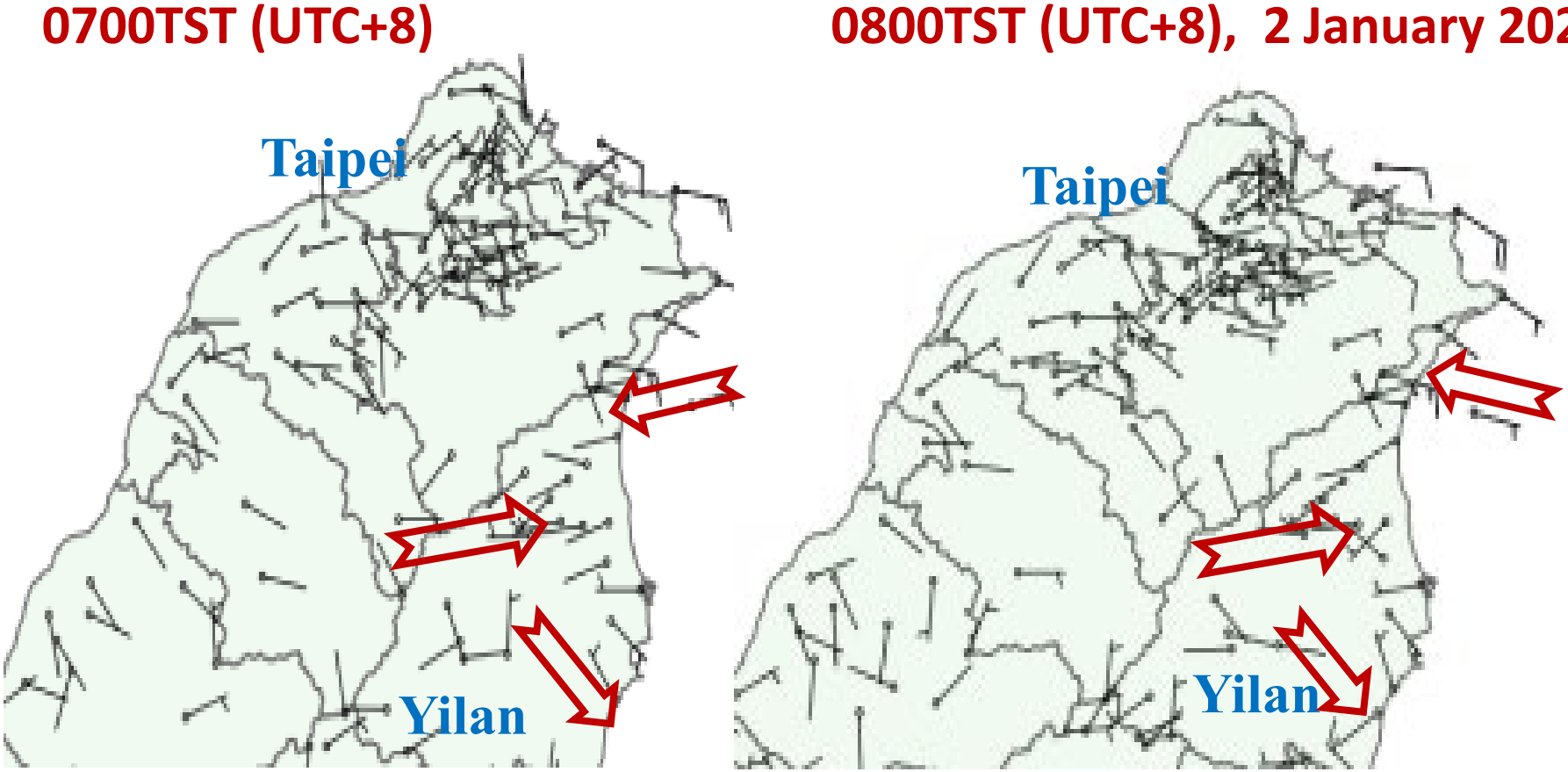
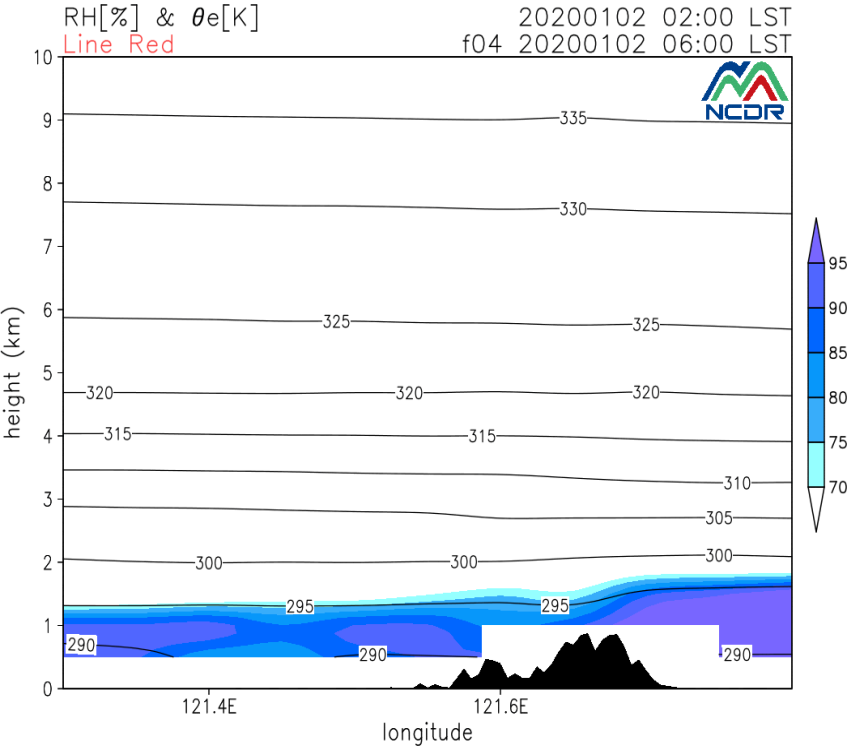
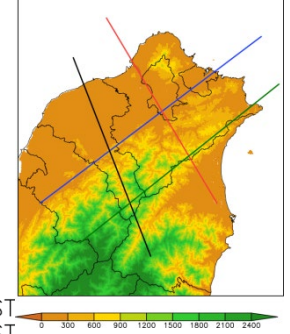


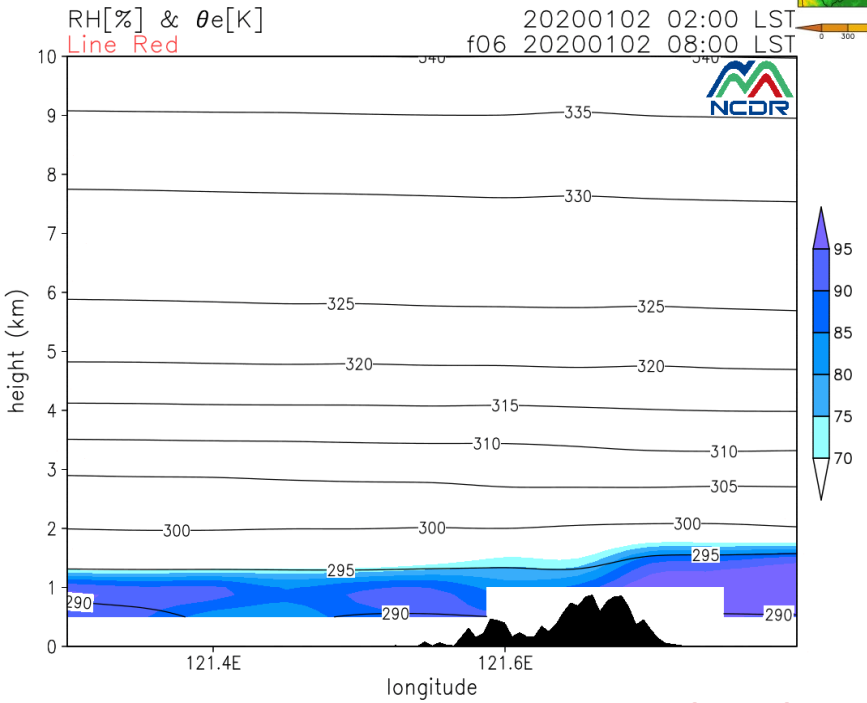
Fig. 5(a) The surface wind map at 0700TST (UTC+8) on 2 January 2020. An obvious convergence zone was formed over the Yilan Plain and the complex terrains. (b) The same as (a) except at 0800TST (UTC+8) on 2 January 2020. (Referred from the NCDR WATCH)

