Mesoscale boundaries and storm initiation during SoWMEX/TiMREX

Radian Rong-Guang Hsiu[1], Ben Jong-Dao Jou[1], and Wen-Chau Lee[2]

1 Department of Atmospheric Sciences, National Taiwan University, Taiwan

2 National Center for Atmospheric Research, Boulder, Colorado

Nov. 4, 2010

3rd SoWMEX/TiMREX Science workshop

Picture at 16:53 , 5/31/08 on S-POL site

Outlines

- 1. Introduction
- 2. Data and Methodology
- 3. Mesoscale boundaries identified and characteristics
- 4. Case study: 20 June storm initiation

Low level convergence zone and storm initiation

- Byers and Braham (1949): First noted
- Purdom (1982): Satellite
- Wilson and Carbone (1984): Proposed using sensitive Doppler radar

Radar Clear echoes:

- Atlas (1960): refractive index gradients
- Wilson et al.(1994): insects

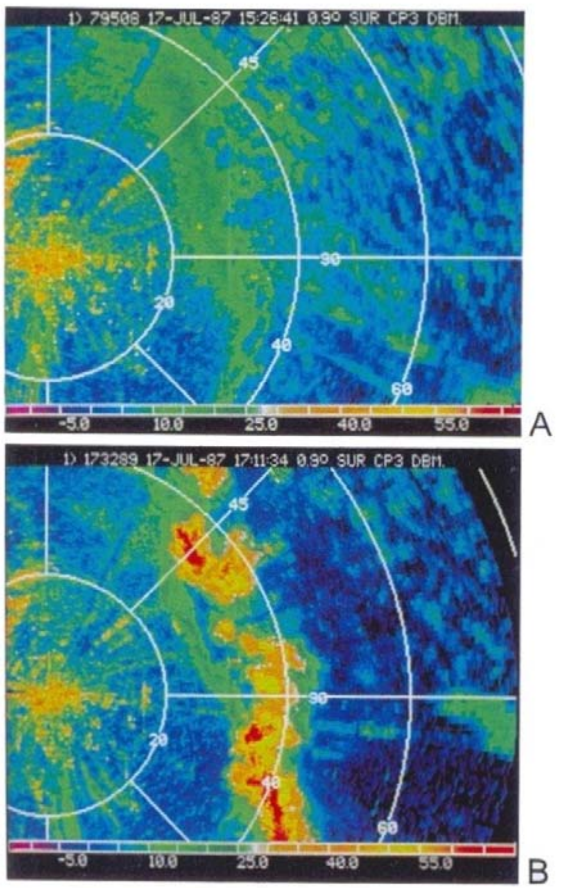
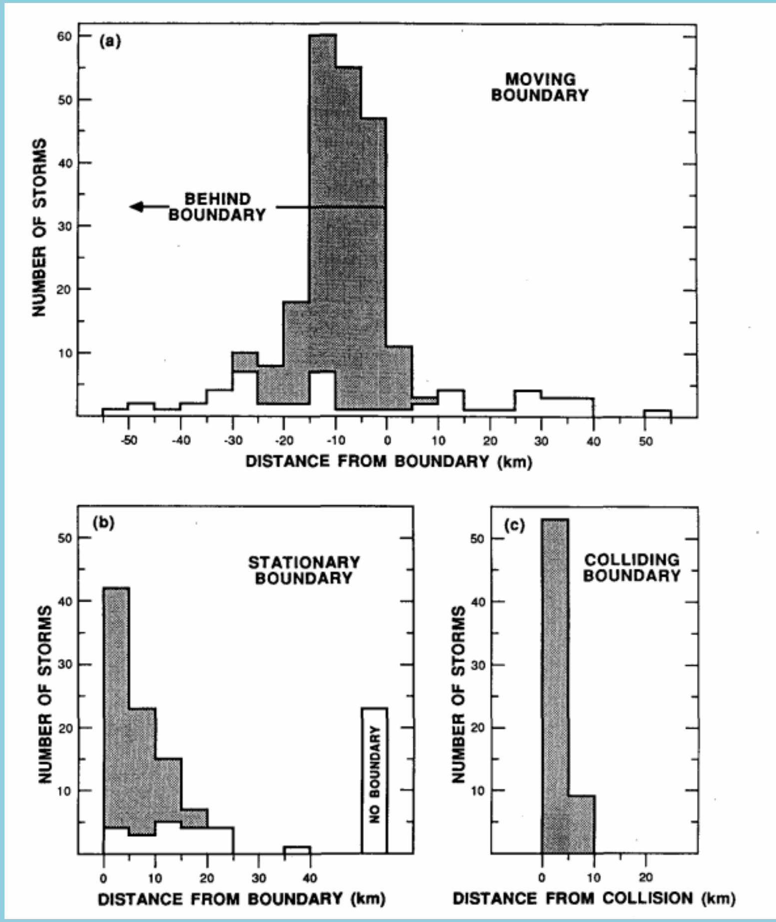


FIG. 4.15. Radar example of convection initiation along a boundary in the Colorado Front Range: (a) low-level reflectivity fine line at 1526 UTC 17 Jul 1987; (b) convection generated along boundary shown in (a) at 1711 UTC on the same day. Figures courtesy of Jim Wilson.

Low level convergence zone and storm initiation

- There is strong evidence that the location of convection initiation is deterministic.
- They found 80% of thunderstorms in the area were initiated close to boundary layer convergence zones.

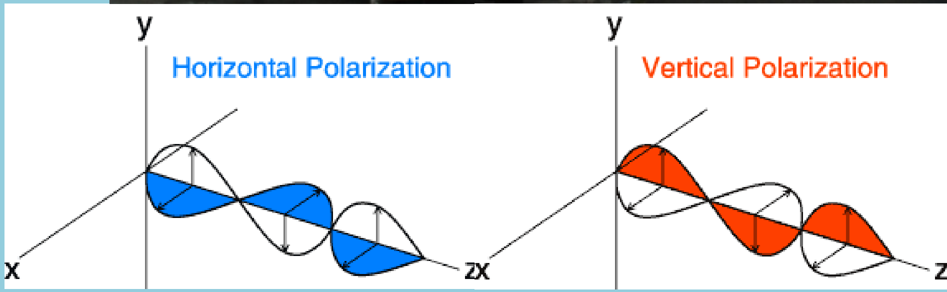
(Wilson and Schreiber 1986)



Shading:
Cases were classified as being boundary initiated

2.Main Tool: S-Pol Radar(NCAR)

- NSF funded
- S-band dual polarization Doppler radar
- Highly mobile (fits in 6 sea containers)
- Antenna diameter 8.5 m
- Beam width 0.91 deg
- Range resolution 150 m
- Wavelength 10 cm

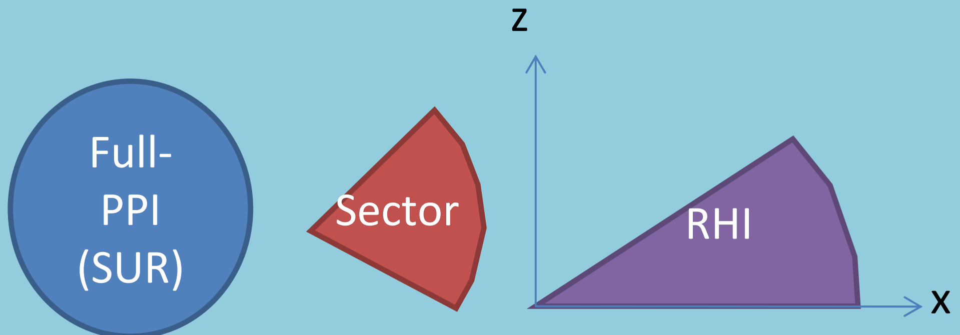


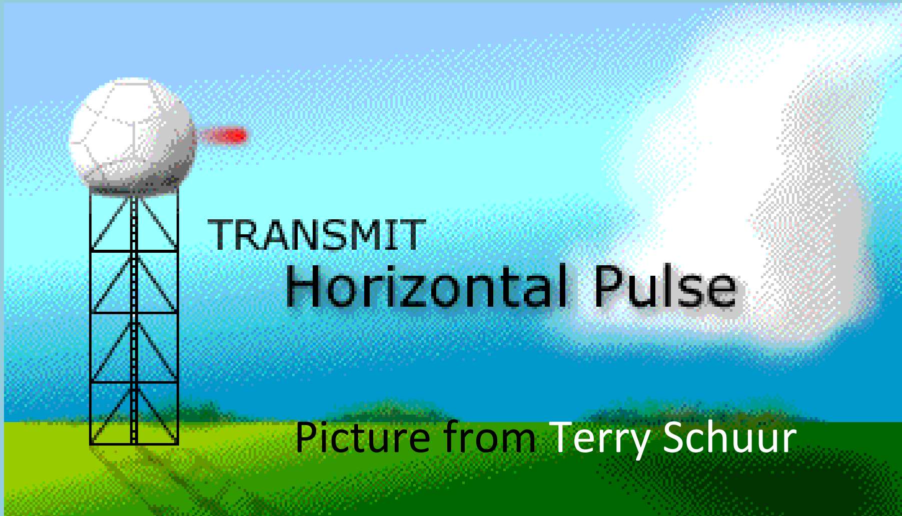
Strong point:

1.Sensitivity

2.Adopt CMD Filter, using fuzzy logic
   to remove most ground clutter

Scanning types:





Picture from Terry Schuur

Survey tool: S-pol enhanced echo graphs

elevation
1.1 °, 1.5°

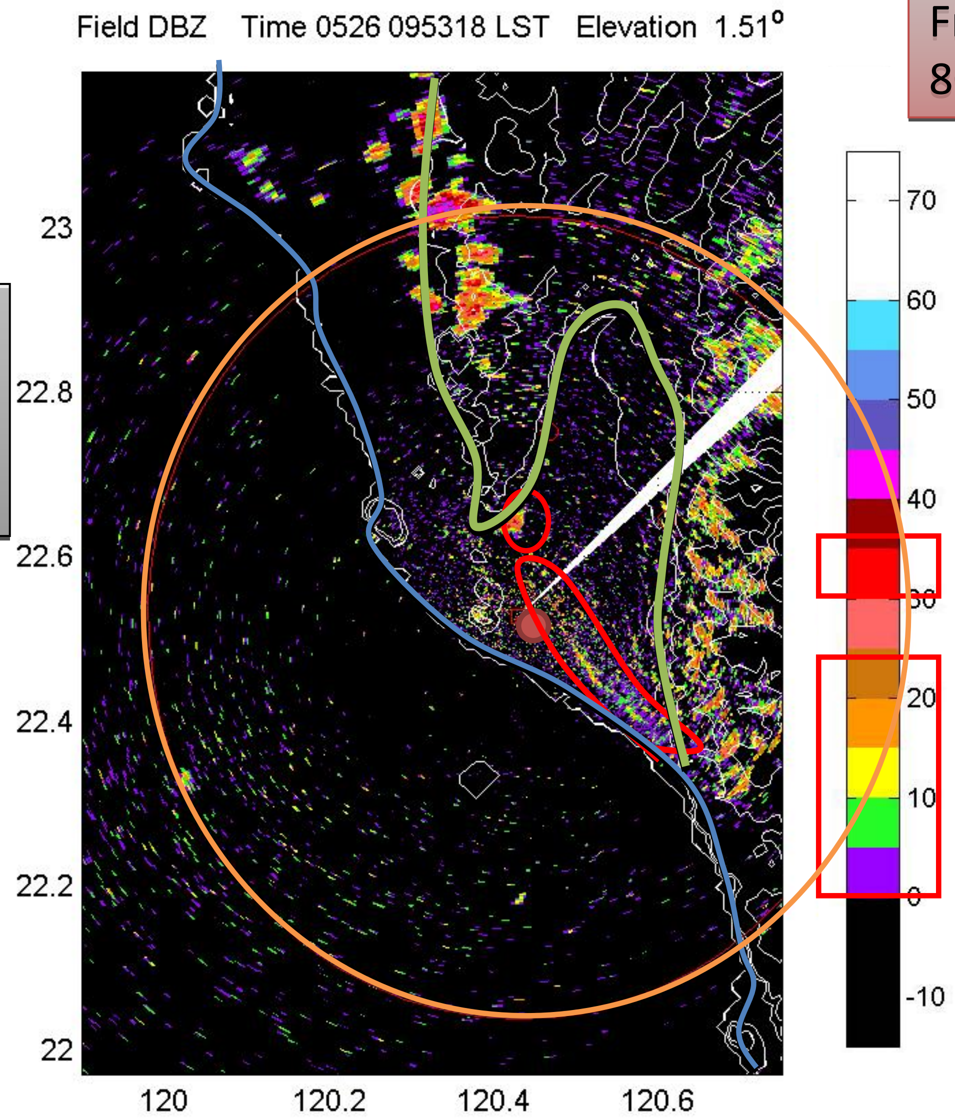
50km range

White line:
Elevation-
0,50,100,
200,500,1000m

Coastal line

Hill & Foothill

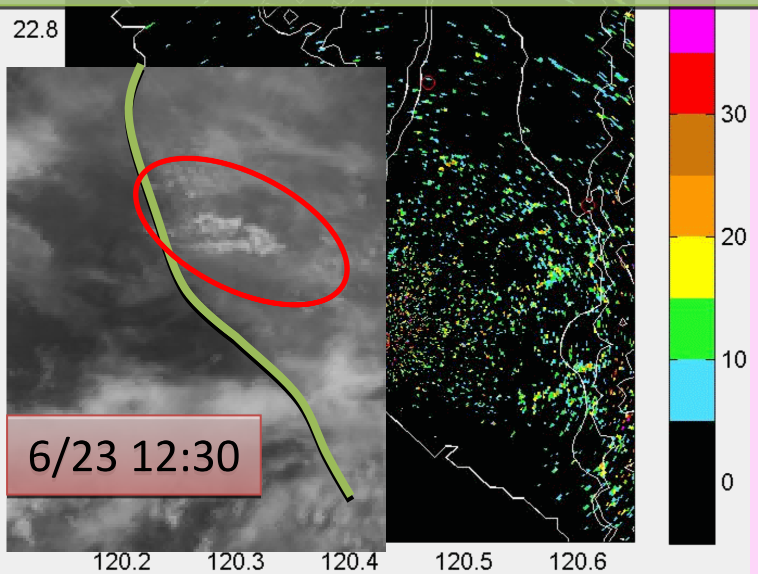
From 5/15~6/30
8078 graphs



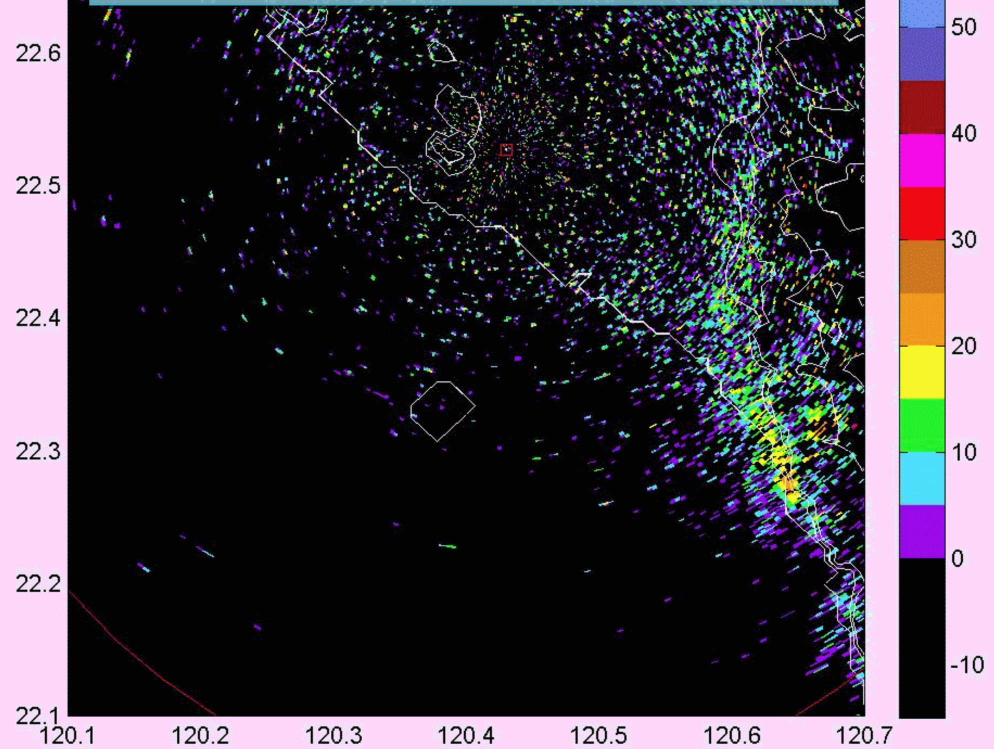
3. Mesoscale boundaries and storm initiation

