中尺度氣象學

(Mesoscale Meteorology)

授課老師: 游政谷

Cheng-Ku Yu

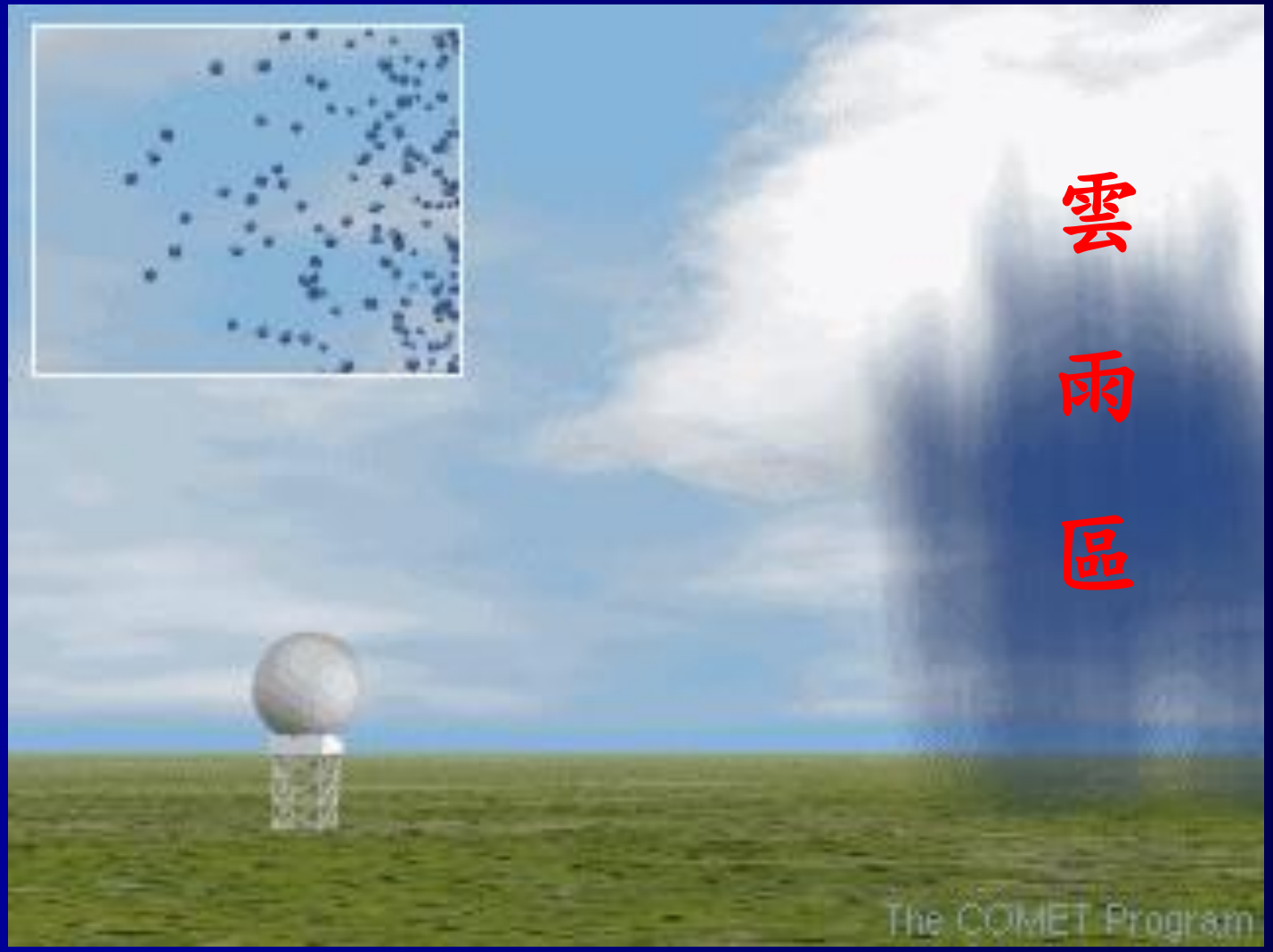
Mesoscale(2): Radar Observations

2-1 氣象雷達簡介

(Introduction to Meteorological Radars)

氣象雷達藉由反射電磁波來反推空間的風雨資訊

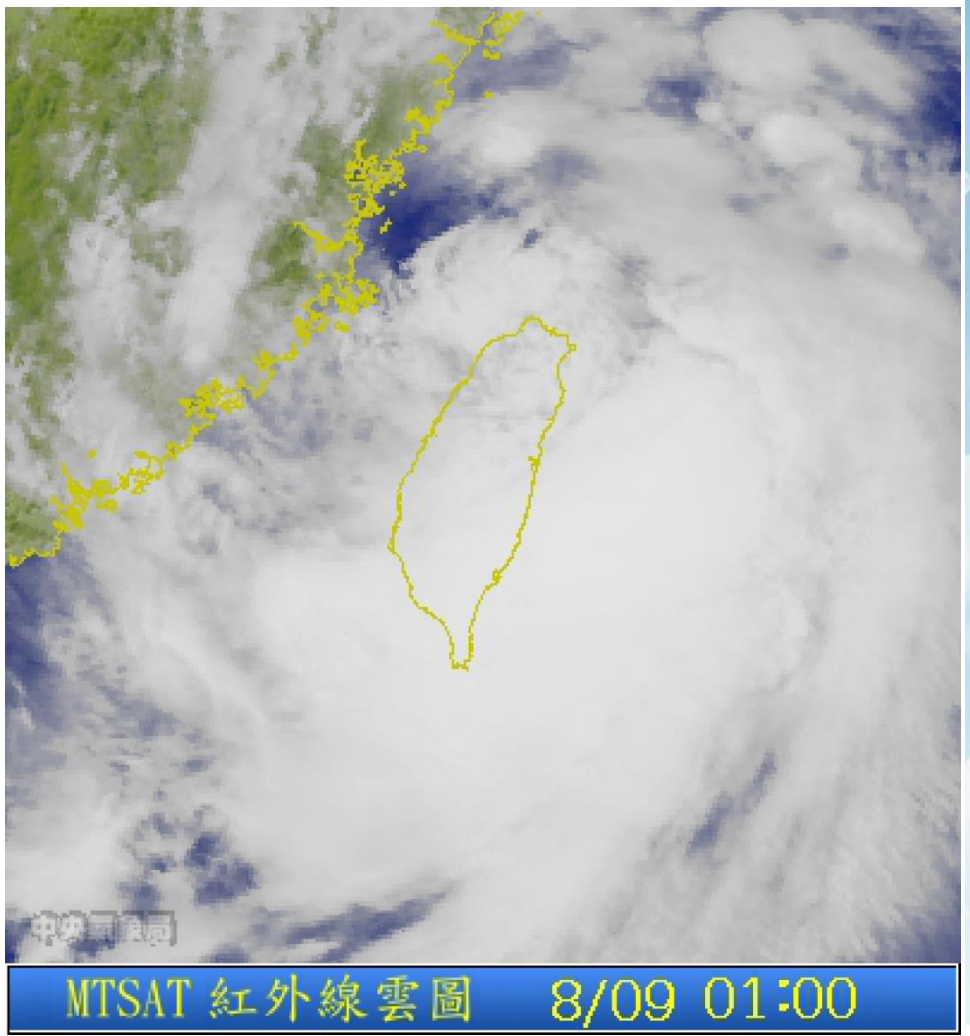
Wind and precipitation information can be retrieved from return echoes of meteorological radars



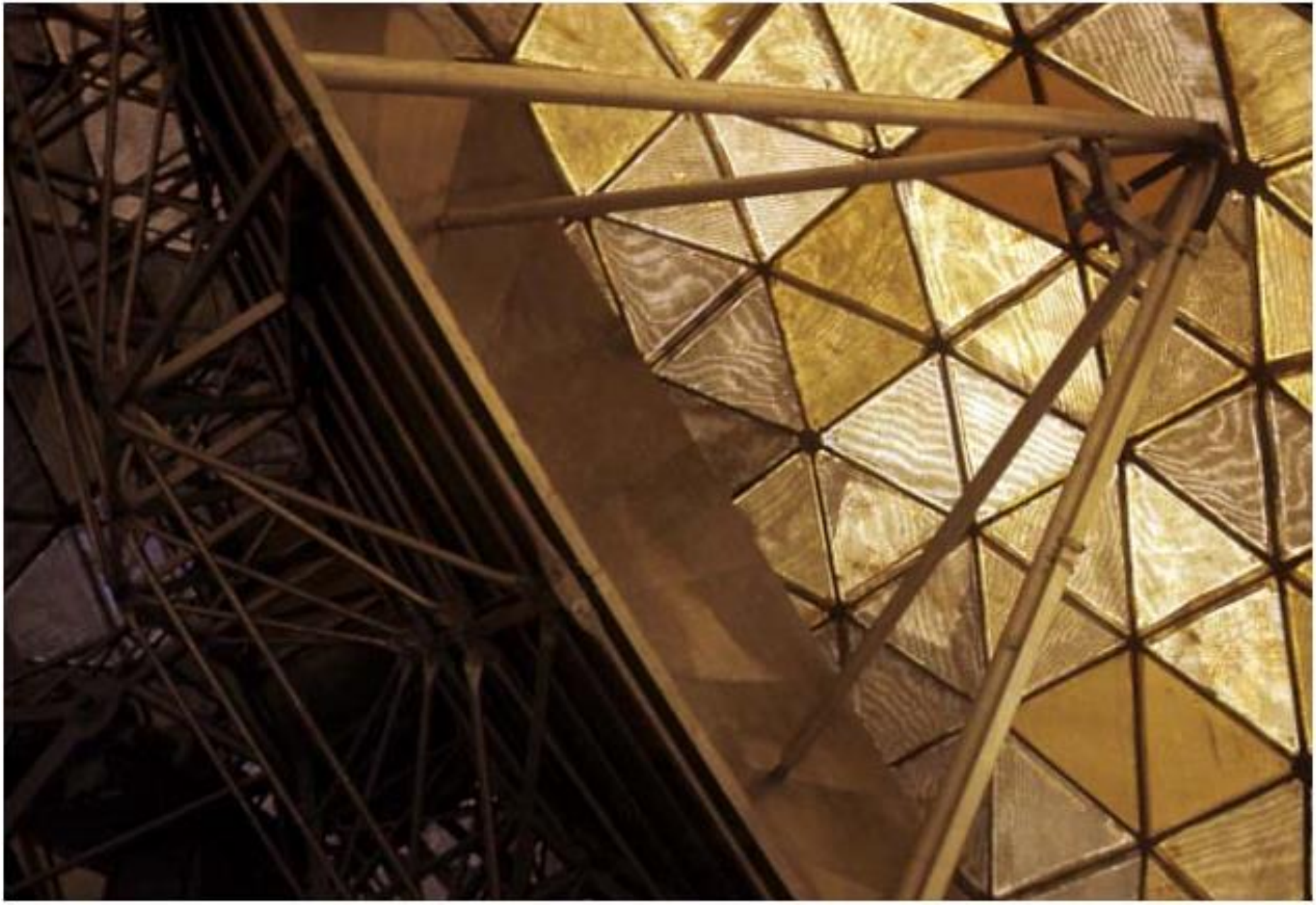
Importance of meteorological radar

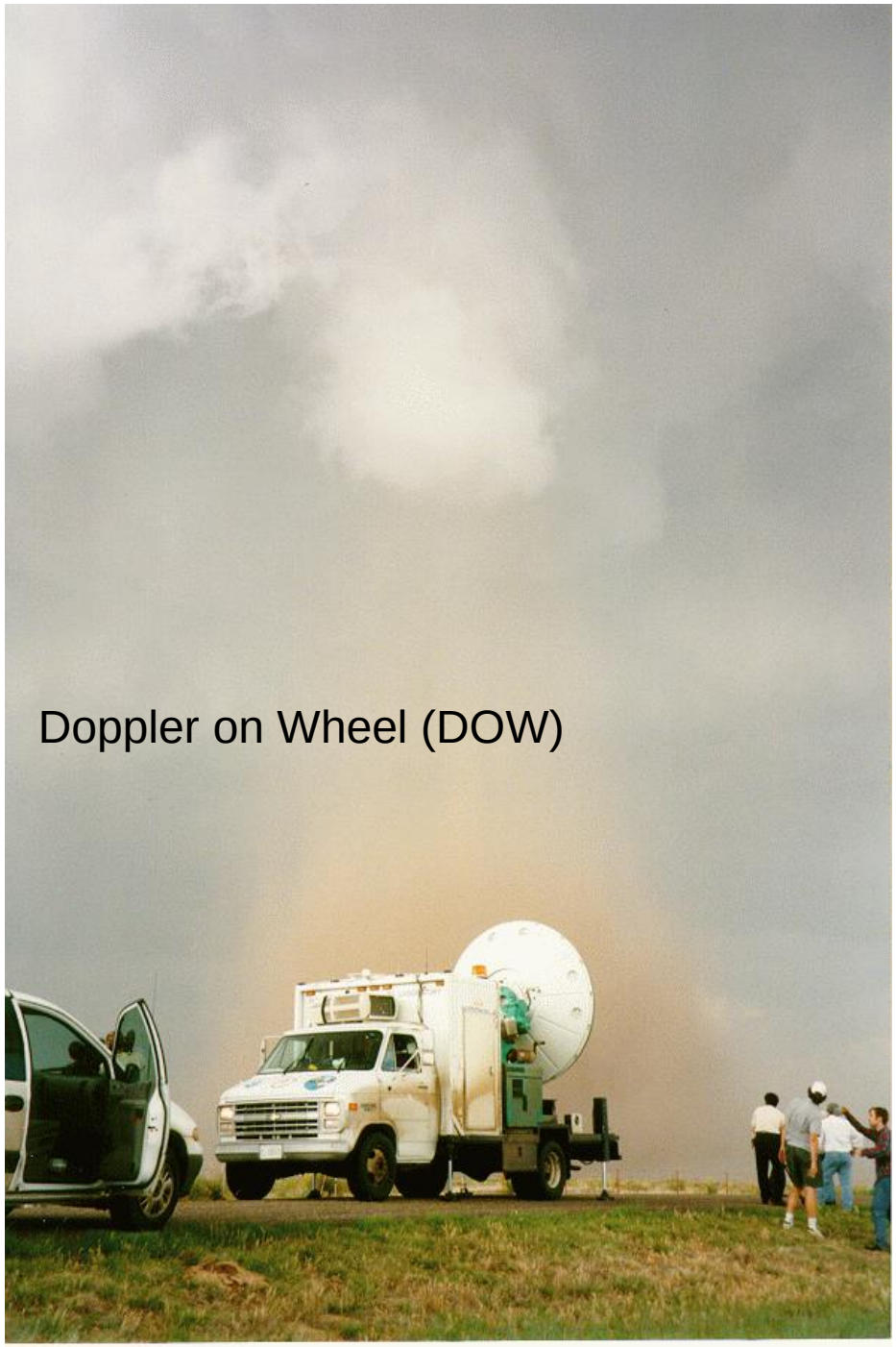
衛星雲圖+都卜勒雷達回波圖

Morakot (2009)



NSSL Doppler radar




Doppler on Wheel (DOW)

NOAA P-3 Aircraft

NOAA P-3 (N42 and N43)

機尾都卜勒雷達

(Tail-mounted X-band Doppler radar)

