An extreme-rain-producing long-lived event during TiMREX: How unusual is it?

Weixin Xu

Edward Zipser

University of Utah, USA

Acknowleged: Dr. Wen-Chau Lee, Prof. Ben Jou
Prof. Yu-Chieng Liou, Dr. Chuntao Liu

3rd SoWMEX/TiMREX Science Workshop
Taipei, Taiwan
3-5 November 2010

Photo by Paul Ciesielski

OUTLINE

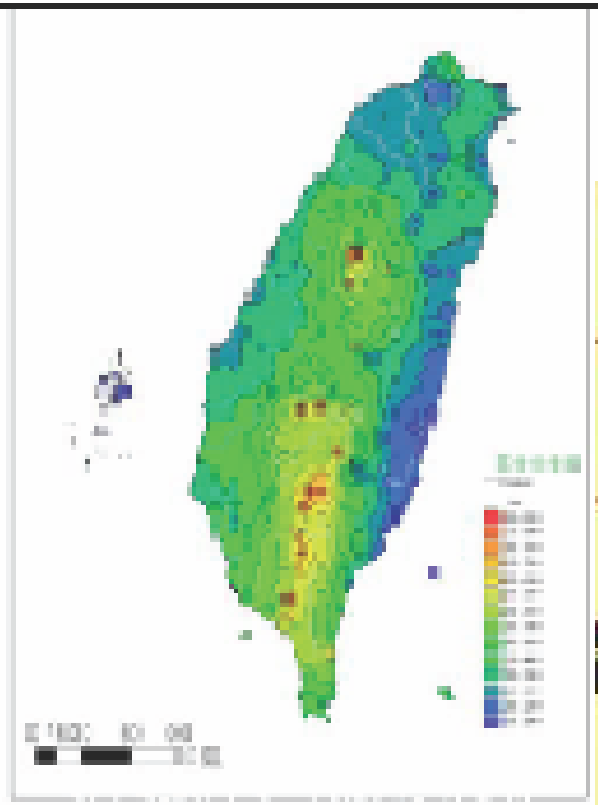
- **Background of heavy rainfall**
  a. Heavy rainfall of climatology and TiMREX
  b. Why study the selected case?

- **Convection and storm evolution**
  a. Storm evolution and morphology
  b. Statistics of convection and precipitation

- **Hypothesis of triggering and maintenance**
  a. Summary of the hypothesis
  b. Evidence supporting the hypothesis

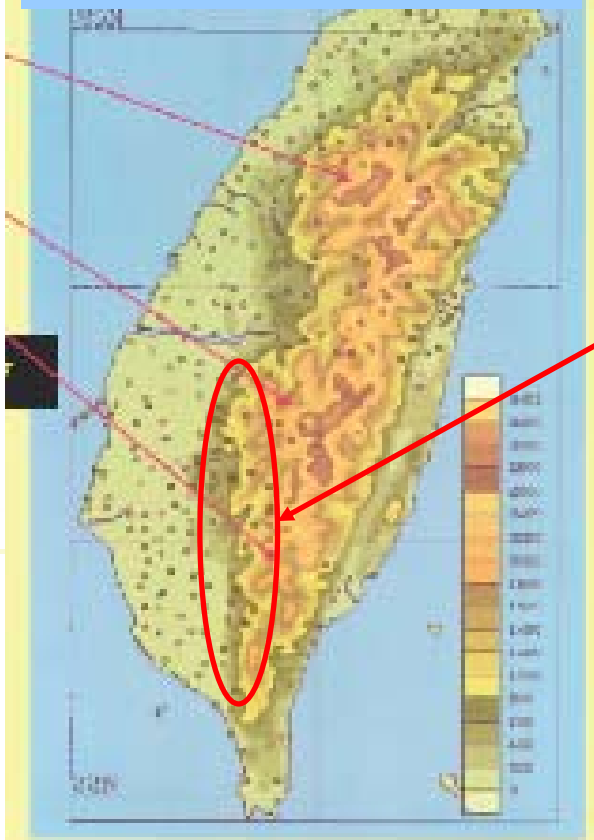
Climatology: Mei-Yu heavy rainfall in Taiwan

Averaged Rainfall

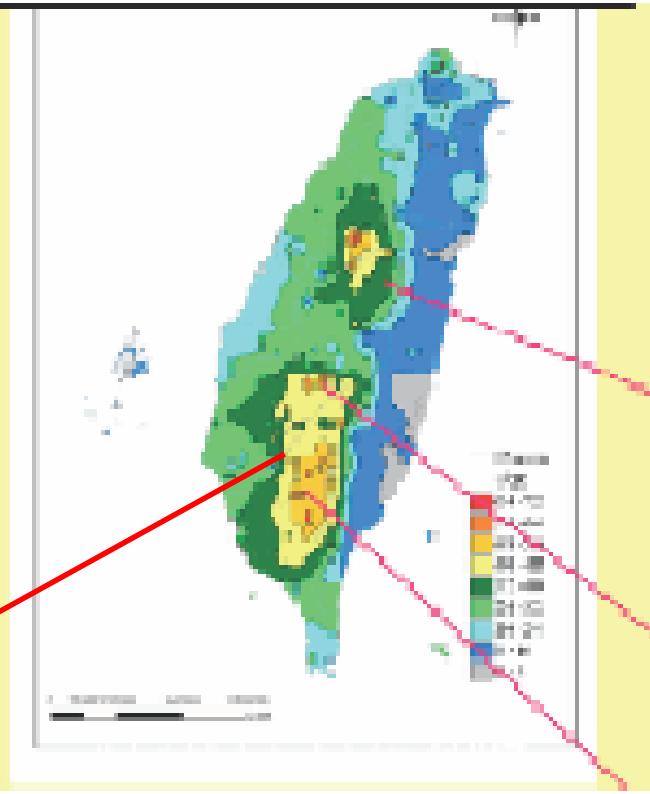


Rainfall statistics
May 15-June15,
1992-2004

Taiwan Topography



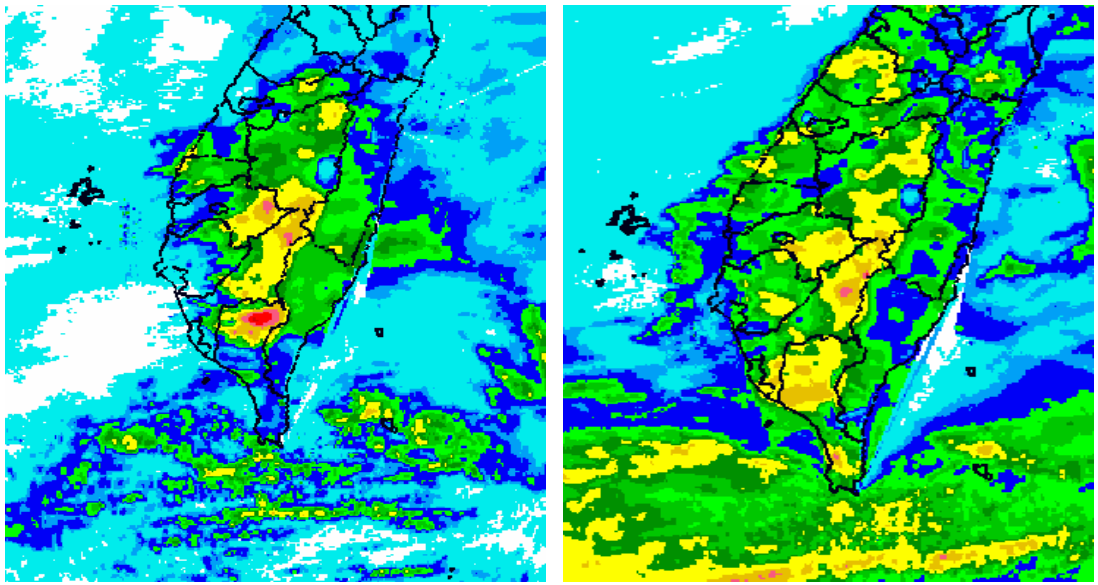
Frequency >50mm/d



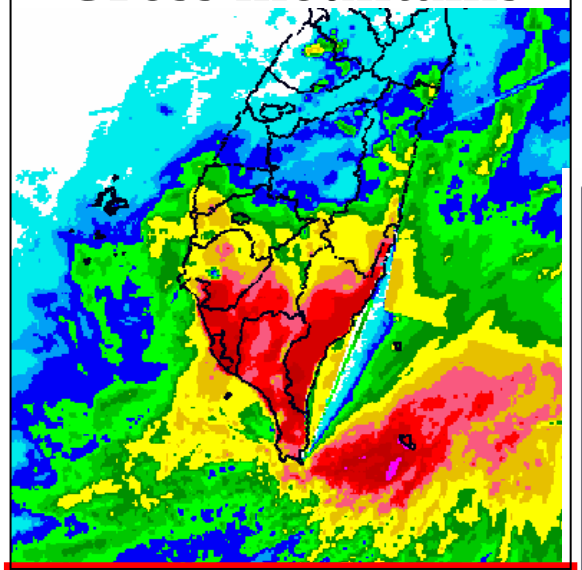
(Courtesy, Lee et al. 2007 TiMREX proposal)

TiMREX: Different locations of heavy rainfall (> 50 mm/day)