RH > 90% over the complex terrains



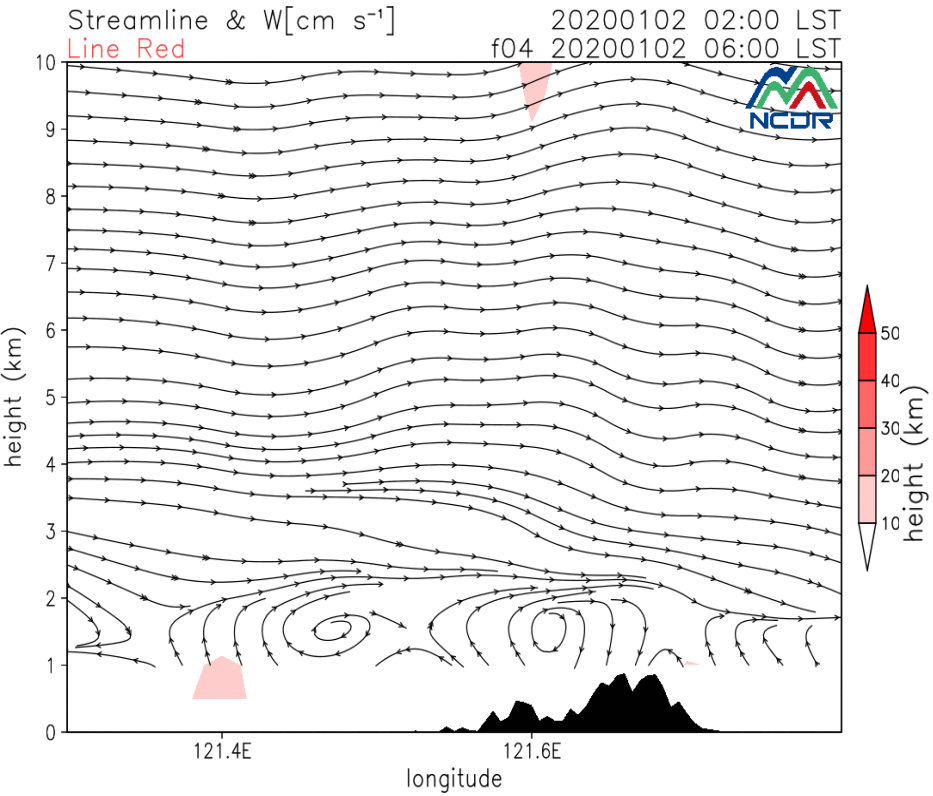
0600TST, 2020/01/02
RH and θ_e FCST

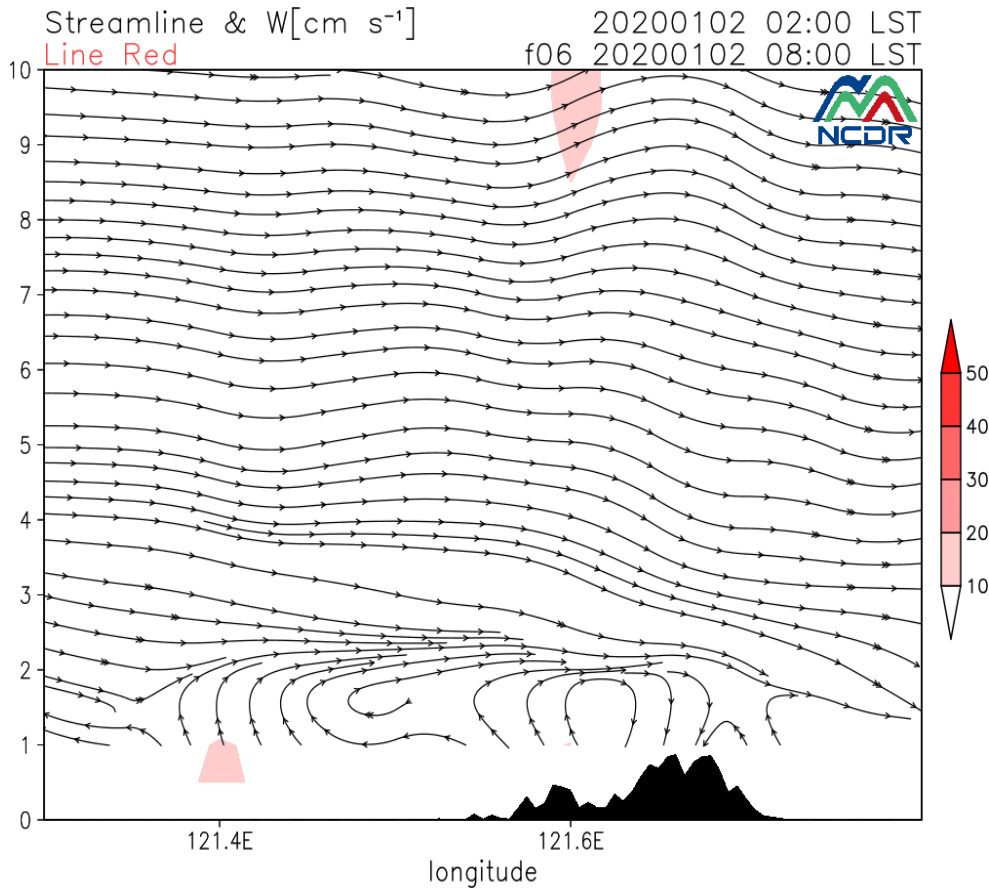




0800TST, 2020/01/02
RH and θ_e FCST

Fig. 6(a) Relative humidity(%) and equivalent potential temperature(°K) forecast valid at 0600 TST(UTC+8) of 2 January 20202 based on the observation of 0200 TST of 2 January 2020. (b) The same as (a) except at 0800 TST (UTC+8) of 2 January 2020. (Referred from NCDR WATCH)





0600TST, 2020/01/02
Streamline and w FCST

0800TST, 2020/01/02
Streamline and w FCST

Fig. 7(a) Streamline and vertical velocity(cm/s) forecast valid at 0600 TST(UTC+8) of 2 January 20202 based on the observation of 0200 TST of 2 January 2020. (b) The same as (a) except at 0800 TST (UTC+8) of 2 January 2020. (Referred from NCDR WATCH)