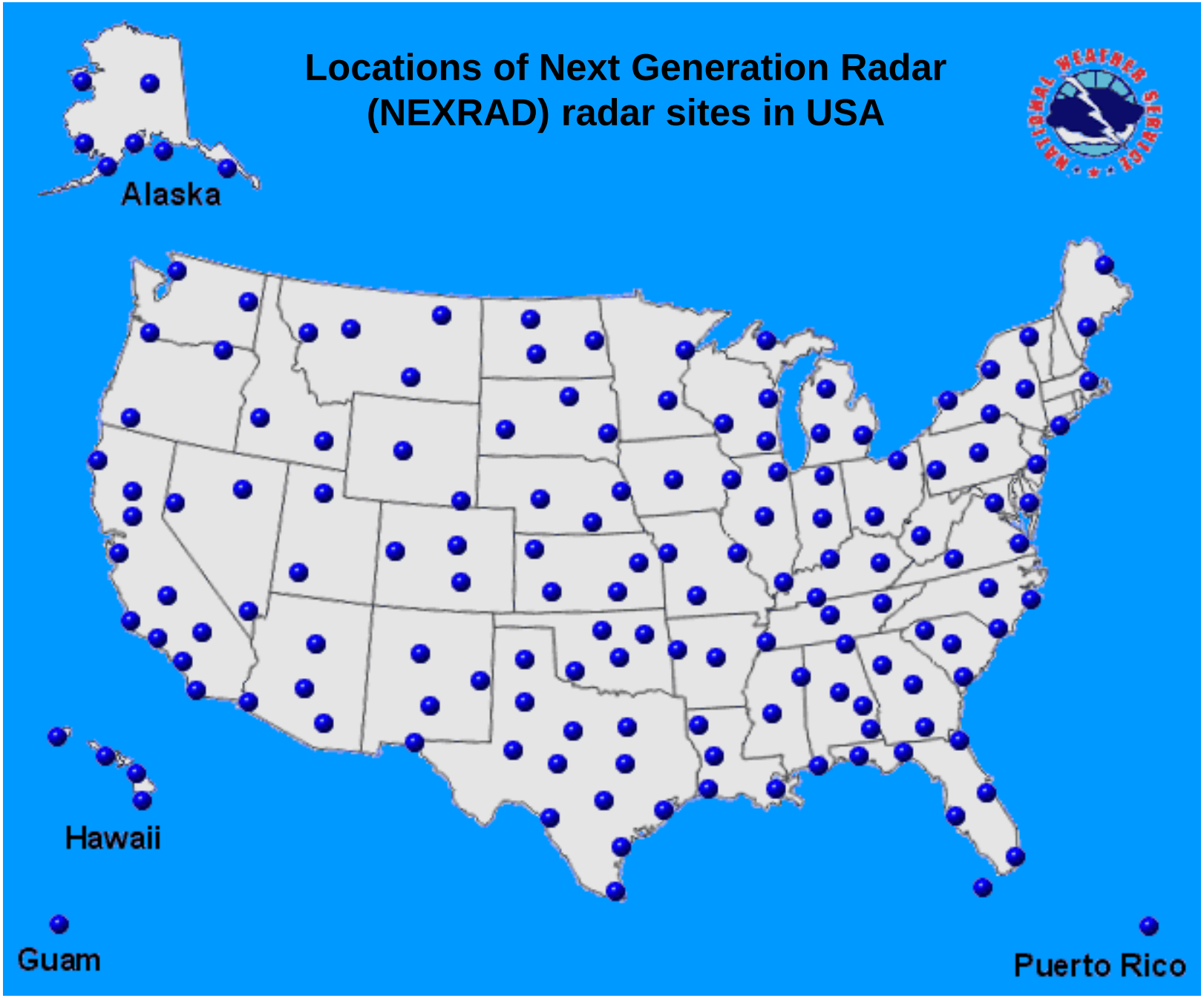
機腹傳統雷達

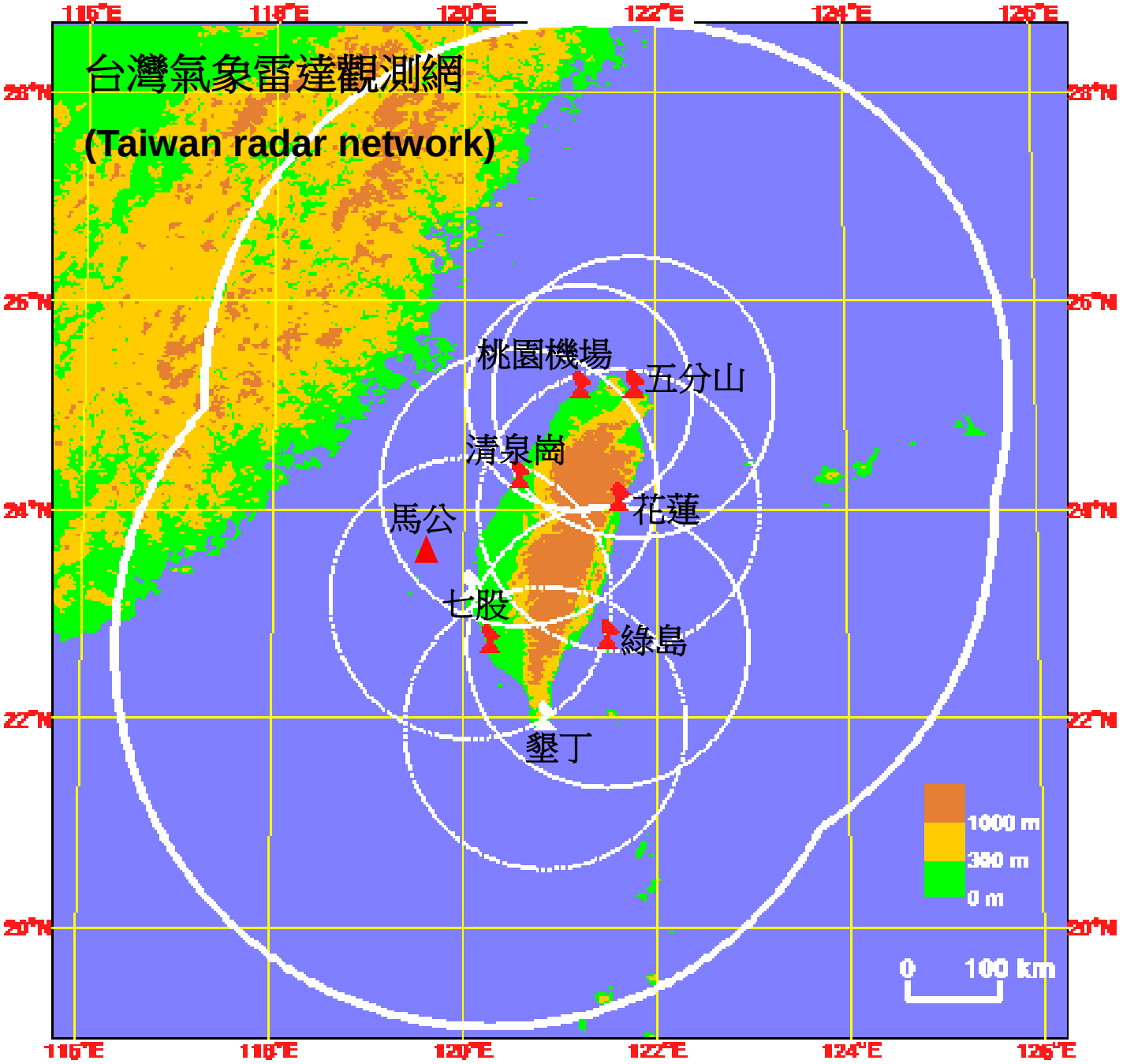
(Conventional C-band lower fuselage radar)

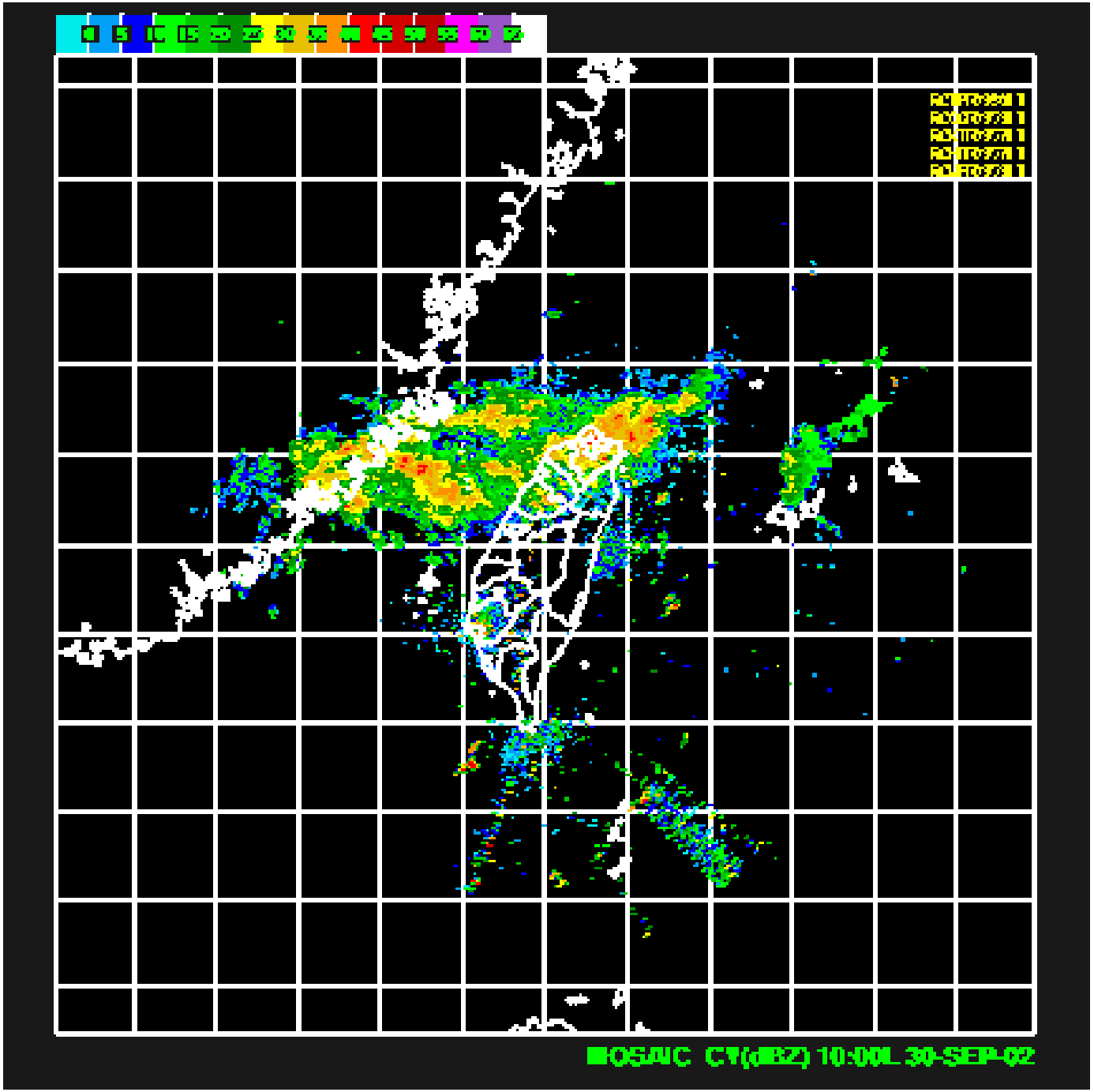
NCAR Electra

拍攝於 因斯布魯克機場 奧地利 **1999**

(Photo taken in the Innsbruck airport during MAP, Austria)


Locations of Next Generation Radar
(NEXRAD) radar sites in USA
Alaska
Hawaii
Guam
Puerto Rico

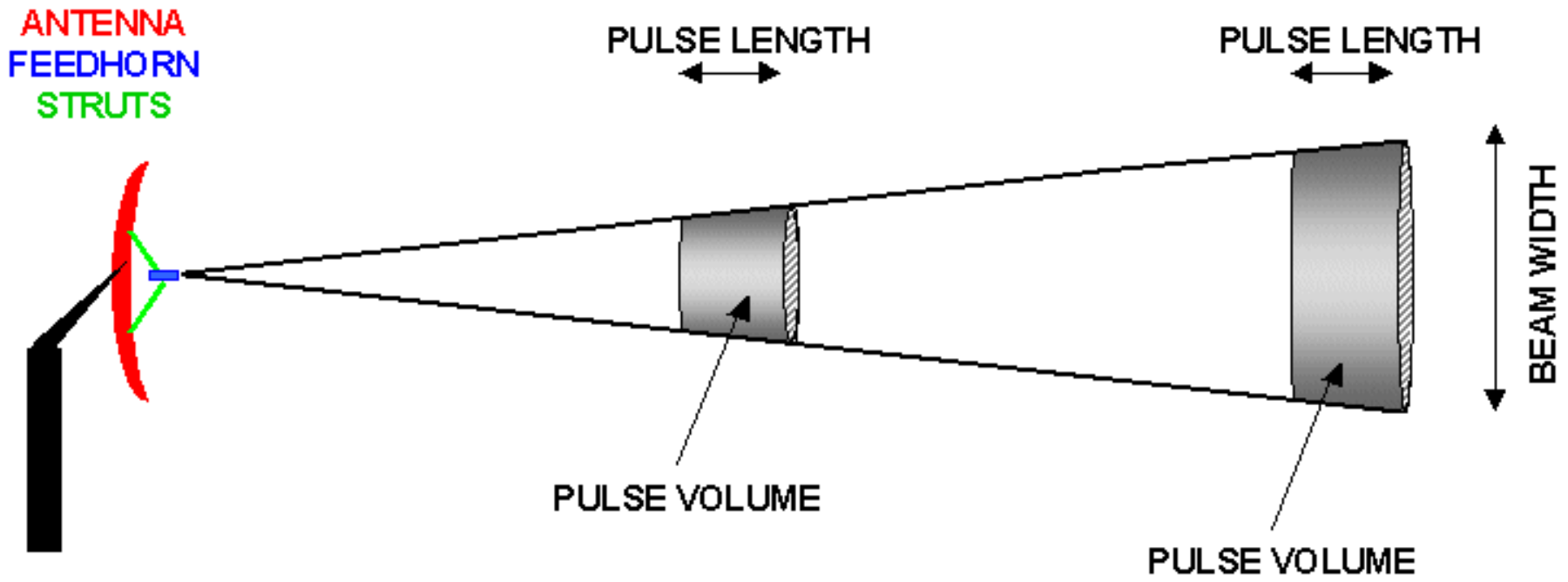

台灣氣象雷達觀測網
(Taiwan radar network)
116°E
118°E
120°E
122°E
124°E
126°E
28°N
26°N
24°N
22°N
20°N
桃園機場
五分山
清泉崗
花蓮
馬公
七股
綠島
墾丁
1000 m
380 m
0 m
0
100 km


OSAIC CV(dBZ) 10:00L 30-SEP-02

2-2 雷達基礎原理 (Fundamental principle and radar equation)

2-3 雷達掃描方式 (Radar scanning)

2-4 雲內風場的求得 (Wind retrieval)