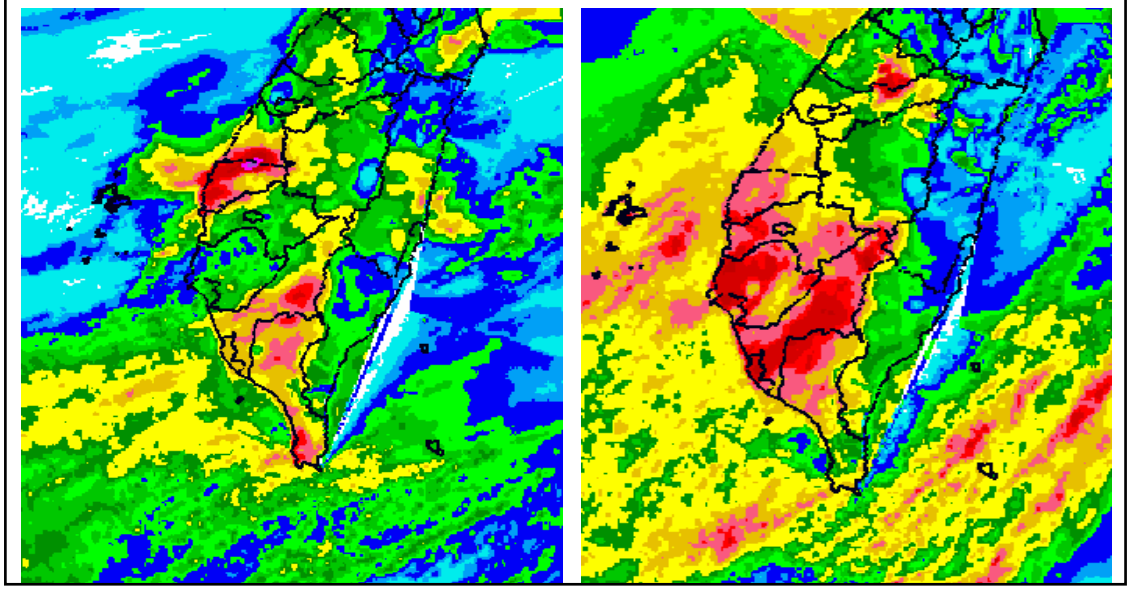
Over Mountains



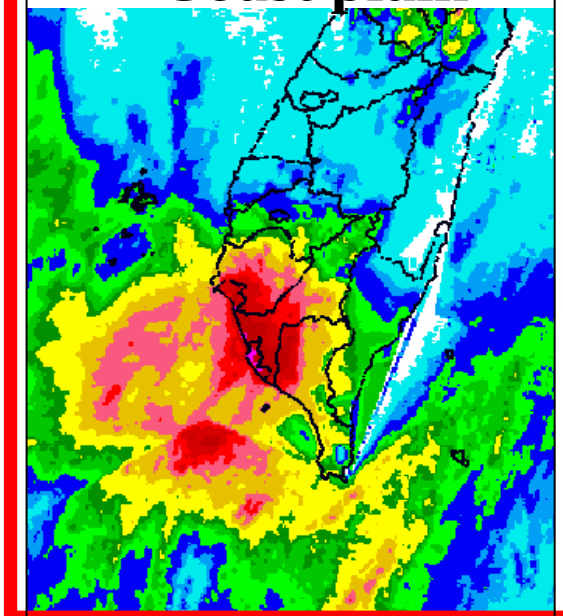
Cross mountains

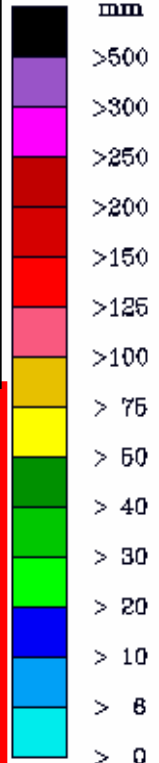


Foothill and Coast



Coast plain





Why this case (June 16, 2008)?

1. “Retreating” Mei-Yu heavy precipitation:

-- Mei-Yu “squall lines” passed Taiwan on June 14; convection stops on June 15; but new convection and heavy rain “redevelop” by 18Z of June 15.

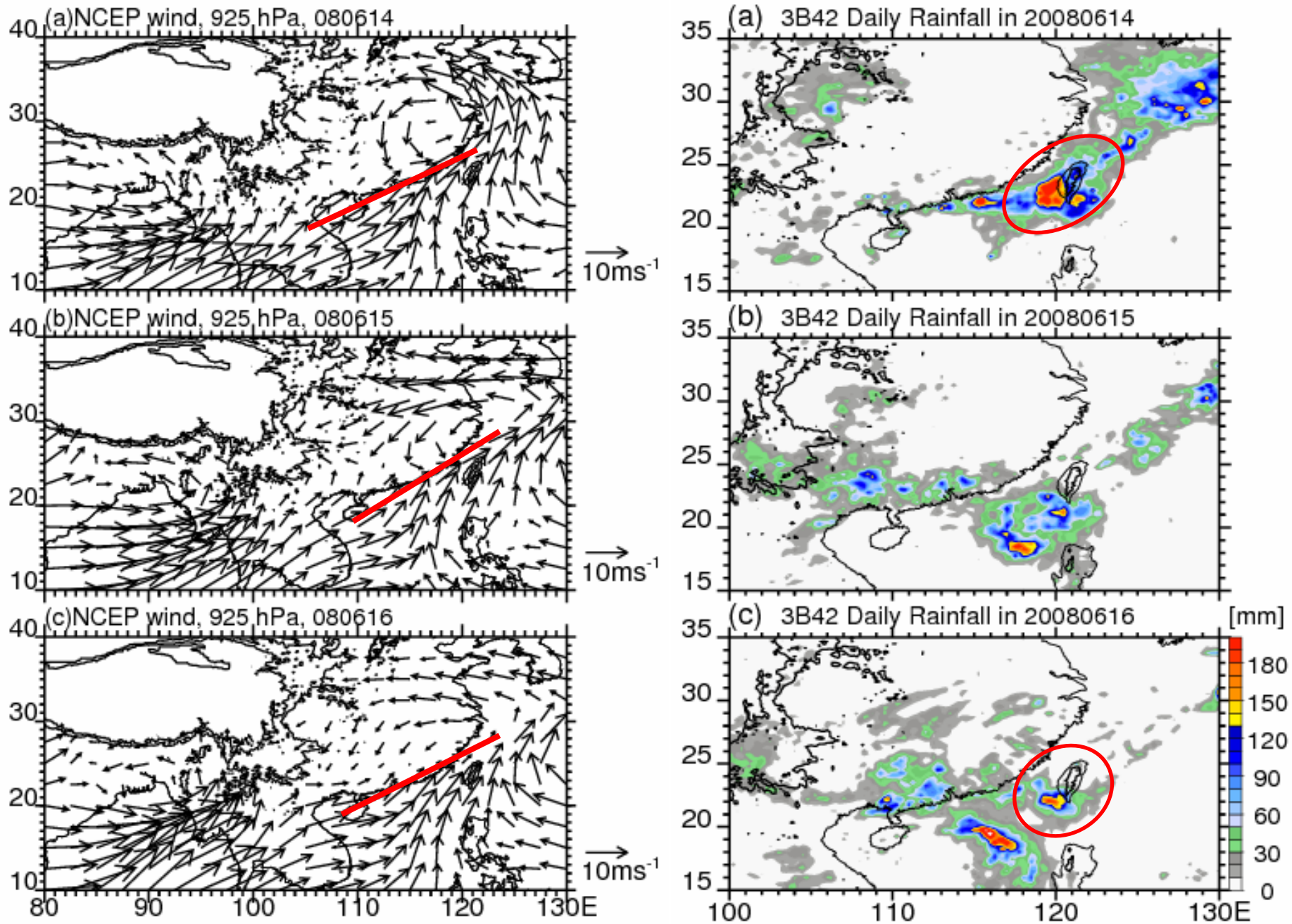
2. Special heavy rain location:

-- Heaviest rain falls on coastal plain but not the upwind mountain slope or the mountain;

3. Long-duration and back-building storm:

-- Long-lived (>15 hrs) large rain shield supported by continuously developing convection from upwind;

NCEP wind @925 hPa; 3B42 daily rain: (June 14-16)



Why this case (June 16, 2008)?

1. “Retreating” Mei-Yu heavy precipitation:

-- Mei-Yu “squall lines” passed Taiwan on June 14; convection stops on June 15; but new convection and heavy rain “redevelop” by 18Z of June 15.

2. Special heavy rain location:

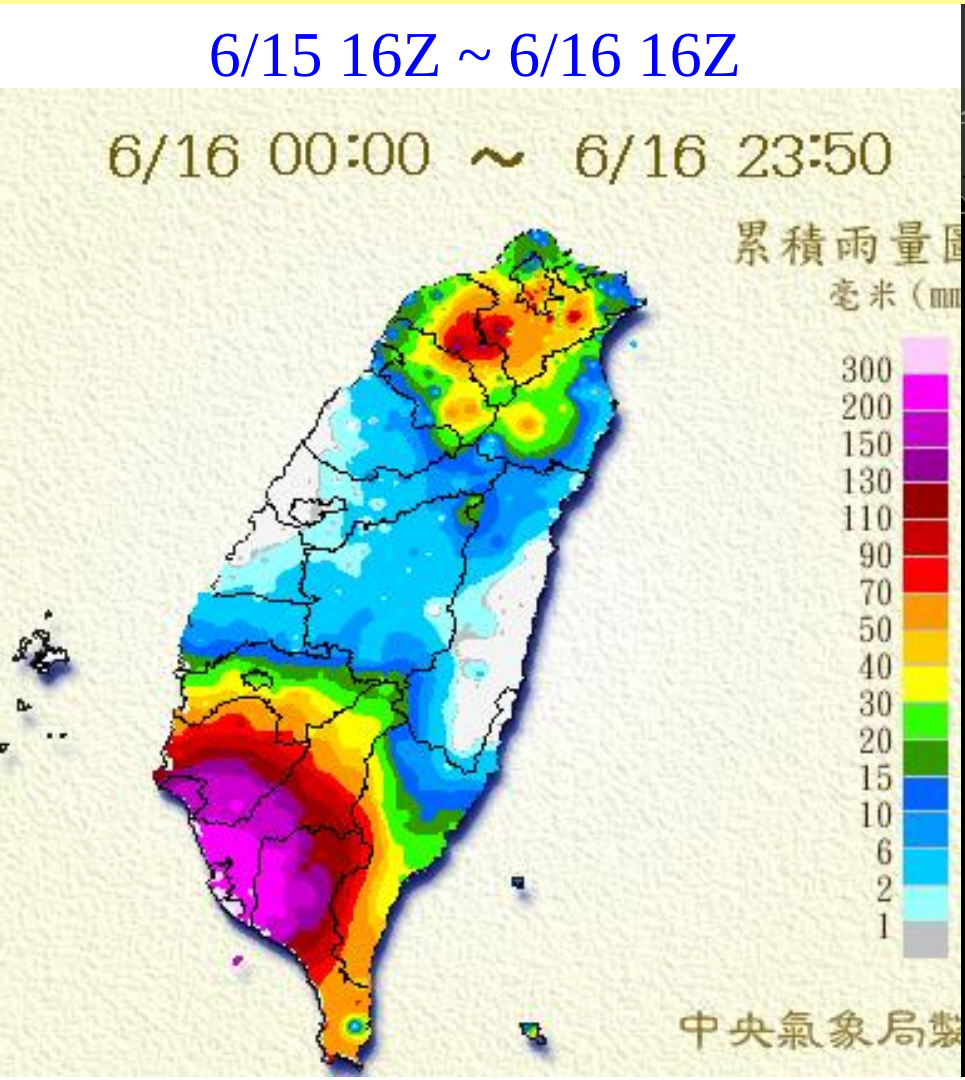
-- Heaviest rain falls on coastal plain but not the upwind mountain slope or the mountain;