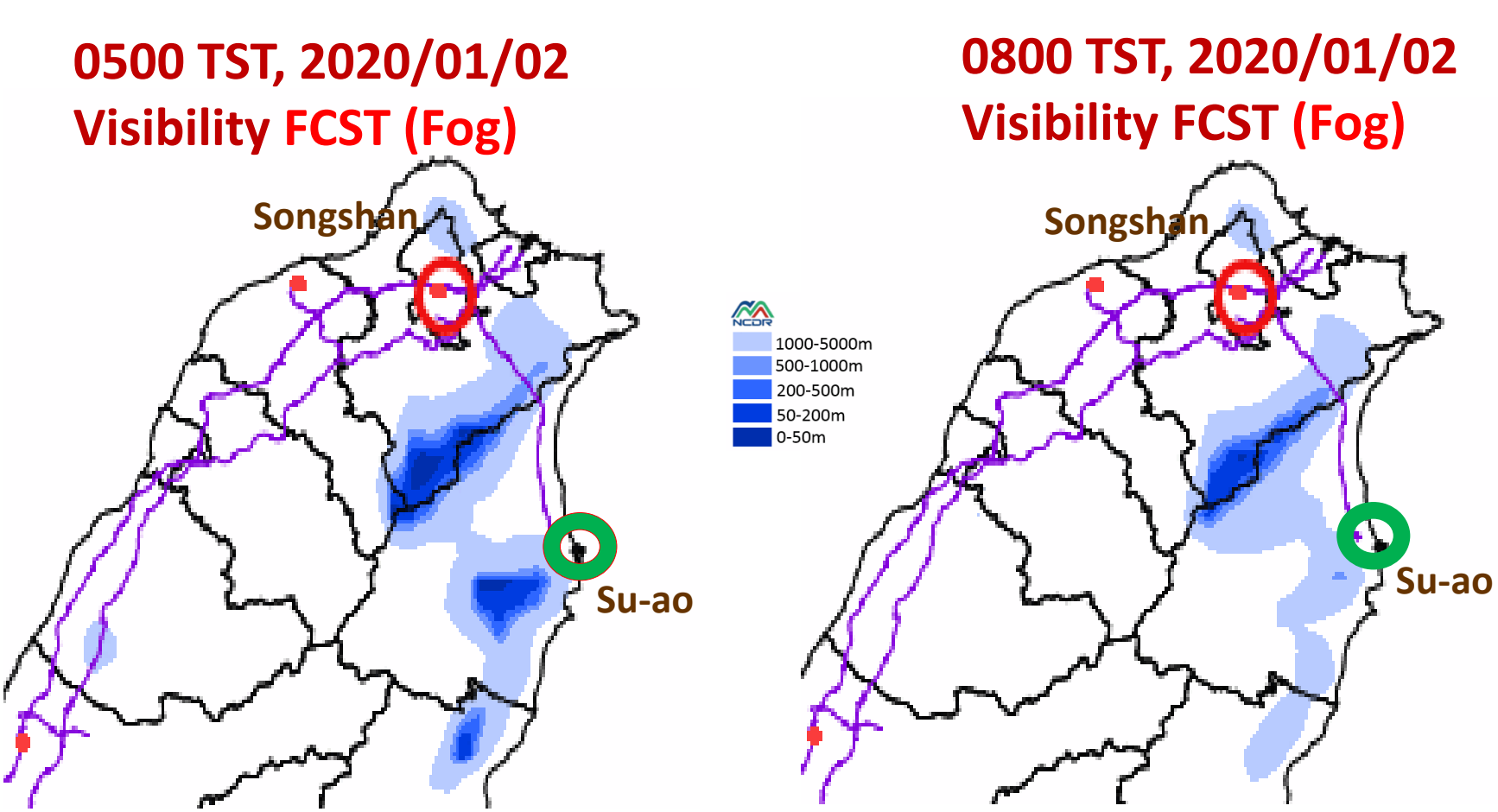
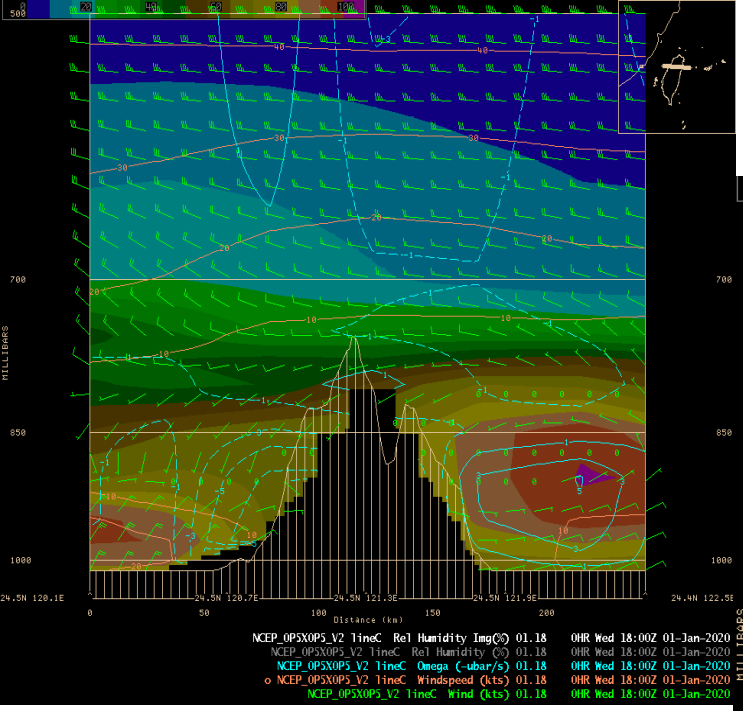
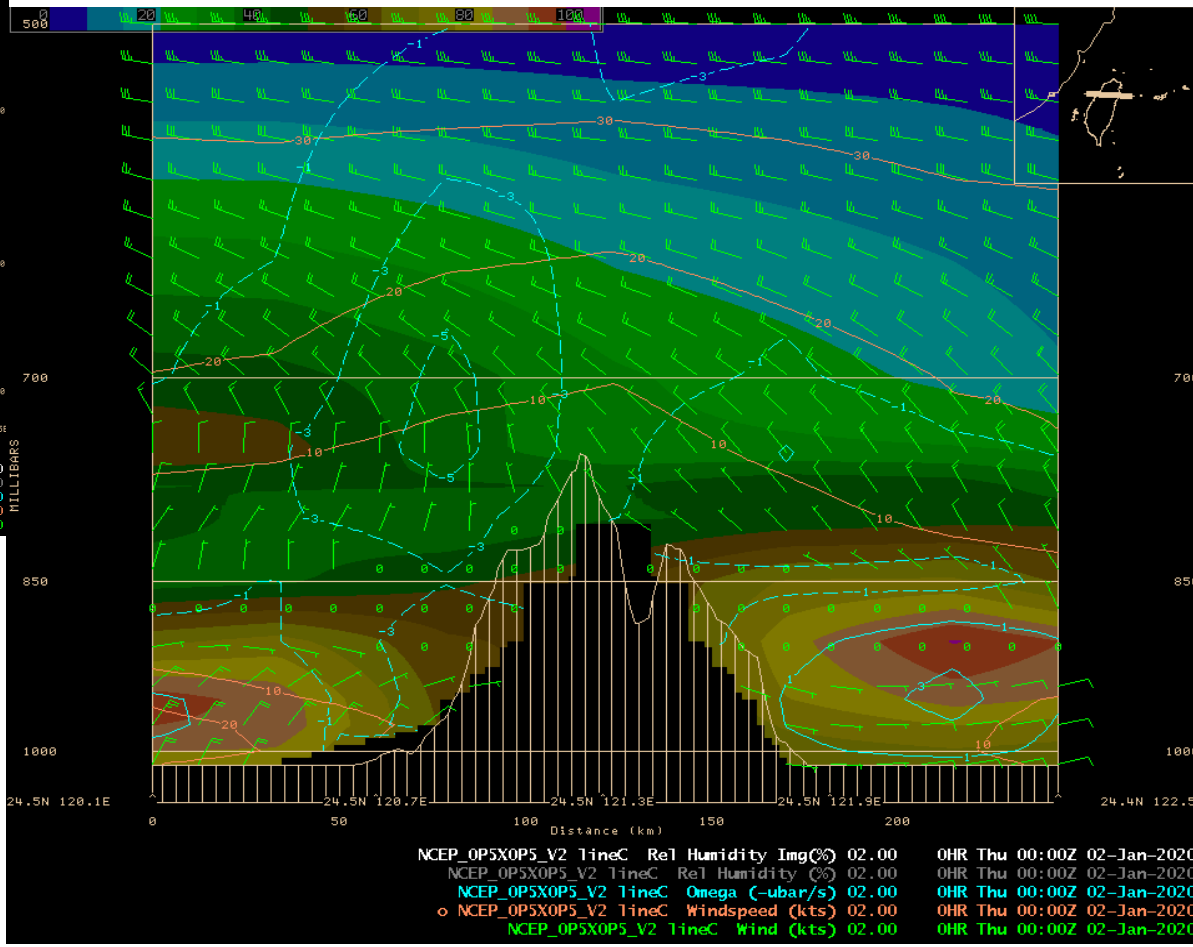