ANTENNA
FEEDHORN
STRUTS
PULSE LENGTH
PULSE LENGTH
BEAM WIDTH
PULSE VOLUME
PULSE VOLUME

雷達回波單位 dBZ

$dBZ=10 \log Z$

Z: 單位體積內所有雨滴直徑6次方的和 $\sum D_i^6 / V$

因此雨滴越多越大　雷達回波就越強

20 dBZ	小雨
> 35 dBZ	大雨
> 55 dBZ	冰雹

透過都卜勒效應可以獲得徑向速度資訊

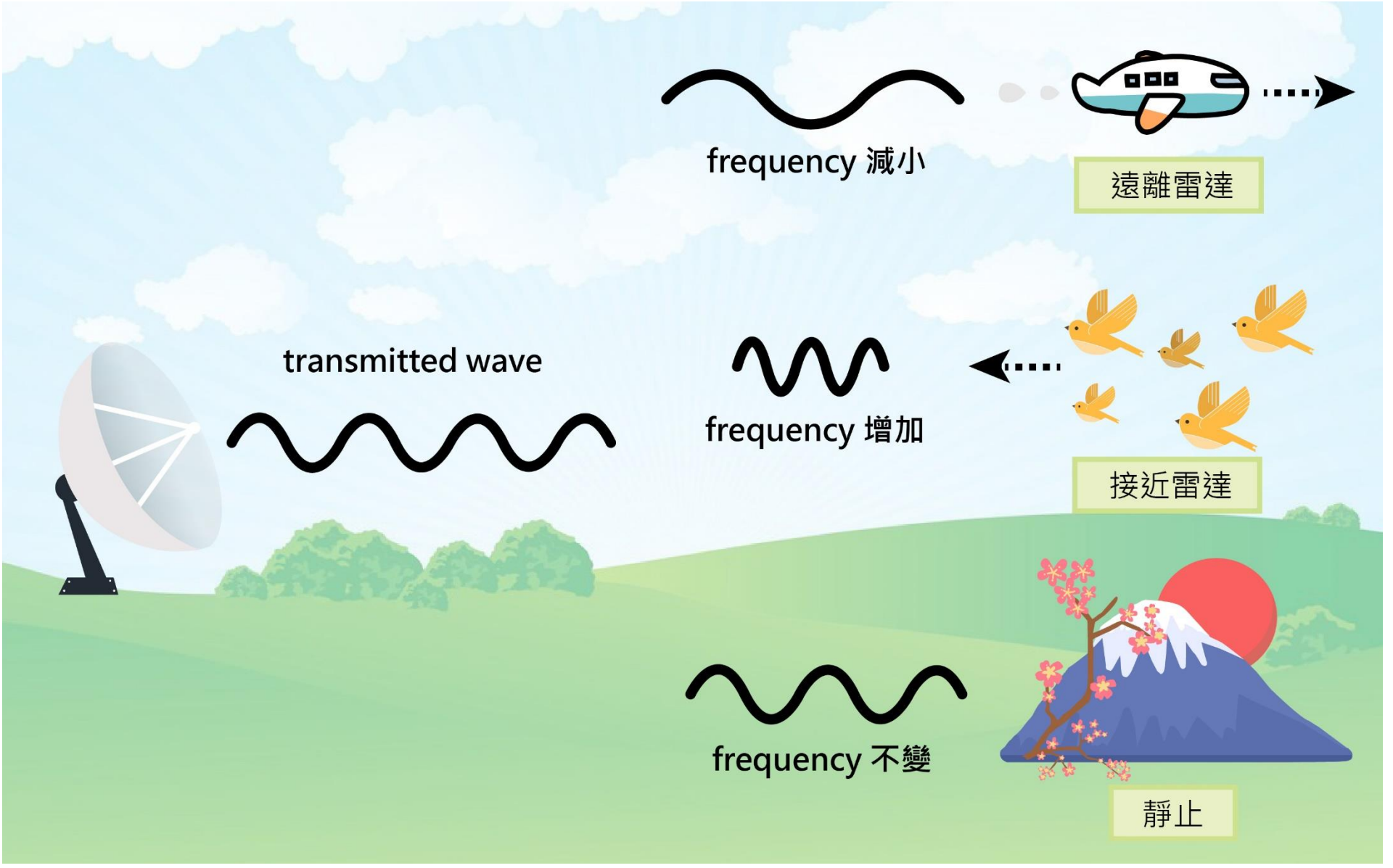
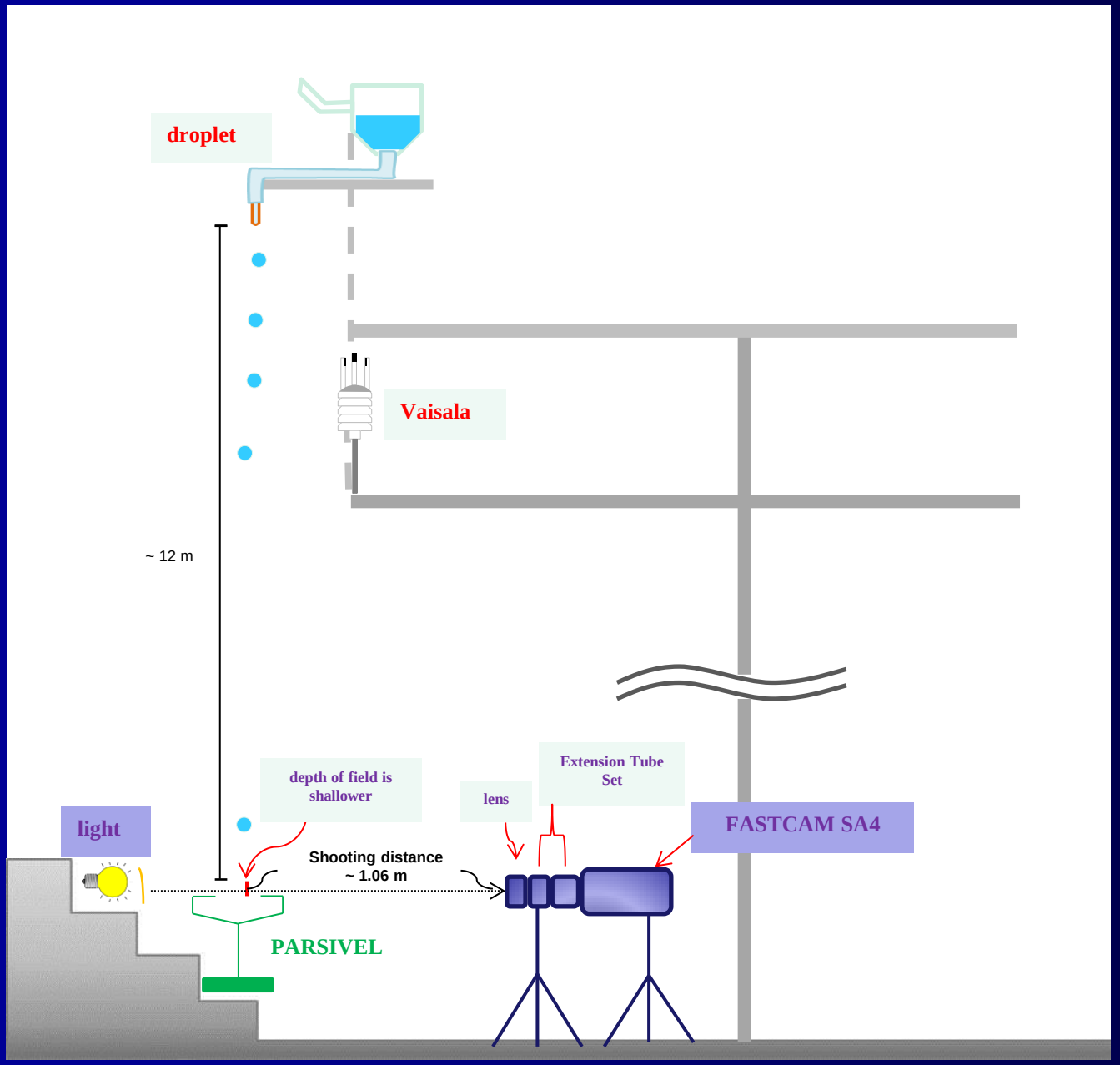


TABLE 8.1. *Terminal Fall Speed as a Function of Drop Size (equivalent spherical diameter) (From Gunn and Kinzer, 1949)*

Diam. (mm)	Fall speed (m/s)	Diam. (mm)	Fall speed (m/s)
0.1	0.27	2.6	7.57
0.2	0.72	2.8	7.82
0.3	1.17	3.0	8.06
0.4	1.62	3.2	8.26
0.5	2.06	3.4	8.44
0.6	2.47	3.6	8.60
0.7	2.87	3.8	8.72
0.8	3.27	4.0	8.83
0.9	3.67	4.2	8.92
1.0	4.03	4.4	8.98
1.2	4.64	4.6	9.03
1.4	5.17	4.8	9.07
1.6	5.65	5.0	9.09
1.8	6.09	5.2	9.12
2.0	6.49	5.4	9.14
2.2	6.90	5.6	9.16
2.4	7.27	5.8	9.17

Instruments and Experimental Settings (Indoor, 2012)

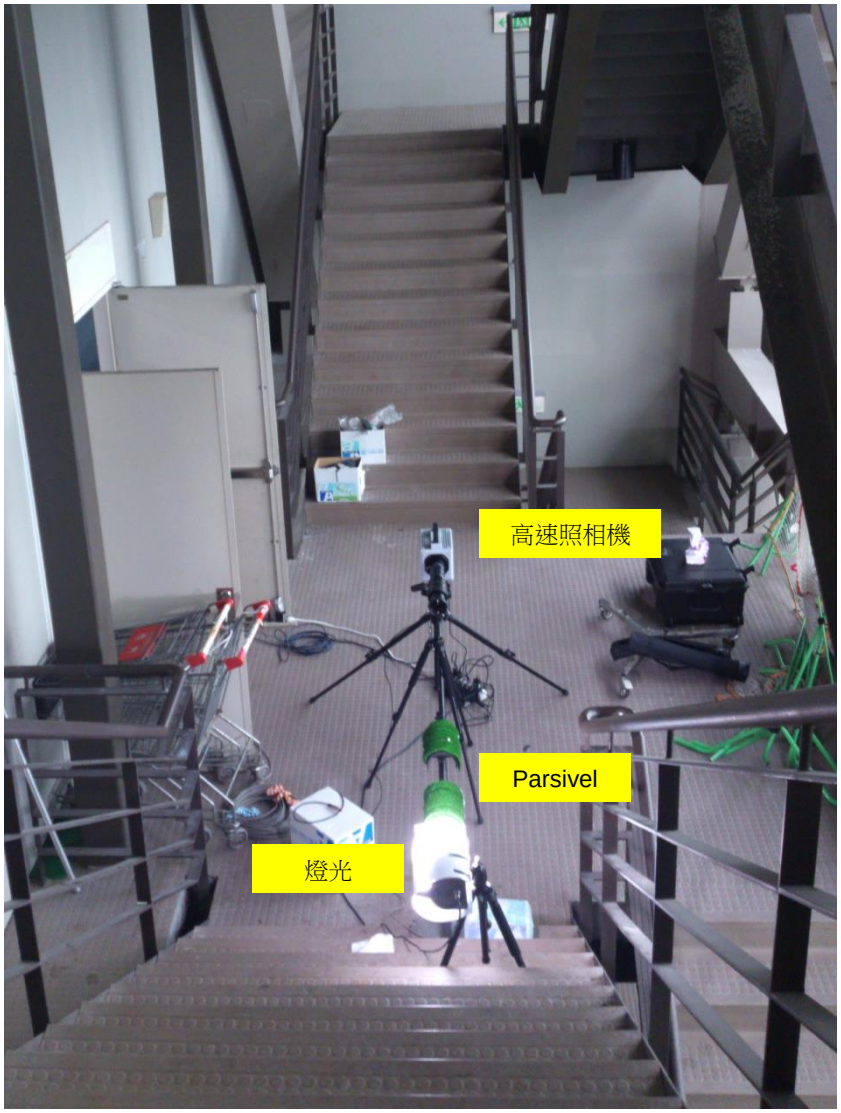


Vaisala
量測氣壓、溫度、濕度、水平風

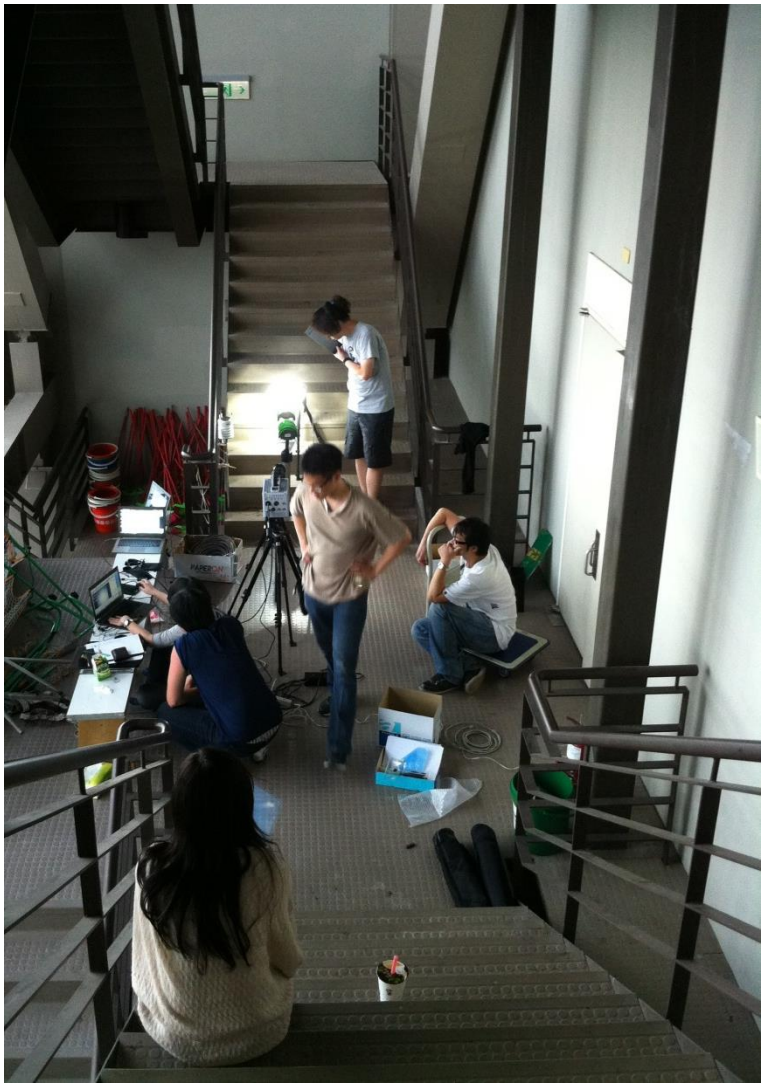
Fast-Camera
高速照相機
拍下瞬時水滴落下情形

Parsivel
雨滴譜儀
量測水滴粒徑和落速

實驗儀器架設的分布位置



實驗儀器架設的分布位置

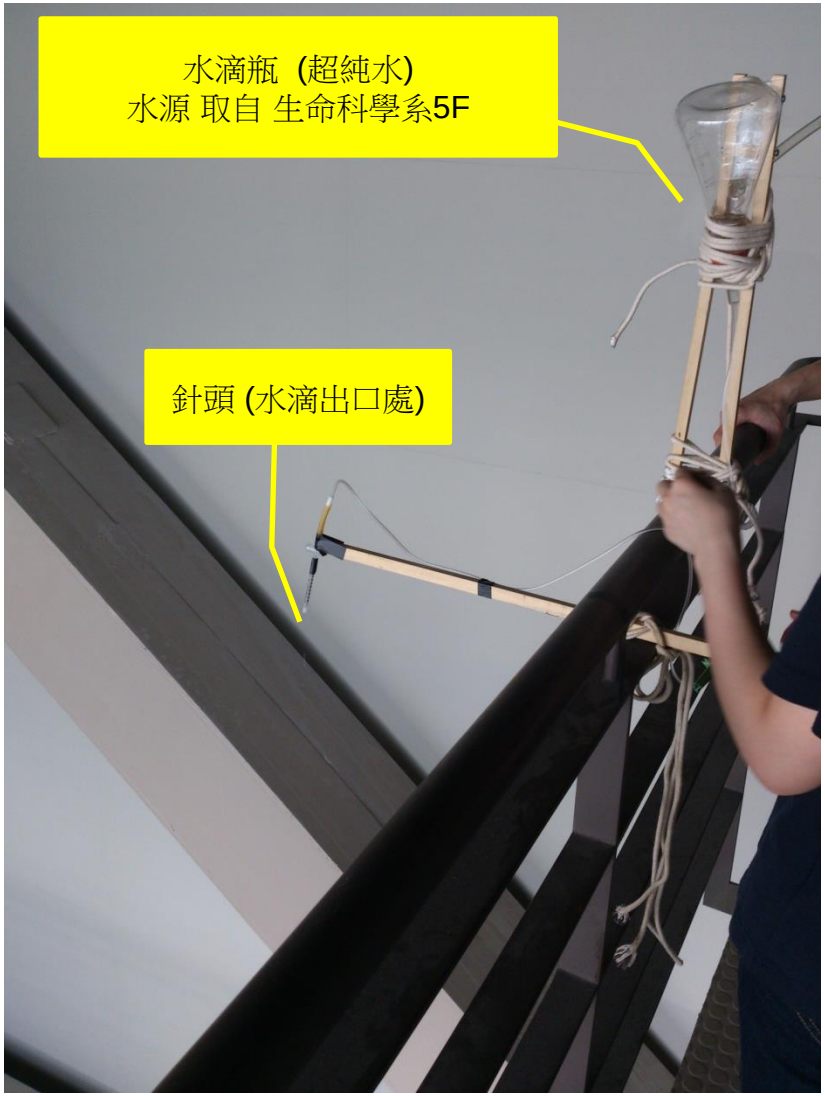


實驗場所


監測水滴是否落在鏡頭的對焦範圍內
PC -1- Vaisala
PC -2- Parsivel
PC-3- Fast Camera
截錄水滴通過鏡頭時的畫面
PAPERON