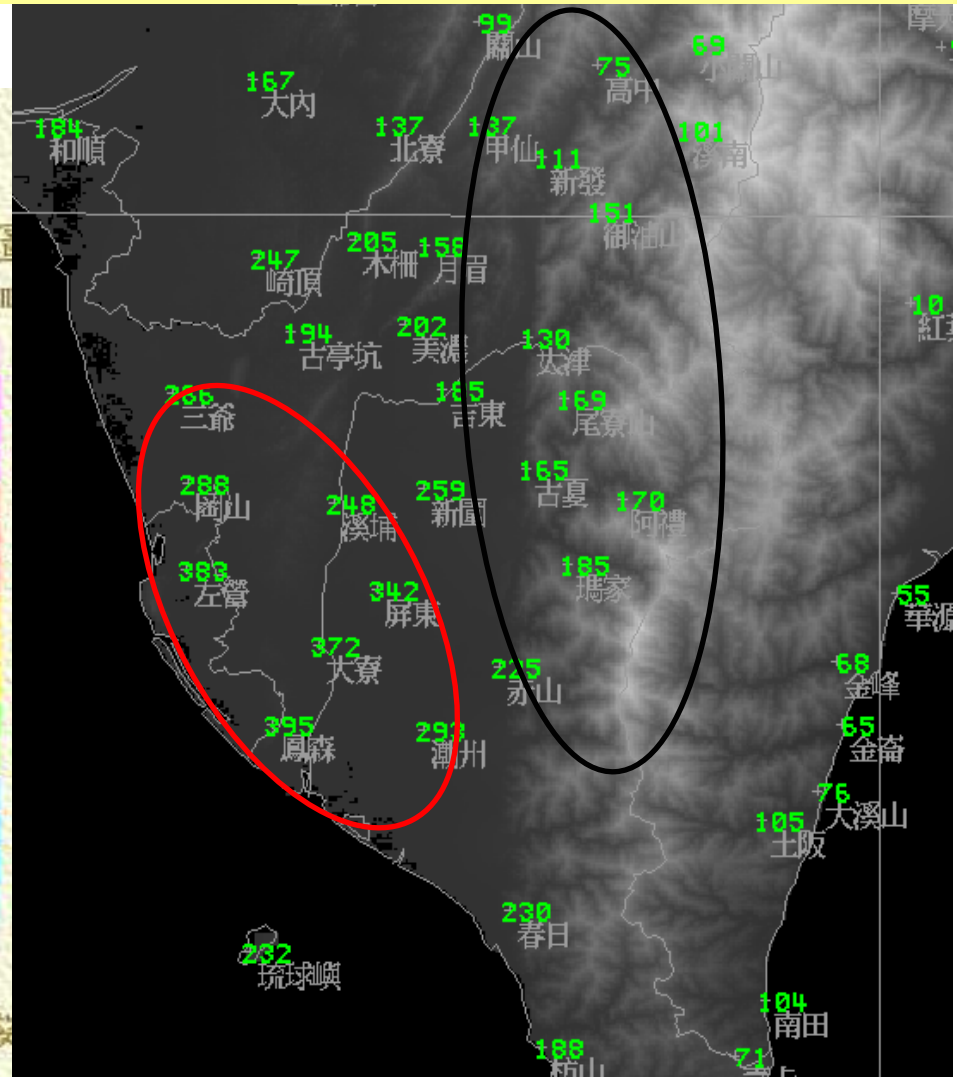
3. Long-duration and back-building storm:

-- Long-lived (>15 hrs) large rain shield supported by continuously developing convection from upwind;

Selected case: Heavy rainfall distribution

6/15 16Z ~ 6/16 16Z





Raining > 15 hours, avg ~ 200 mm, max ~ 400 mm.
Heaviest rain falls on coast, NOT foothill or mountains!

Why this case (June 16, 2008)?

1. “Retreating” Mei-Yu heavy precipitation:

-- Mei-Yu “squall lines” passed Taiwan on June 14; convection stops on June 15; but new convection and heavy rain “redevelop” by 18Z of June 15.

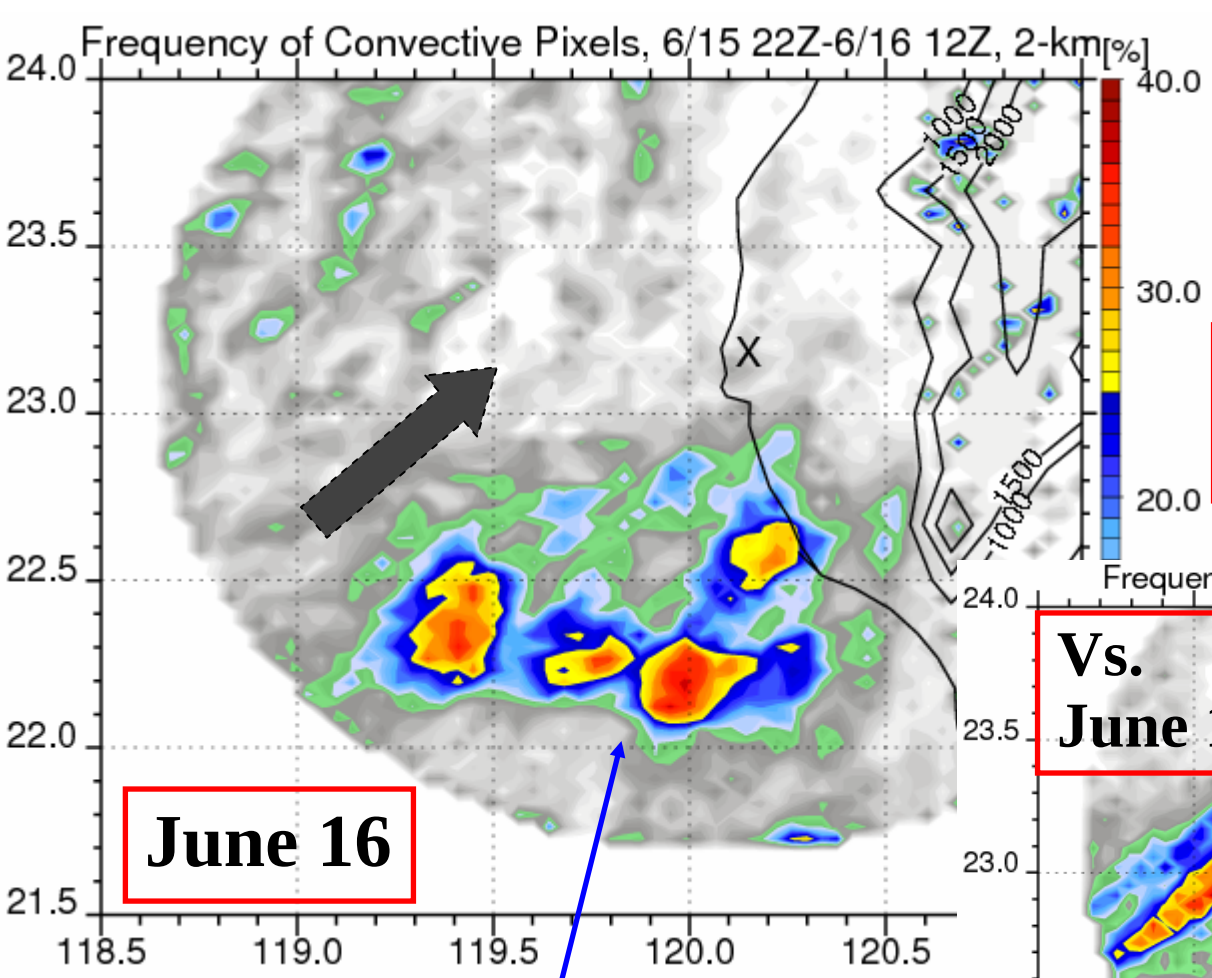
2. Special heavy rain location:

-- Heaviest rain falls on coastal plain but not the upwind mountain slope or the mountain;

3. Long-duration and back-building storm:

-- Long-lived (>15 hrs) large rain shield supported by continuously developing convection from upwind;

Statistics of convection: Frequency of convective pixels

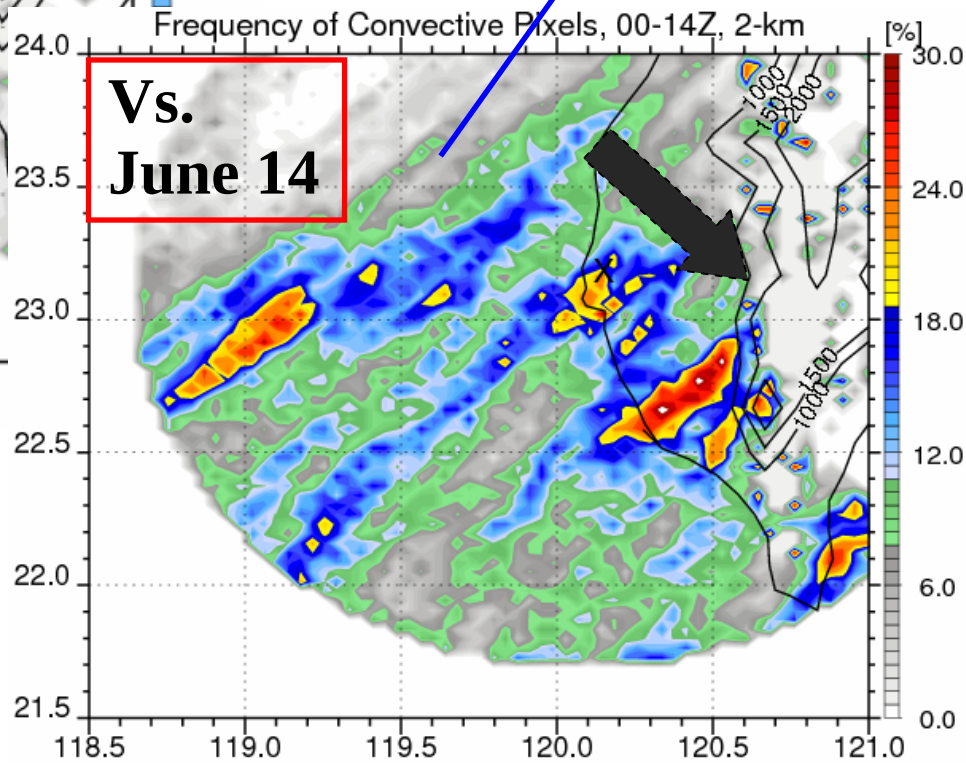


Data: RCGG radar;

Storm motion:

Squall lines propagate discontinuously!

June 16



Vs. June 14

Quasi-stationary convective lines with decayed convection move downstream.

Motivation

1. **What are the triggering and maintenance mechanisms of the long-lived rainy storm?**

[MCV/stationary vortex; orographic blocking/lifting; barrier jet and LLJ convergence; nocturnal offshore flow; back-building along surface boundary; etc.]

2. **How special is the storm morphology, convection, and vertical structure?**

[How different is the convection, storm evolution, and vertical precipitation structure from the classic convective systems (e.g. squall line)?]

OUTLINE

- **Background of heavy rainfall**
  a. Heavy rainfall of climatology and TiMREX
  b. Why study the selected case?