Onshore and offshore boundaries during the clear day

- Weak echo line form near and parallel to the shore.
- Form in the morning.
- Form on land and move onshore.
- When precipitation echo(>30 dBZ) propagated to the shore, then the weak echo line form→**Unknown overland**

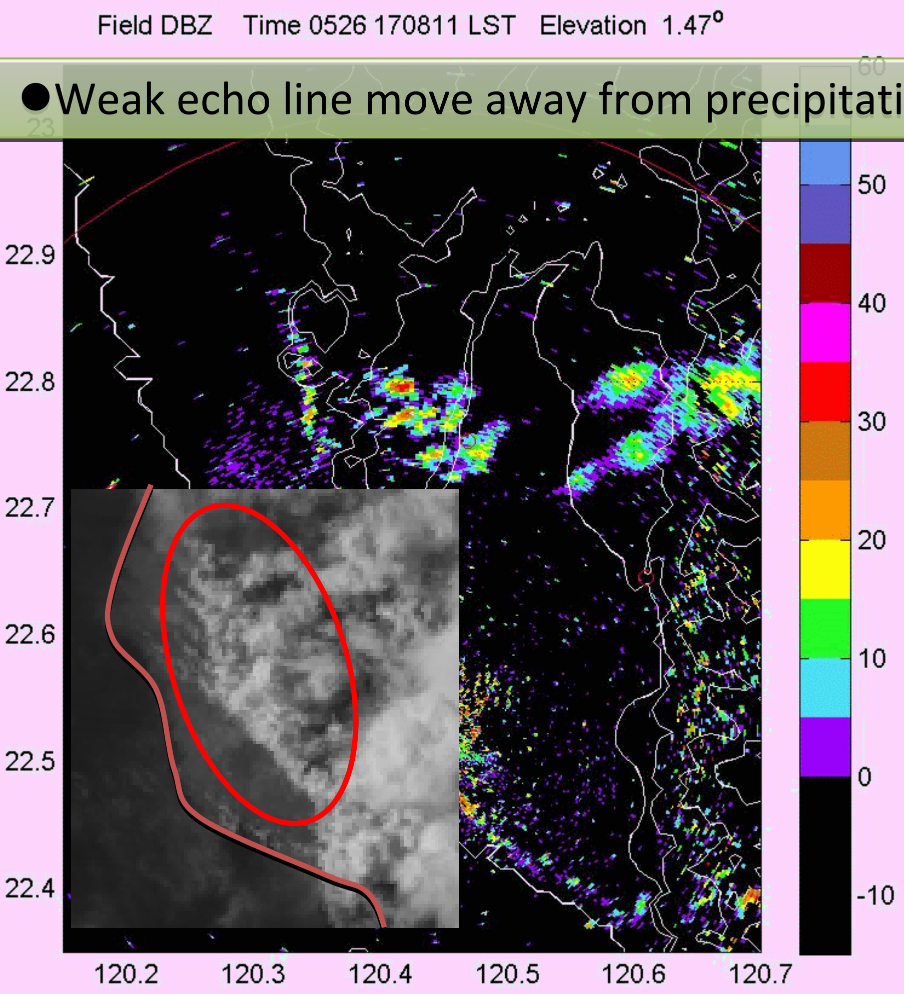


- Weak echo line form near and parallel to the shore.
- Form at nighttime.
- Form over sea and move offshore.

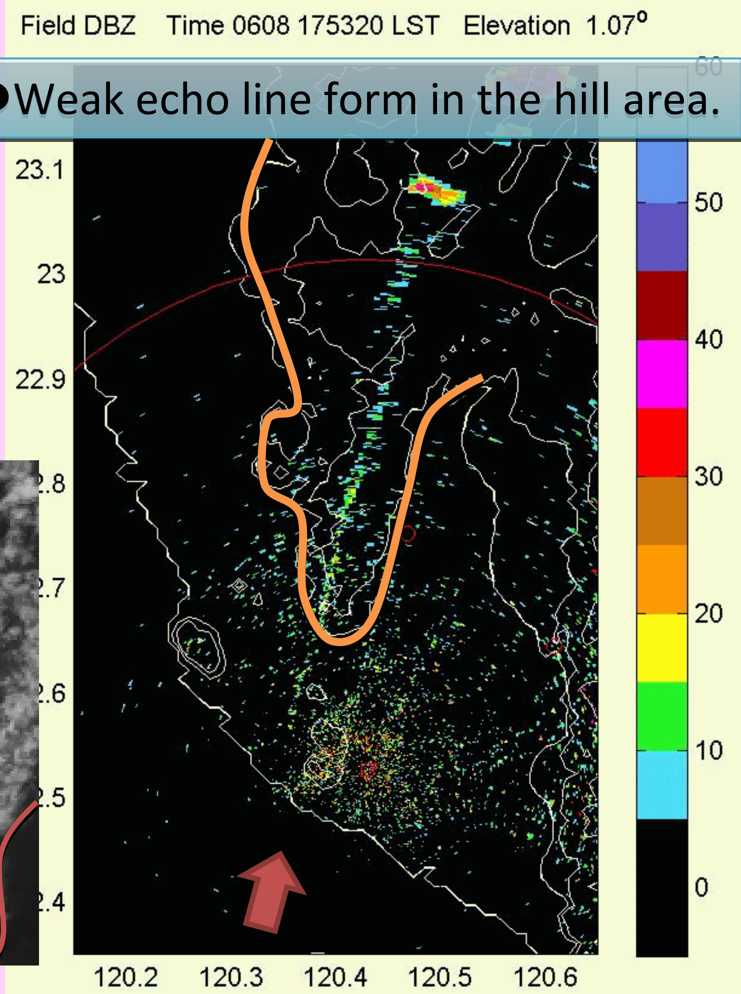


Storm outflow boundaries vs convergence line over hill

●Weak echo line move away from precipitation echo.

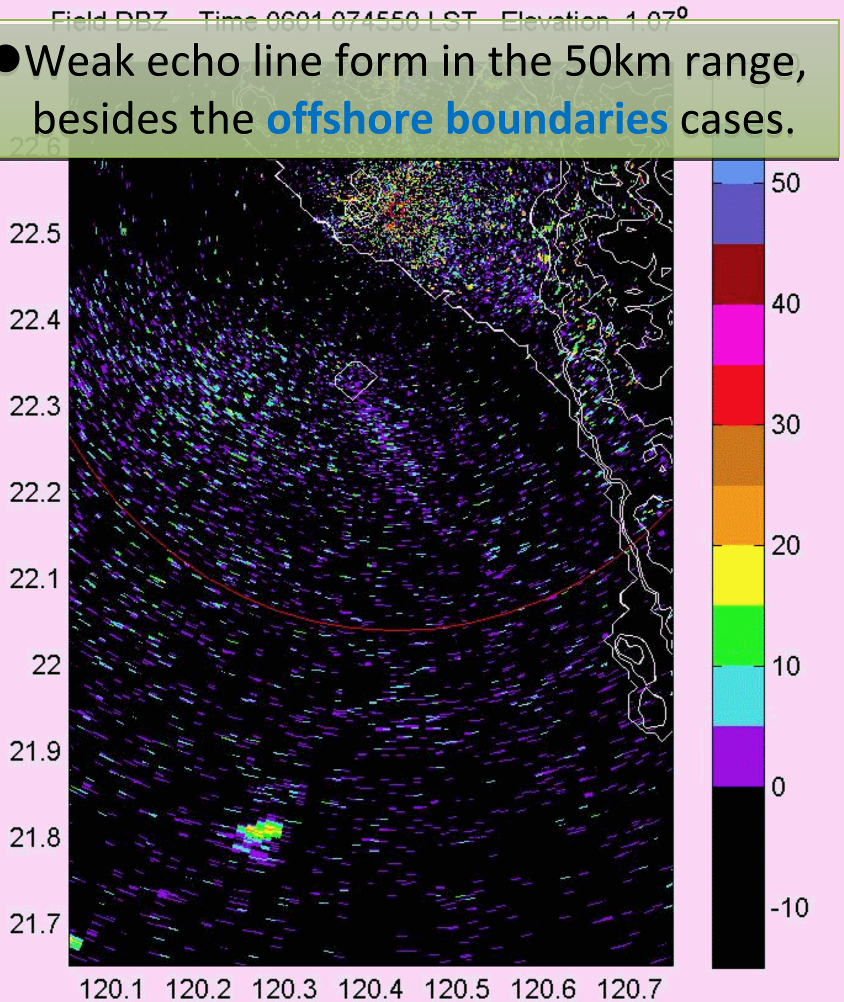


●Weak echo line form in the hill area.

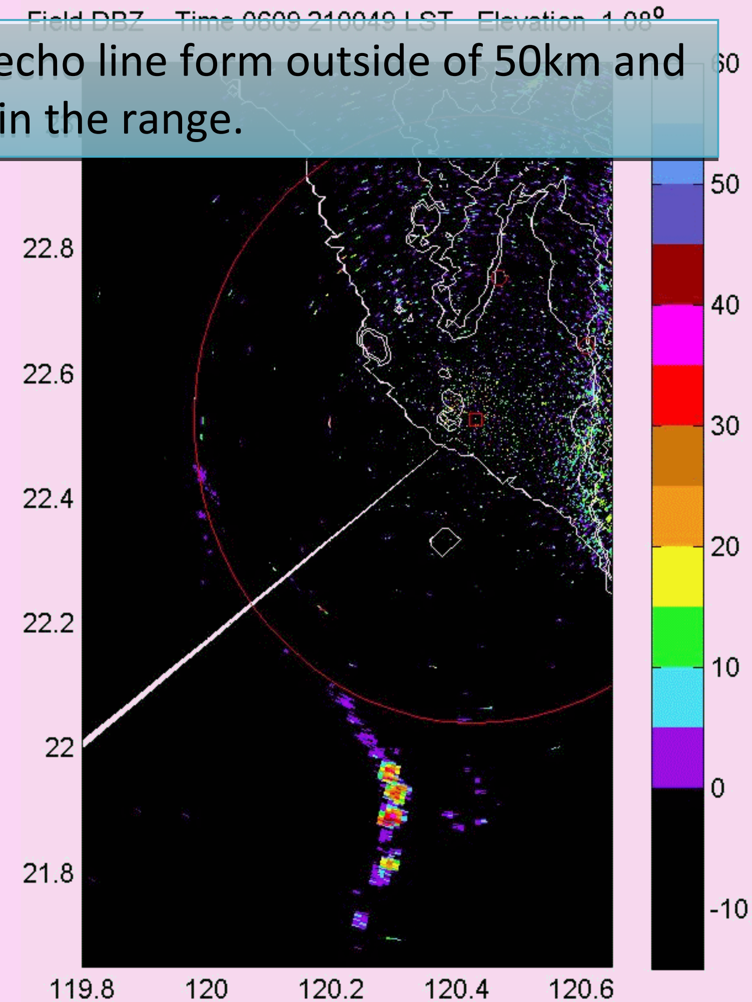


Weak echo lines over sea: local vs remote

- Weak echo line form in the 50km range, besides the **offshore boundaries** cases.



- Weak echo line form outside of 50km and move in the range.



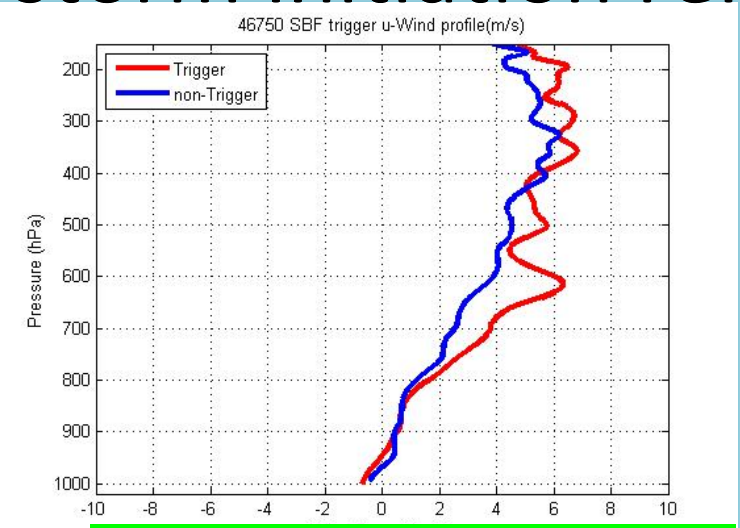
Features of Mesoscale Boundaries during SoWMEX/TiMREX

Classification	Case number	Averaged lifetime (hh:mm)	Storm initiation in %	Time of occurrence Day : Night
Onshore boundaries	26	04:30	38	day
Offshore boundaries	7	02:02	0	night
Storm outflow Boundaries	24	01:45	75	18:6
Weak echo lines over hill	9	02:52	78	day
Weak echo lines over sea-remote	27	04:15	85	12:13 (2 cases across both night to day)
Weak echo lines over sea-local	23	03:05	48	1:22
Unknown overland	30	01:55	30	23:7
Total	146	02:52	54	89:57

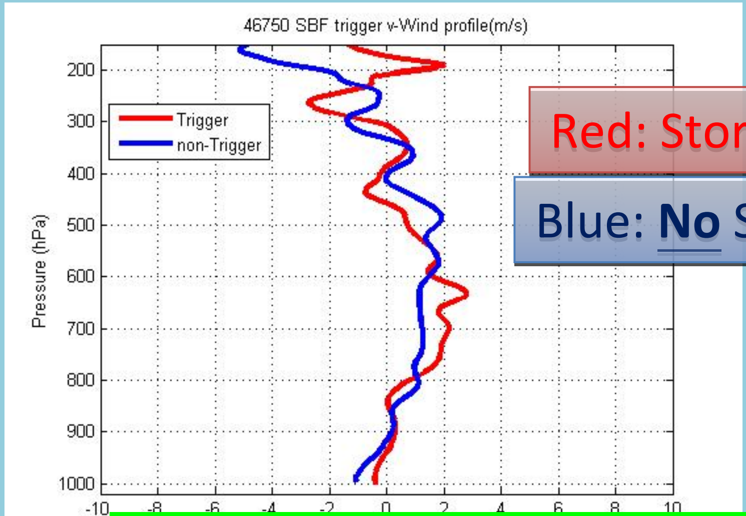
Composite sounding at 08:00 for Yes v.s. No storm initiation related to onshore boundaries