實驗場所II

水滴出處的位置圖

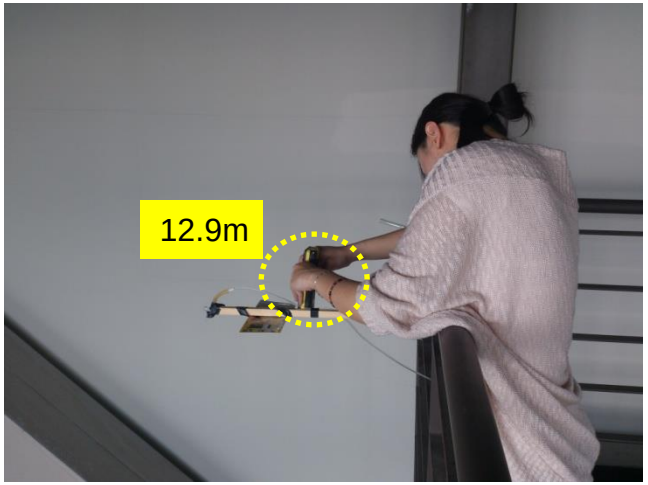


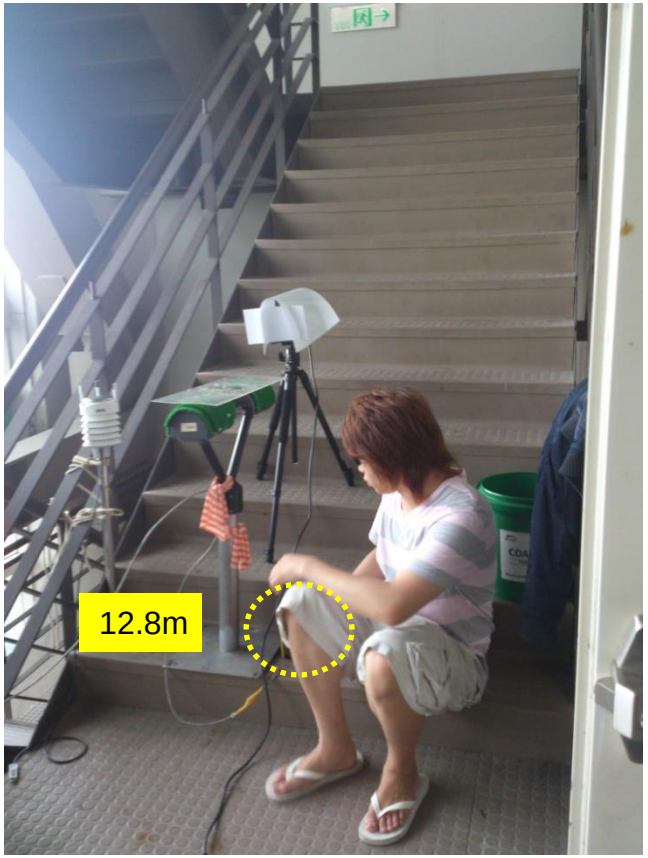
水滴出處 (近拍)

雷射測距儀

Parsivel底座至水滴木條架平均高度12.85m
Parsivel底座至雷射光觀測區的高度約0.7m

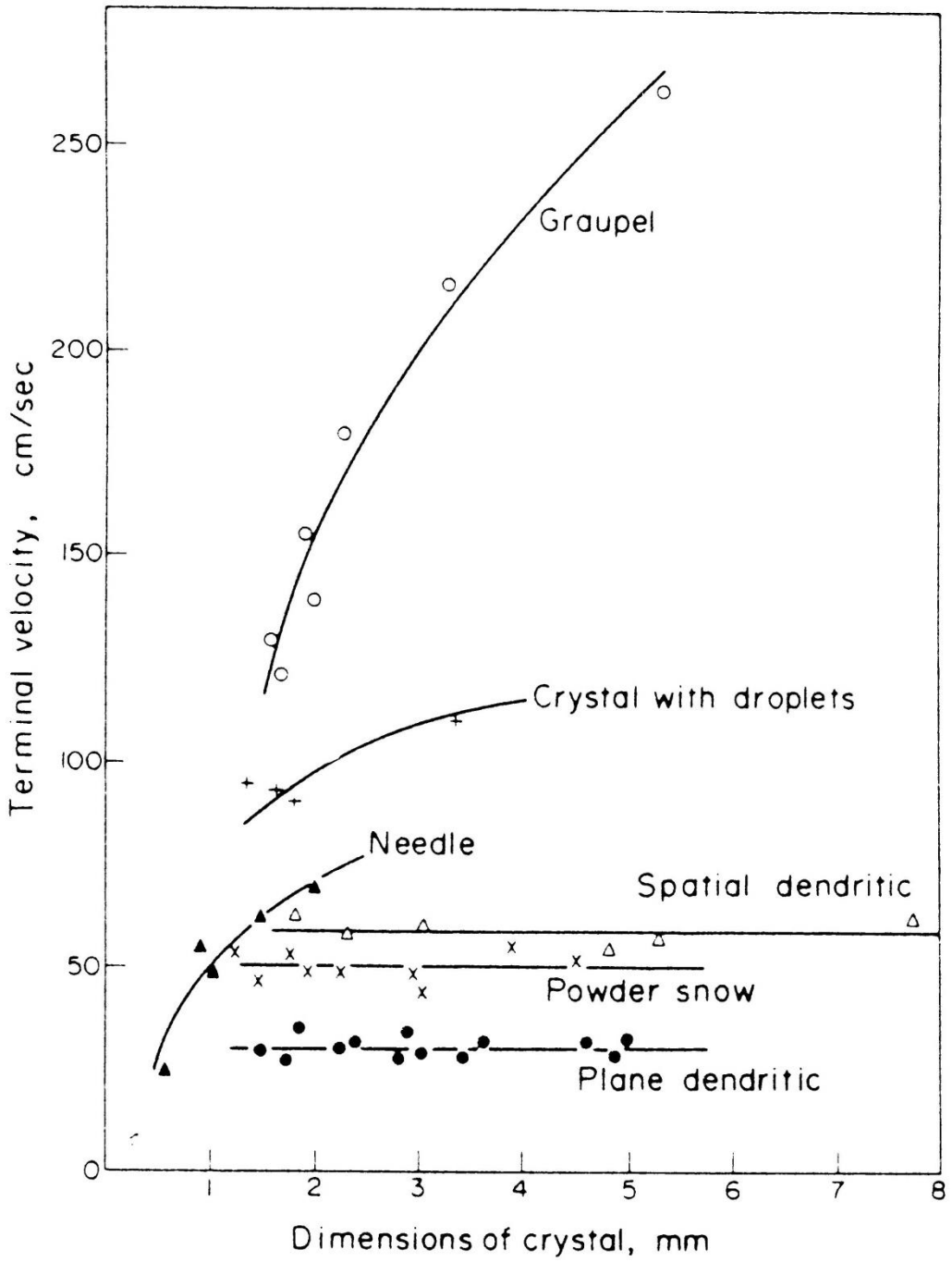
水滴相當於從12公尺高度落下。





Falling drops at various sizes photoed by high-speed camera

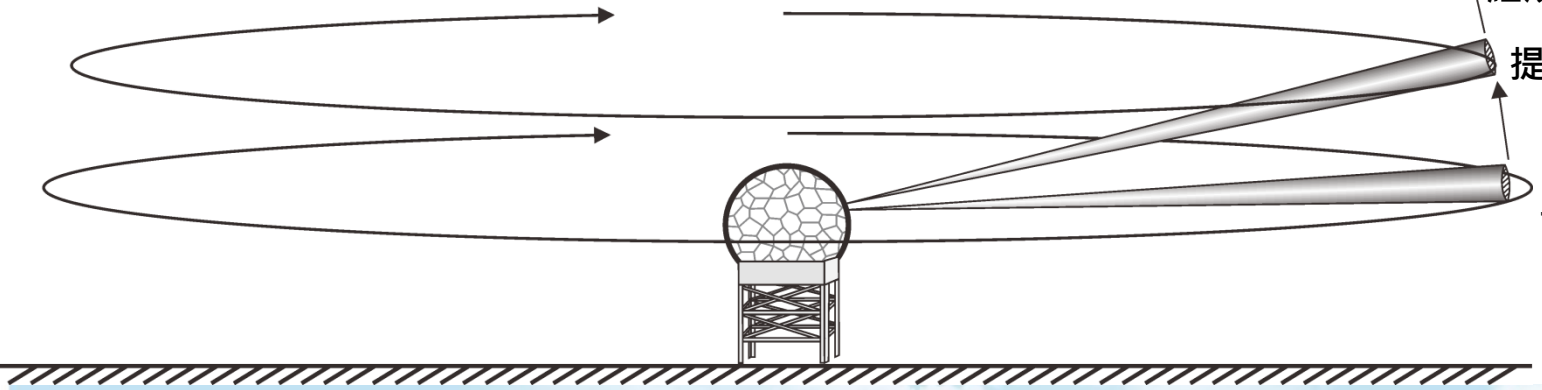
Mesoscale and Orographic Precipitation Lab (MOPL), Department of Atmospheric Sciences, National Taiwan University, Taiwan



Terminal velocities of ice crystals

(from Fletcher 1962)

PPI scanning



依此類推，完成9個仰角(0.4、1.4、2.3、3.3、4.2、6.0、9.8、14.5及19.5度)的掃描，組成一體積掃描

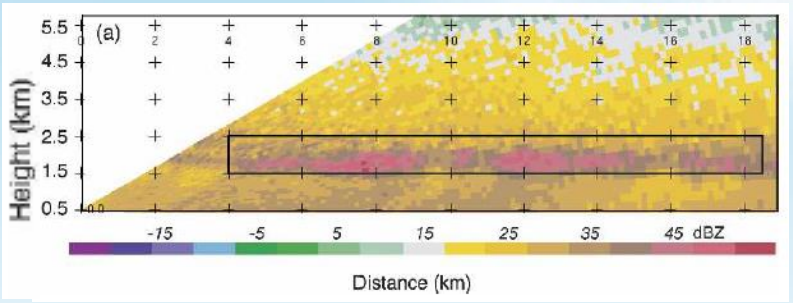
提升仰角，再順時針掃描

固定仰角，順時針掃描一圈

固定式 - 地面雷達（掃描策略）

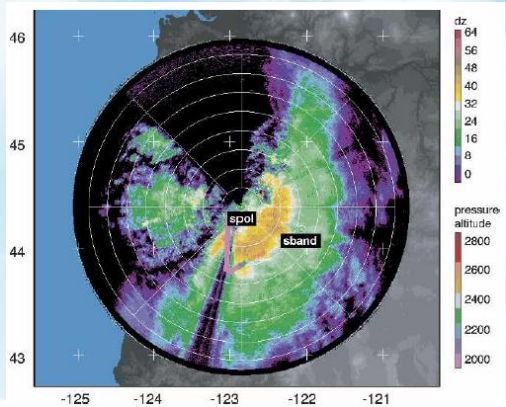
RHI
(Range Height Indicator)

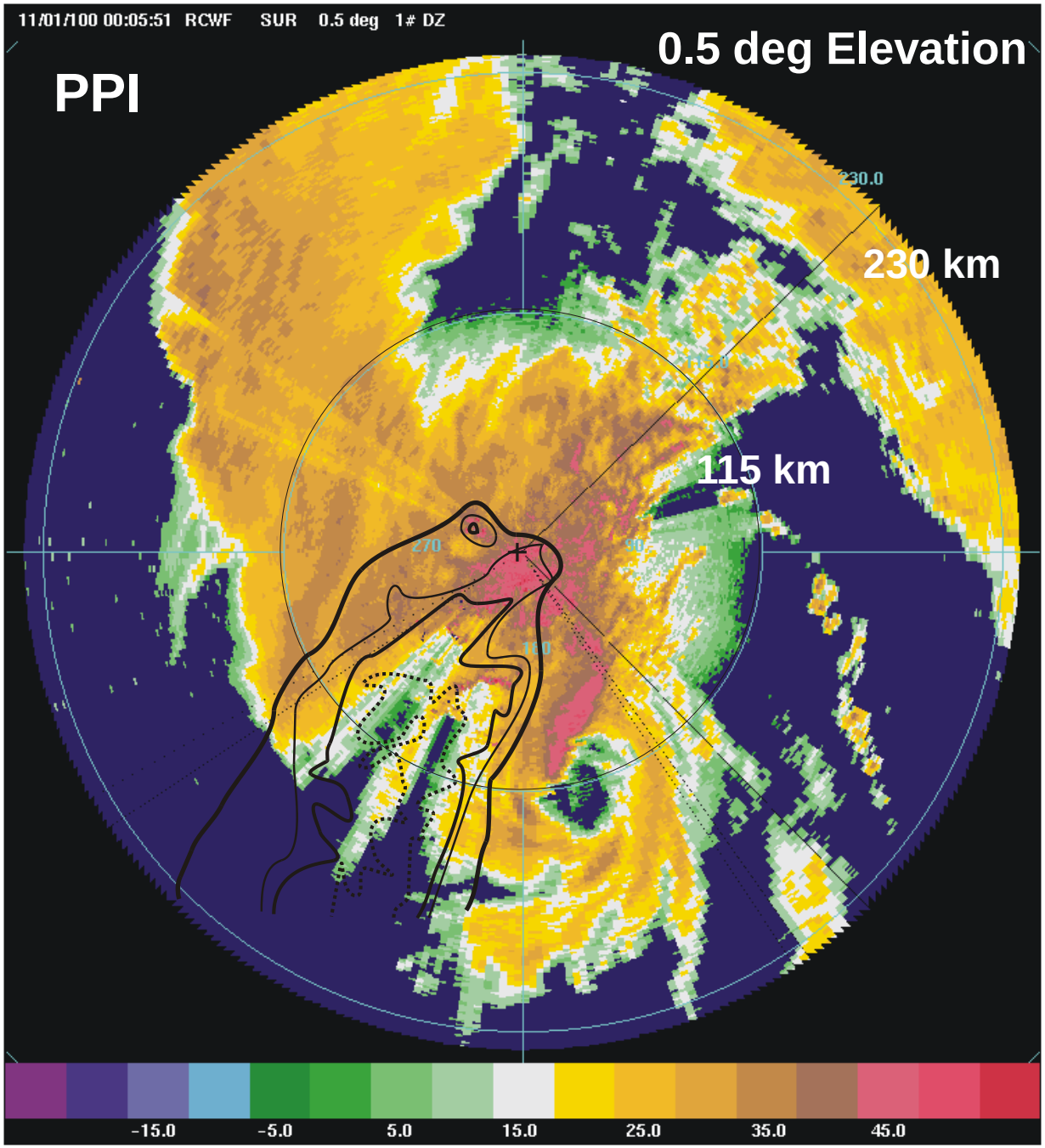
Video play ▸▸



PPI
(Plan Position Indicator)