- **Convection and storm evolution**
  a. Storm evolution and morphology
  b. Statistics of convection and precipitation

- **Hypothesis of triggering and maintenance**
  a. Summary of the hypothesis
  b. Evidence supporting the hypothesis

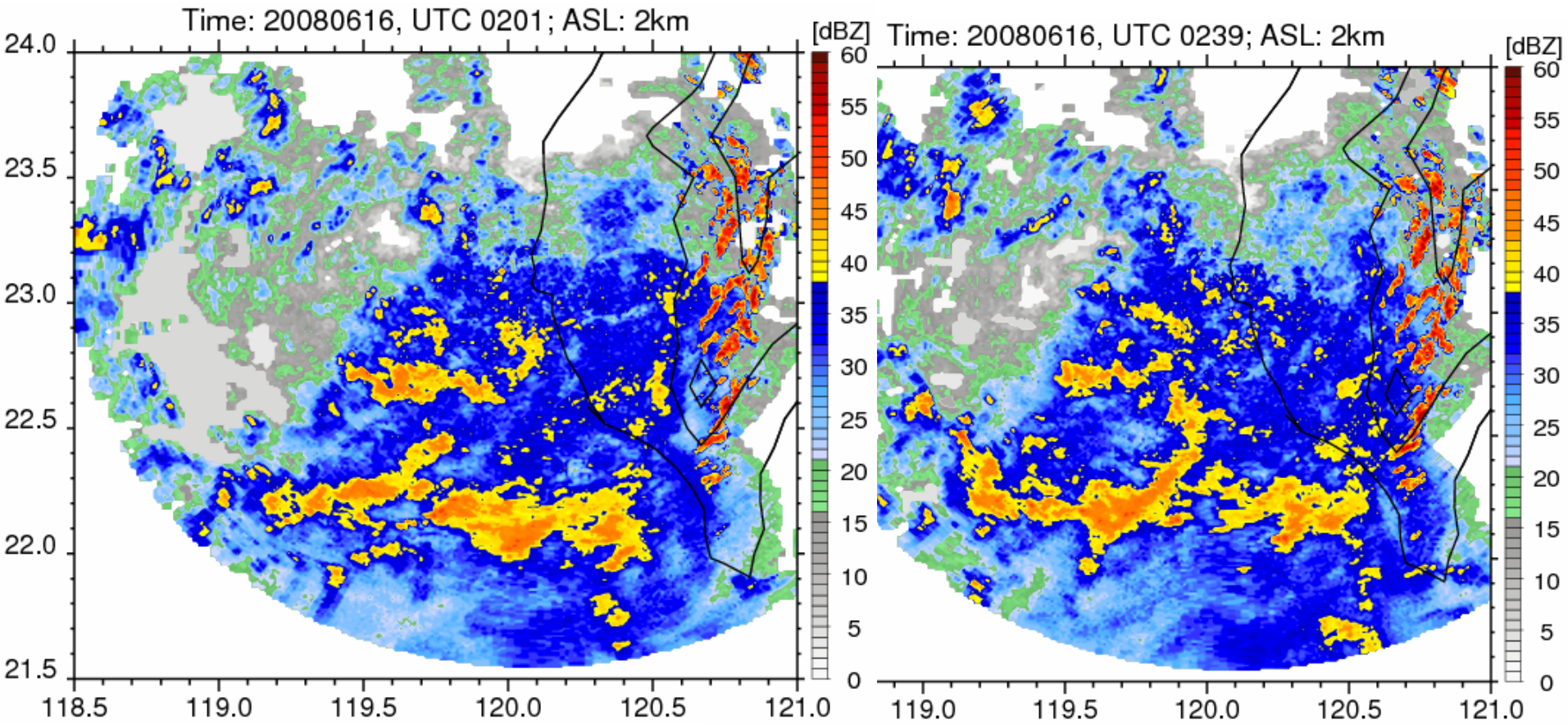
a. Storm evolution: summary (two stages)

1. (00-06Z) quasi-stationary convective lines:

1). convective lines develop along low-level convergence;

2). some convective cells move to SW coast but decay;

3). new cells develop upstream and feed the system;



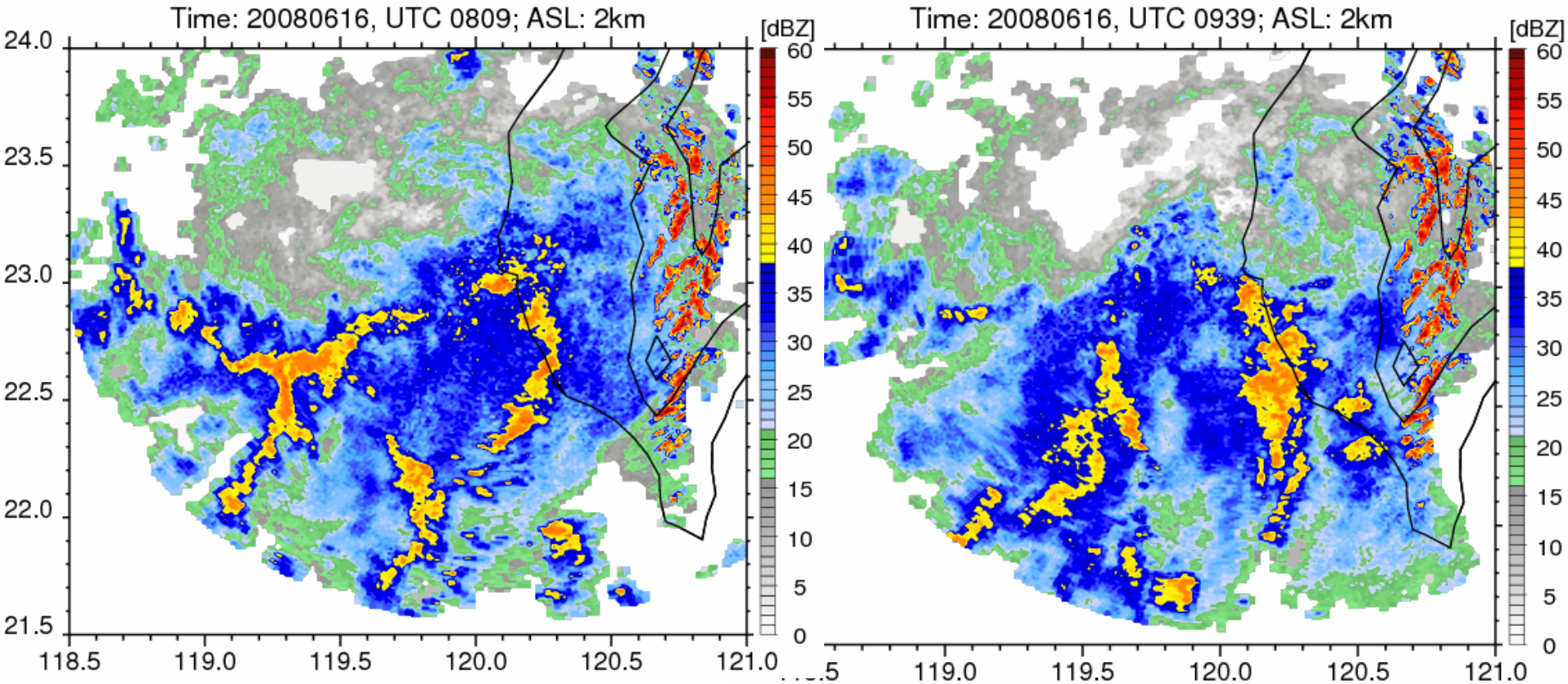
a. Storm evolution: summary (two stages)

2. (07-12Z) progressing convective lines:

1). new cells merge into SW-NE convective lines;

2). convective lines move over SW coast and decay inland;

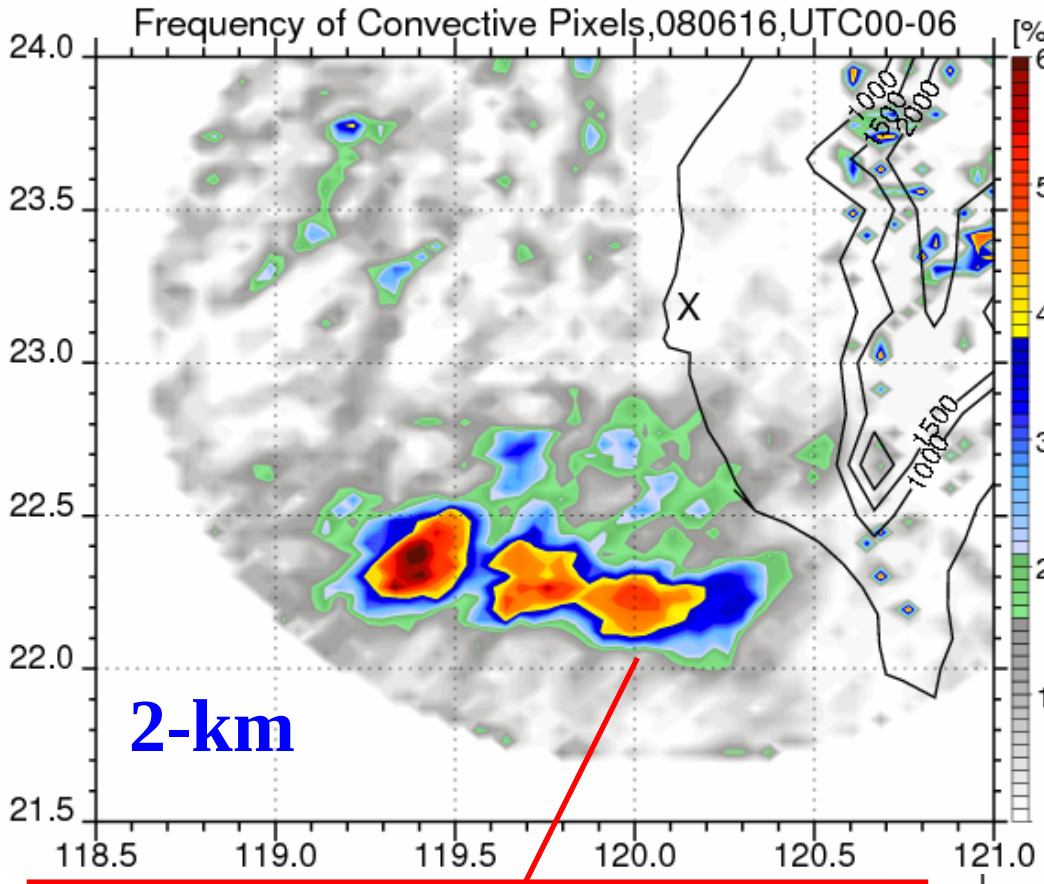
3). this transitions coincide with the progression of LLJ;



b. Statistics: convection of two different stages

6/16 00-06Z

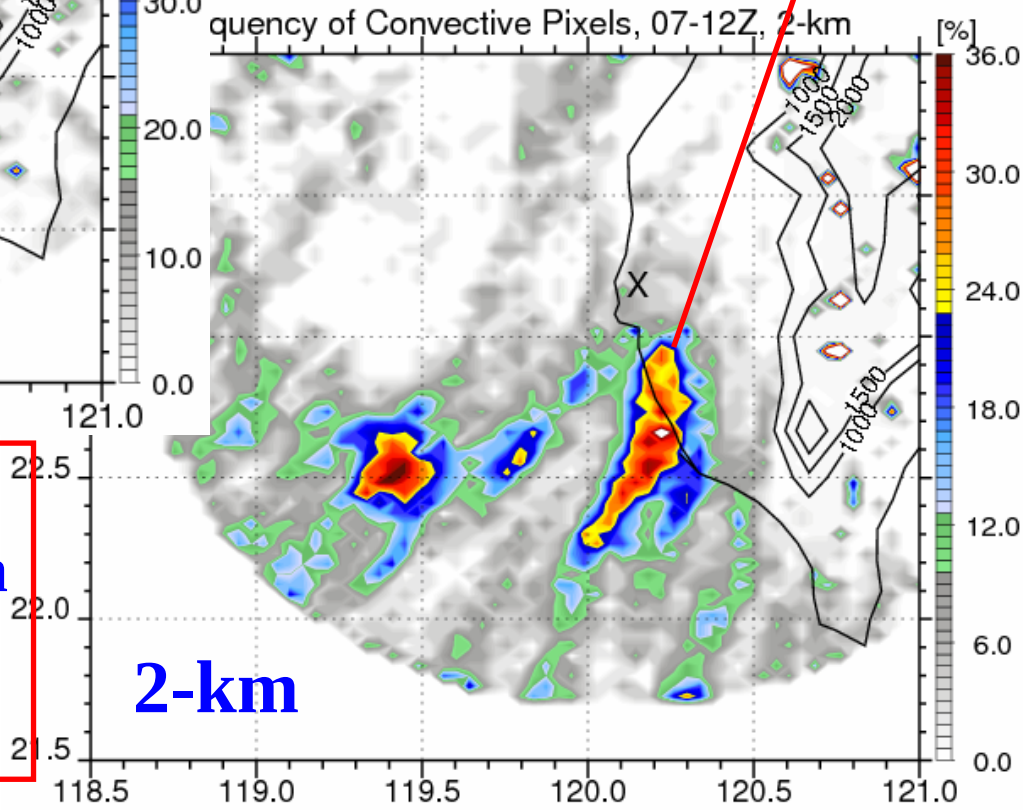
(Conv Algorithm: Steiner et al. 1995)