Red: Storm Initiation

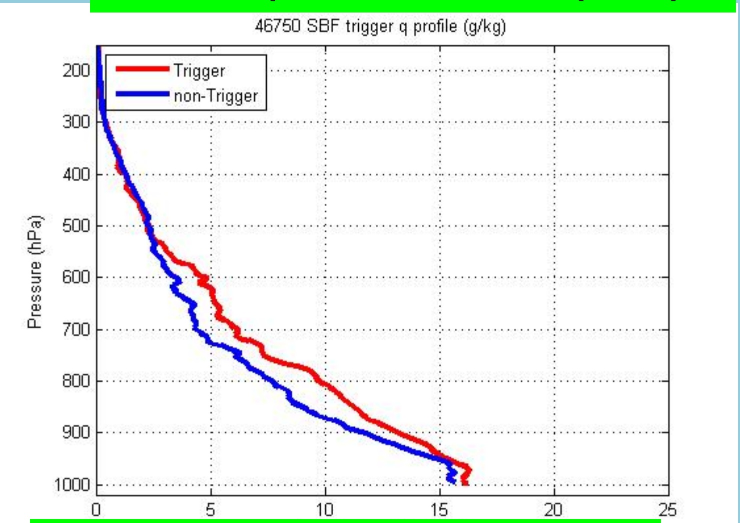
Blue: **No** Storm Initiation



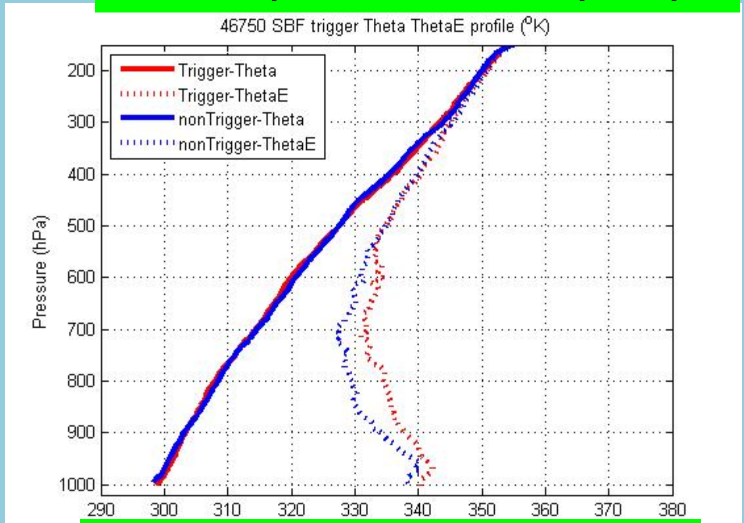
U-component Wind(m/s)



V-component Wind(m/s)

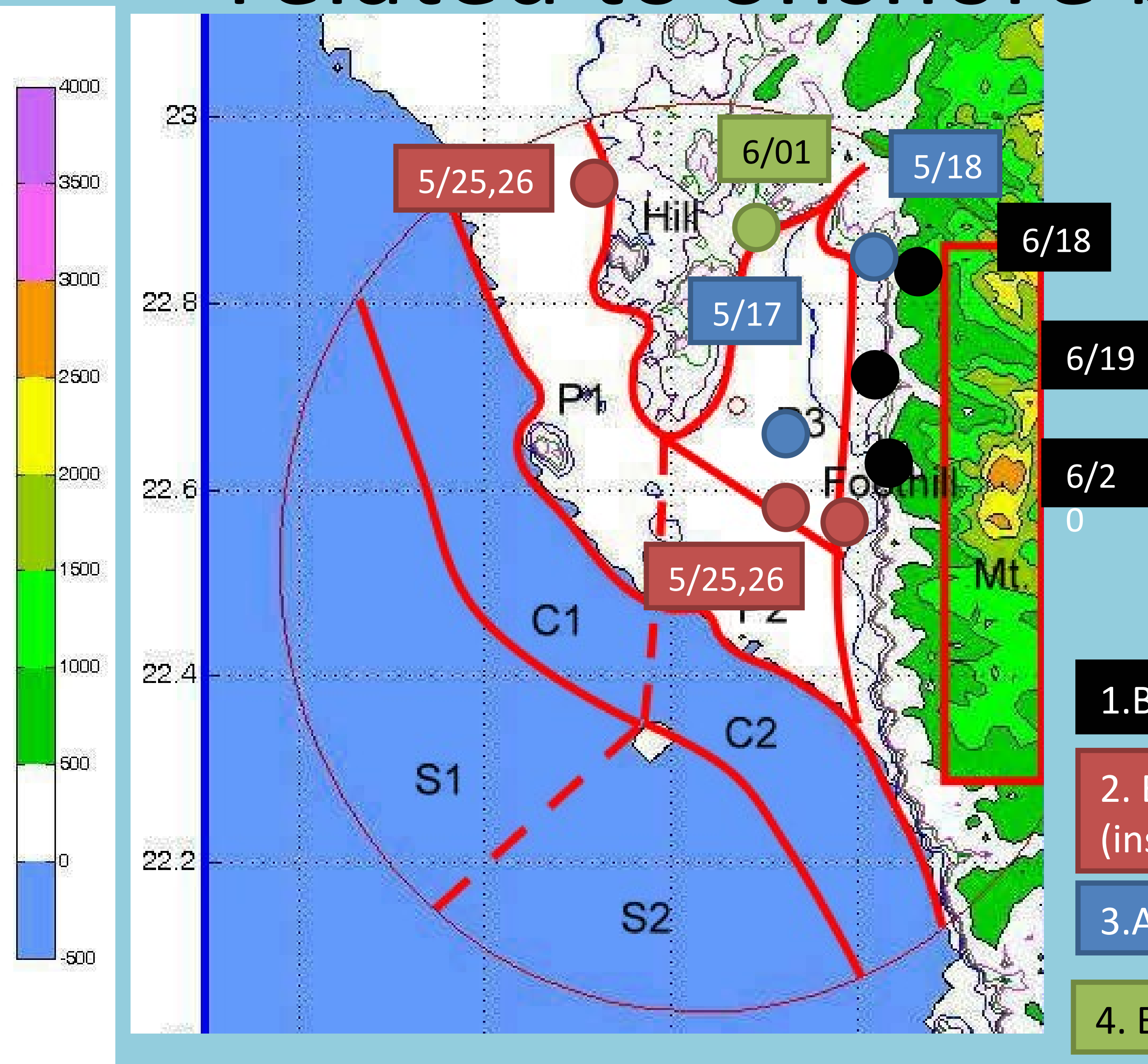


Specific Humidity(g/kg)



Theta, ThetaE(° K)

First echo of storm initiation related to onshore boundaries



1.Boundary goes into mountain.

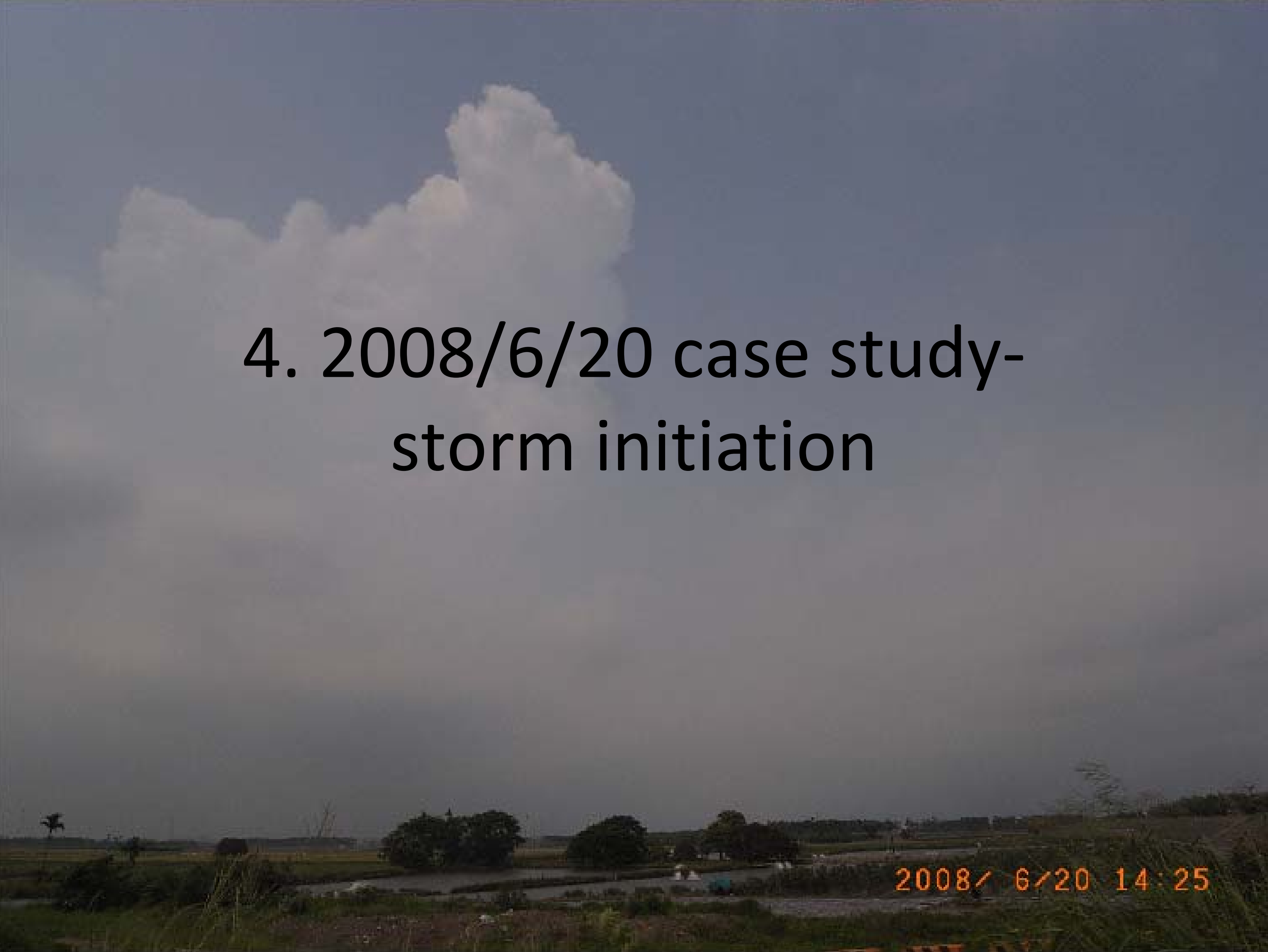
2. Boundary trigger storm when coming.
(instability– front system)

3.After boundary make a con. line.

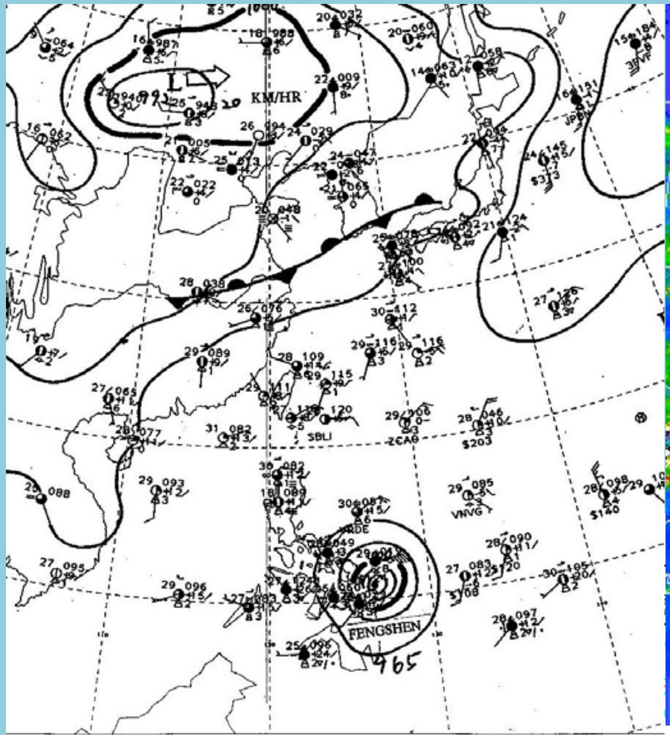
4. Boundary collide hill stationary line, stay the

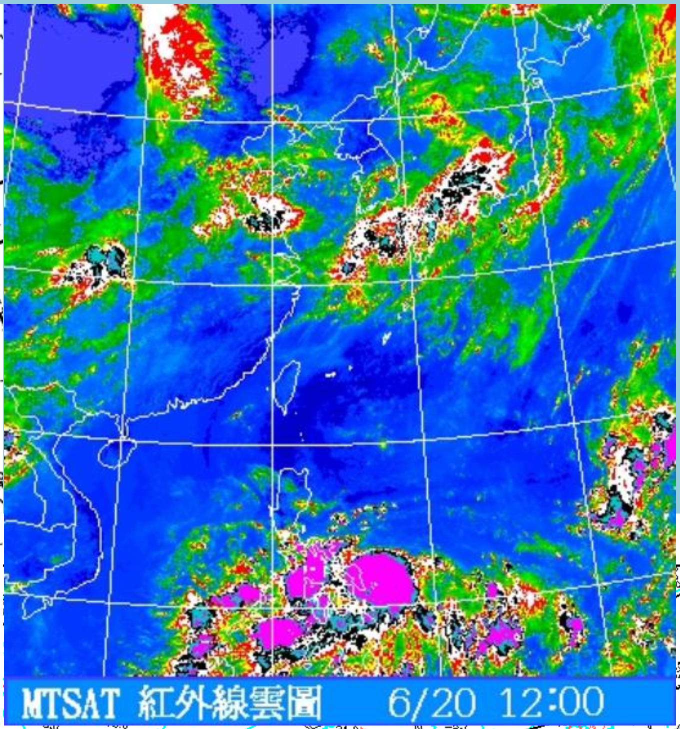
It seems the location of storm initiations related SBFs rel

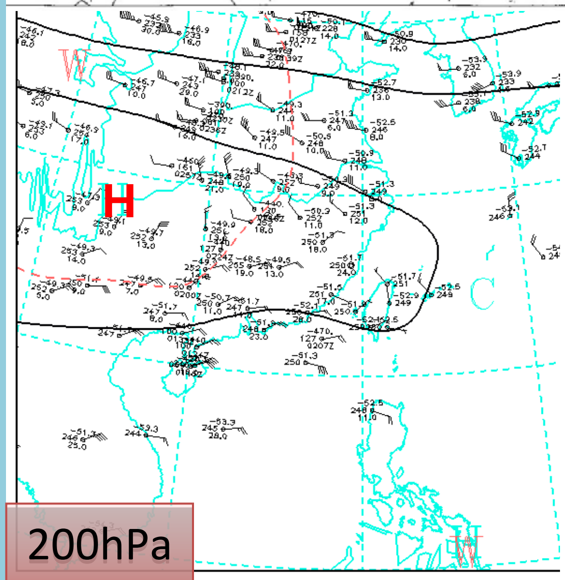
4. 2008/6/20 case study- storm initiation