Fig. 9(a) Visibility forecast valid at 0500 TST (UTC+8) of 2 January 20202 based on the observation of 0200 TST of 2 January 2020. (b) The same as (a) except at 0800 TST (UTC+8) of 2 January 2020. The forecast offers the visibility difference initiated by the surface fog, excluding the effect of air pollution. The solid red and green circles represent the location of Taipei Songshan Airport and Su-ao Port, respectively, and the purple lines stand for the regular flight route C10. (Referred from NCDR WATCH)



0800TST, 2020/01/02. RH(%),ω(-μbar/s), WD & WS(kts) on WINS



0200 TST, 2020/01/02
RH, Omega, WD & WS

ω= - 1 μ bar/s
= - 0.1 Pa/s

w= $-\ \omega/\rho g$
= - (-0.1 Pa/s) / {(1.2kg/m^3)(9.8m/s^2)}
= +0.0085 m/s ~ +0.01 m/s = +1 cm/s

Fig. 8(a) The vertical cross section of relative humidity (%), omega (- μbar/s), wind direction and wind speed (kts) along 24.5ºN between 120.1ºE and 122.5ºE based on the WINS (Weather Integration and Nowcasting System) data of Central Weather Bureau at 0200TST (UTC+8) on 2 January 2020. (b) The same as (a) except at 0800TST (UTC+8) on 2 January 2020. (Resulted from CWB/WINS) (尖石鄉馬洋山2863m)

Fig. 10 The weather situation at that time in the UH-60M helicopter crash site offered by MND on 15 February 2020.

黑鷹失事5人遭懲處　空軍司令、副司令記過　2020/02/15　三立新聞政治中心（圖／國防部提供）

Remote Sensing Analysis: Radar Network and Satellite Imageries

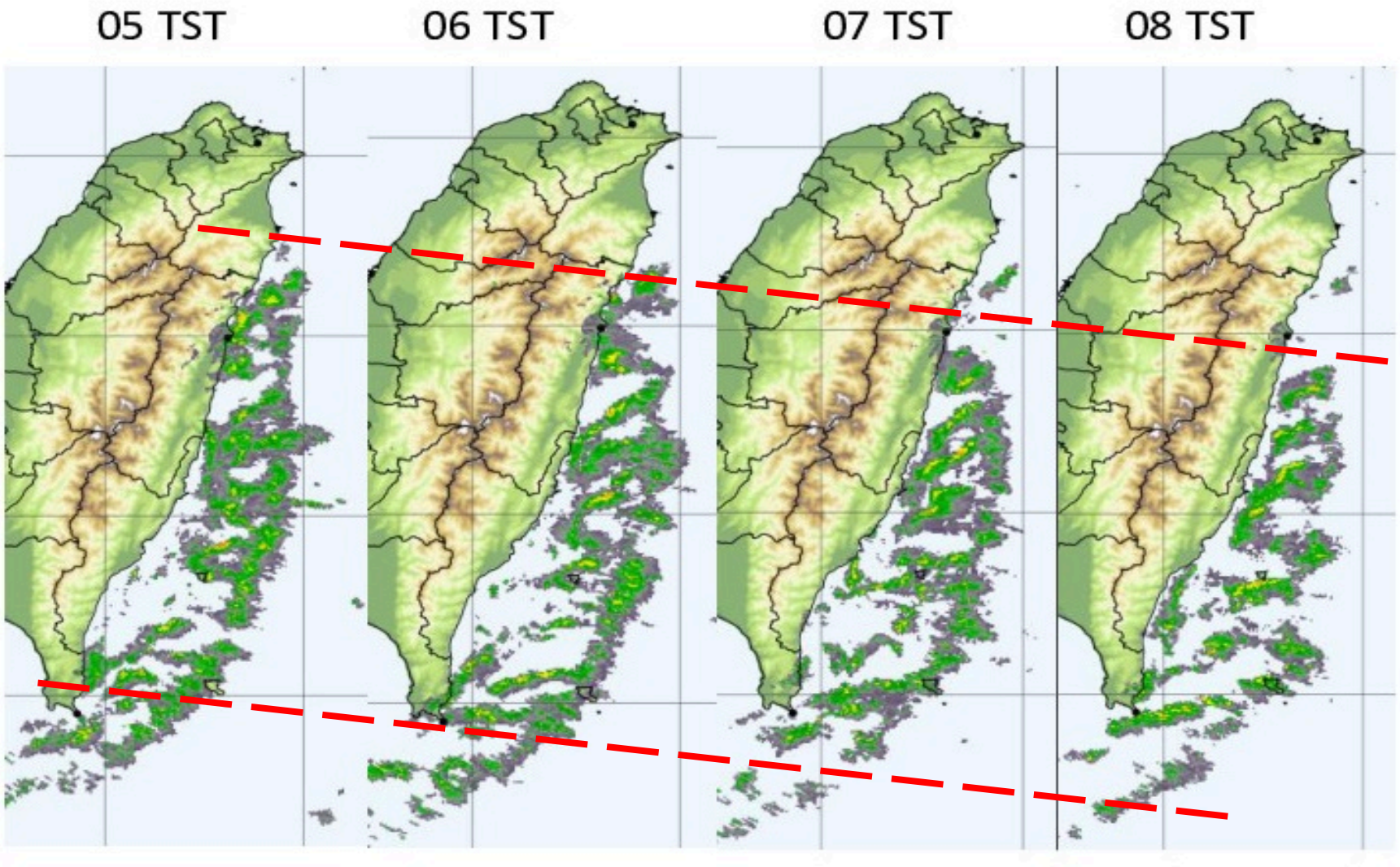
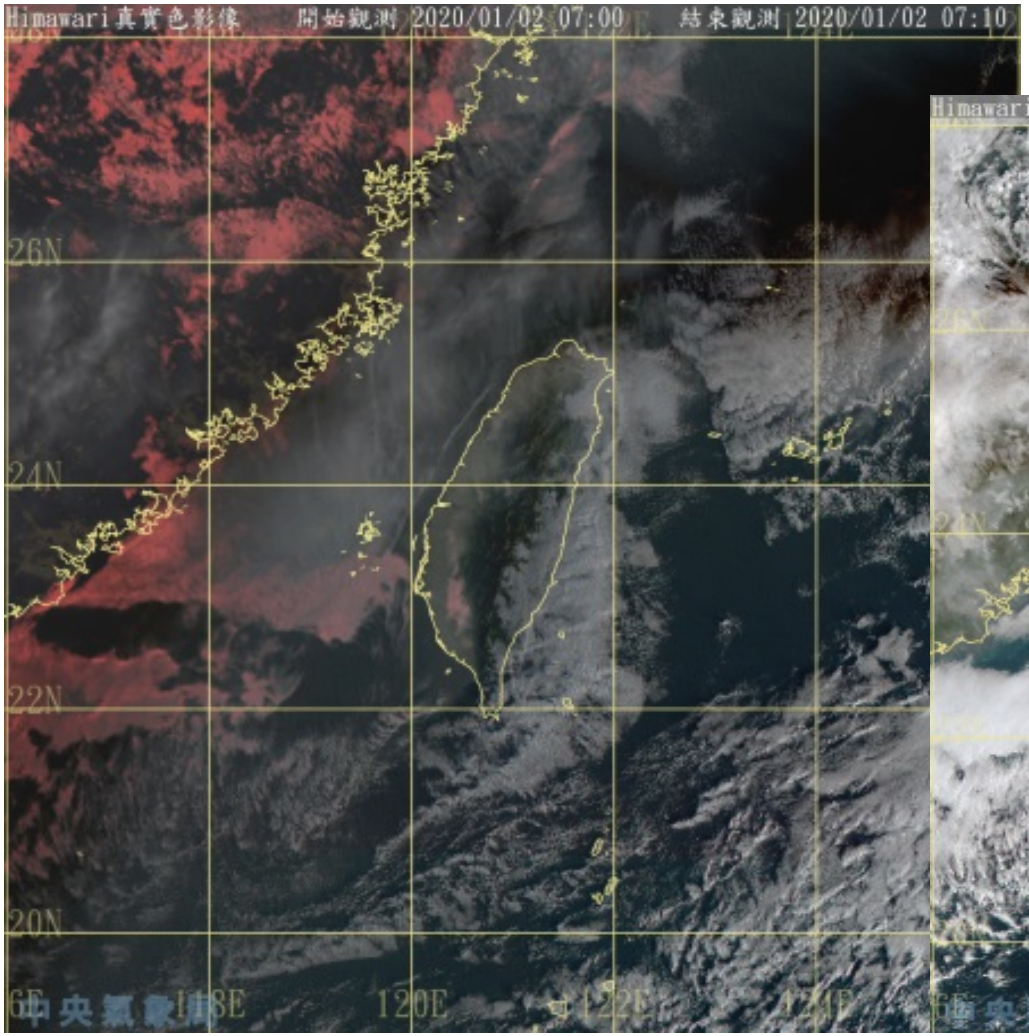
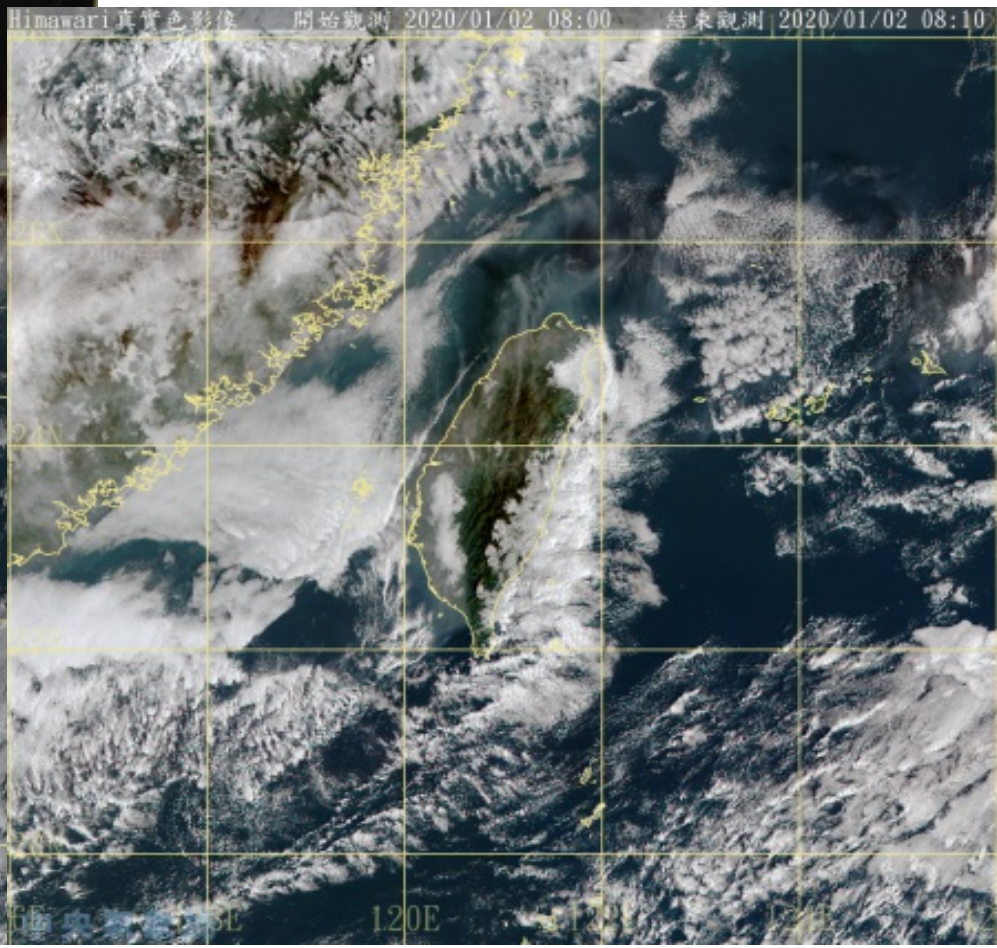