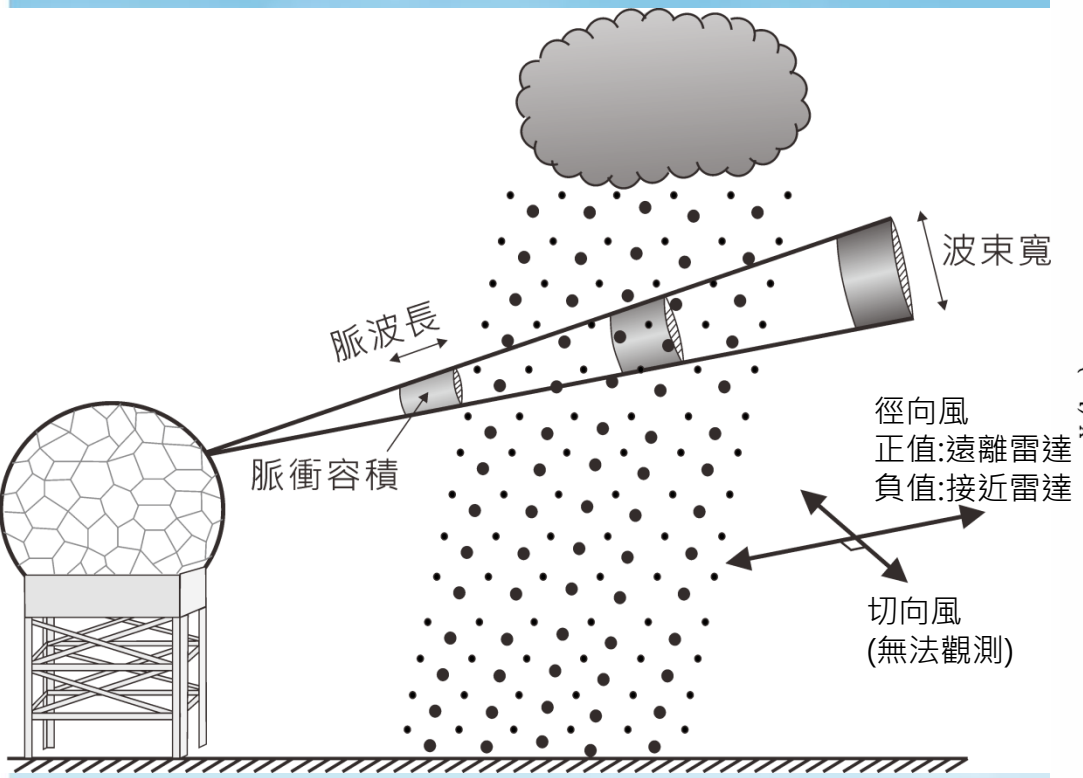
Video play ▸▸

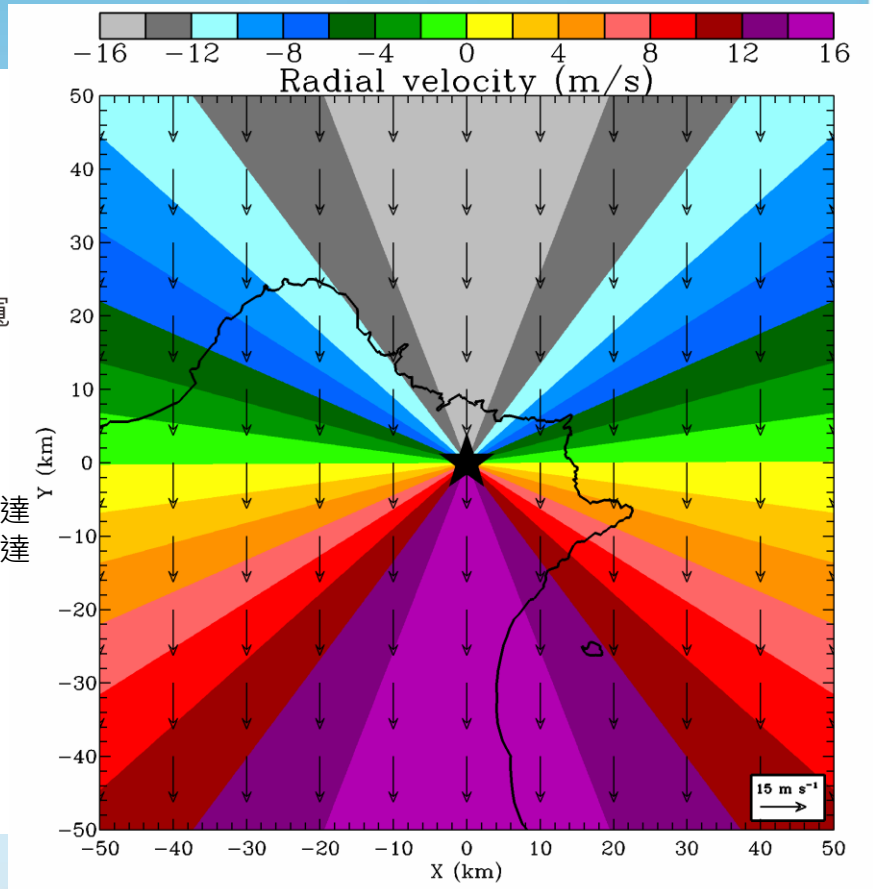



11/01/100 00:05:51 RCWF SUR 0.5 deg 1# DZ
PPI
0.5 deg Elevation
230.0
230 km
115 km
270
90
180
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0

雷達觀測徑向風場

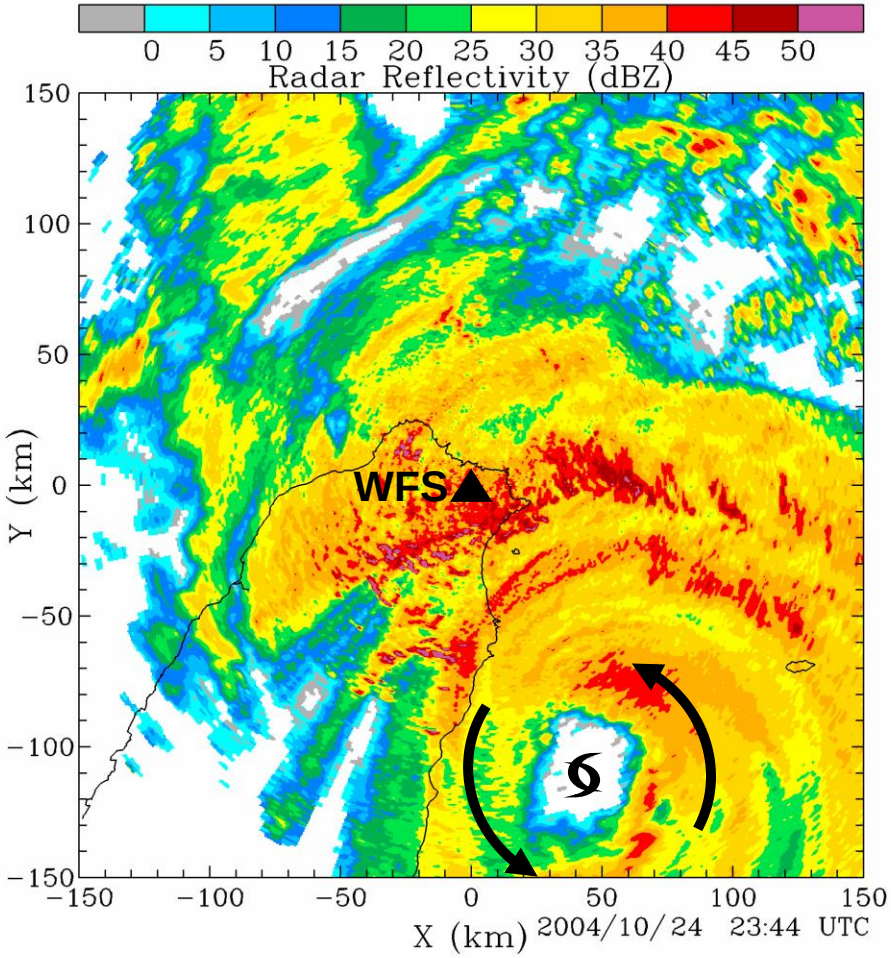
都卜勒徑向風場範例(北風 15 m s^{-1})

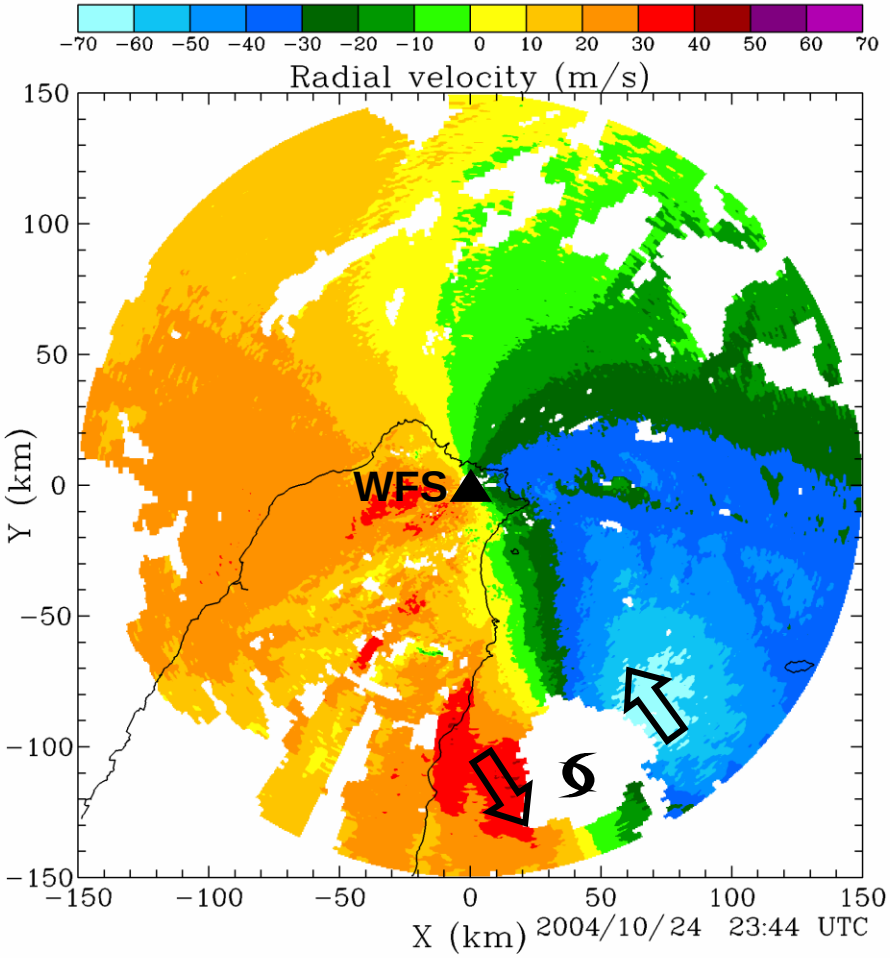




2004年納坦颱風 (NOCK-TEN)

五分山雷達(WFS, 0.4度仰角PPI)





Rotating cloud associated with the mesocyclone of a supercell storm (Markowski and Richardson 2010)

Figure 8.17 A midlevel mesocyclone is the defining visual characteristic of a supercell storm. Little imagination is needed to sense the cyclonic vertical vorticity associated with the storm updraft. Photograph by Herb Stein (the Dopper On Wheels radar is in the foreground).

A real sample of radar PPI scan showing signatures of supercells (Markowski and Richardson 2010)

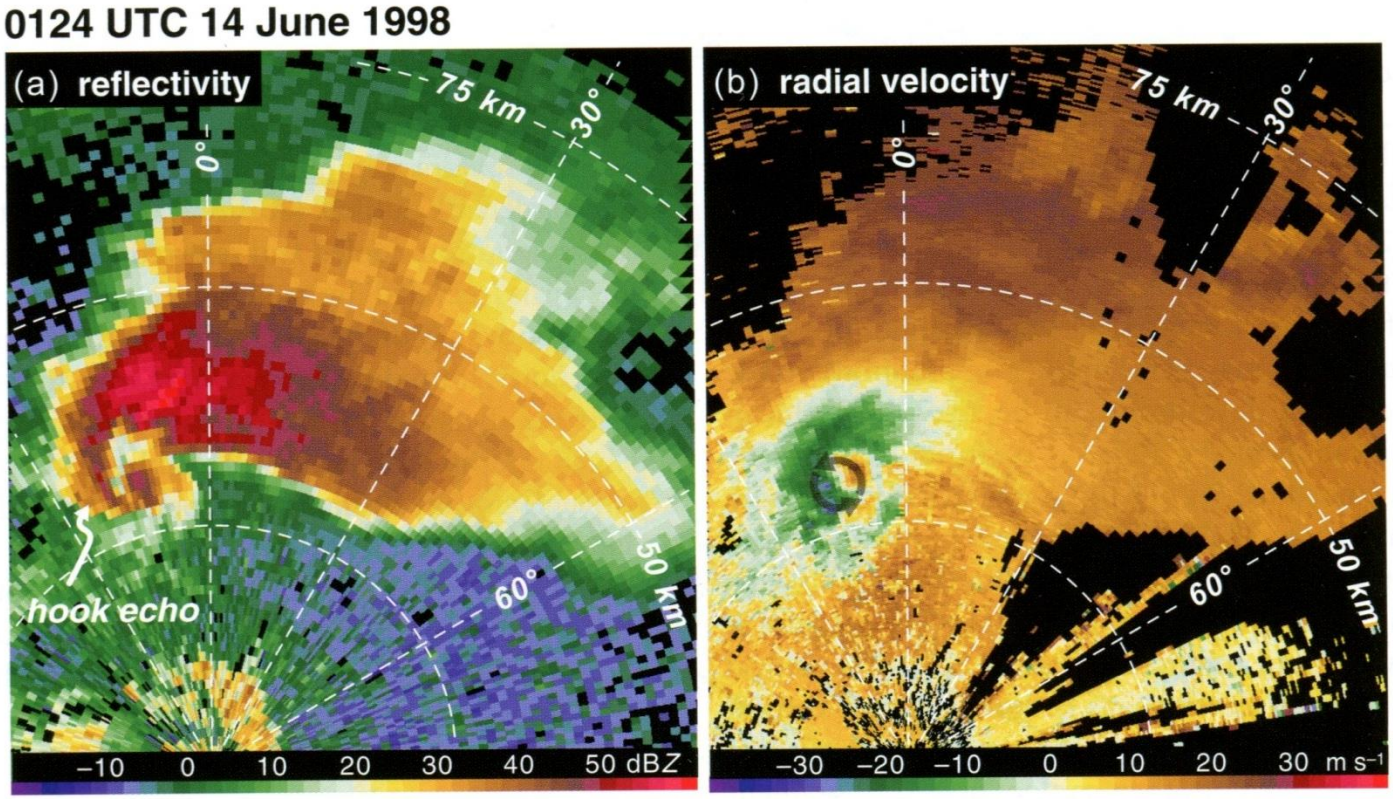


Figure 8.18 A hook echo in reflectivity data and an inbound–outbound couplet in radial velocity data are the defining radar characteristics of supercells in low-altitude radar scans. The images are (a) reflectivity and (b) radial velocity from the Oklahoma City, OK, radar at 0124 UTC 14 June 1998. The inbound–outbound radial velocity couplet is oriented such that the zero contour is approximately parallel to the radials, with inbound (outbound) velocities to the west (east), thereby implying cyclonic vertical vorticity.