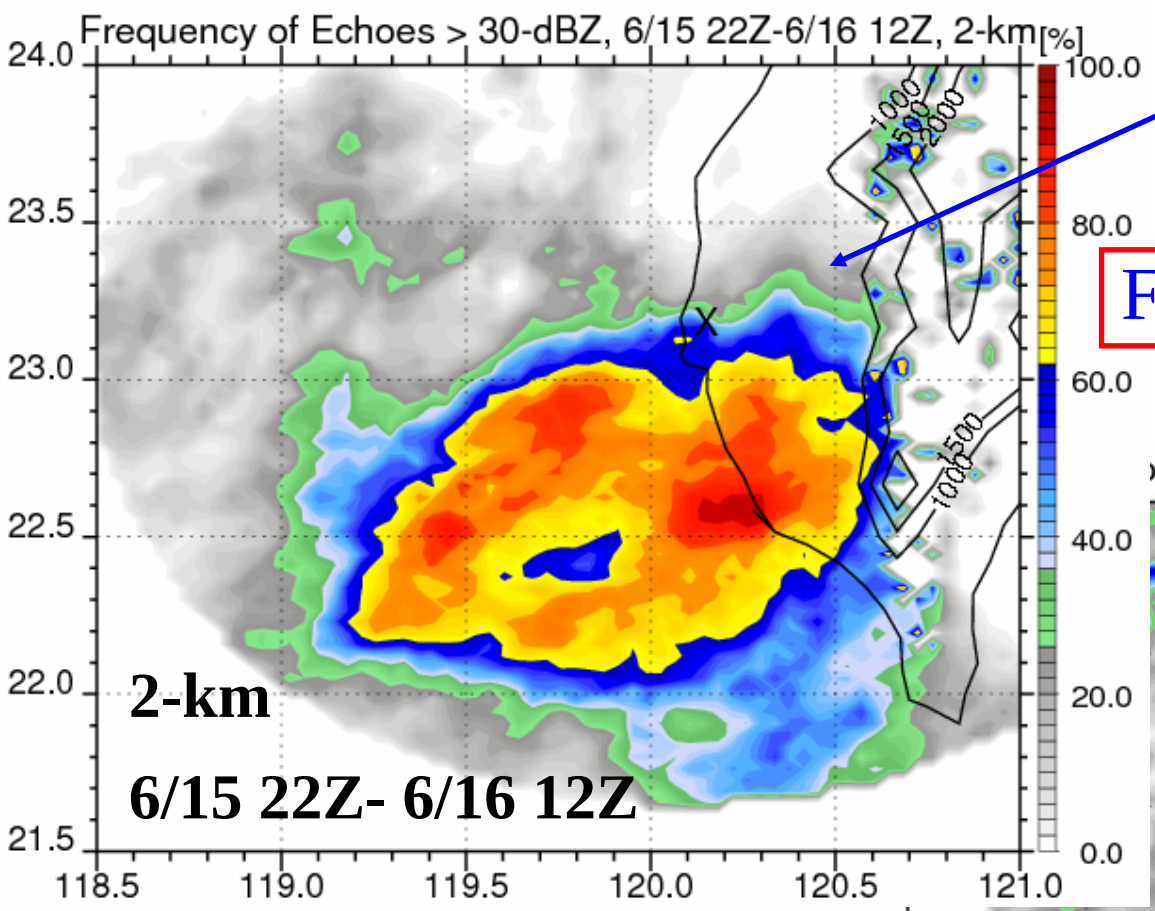
00-06Z: west-east convective lines stay off shore; convection does NOT develop on shore (too stable?).

07-12Z: convective lines move SW-NE; convection develops only on coast edge.

6/16 07-12Z

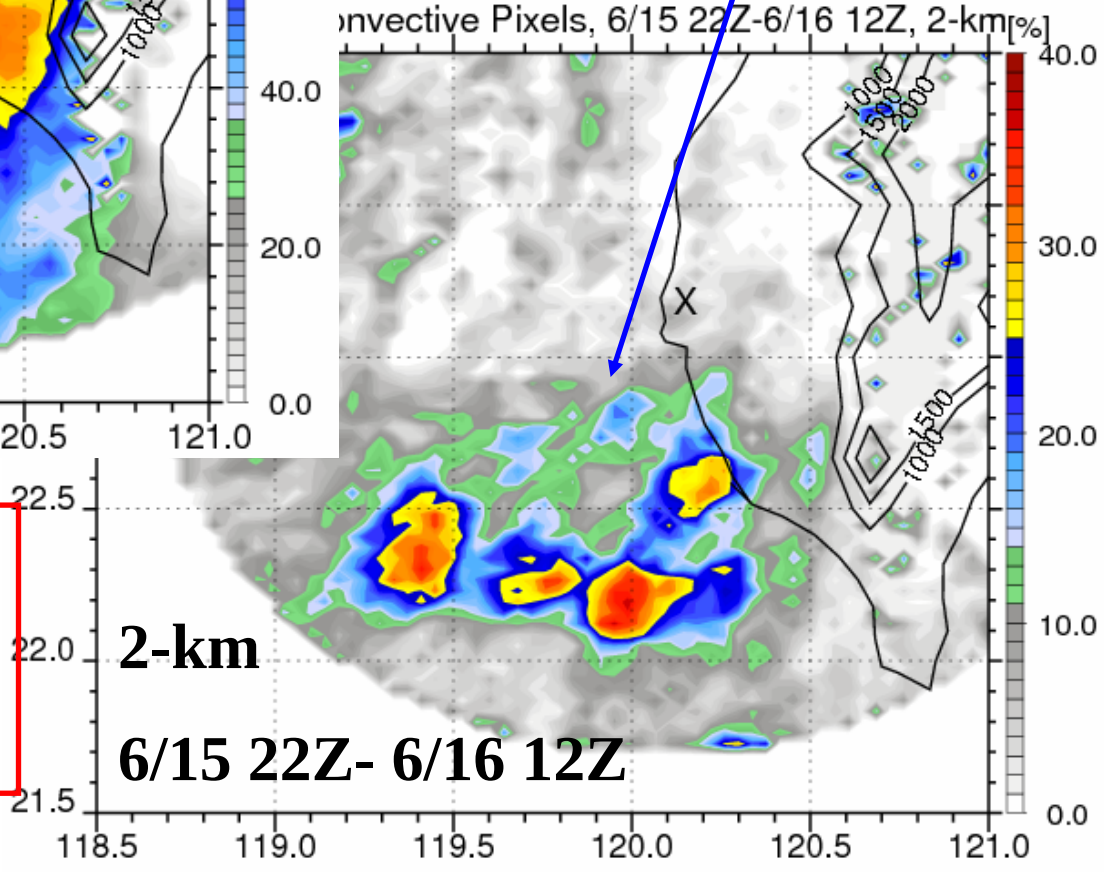


b. Statistics: heavy precipitation vs. convection



Significant rain:
Frequency of >30dBZ

Frequency of convection:



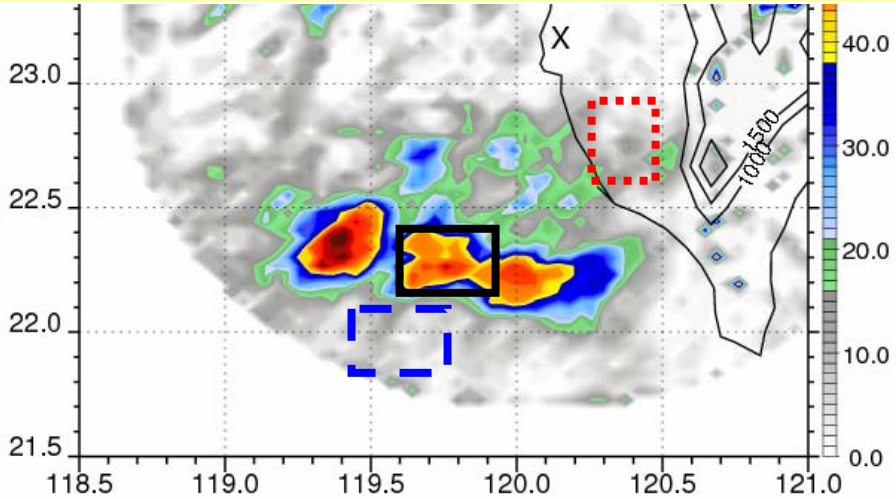
Heavy rain over southwest Taiwan mainly contributed by stratiform rain!!