Fig. 11 (a) Composite radar reflectivity at 0500TST on 2 January 2020. (b) The same as (a) except at 0600TST on 2 January 2020. (c) The same as (a) except at 0700TST on 2 January 2020. (d) The same as (a) except at 0800TST on 2 January 2020. (Referred from the Central Weather Bureau)

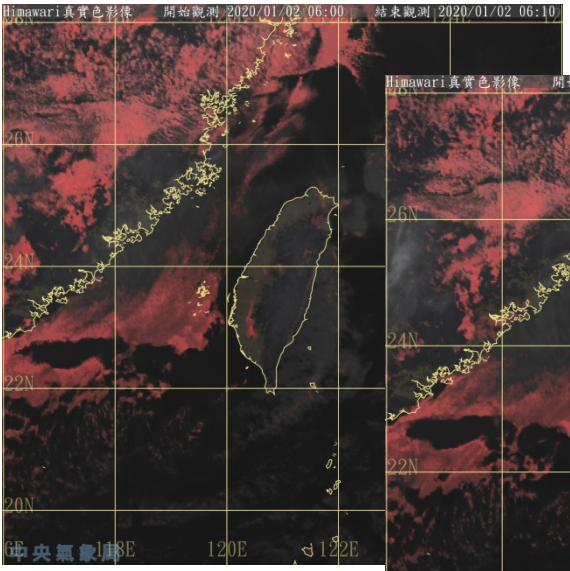




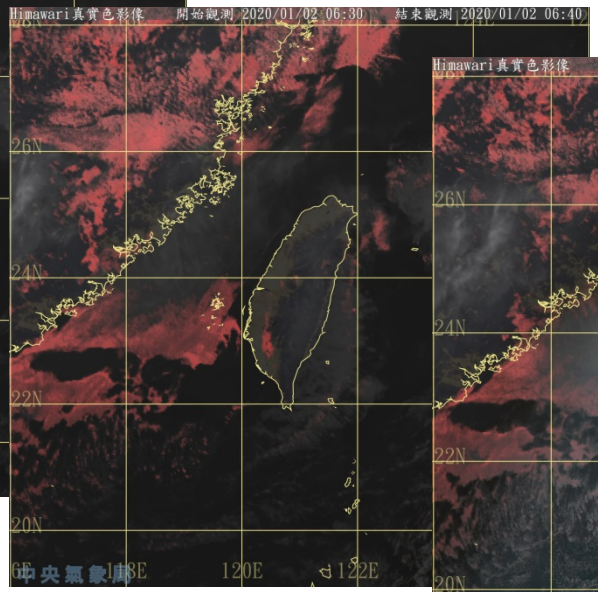
0700TST, Geo Color **0800TST, True Color**

Fig. 12 (a) Himawari8 true color satellite image at 0700TST (UTC+8) on 2 January 2020. (b) The same as (a) except at 0800TST on 2 January 2020. (Referred from the Central Weather Bureau)