RHI examples

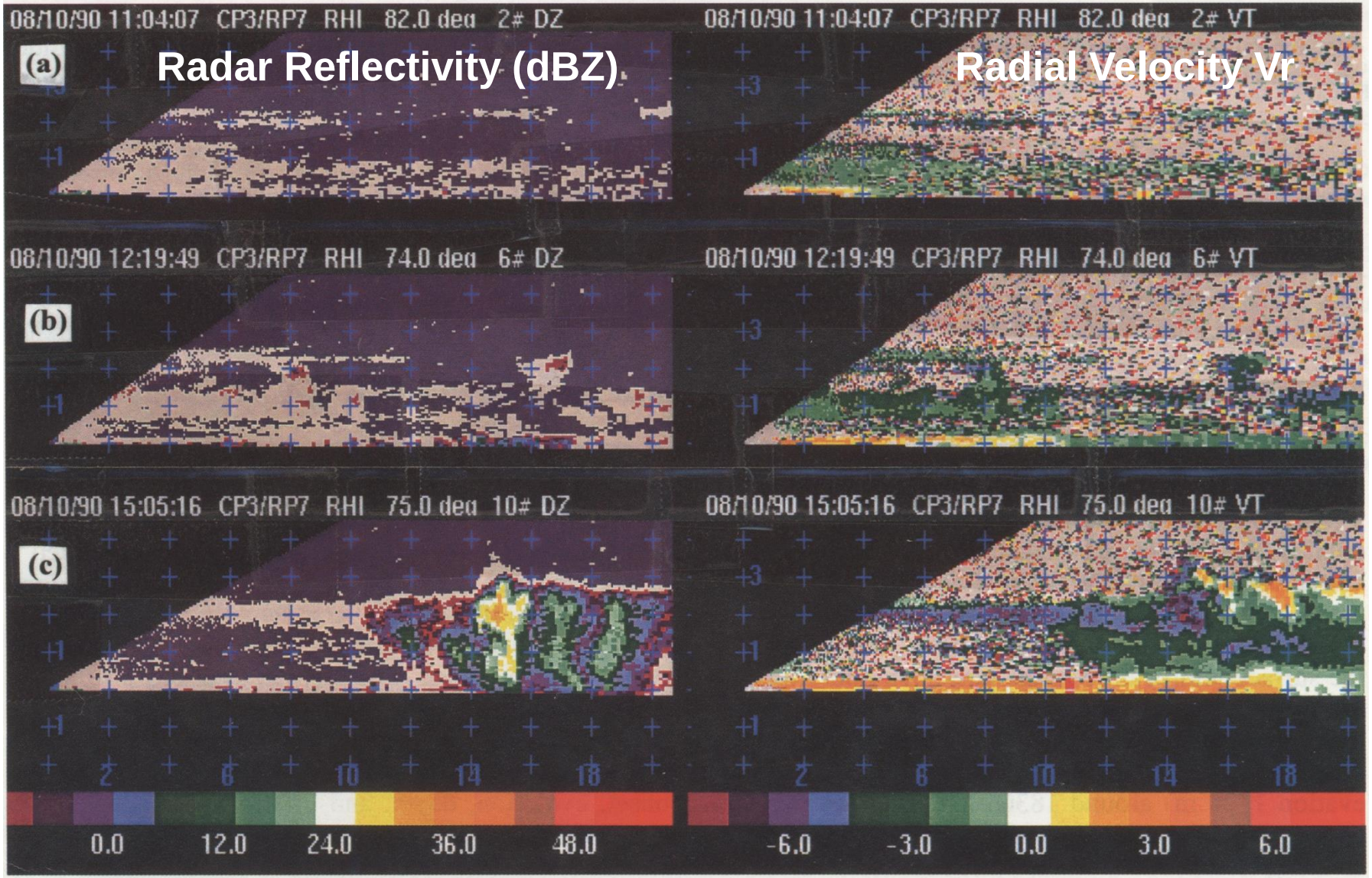
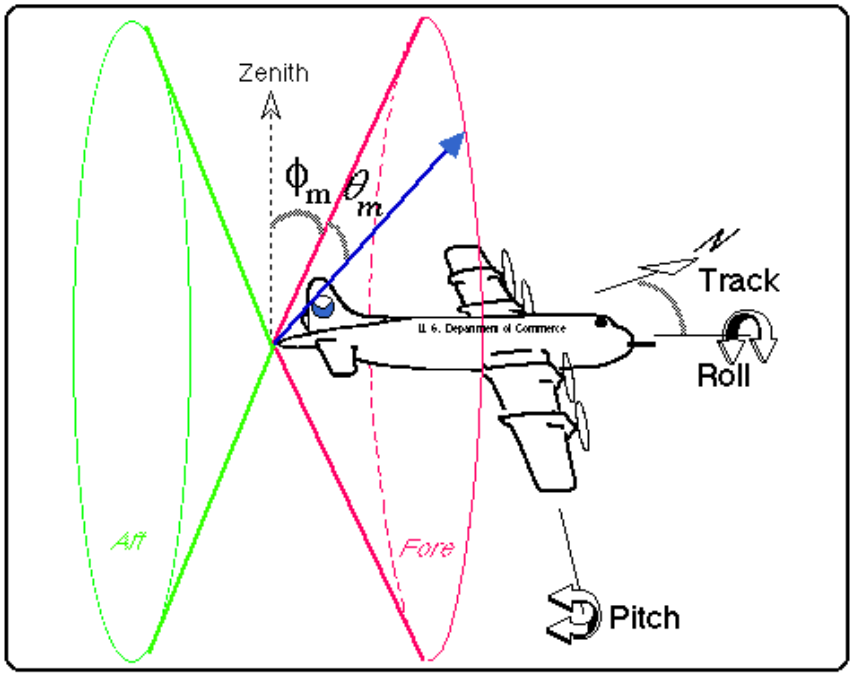
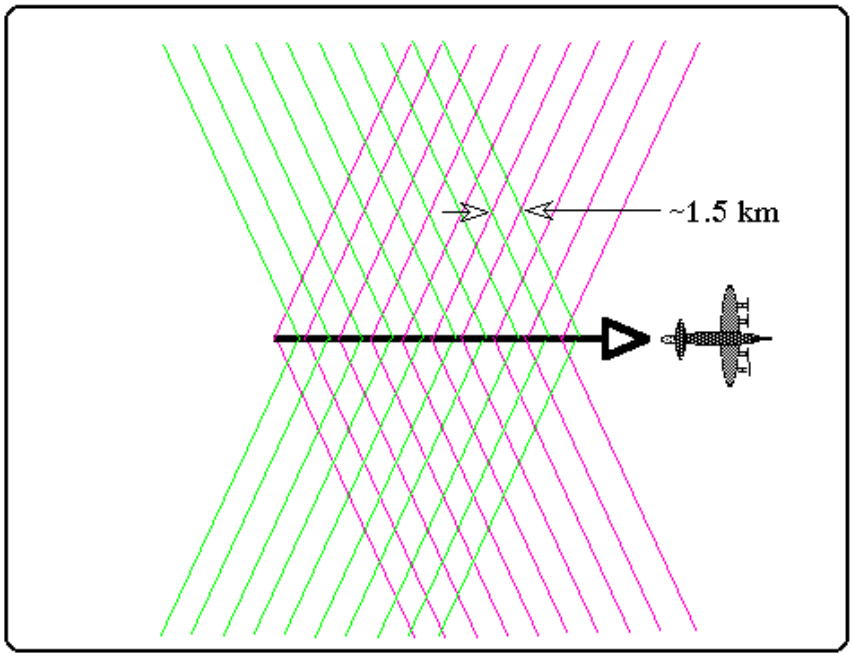


FIG. 17. Reflectivity (dBZ) (left panel) and radial velocity (m s^{-1}) (right panel) on radar RHI sections between 74° and 82° azimuth at Paradise Park (CP-3) at ~1104 UTC (~0104 HST), ~1220 UTC (~0220 HST), and ~1505 UTC (~0505 HST). The horizontal and vertical coordinates are in kilometers.

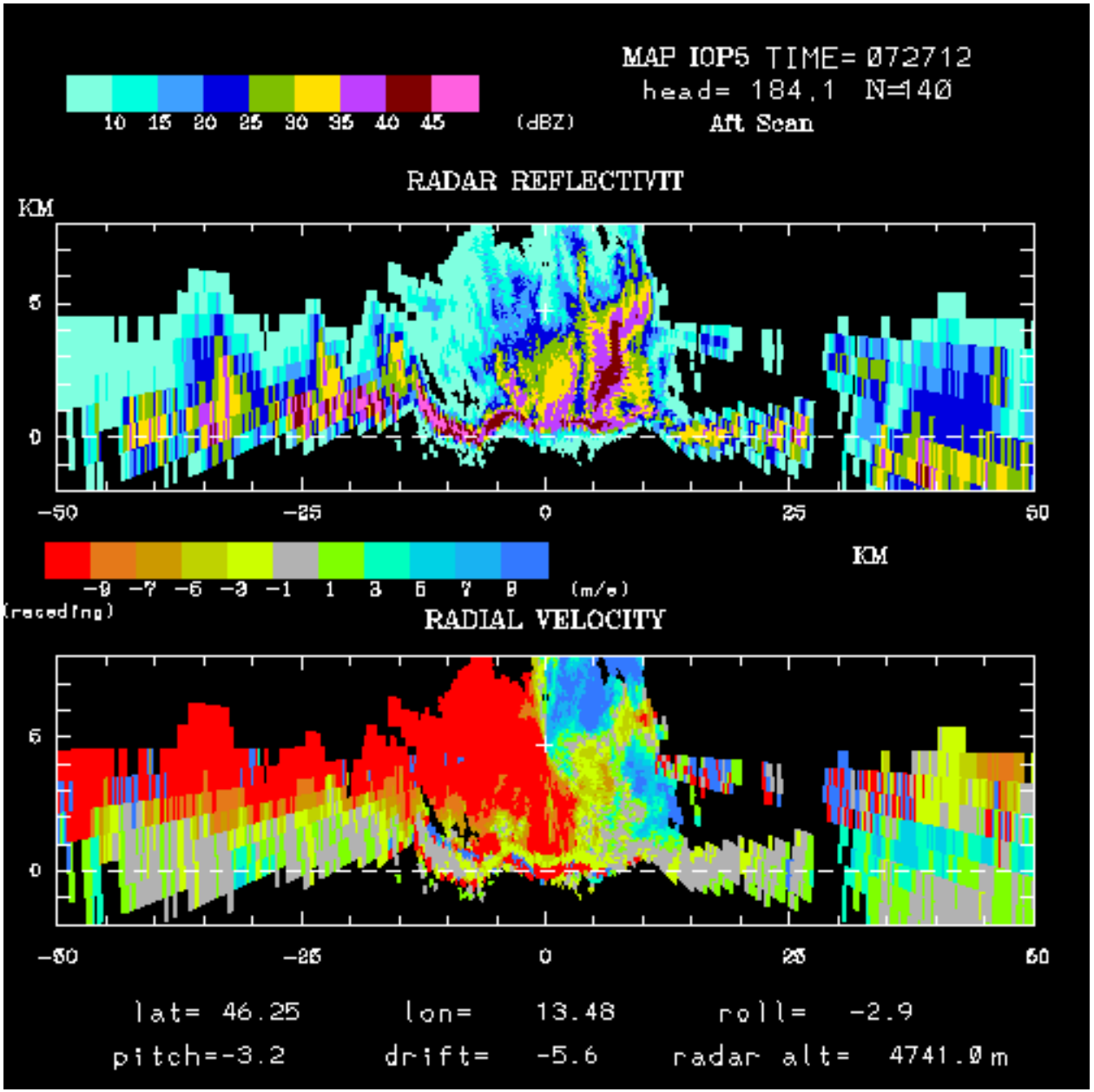


飛機都卜勒雷達掃描方式之示意圖(Scanning of airborne Doppler radar)



雷達資料在空間中之分佈 (Spatial distribution of radar data)

RHI Display of Airborne Doppler Radar Data



Conceptual representation of shallow NBB rain in California's coastal mountains, and the inability of the operational WSR-88D radars to adequately observe it. (White et al. 2003)