b. Statistics: time series of convection and precipitation

Box 1: conv. max

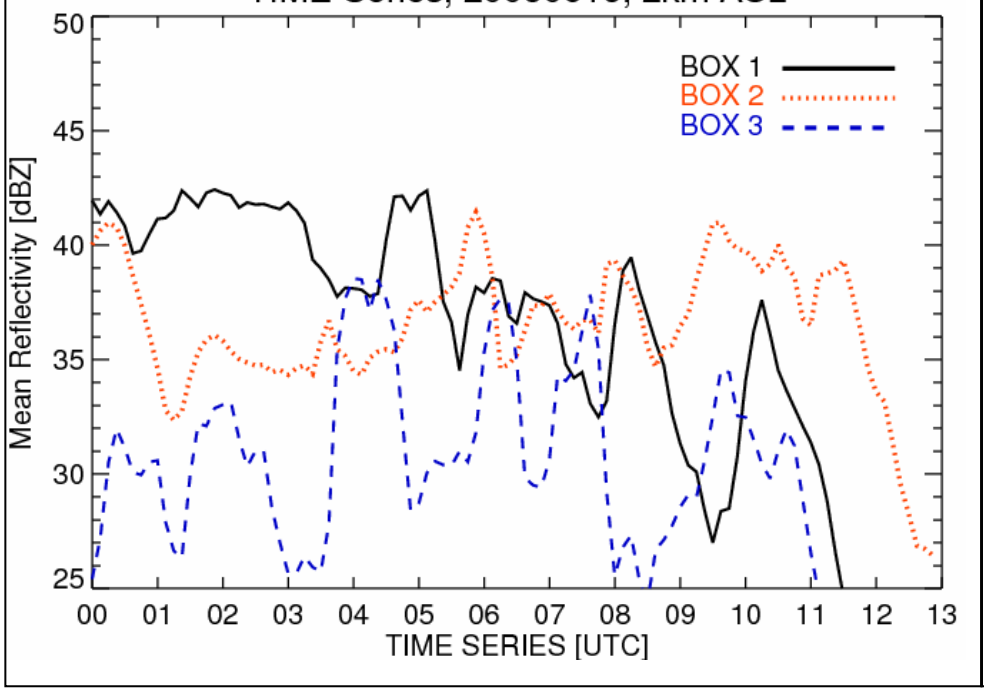
Box 2: coast

Box 3: upstream

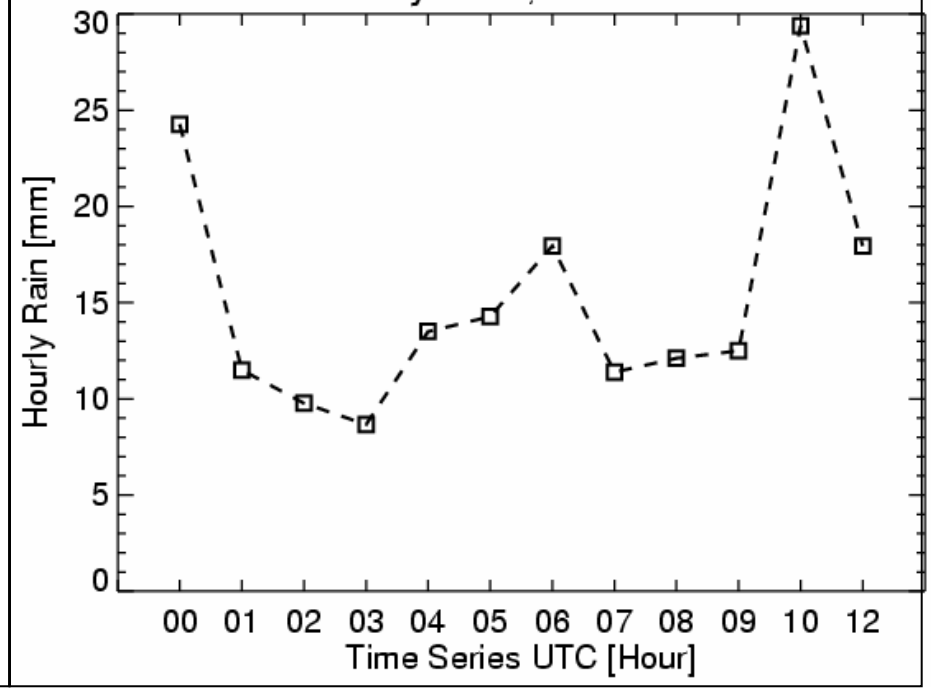


Data:
RCGG radar;
Rain guage.

Mean radar reflectivity



Mean hourly rain, Box 2



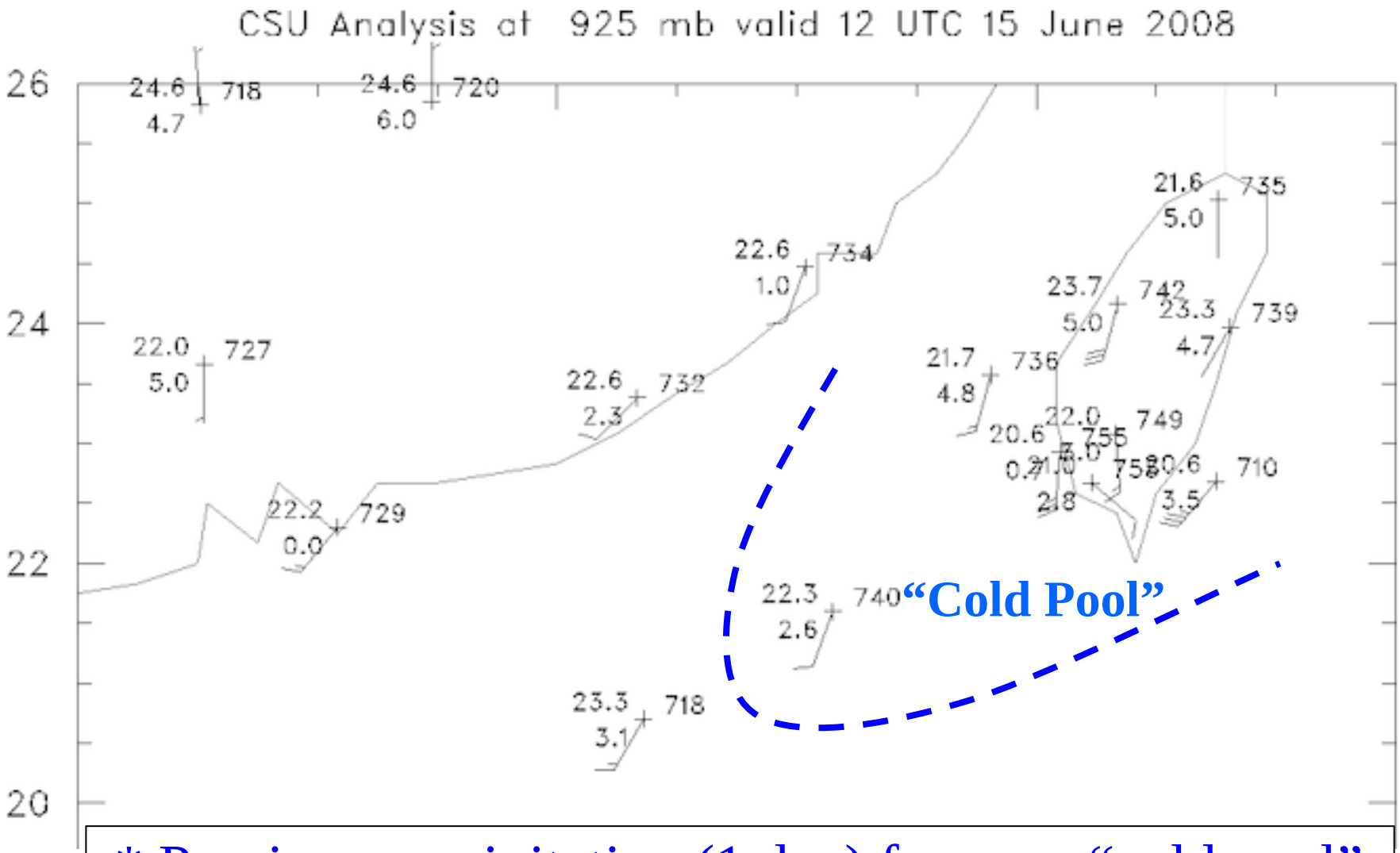
OUTLINE

- **Background of heavy rainfall**
  a. Heavy rainfall of climatology and TiMREX
  b. Why study the selected case?

- **Convection and storm evolution**
  a. Storm evolution and morphology
  b. Statistics of convection and precipitation

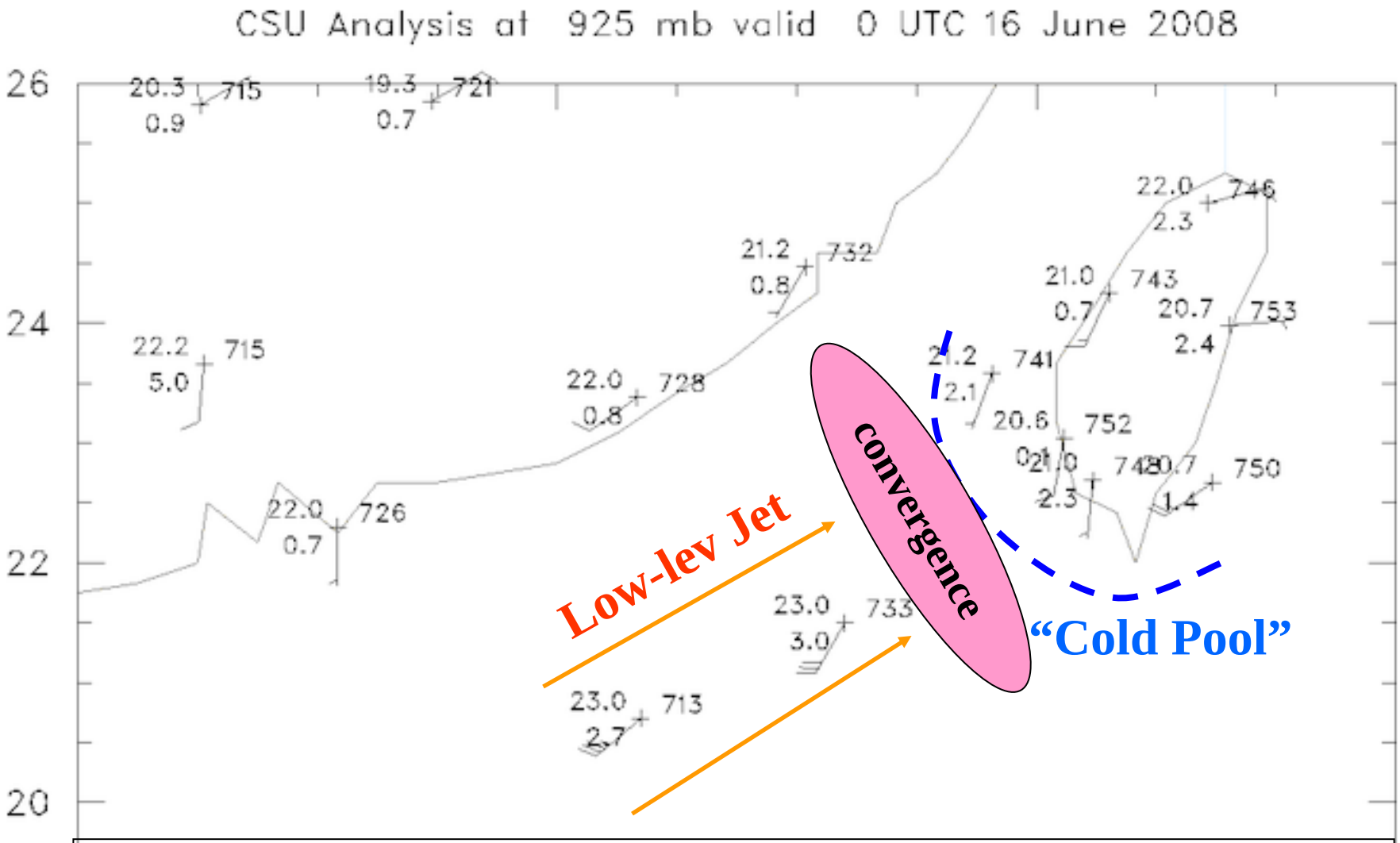
- **Hypothesis of triggering and maintenance**
  a. Summary of the hypothesis
  b. Evidence supporting the hypothesis