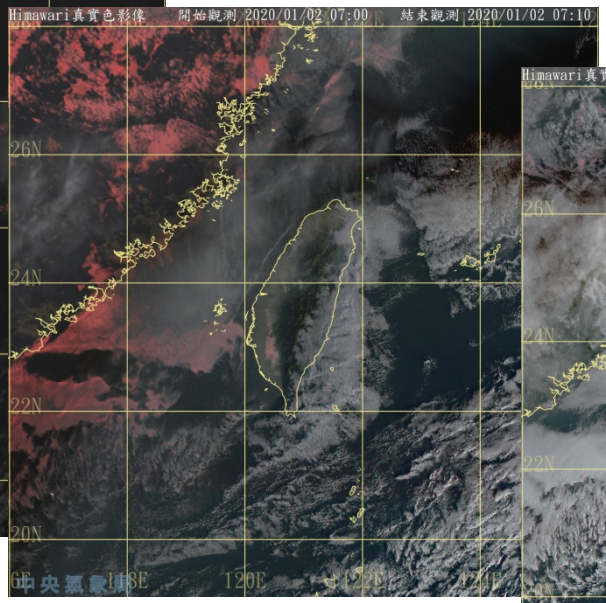
True Color & IR1



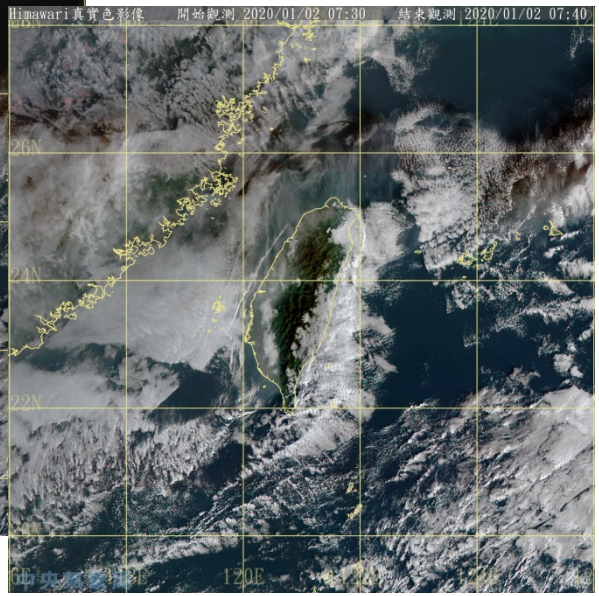
0600TST



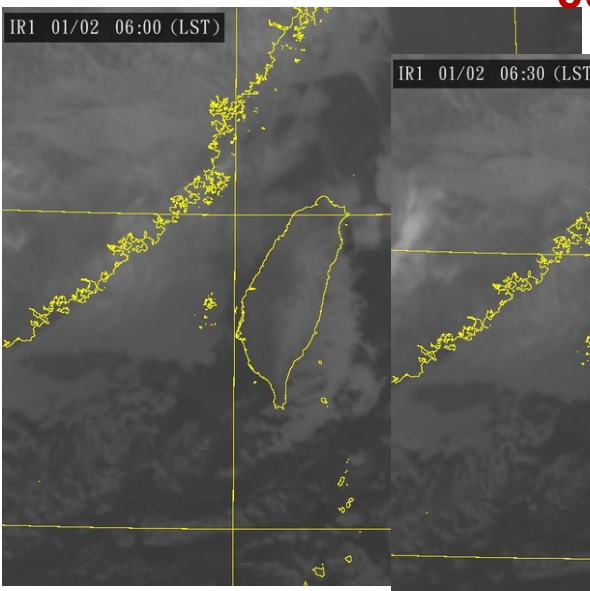
0630TST

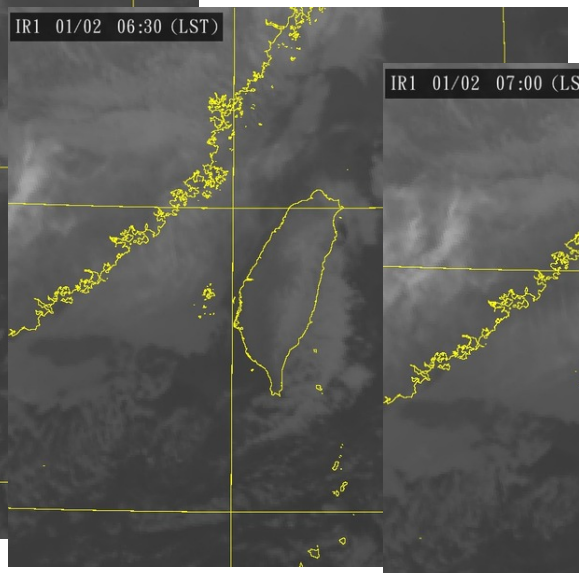


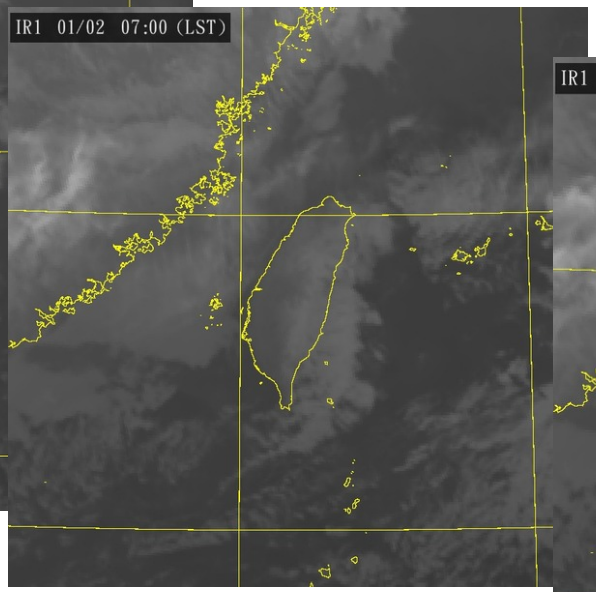
0700TST

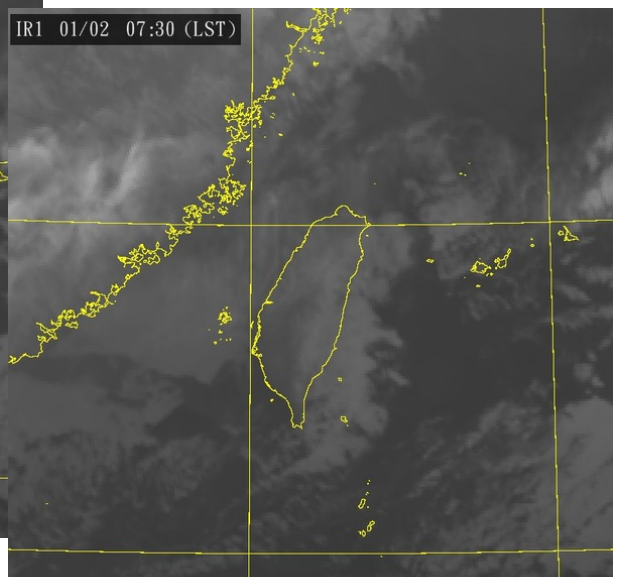


0730TST



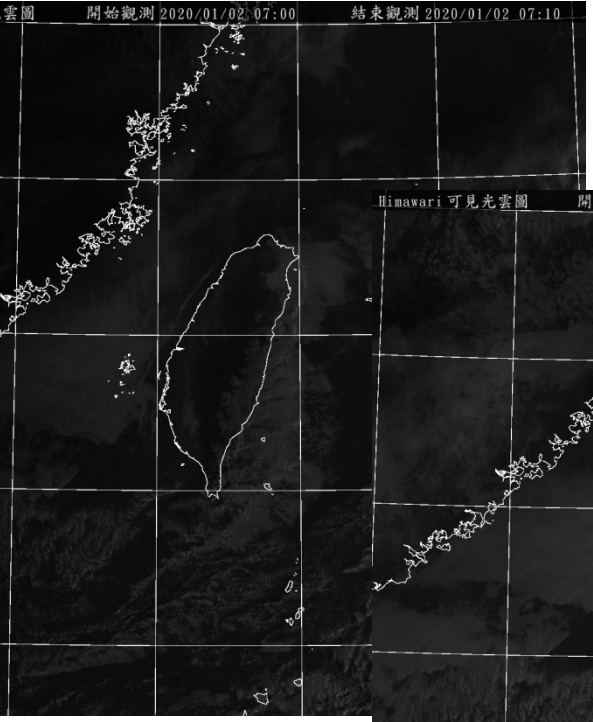




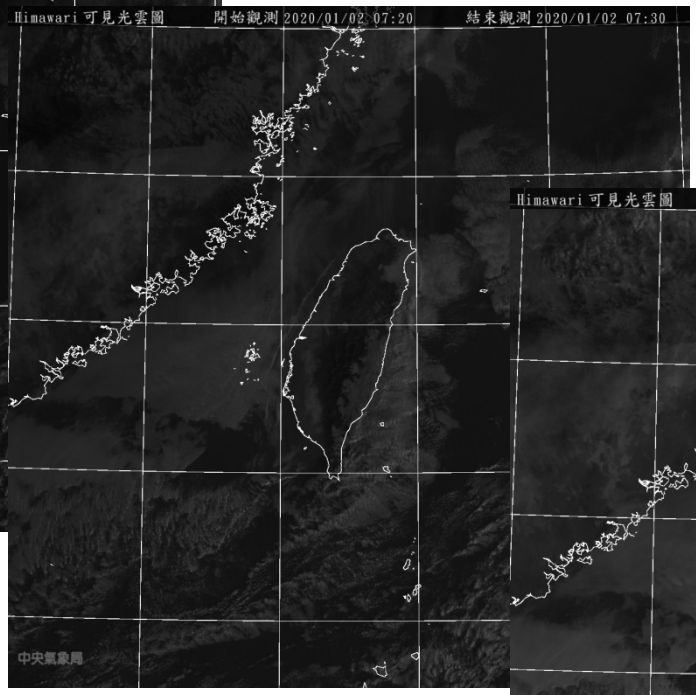


0600TST, 0630TST, 0700TST & 0730TST on 2 January 2020.

The plane took off by 0754TST, 2020/01/02.

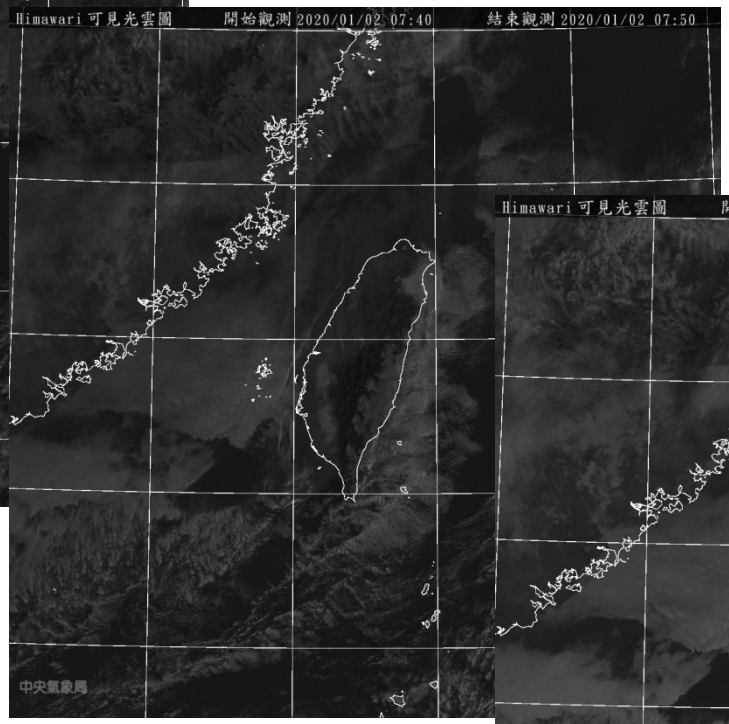


0700TST
Visible



0720TST
Visible

0740TST
Visible



0080TST
Visible

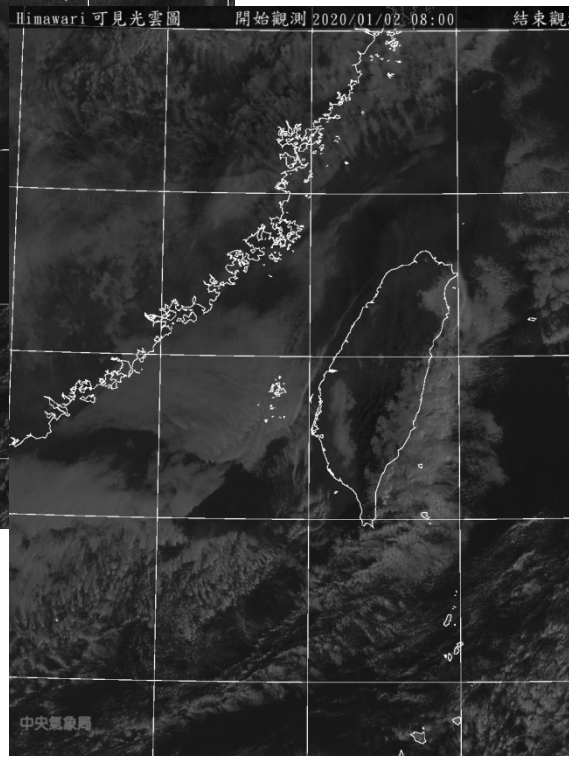


Fig. 12 Himawari8 visible satellite images at 0700TST, 0720TST, 0740TST & 0800TST on 2 January 2020. (Referred from the Central Weather Bureau)

JMA Himawari8 AHI Band			Wavelength (μm)	Spatial Resolution at SSP (km)
01	V1	Visible	0.47	1.0
02	V2	Visible	0.51	1.0
03	VS	Visible	0.64	0.5
04	N1	Near Infrared	0.86	1.0
05	N2	Near Infrared	1.6	2.0
06	N3	Near Infrared	2.3	2.0
07	IR4	Infrared	3.9	2.0
08	IR3	Infrared WV	6.2	2.0