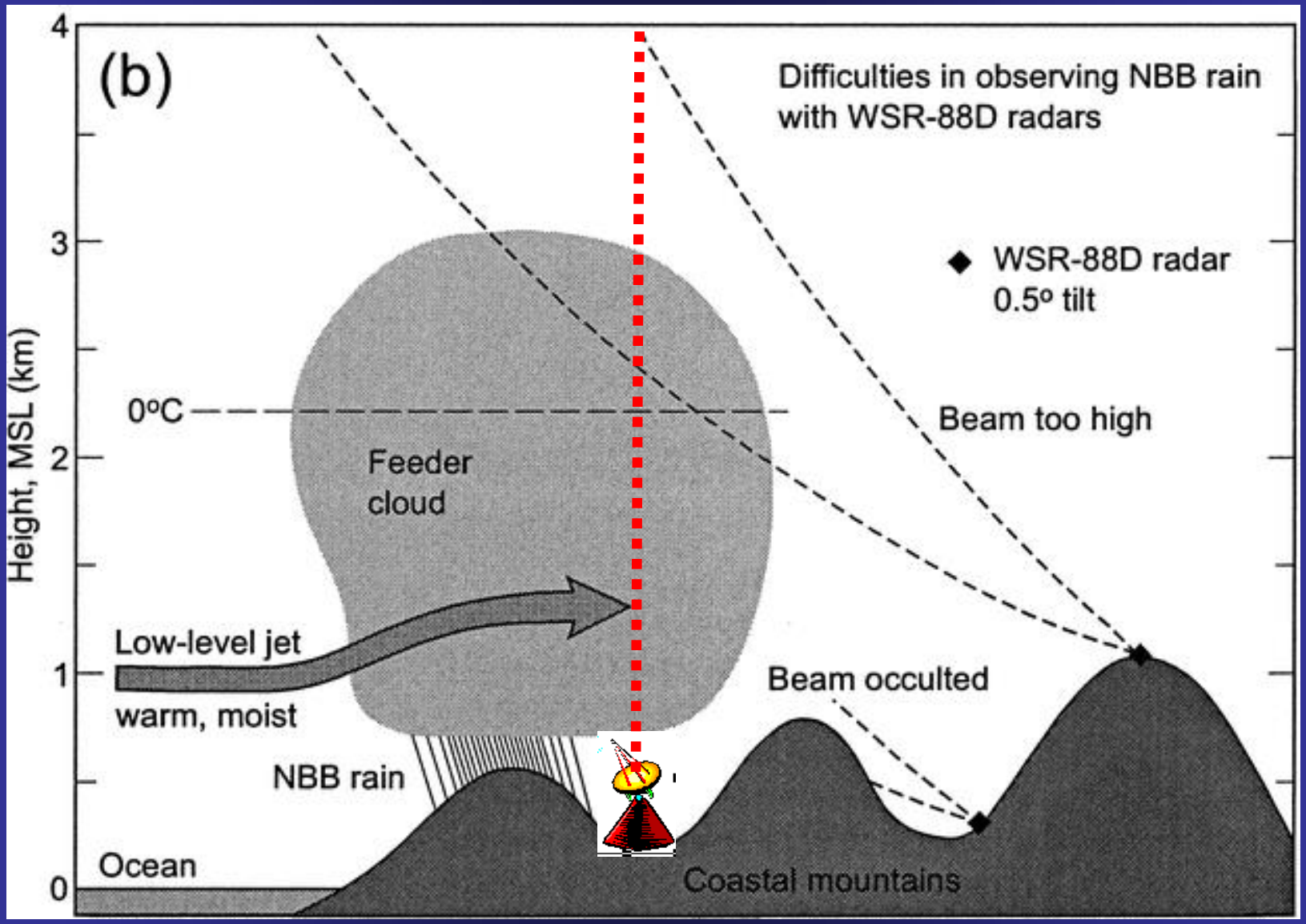
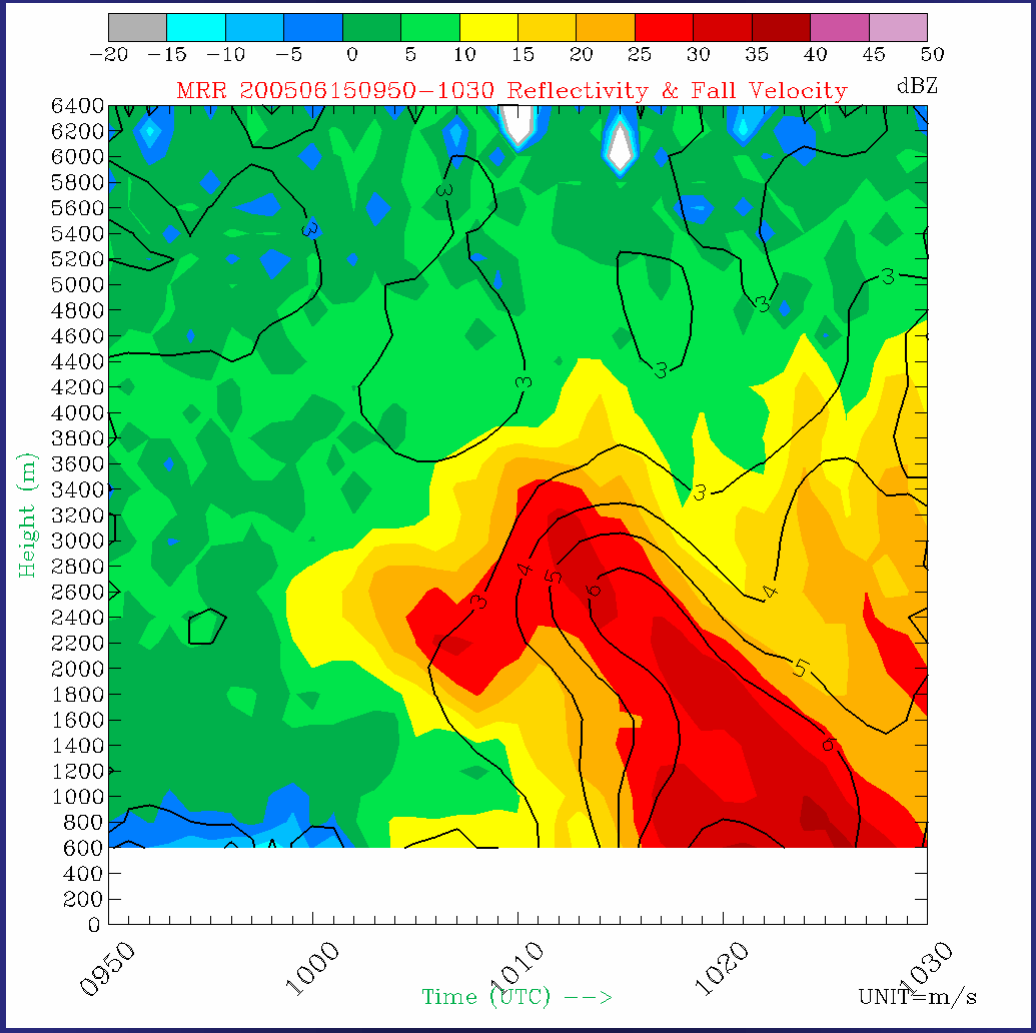


Photo of the MRR-2

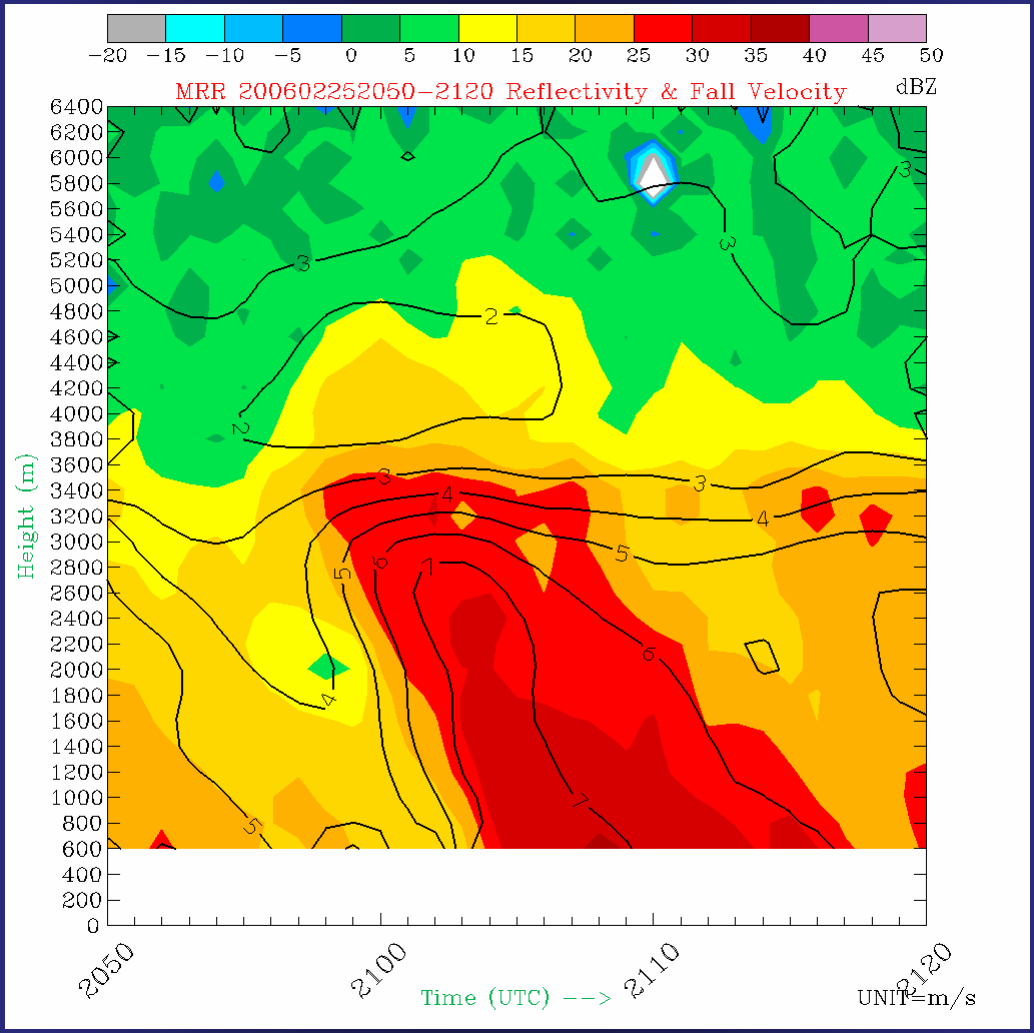
Installation
2005/06/09/0300
Receive the data
2005/06/10/0900

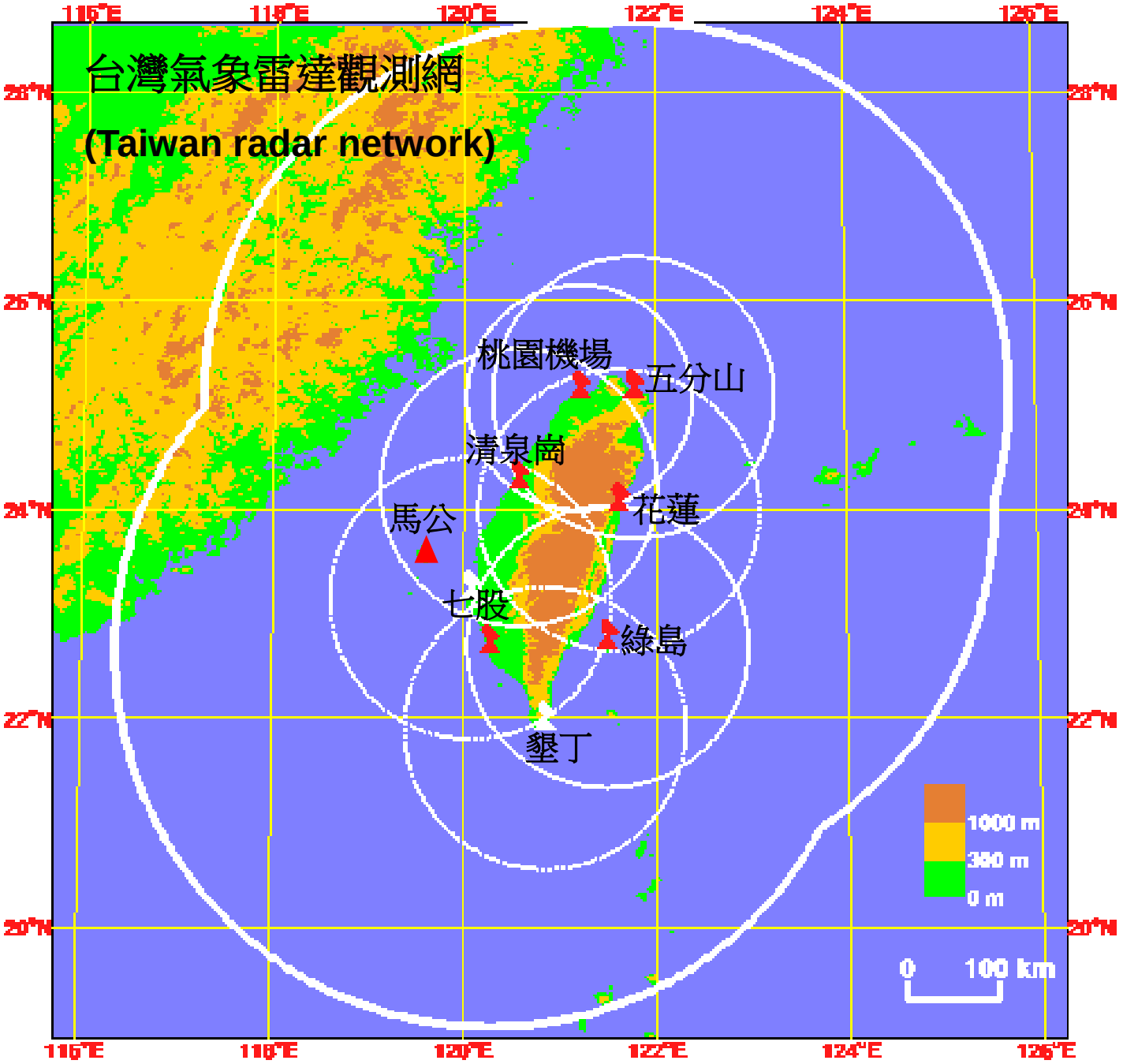
地面降雨前，可預先觀測到高空水滴之形成與發展
(梅雨鋒2005/6/15/0950~1030 UTC)
(Time-height cross section of vertical pointing radar, MRR, showing the downward development of heavy precipitation associated with Mei-yu front)



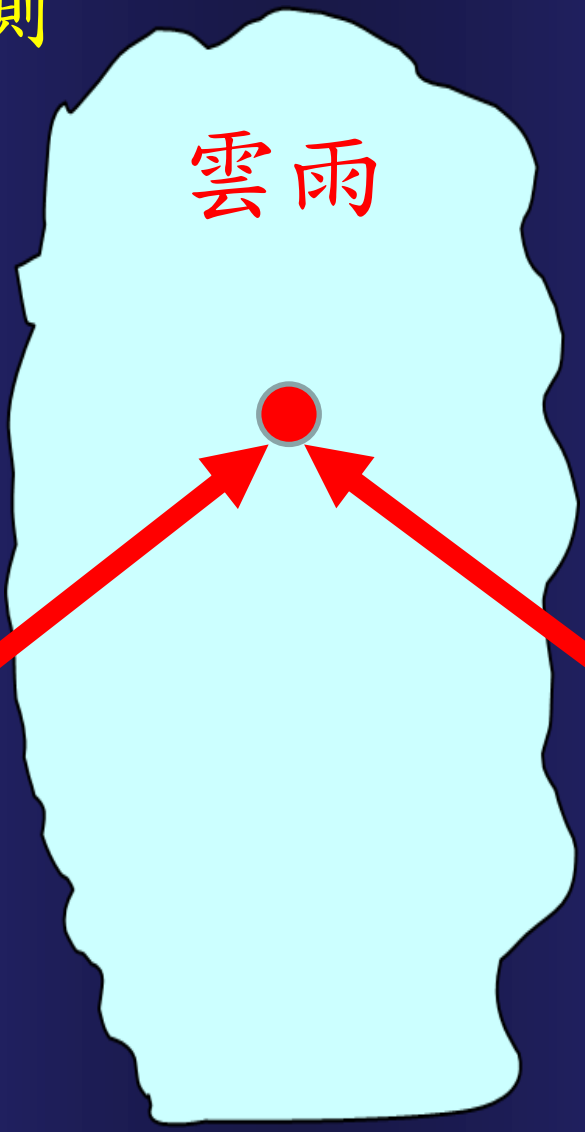
東北季風2006/02/25/2050~2120 UTC

Time-height cross section of vertical pointing radar, MRR, showing the downward development of winter-time heavy precipitation in northern Taiwan



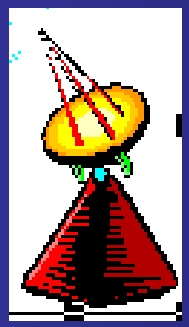

台灣氣象雷達觀測網
(Taiwan radar network)
116°E
118°E
120°E
122°E
124°E
126°E
28°N
26°N
24°N
22°N
20°N
桃園機場
五分山
清泉崗
花蓮
馬公
七股
綠島
墾丁
1000 m
380 m
0 m
0
100 km