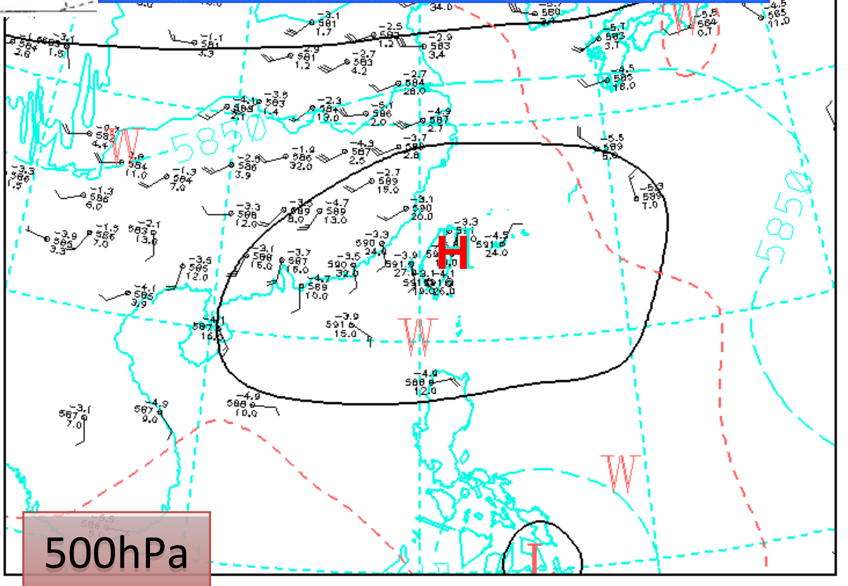


06/20 synoptic environment

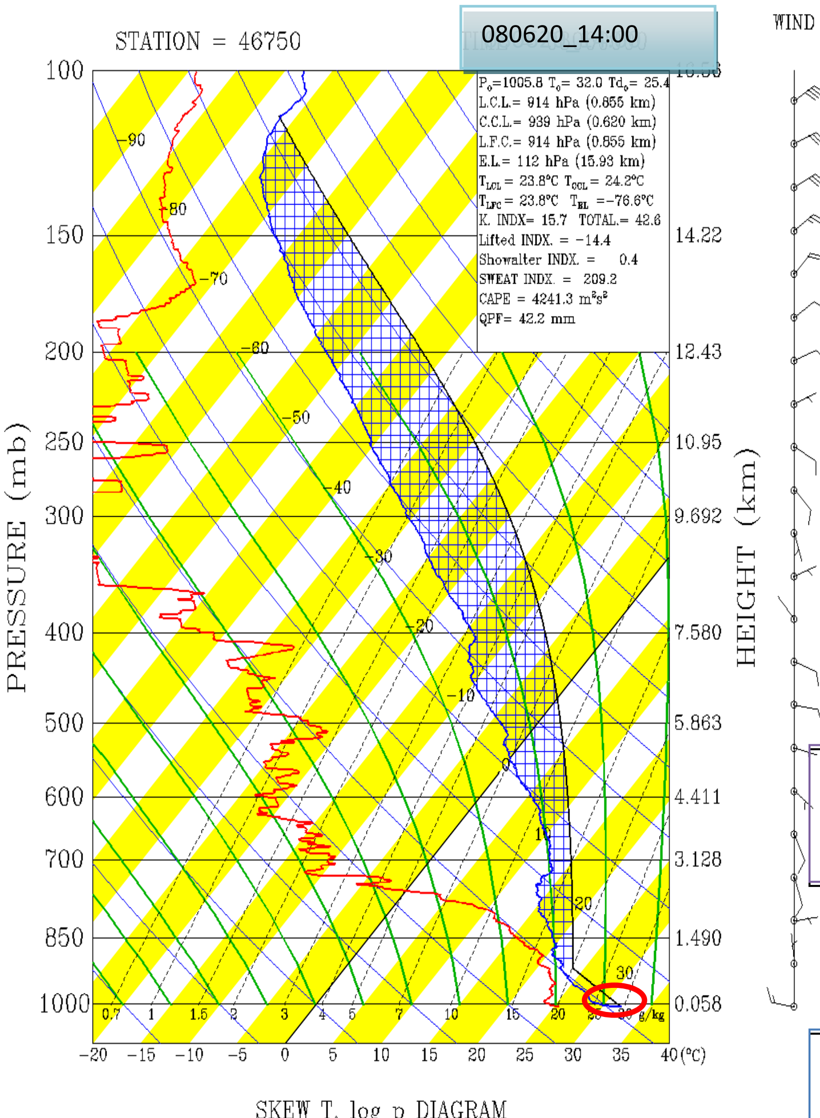


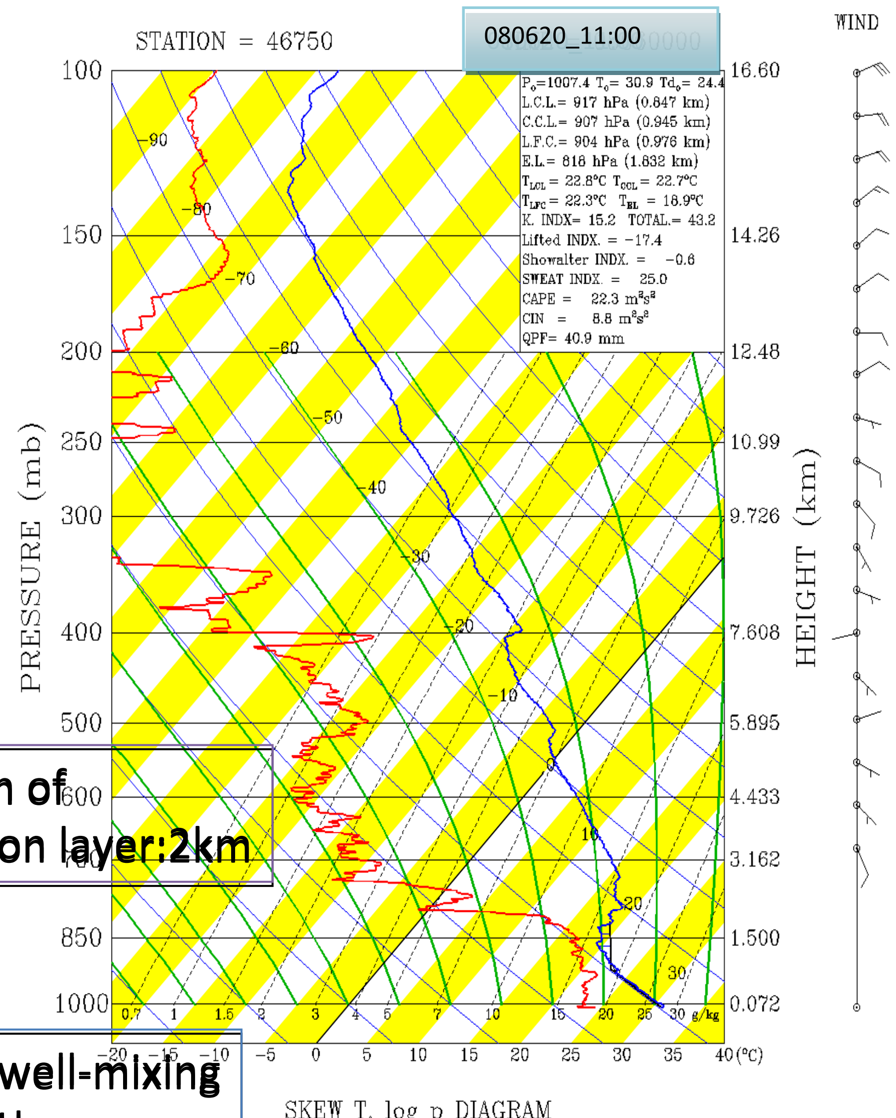






Pingtung Sounding

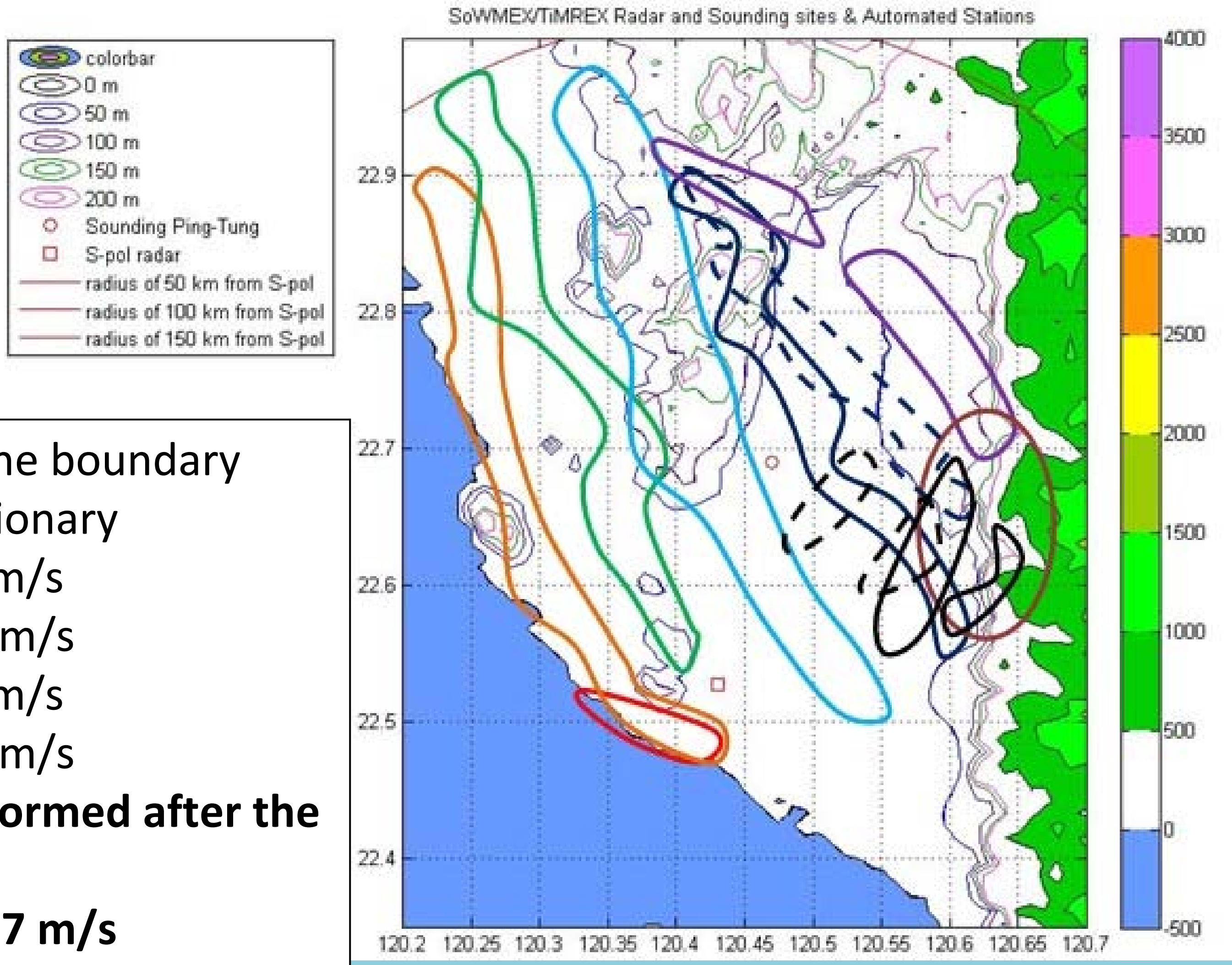




Bottom of inversion layer:2km

top of well-mixing layer:1km

6/20 Sea breeze front movement



Speed of the boundary
08-09:Stationary
09-10:1.6 m/s
10-11: 2.2 m/s
11-12: 2.8m/s
12-13: 3.0 m/s
The echo formed after the boundary
12.5-13: 4.7 m/s

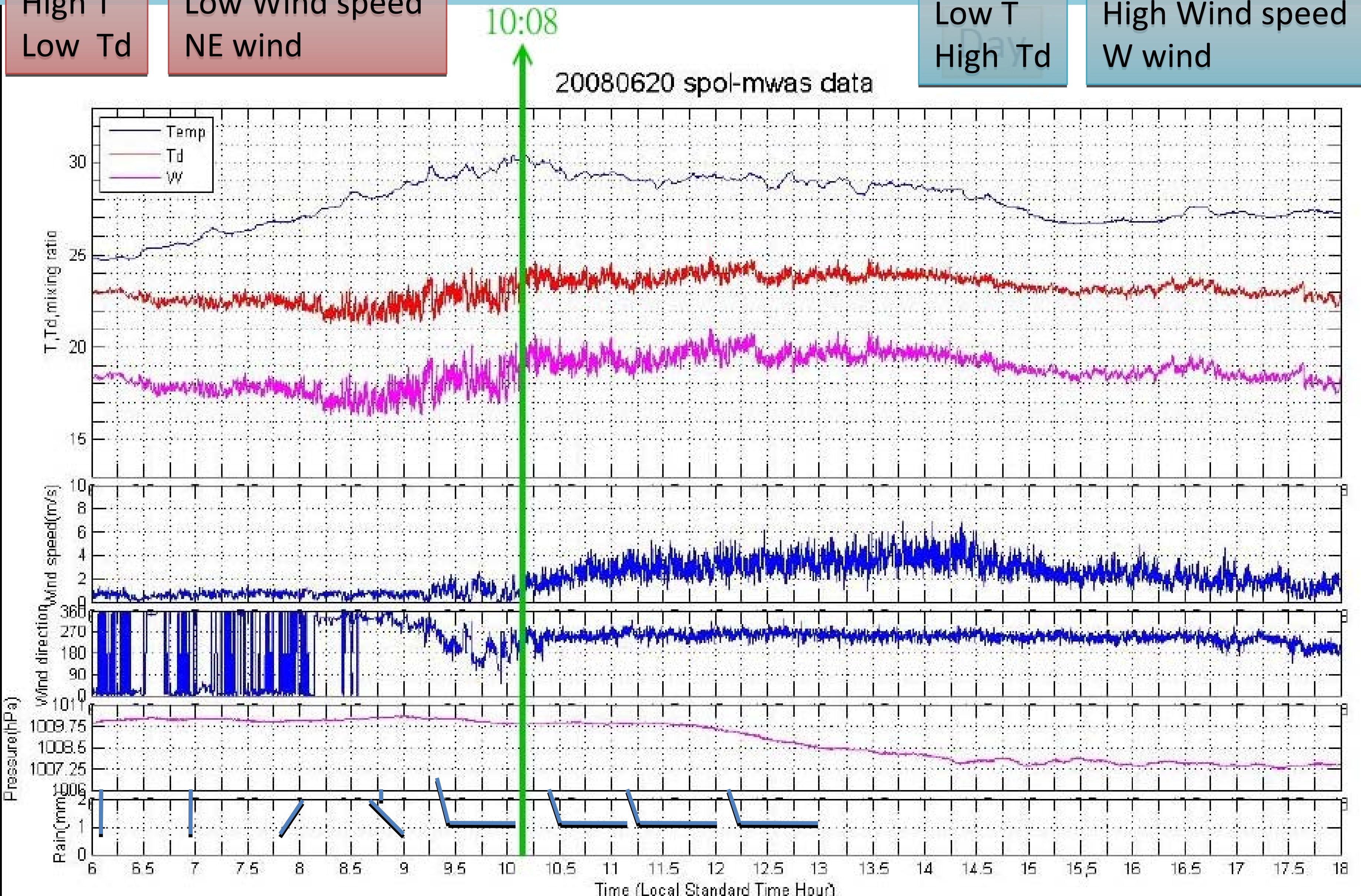
S-POL station surface data(per 10 sec.)