09	W2	Infrared	6.9	2.0
10	W3	Infrared	7.3	2.0
11	MI	Infrared	8.6	2.0
12	O3	Infrared	9.6	2.0
13	IR1	Infrared	10.4	2.0
14	L2	Infrared	11.2	2.0
15	IR2	Infrared	12.4	2.0
16	CO	Infrared	13.3	2.0

Table 2. Specification of 16 bands of Himawari8 AHI (Advanced Himawari Imager). (Referred from the Japan Meteorological Agency, 2016)

SSP: sub satellite point

Flight Trajectory and On-Ground Hazards

Fig. 13. (a) The C-10 visual flight route map. (b) The reconstruction of flight trajectory for ROCAF UH-60M helicopter on 2 January 2020, including time(TST), and dialogue remarks in the cockpit. (Referred from the ROC MND Preliminary Investigation Report of the UH-60M Incident on 15 February 2020)

資料來源：黑鷹失事5人遭懲處　空軍司令、副司令記過　2020/02/15　三立新聞政治中心

Fig. 15. The overlay of flight trajectory and topography during the last minute before ROCAF UH-60M helicopter accident on 2 January 2020, including time(TST), plane altitude(ft), and dialogue remarks in the cockpit. (Referred from the ROC MND Preliminary Investigation Report of the UH-60M Incident on 15 February 2020)