雙都卜勒雷達觀測

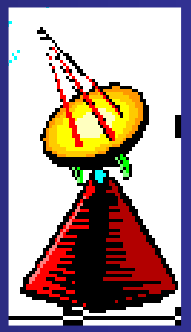


利用同一個空間位置有兩個不同方向的徑向速度值來求取實際風場資訊

A 雷達

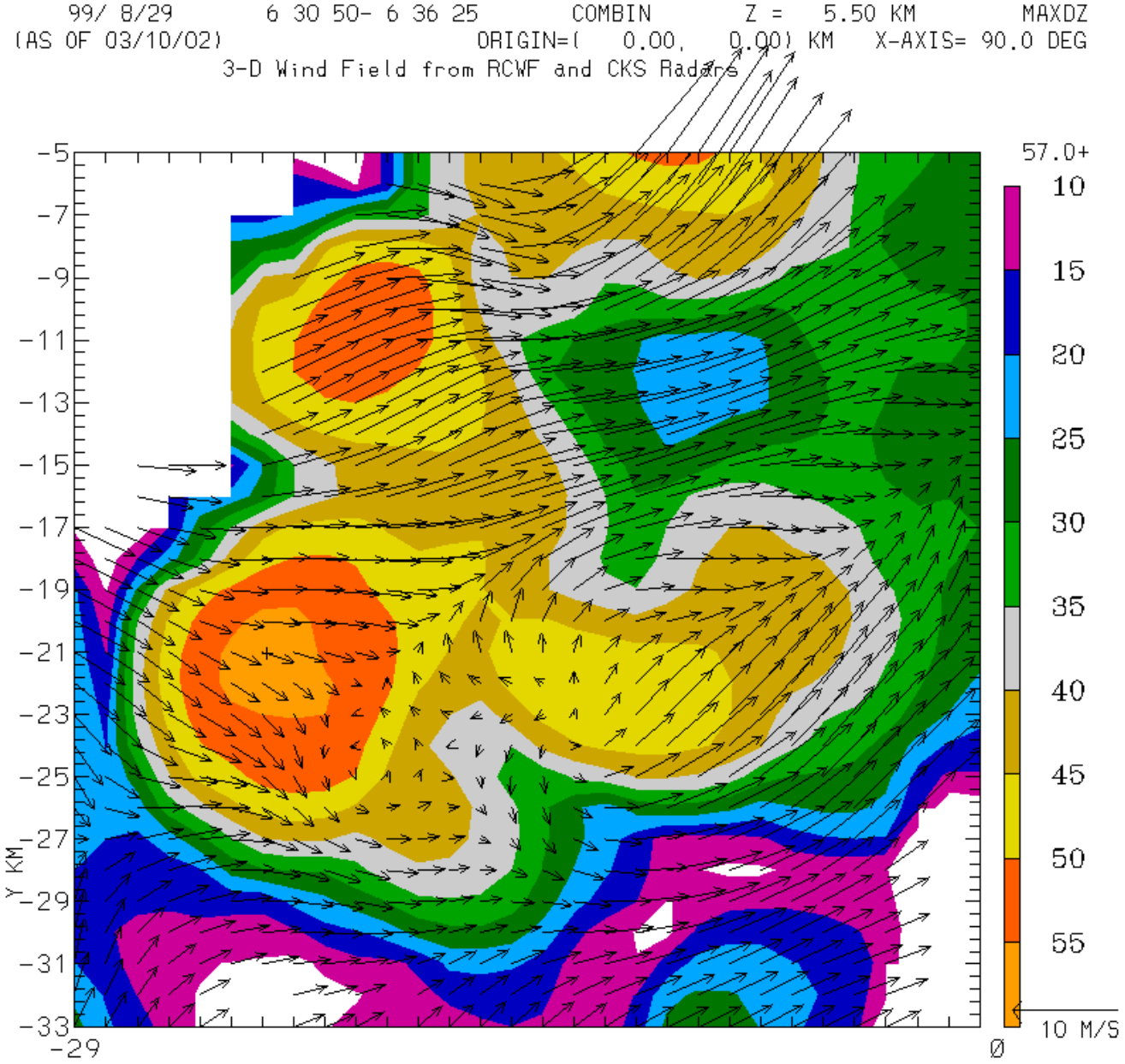


B 雷達



地面雷達雙都卜勒合成風場 (五分山與桃園機場雷達)

(Dual-Doppler-derived wind and precipitation for a severe storm over Taipei)

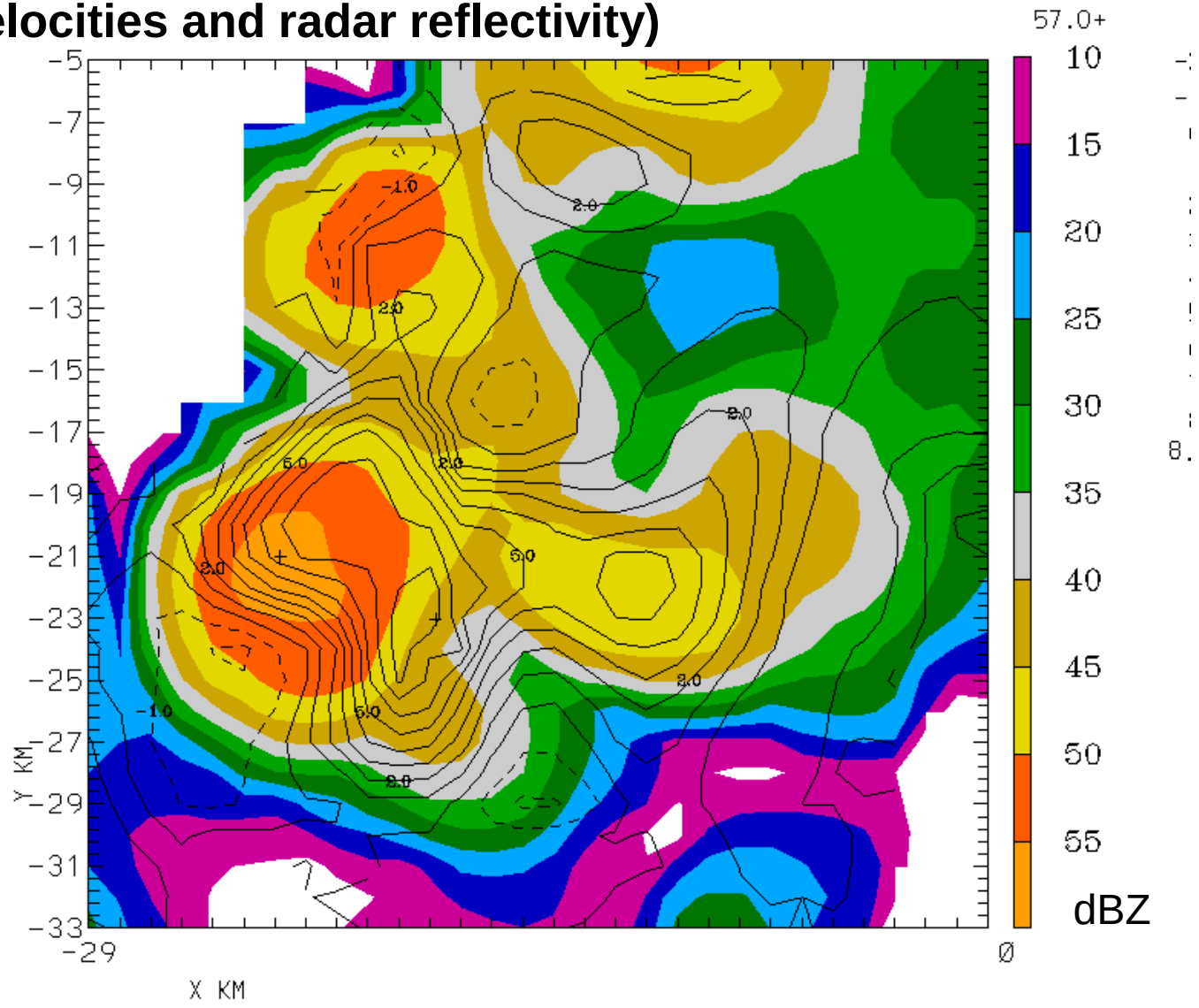


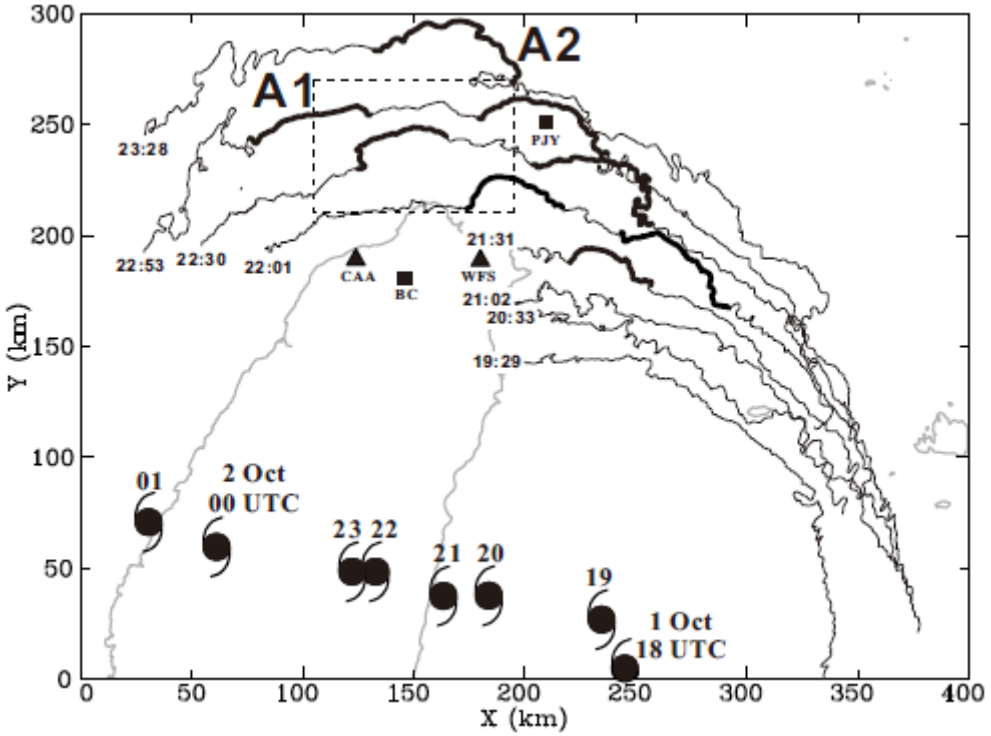
RCWF (0.0,0.0)

CKS (-57.0,-0.3)

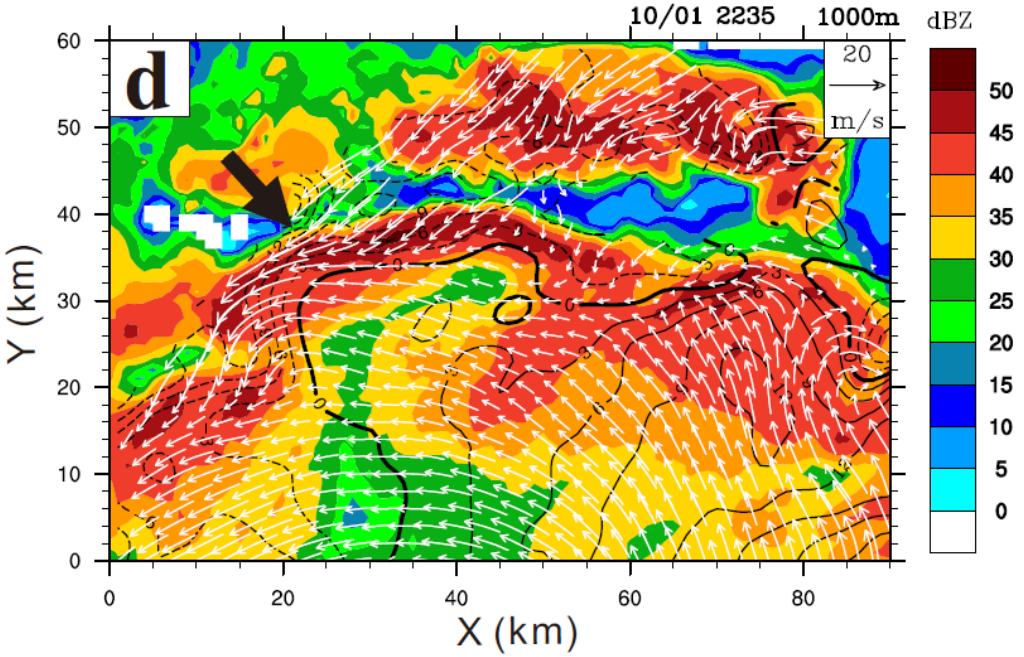
垂直速度場與降水回波

(vertical velocities and radar reflectivity)

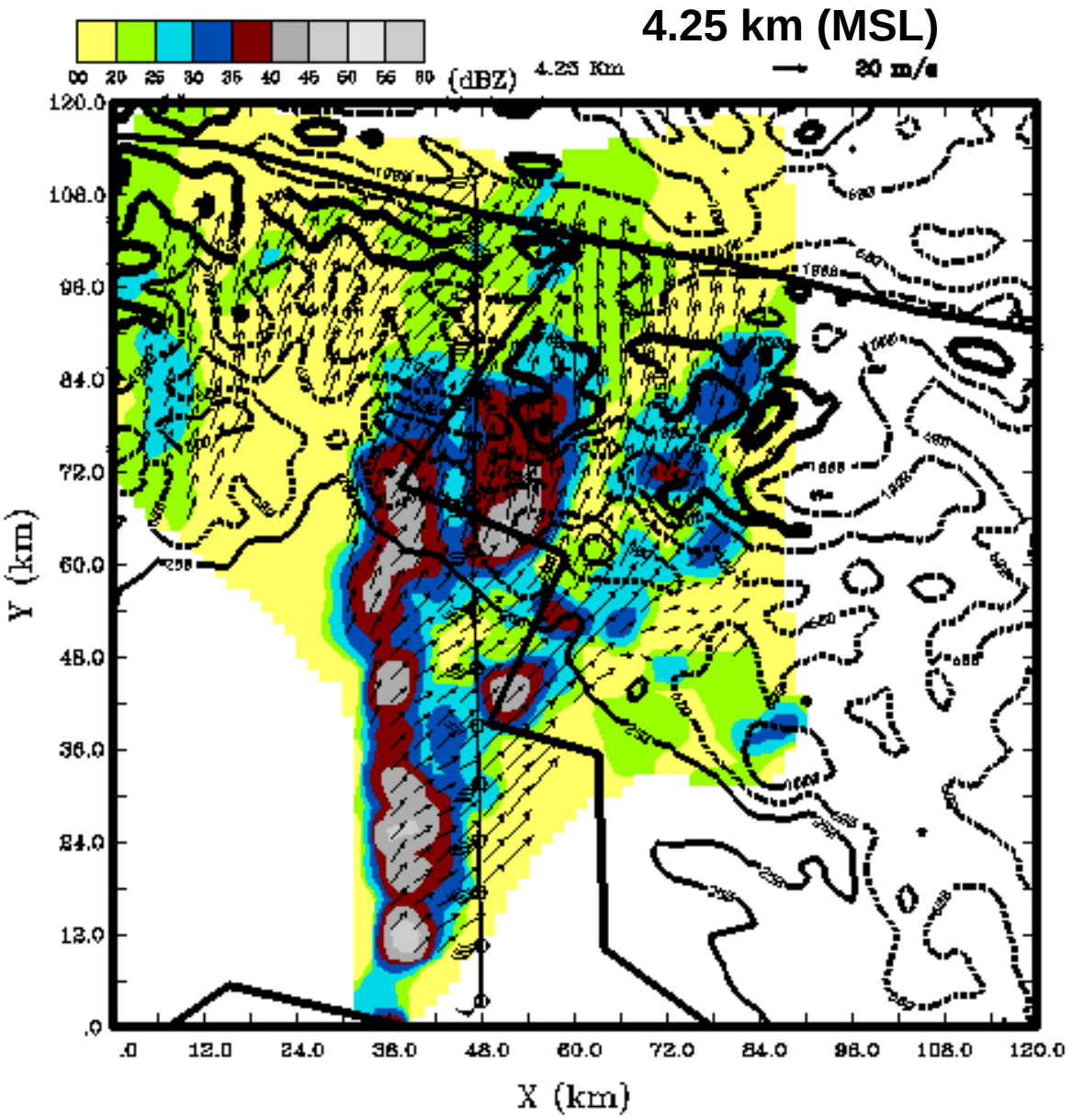




Yu and Tsai (2013, JAS)



Airborne Dual-Doppler Synthesis Horizontal Winds



Ground-based dual-Doppler and polarimetric radar observations in Mesoscale Alpine Programme