High T
Low Td

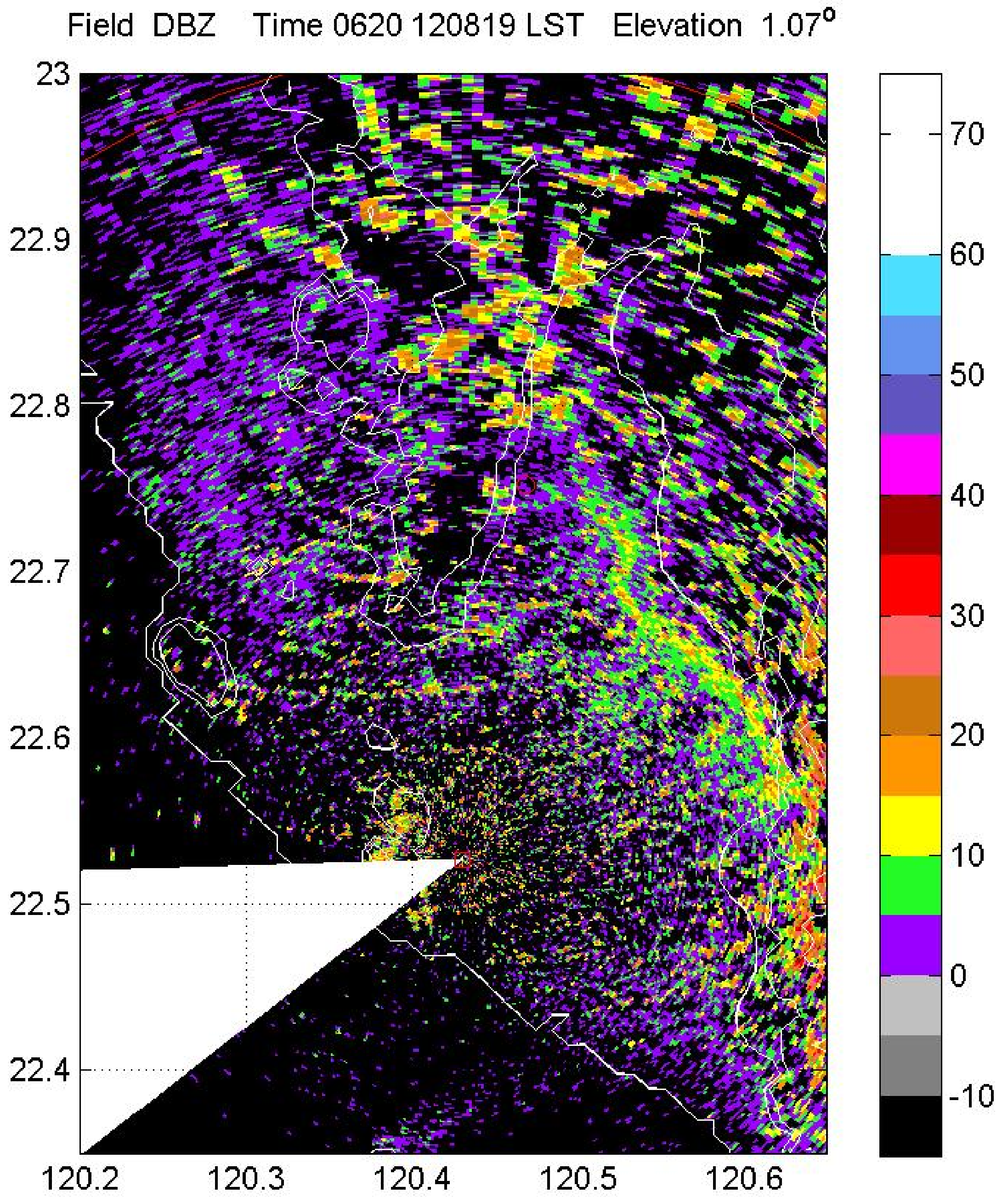
Low Wind speed
NE wind

Low T
High Td

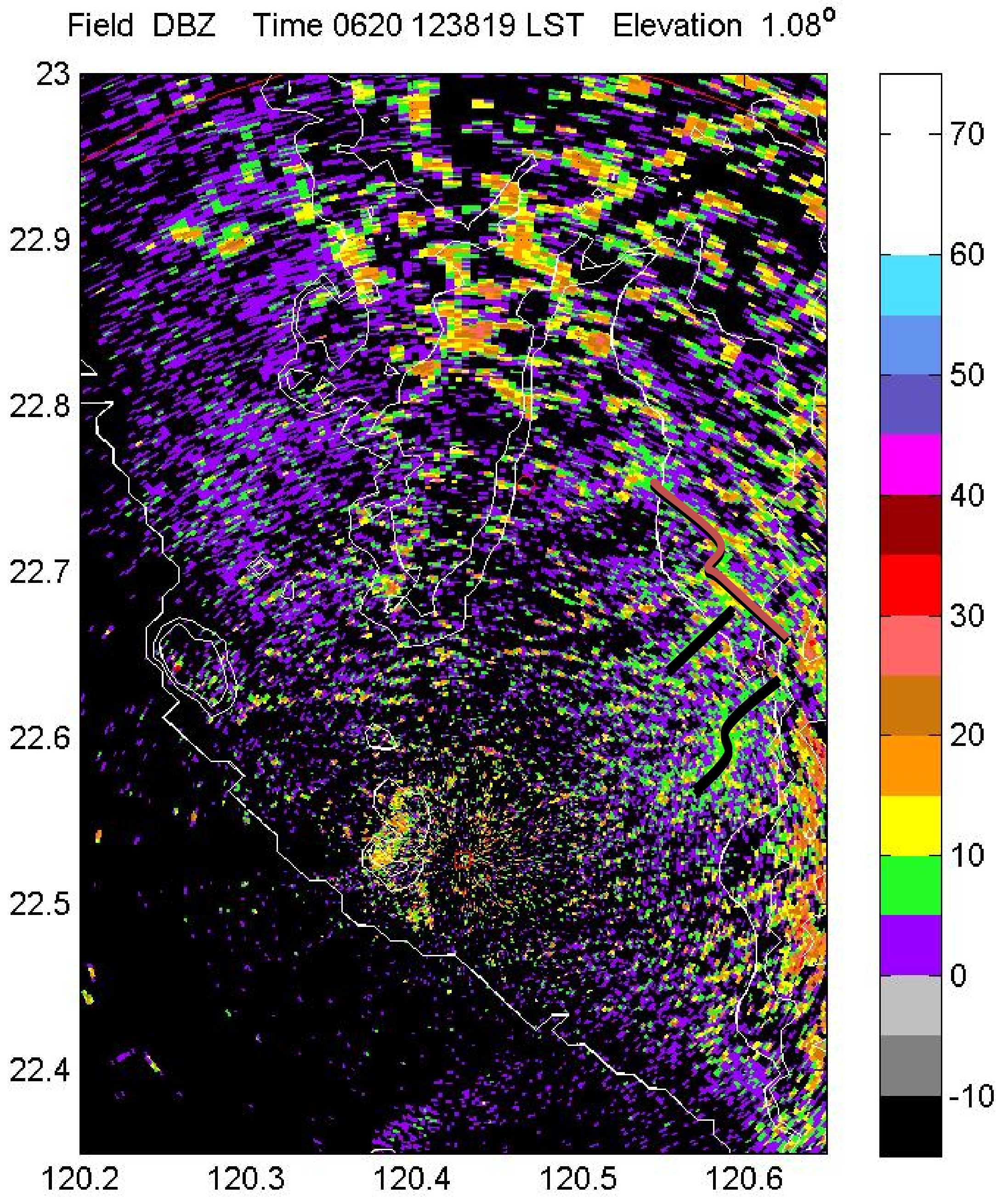
High Wind speed
W wind



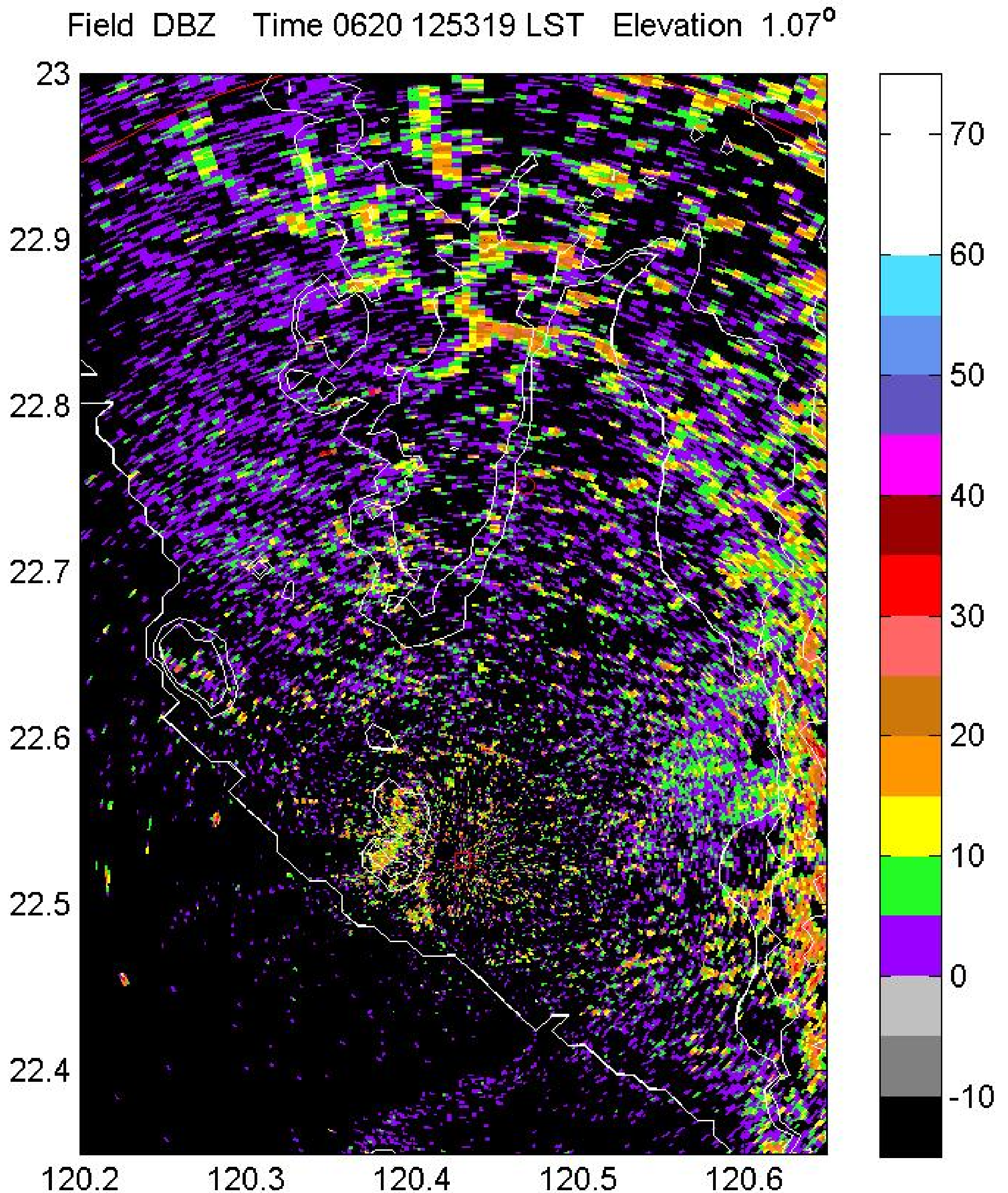
12:08 LST reflectivity



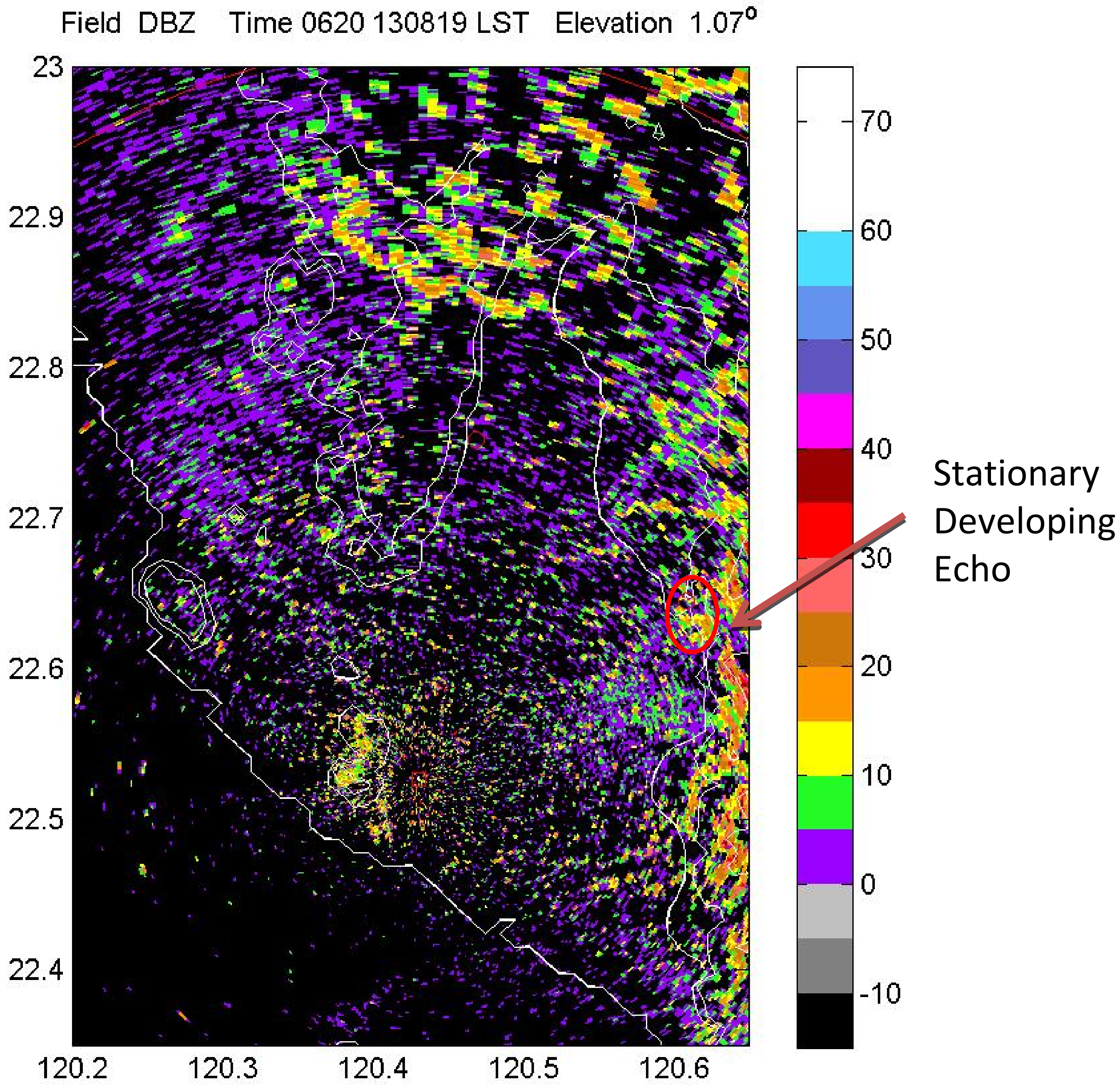
12:38 LST reflectivity



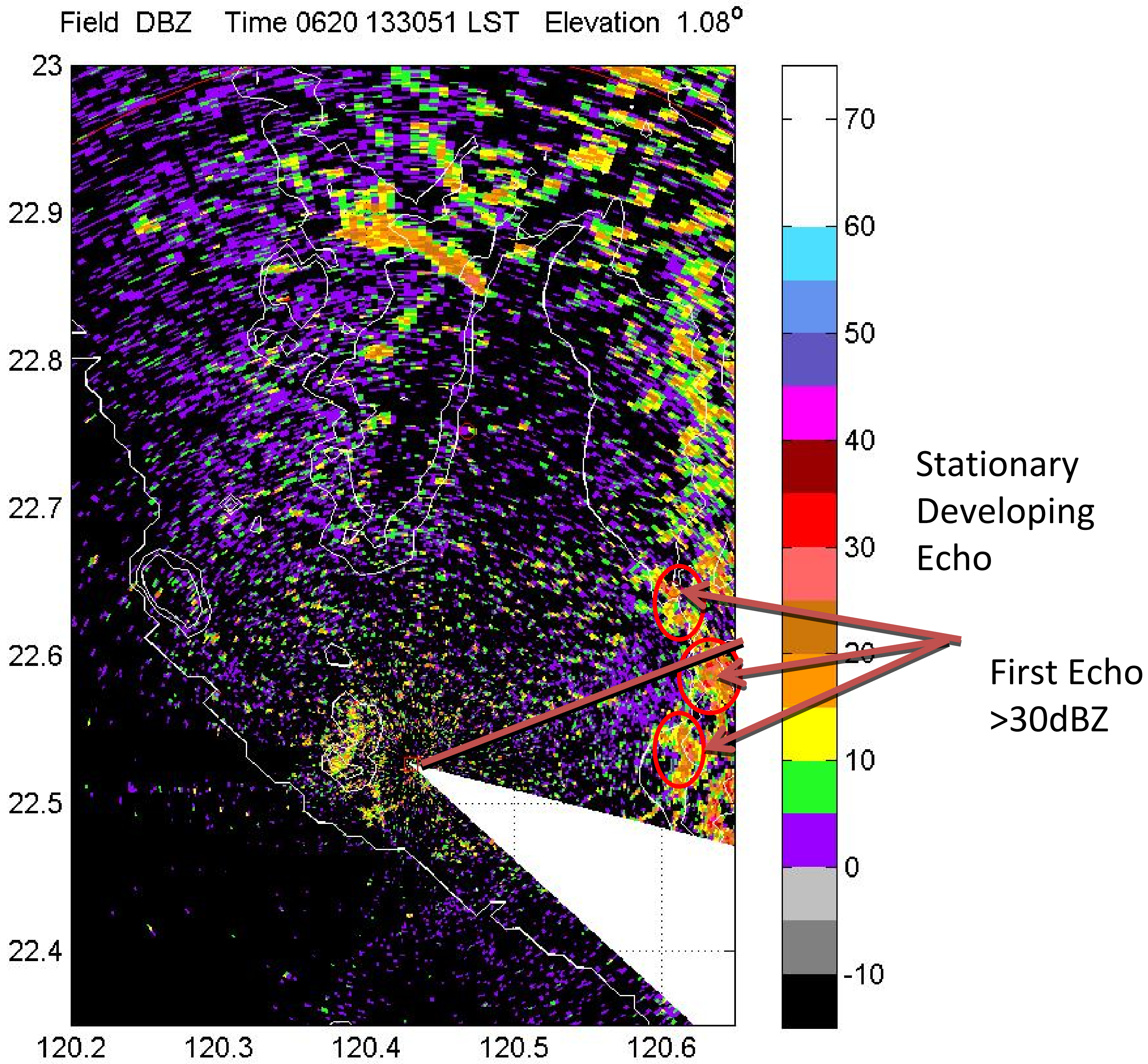
12:53 LST reflectivity

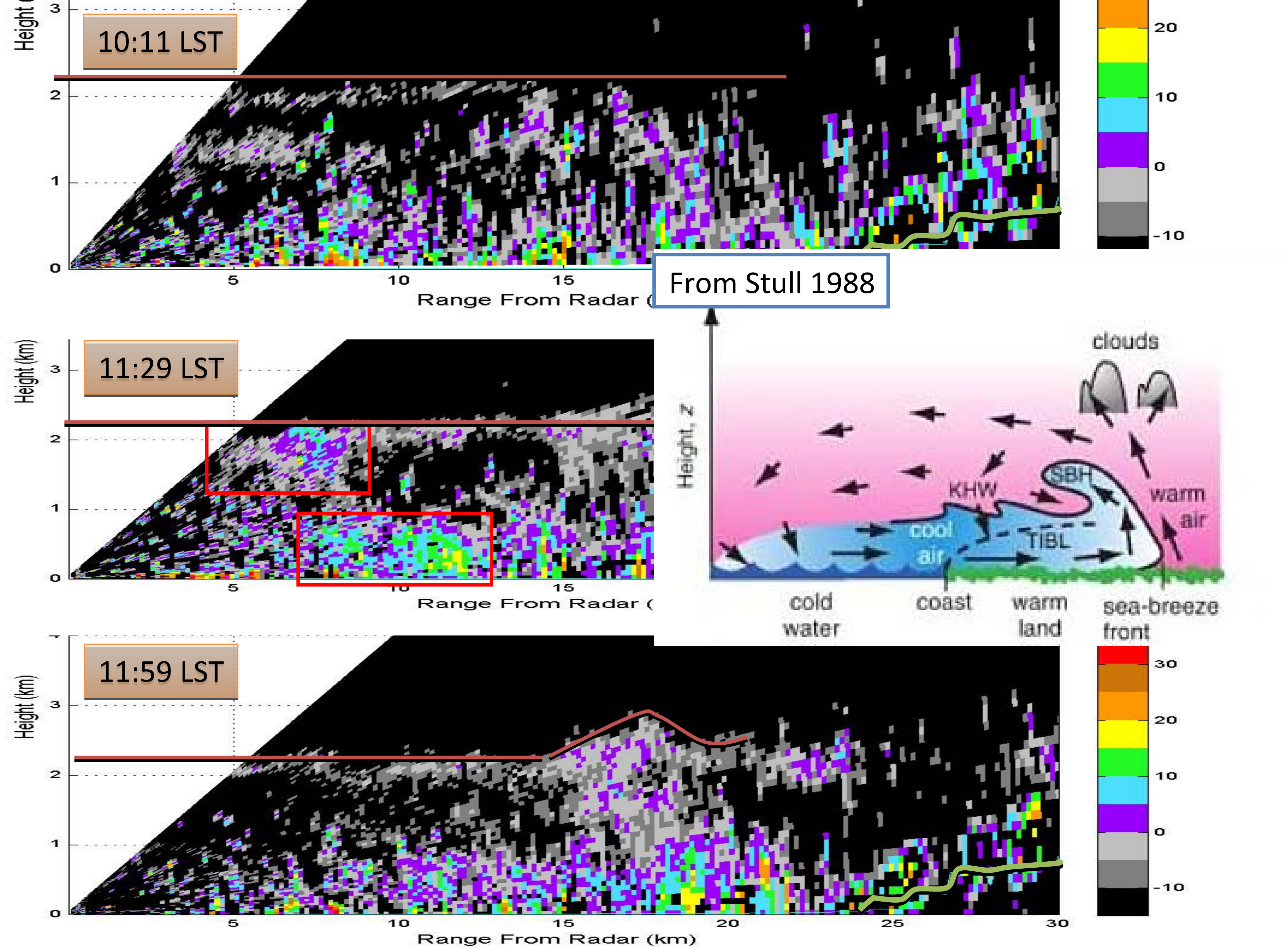


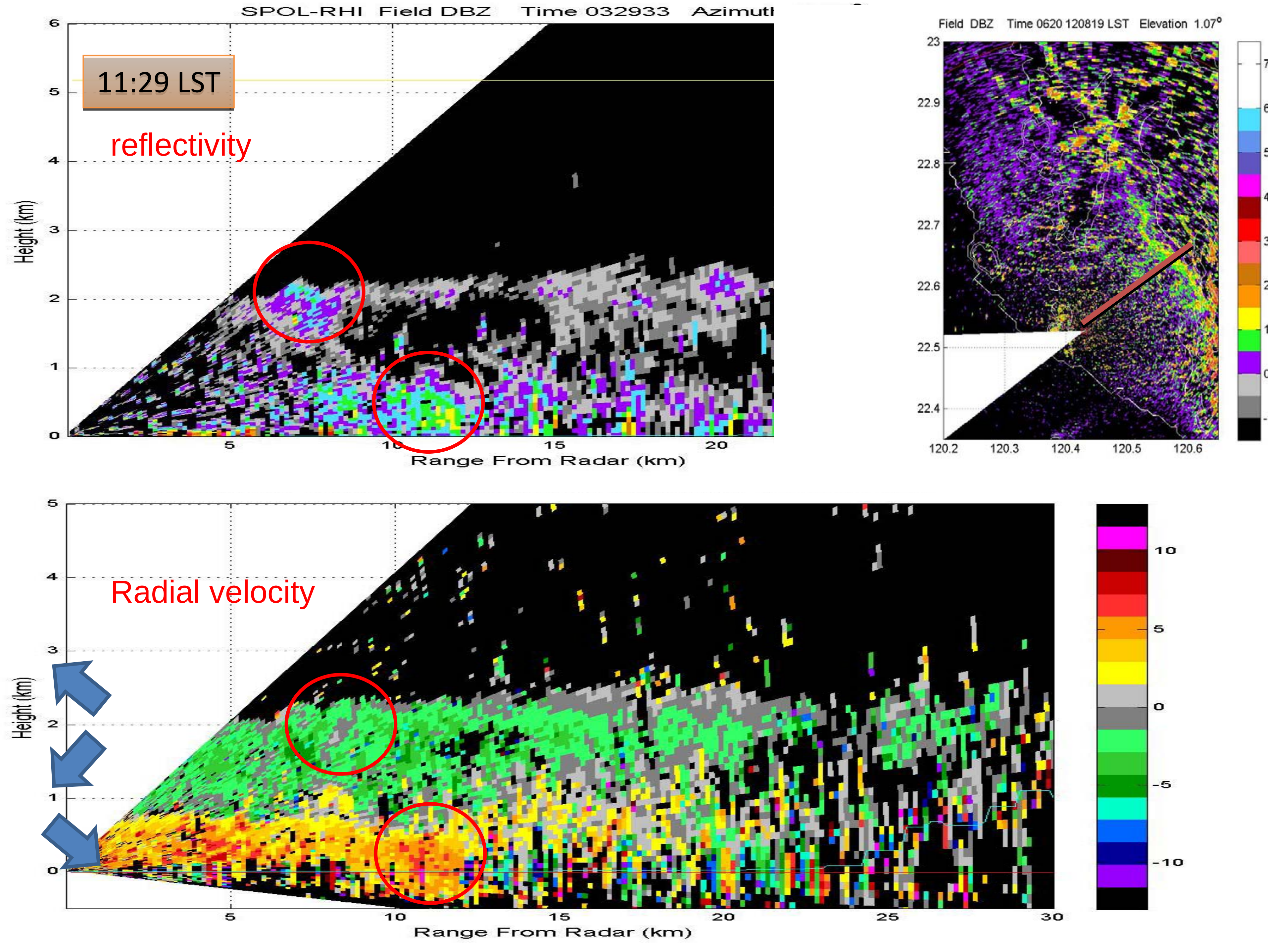
13:08 LST reflectivity



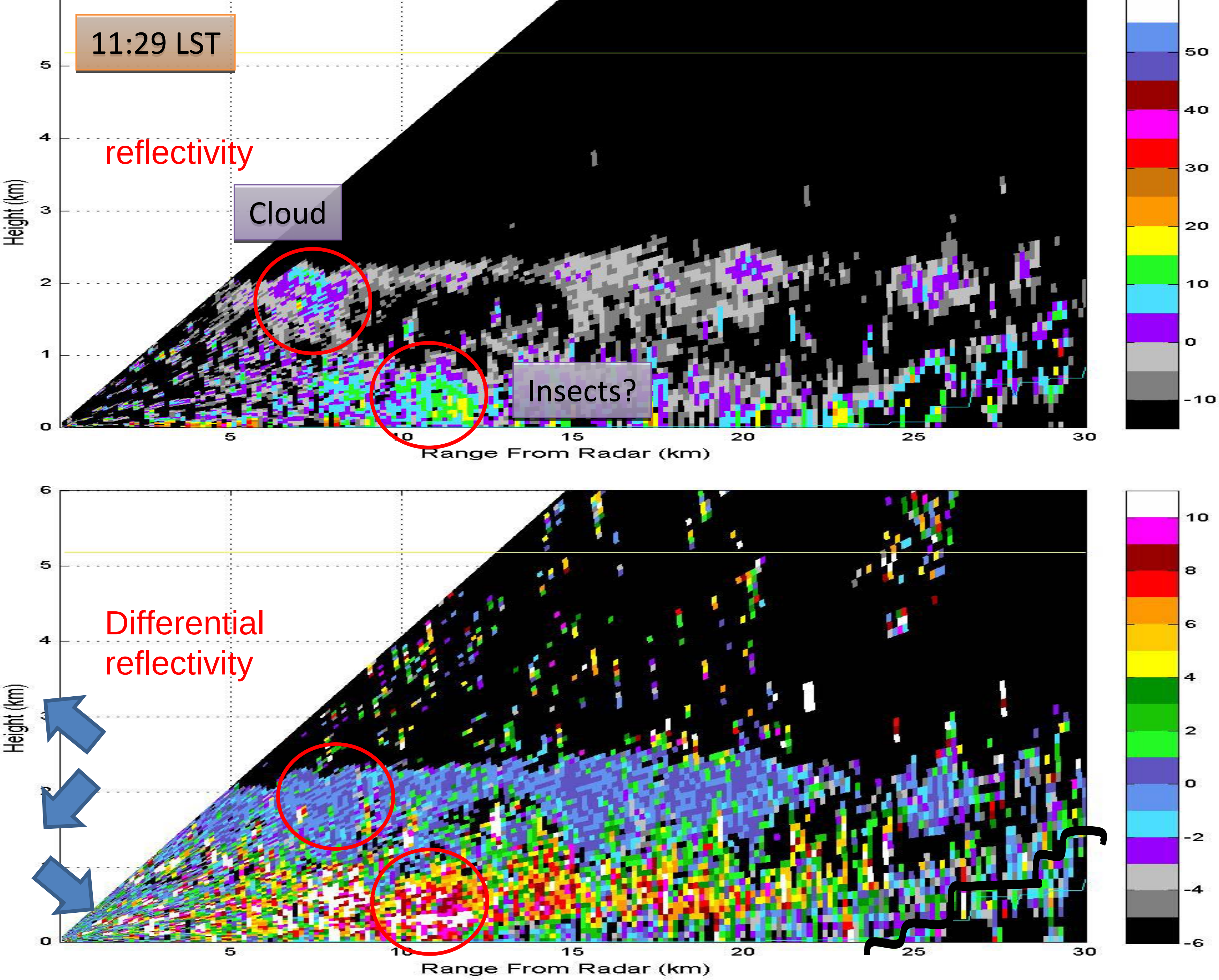
13:30 LST reflectivity