a. Summary of hypothesis: Triggering of convection



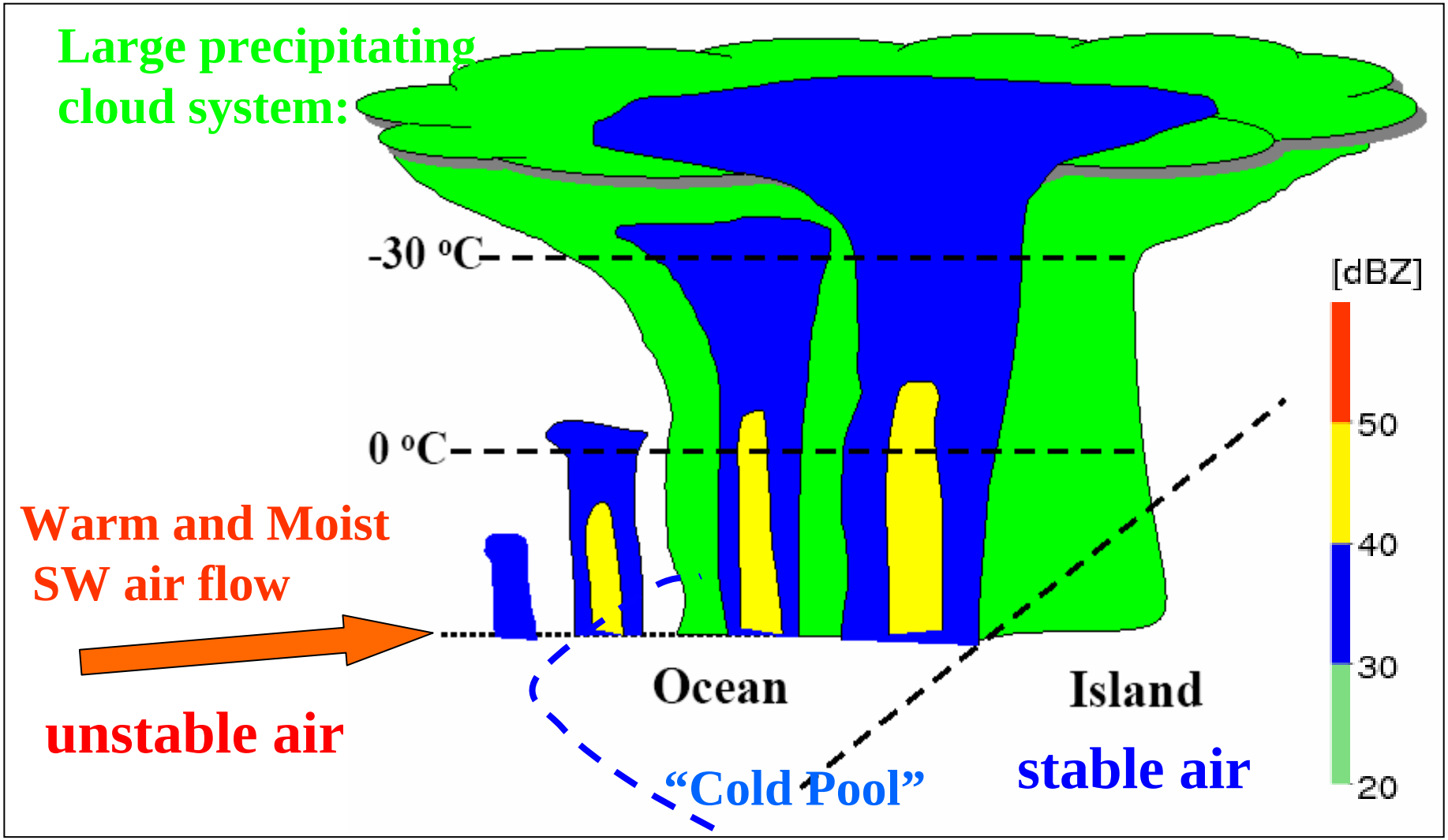
* Previous precipitation (1 day) forms a "cold pool" and becomes barrier to the warm moist SW airflow.

a. Summary of hypothesis: Triggering of convection



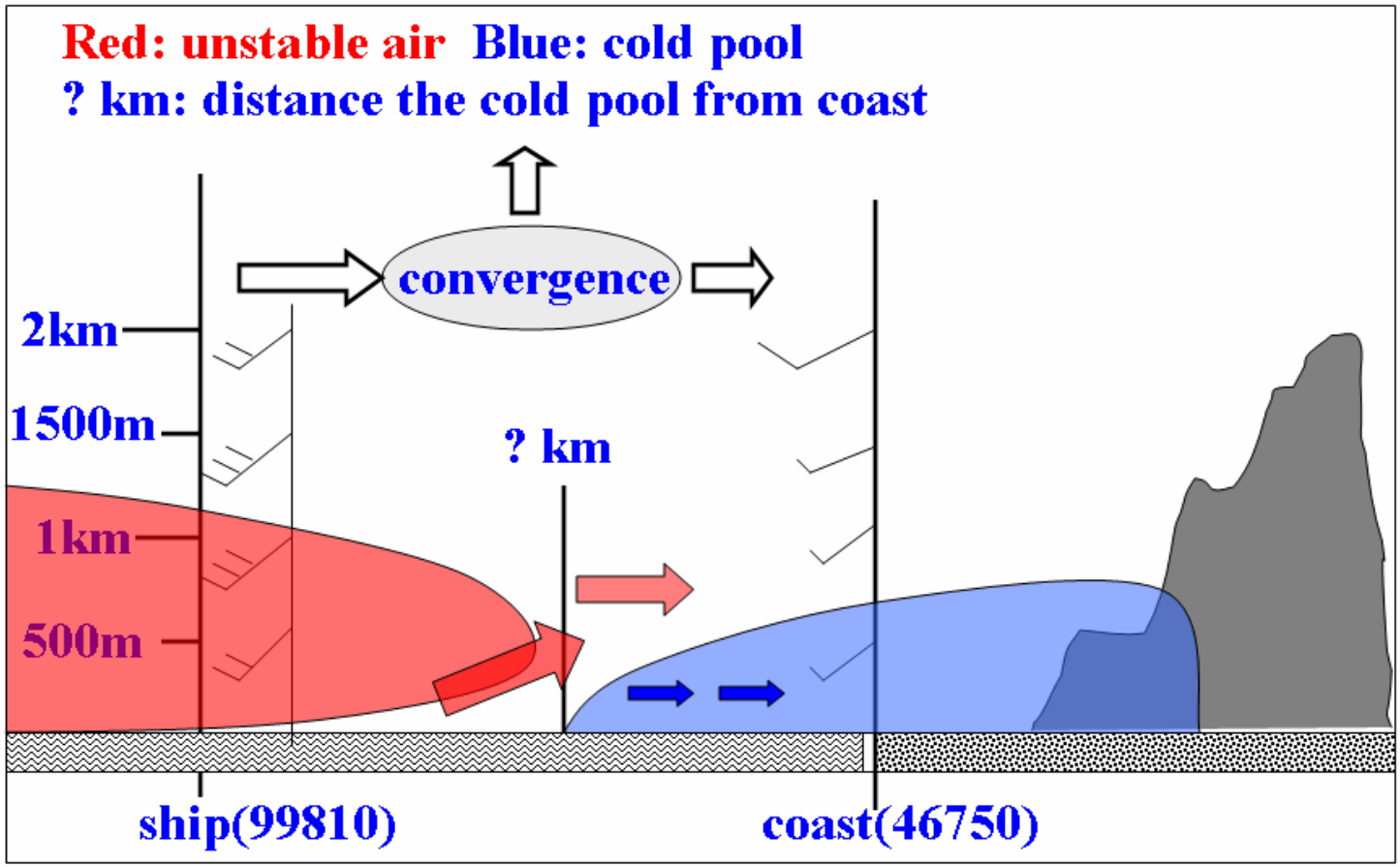
* LLJ and sea-air flux partially restores low level warm and moist air upstream; UNSTABLE enough for deep convection!

a. Summary of hypothesis: Maintenance--back building



* Convective cells keep developing upstream feed the large precipitating cloud but can NOT develop onshore!

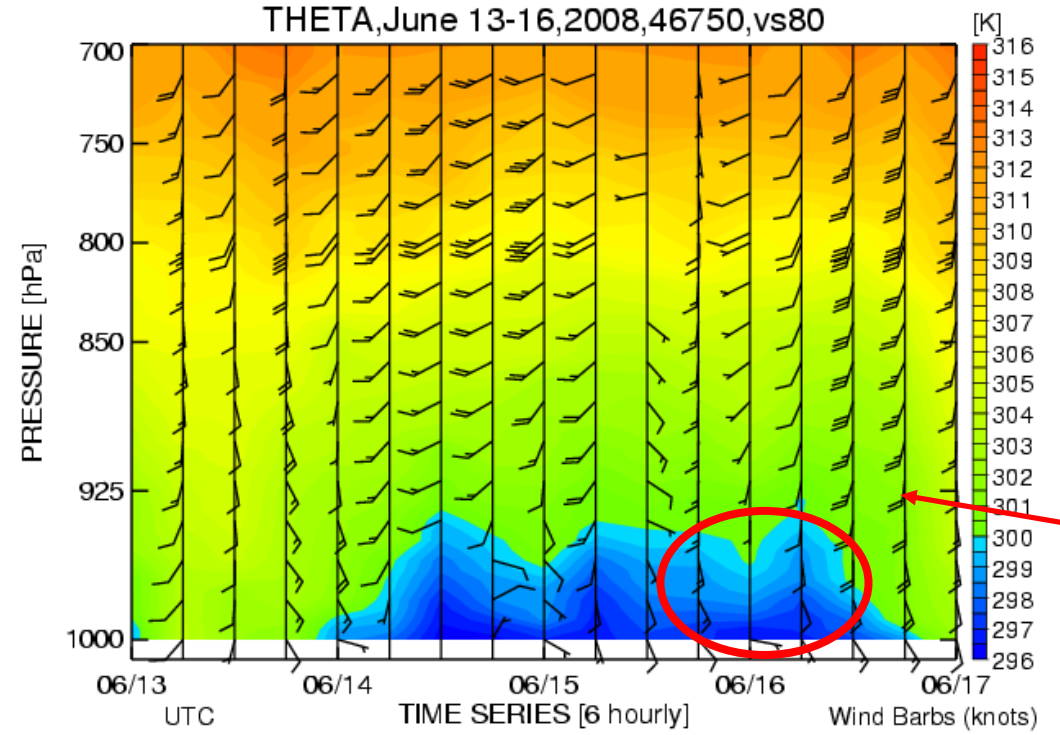
a. Summary of hypothesis: Evidence supporting it