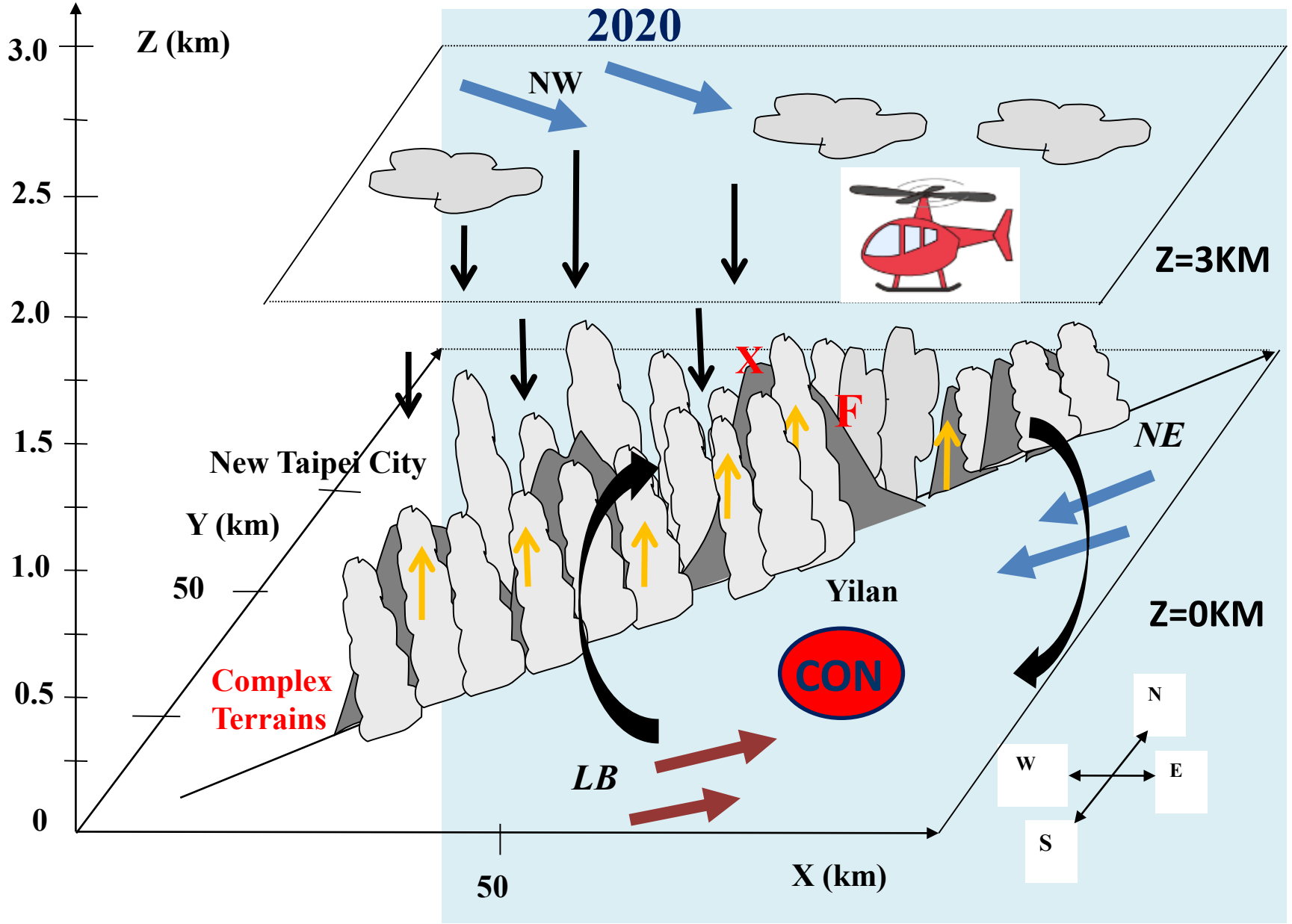
TIME (TST)	0102 0803 50.9	0102 0806 05.3	0102 0806 14.3	0102 0806 22.8	0102 0806 40.8	0102 0806 48.1	0102 0806 51.4	0102 0806 54.8	0102 0806 55.9	0102 0806 56.6	0102 0806 59.1	0102 0807 00.2	0102 0807 01.2
Plane alt. (ft)	2631	3357	3384	3516	3709	3740	3708	3646	3615	3604	3560	3552	3551
Barrier dis. (ft)	1592	1155 (1)	985	786	531	331	381 (2)	332	253 (3)	257	238	170	87
Plane speed (knot)	105	77	77.3	56.1	67.7	75	85.2	99.6	103.3	106	117	119.4	118.8

Table 2. Selected flight data list for occurrence UH-60M helicopter on 2 January 2020, including plane altitude (ft), barrier distance (ft), and plane speed (knot, 1 knot =1nautical mile/hour). "TST" represents the Taiwan Standard Time (UTC+8). The electronic tac map in the cockpit will turn to red while the barrier distance is under 500 ft. (Referred from the ROC MND Preliminary Investigation Report of the UH-60M Incident, 2020)

(1) 080605.3 副駕駛：「建議教官再爬升，繼續爬升高度」。
(2) 080651.4 副駕駛：「教官高度」。
(3) 080655.9 副駕駛：「教官現在高度」。

資料來源：黑鷹失事前通聯紀錄曝光。關鍵評論，2020/02/15。

Fig. 16 Conceptual scenario on the fatal crash of a Sikorsky UH-60M helicopter at 080701.2TST, 02 January 2020



3-D Conceptual Model on Weather Pattern in C-10 Flight Route on 02 Jan. 2020 under the Presence of Taiwan Orography

Fig. 16 The schematic conceptual model for the weather pattern in C-10 flight route on 02 January 2020 under the presence of Taiwan orography. Under the large scale weather conditions of weak NE monsoon and abundant moisture supply over the north Taiwan, an obviously local convergence zone was formed over the Yilan Plain due to the interaction of prevailing NE wind and land breeze as well as the blocking of complex terrains. In the figure, the "NE" and "LB" stand for the northeast monsoon and land breeze, respectively. The black and yellow arrows are for downflows and upflows, respectively, and "X" is the peak of Hongludi ridge in altitude of 1166 m (3826 ft). Also, "F" shows the final site of ROCAF UH-60M helicopter incident in altitude of 1120m (3675ft). The more detailed description was shown in Hor, et.al., 2020.

Hor, T.H., T.Y. Shyu, and H.Y. Tseng, 2020: Analysis on the Weather Circumstance Involved in the UH-60M Helicopter Incident on 2 January 2020. 2020 CWB Conference on Weather Analysis and Forecasting. Taipei, Taiwan.

Discussions

1. Long lasting low cloud/fog was over the complex terrains with scattered cloud over the Yilan plain.
2. The electronic tac map releases alert in red color on display. After three oral reminders by co-pilot, some actions must be taken.
3. The dispatch of lead aircraft or weather reconnaissance aircraft sounds necessary.
4. The critical time for transfer from VFR (visual flight rules) to IFR (instrument flight rules).
5. The choice of C10 flight route instead of C2.

Conclusions 1/2

- The vertical cross section of relative humidity (%), omega (- μbar/s) and wind speed (kts) along 24.5°N between 120.1°E and 122.5°E based on the WINS data at 0200TST (UTC+8) and 0800TST (UTC+8) on 2 January 2020 delivered more reliable evidences, mentioning a locally vertical circulation with obvious upward motions in magnitude of 10^{-2} m/s under the 850 hPa level over the plain area and slight downward motions over the complex terrains.
- Visibility forecast conducted by NCDR offered the visibility difference initiated by the surface fog, and illuminated the worst visibility was in the range of the 0-50 m over the complex terrains.

Conclusions 2/2

- It concludes that the persistent low cloud/fog and the unstable flow over the complex terrain might reduce the reliability of visibility and increased the flight risk in VFR (visual flight rules). Those weather conditions will threat the aviation safety greatly. It implies that during this mission the pilots should get ready to conduct IFR (instrument flight rules) mode at any time over the complex terrains.
- On 15 February 2020, ROCAF reported the preliminary investigation, pointing out that the combination of environmental (weather and terrain) and human factors was behind the accident. The conclusions in the study can confirm the similar scenario on the weather part.

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Suggestions
&
Comments !

https://www.helicopterspecs.com/2019/08/sikorsky-uh-60m.html

Specifications (UH-60M)

- **Length: 64 ft 10 in (19.76 m) including rotors**
- **Fuselage length: 50 ft 1 in (15.27 m)**
- **Width: 7 ft 9 in (2.36 m)**
- **Height: 16 ft 10 in (5.13 m)**
- **Main rotor diameter: 53 ft 8 in (16.36 m)**
- **Maximum speed: 183 mph (294 km/h)**
- **Cruise speed: 170 mph (280 km/h)**
- **Service ceiling: 19,000 ft (5,800 m)**
- **Rate of climb: 1,315 ft/min (6.68 m/s)**

https://en.wikipedia.org/wiki/Sikorsky_UH-60_Black_Hawk#Specifications_(UH-60M)