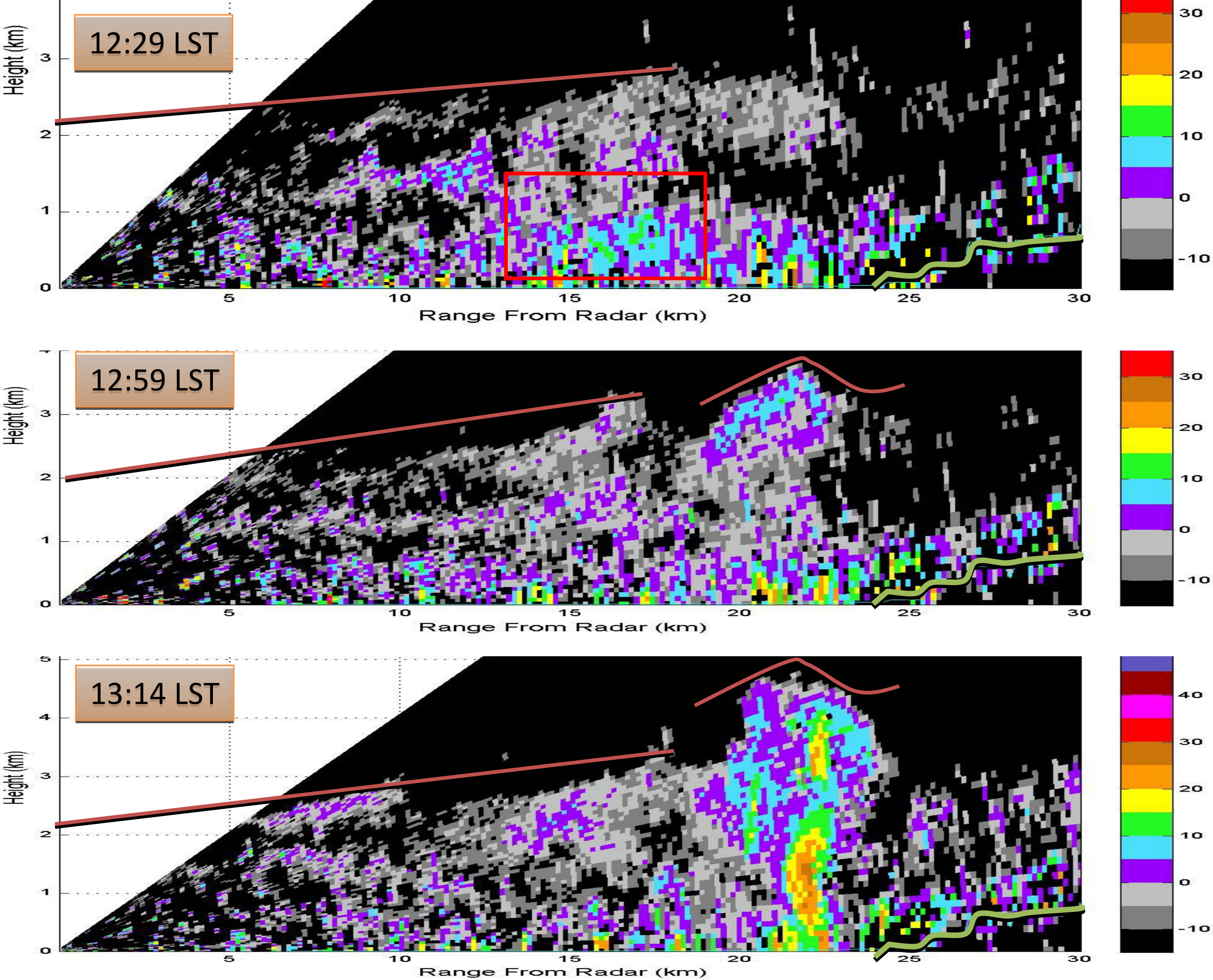

10:11 LST
11:29 LST
11:59 LST
From Stull 1988
Height (km)
Range From Radar (km)
clouds
Height, z
KHW
SBH
warm air
cool air
TIBL
cold water
coast
warm land
sea-breeze front



SPOL-RHI Field DBZ Time 032933 Azimuth
11:29 LST
reflectivity
Height (km)
Range From Radar (km)
Field DBZ Time 0620 120819 LST Elevation 1.07°
Radial velocity
Height (km)
Range From Radar (km)

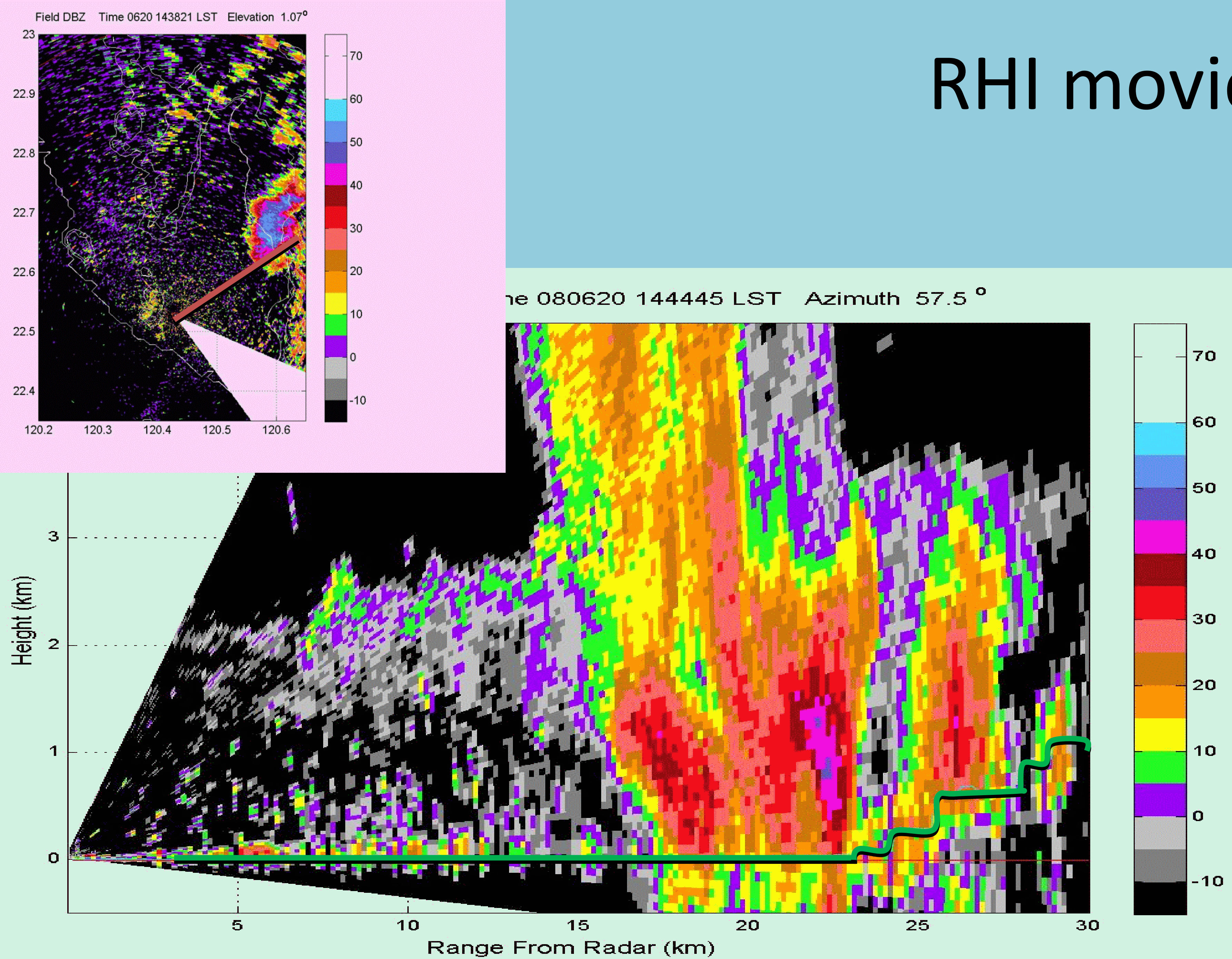


11:29 LST
reflectivity
Cloud
Insects?
Height (km)
Range From Radar (km)
Differential
reflectivity
Height (km)
Range From Radar (km)

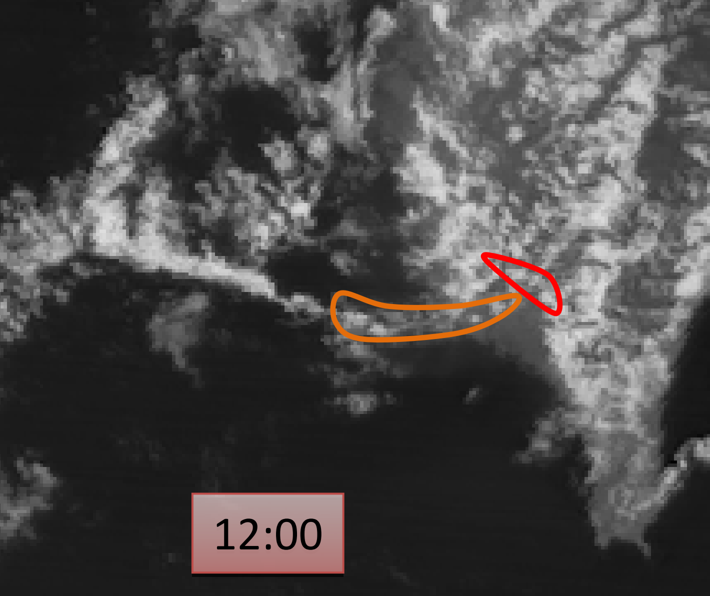


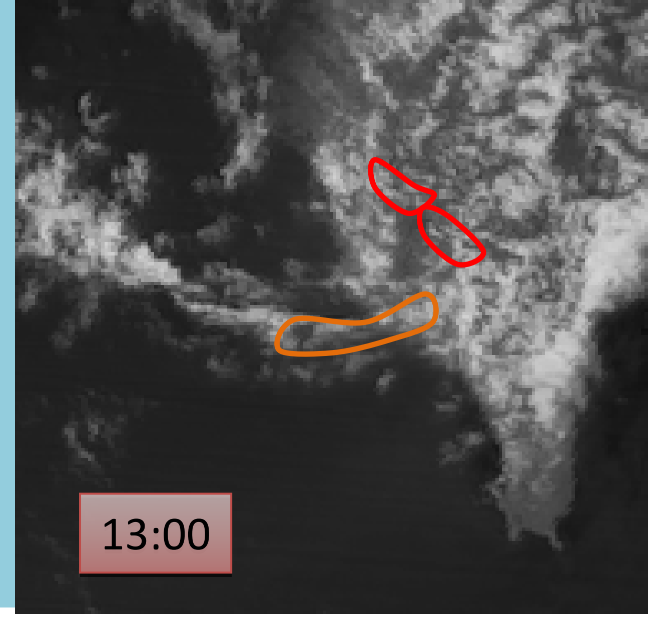
12:29 LST
Height (km)
Range From Radar (km)
12:59 LST
Height (km)
Range From Radar (km)
13:14 LST
Height (km)
Range From Radar (km)

RHI movies

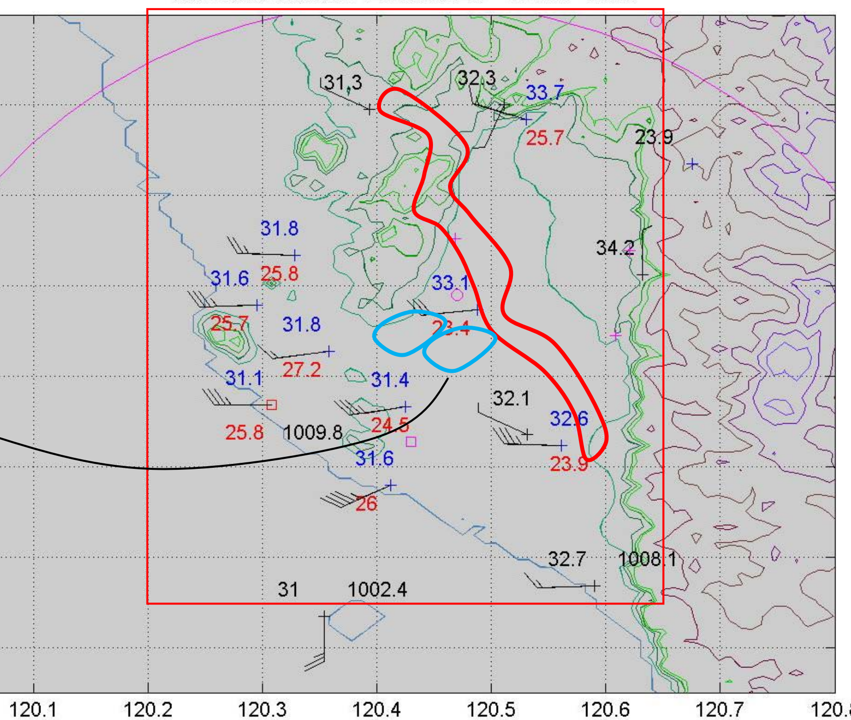


Field DBZ Time 0620 143821 LST Elevation 1.07°
23
22.9
22.8
22.7
22.6
22.5
22.4
120.2
120.3
120.4
120.5
120.6
70
60
50
40
30
20
10
0
-10
ne 080620 144445 LST Azimuth 57.5 °
Height (km)
3
2
1
0
5
10
15
20
25
30
Range From Radar (km)
70
60
50
40
30
20
10
0
-10

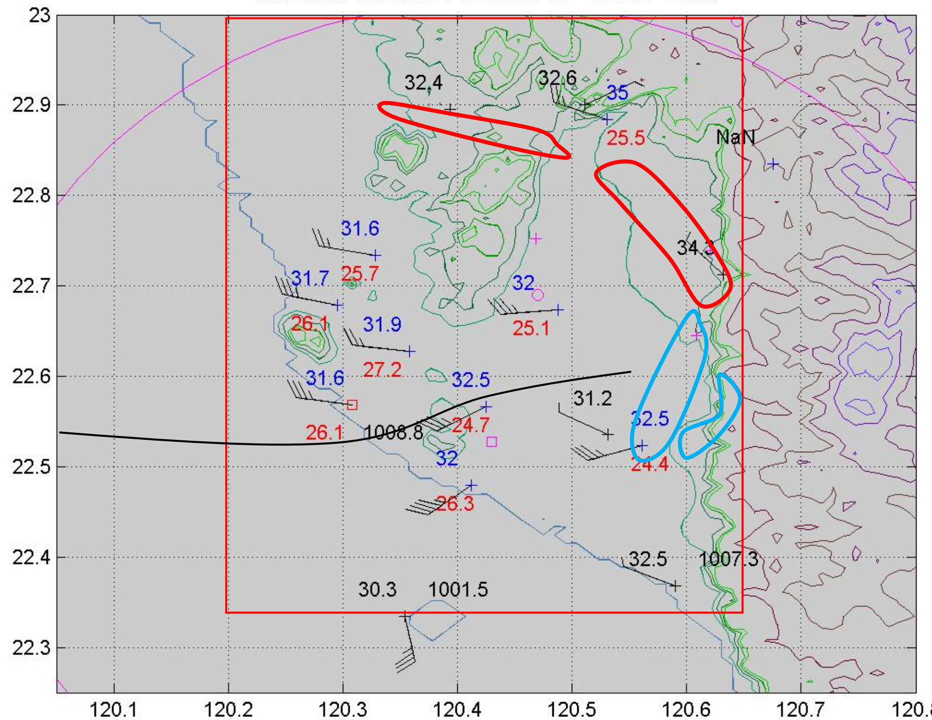




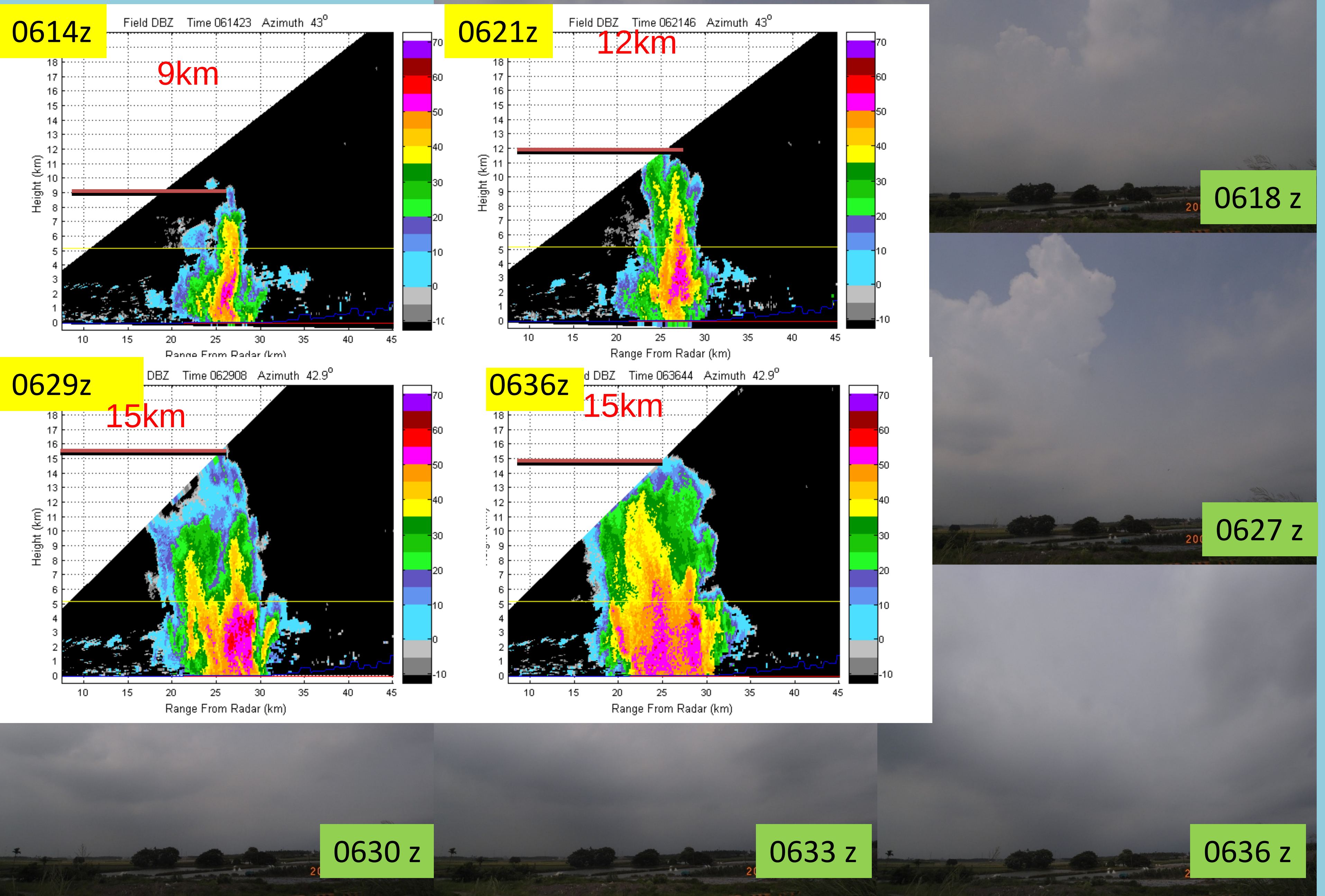
Surface station 20080620--12:00 data

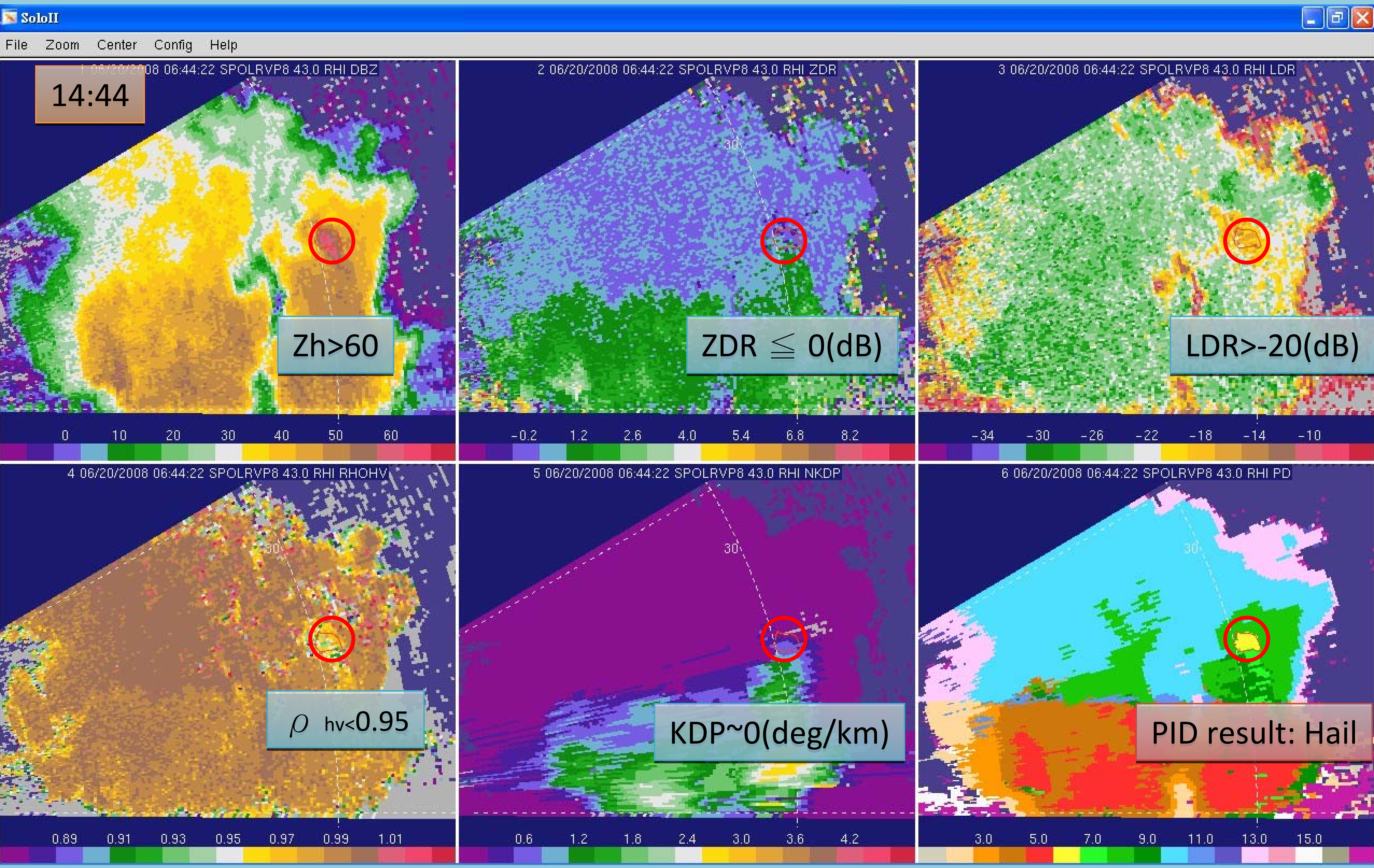


Surface station 20080620--13:00 data



Pictures v.s RHI scans




SoloII
File Zoom Center Config Help
14:44
1 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI DBZ
Zh>60
0 10 20 30 40 50 60
2 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI ZDR
ZDR ≦ 0(dB)
-0.2 1.2 2.6 4.0 5.4 6.8 8.2
3 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI LDR
LDR>-20(dB)
-34 -30 -26 -22 -18 -14 -10
4 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI RHOHV
ρ hv<0.95
0.89 0.91 0.93 0.95 0.97 0.99 1.01
5 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI NKDP
KDP~0(deg/km)
0.6 1.2 1.8 2.4 3.0 3.6 4.2
6 06/20/2008 06:44:22 SPOLRVP8 43.0 RHI PD
PID result: Hail
3.0 5.0 7.0 9.0 11.0 13.0 15.0

conclusions

- Storm outflow boundaries , weak echo line over hill and weak echo line oversea(remote) are highly related to storm initiation.
- The storm initiation or not with sea breeze front is also studied using Pingtung composite sounding. It is found that the atmosphere has higher humidity below 550 hpa with storm initiation.
- From 6/20 case study, SBF provide moisture air for PBL, but no storm initiation until the mesoscale boundaries and terrain interaction. After sea-breeze fronts pass, there is a convergence line to form weak echo line and help storm initiation.

Thanks for your attention!

Mesoscale boundaries

- Smaller scale air mass boundaries that are mesoscale even in the along-front dimension.
- In contrast to synoptic front, the formation of these mesoscale air mass boundaries, does not require geostrophic deformation acting on a preexisting density gradient.
- Mesoscale boundaries have a variety of origins. They most commonly arise from horizontally differential latent heating/cooling or the differiental heating/cooling of the earth's surface.

(cited from Markowski and Richardson 2010)

1.1 Mesoscale boundaries

- Definition: all well-defined boundaries are solenoidally-forced *(Markowski and Richardson)*
- Convection Initiation with mesoscale boundary layer forcing mechanisms *(Jorgenson and Weckwerth 2003)* :

-Gust fronts

-Sea-breeze fronts

-Drylines

-Horizontal Convective Rolls

-Orographic and topographic effects

-Boundary intersection

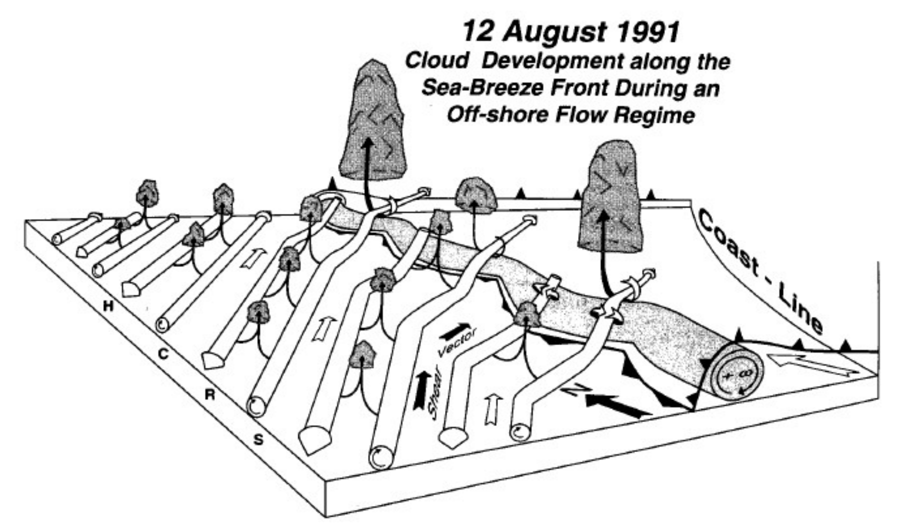
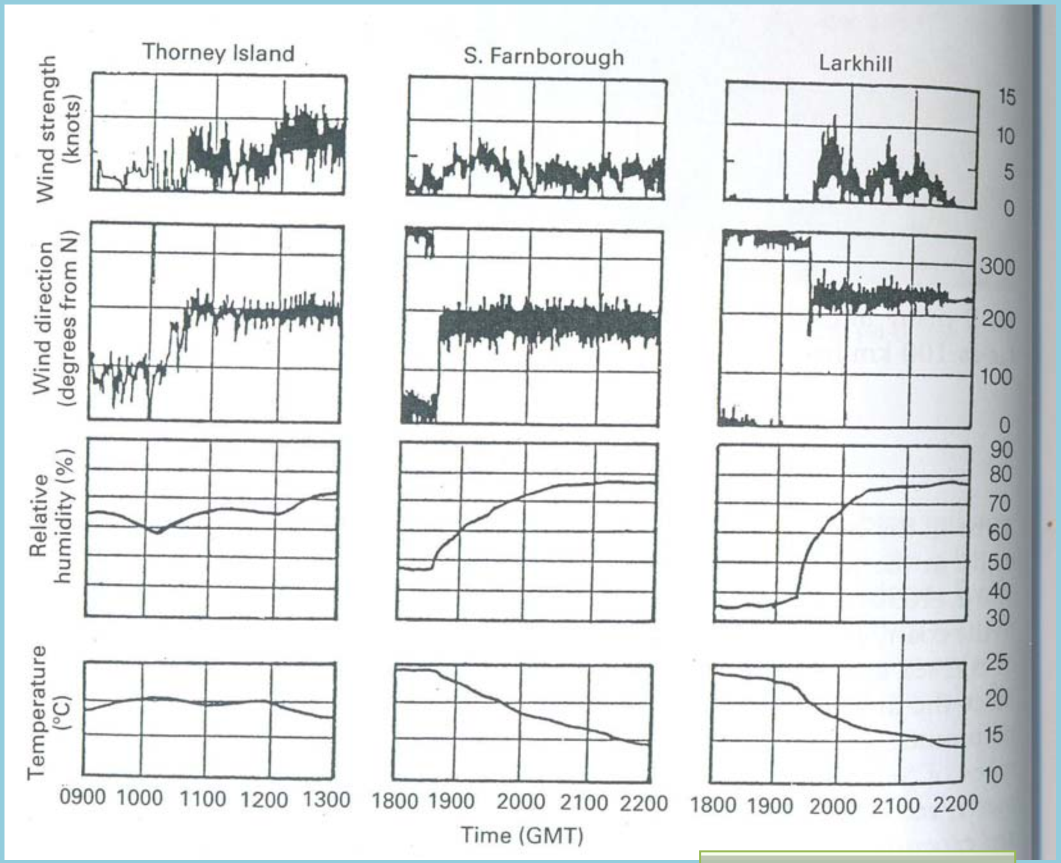


FIG. 8. Schematic diagram showing the interaction between the sea-breeze front and HCRs and how it relates to cloud development on 12 August 1991. The sea-breeze front is delineated by the heavy, barbed line. The head circulation is lightly shaded. The horizontal vorticity vectors associated with the counterrotating roll circulations are shown. Clouds along the HCRs and at the intersection points along the front are shaded gray. The shear vector (solid, 2D arrow) and low-level winds (white, 2D arrow) are also shown.

Jonathan et al. 2007

a simple threshold of $\rho_{HV}(0) < 0.6$. The polarimetric properties of birds and insects have been intensively studied (e.g., Wilson et al. 1994; Zrnic and Ryzhkov 1998; Zhang et al. 2005). Insects have ratios of horizontal-to-vertical cross sections of 3:1 and equivalent spherical diameters of 10 mm. The differential reflectivity of insects has been observed to remain constant with viewing angle, whereas the differential reflectivity with birds varies between –2 and 4 dB at S band, depending on the size of the birds and the viewing angle. Mie scattering occurs with birds; thus, different values of Z_{DR} are expected at X and C bands.



Simpson 1994

Boundary layer Convergence line identification

Wilson& Schreiber(1986)

Mark the case:

- Radar signature of **thin line of enhanced reflectivity** and/or a line of apparent **convergence flow in Doppler velocity** .
- Reflectivity: **1-3km wide line** is required to be **>10km long** and **present for** a minimum of **15 min**.
- Range: **0-50km** from radar; **0.7 elevation** PPI scan.(0~1 km high)

  (The depth of convergence lines is usually about 1km)

Classification

- Exam **synoptic scale maps**, **single Doppler radar**, **and mesonet stations**.
- In previous studies, convergence lines have attributed to **synoptic scale front**, **sea breeze front**, and **gust front**.