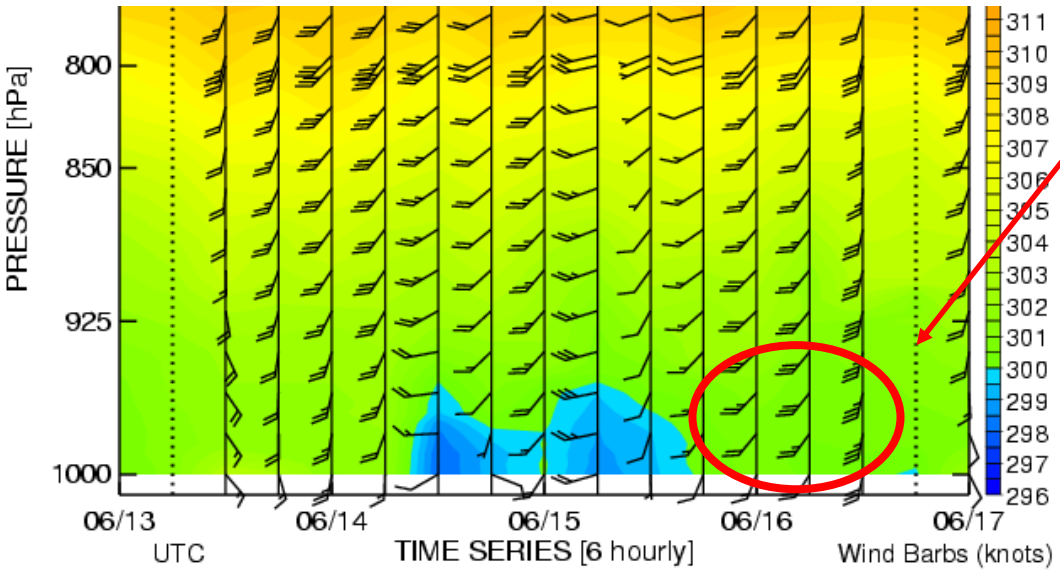


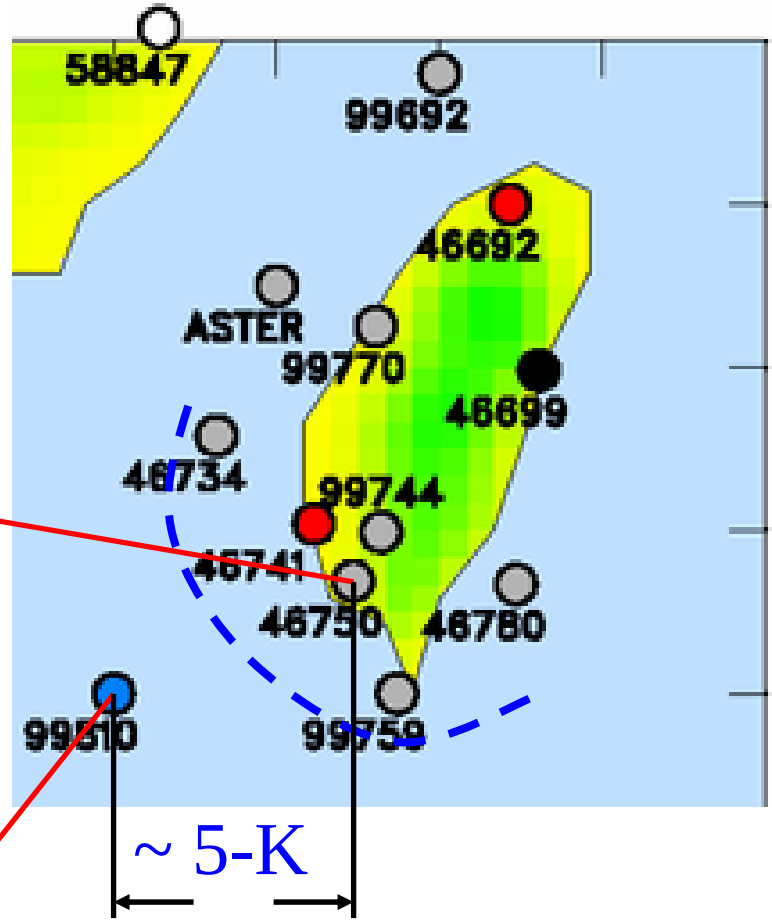
Checking List of evidence:

1. Ship sounding: warm and moist unstable air;
2. Coast sounding: “cold pool” and stable air;
3. Dual Doppler synthesis wind: 2-4 km convergence;
4. Radar surface wind boundary: surface boundary of cold pool.

b. Evidence from soundings : (Theta– time series)





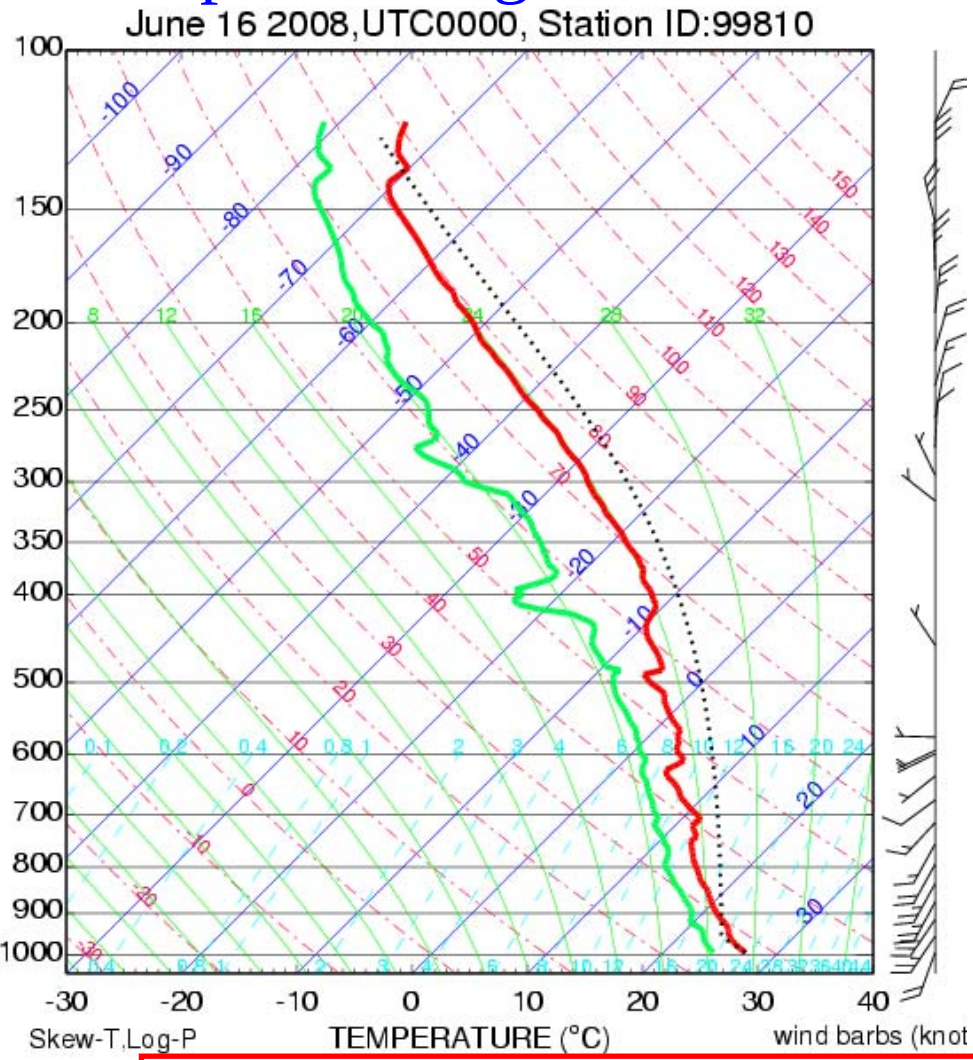


Cold pool (3°C) between ship and coast!

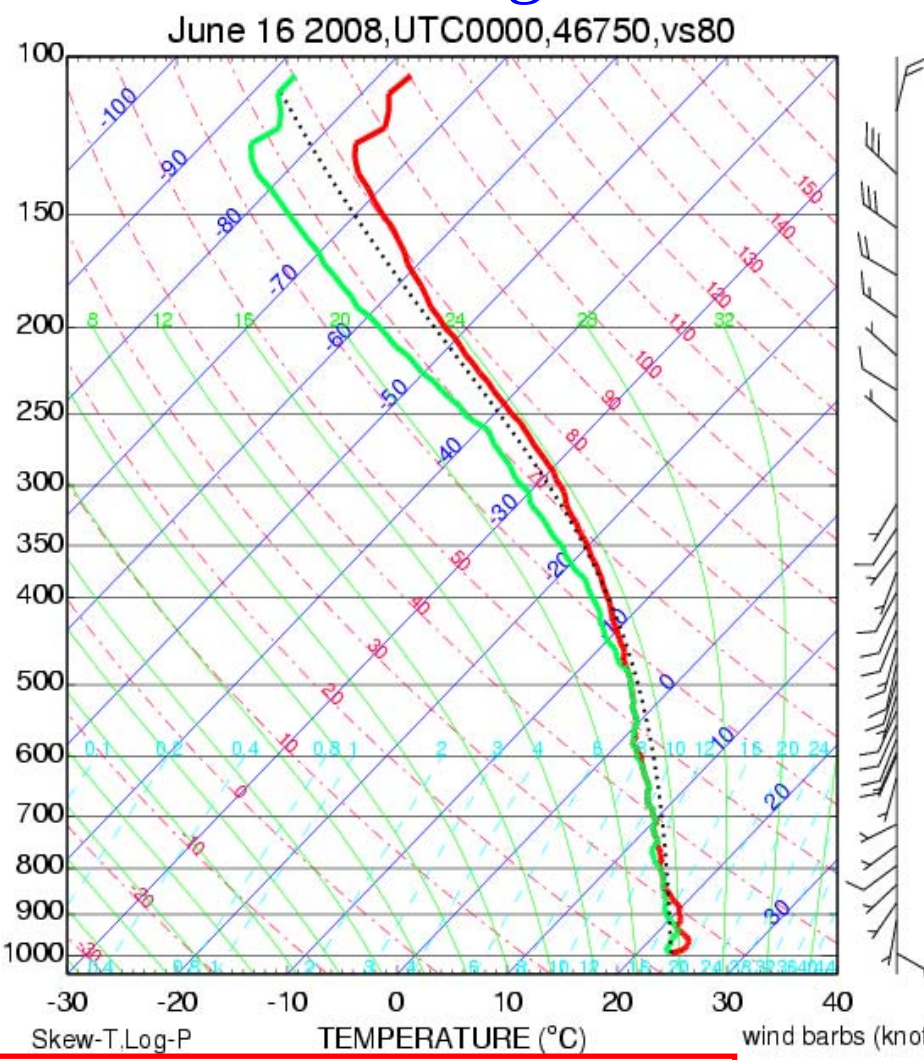
~ 600 m deep over coast.

b. Evidence from soundings : (vertical profiles)

ship sounding 6/16 00Z

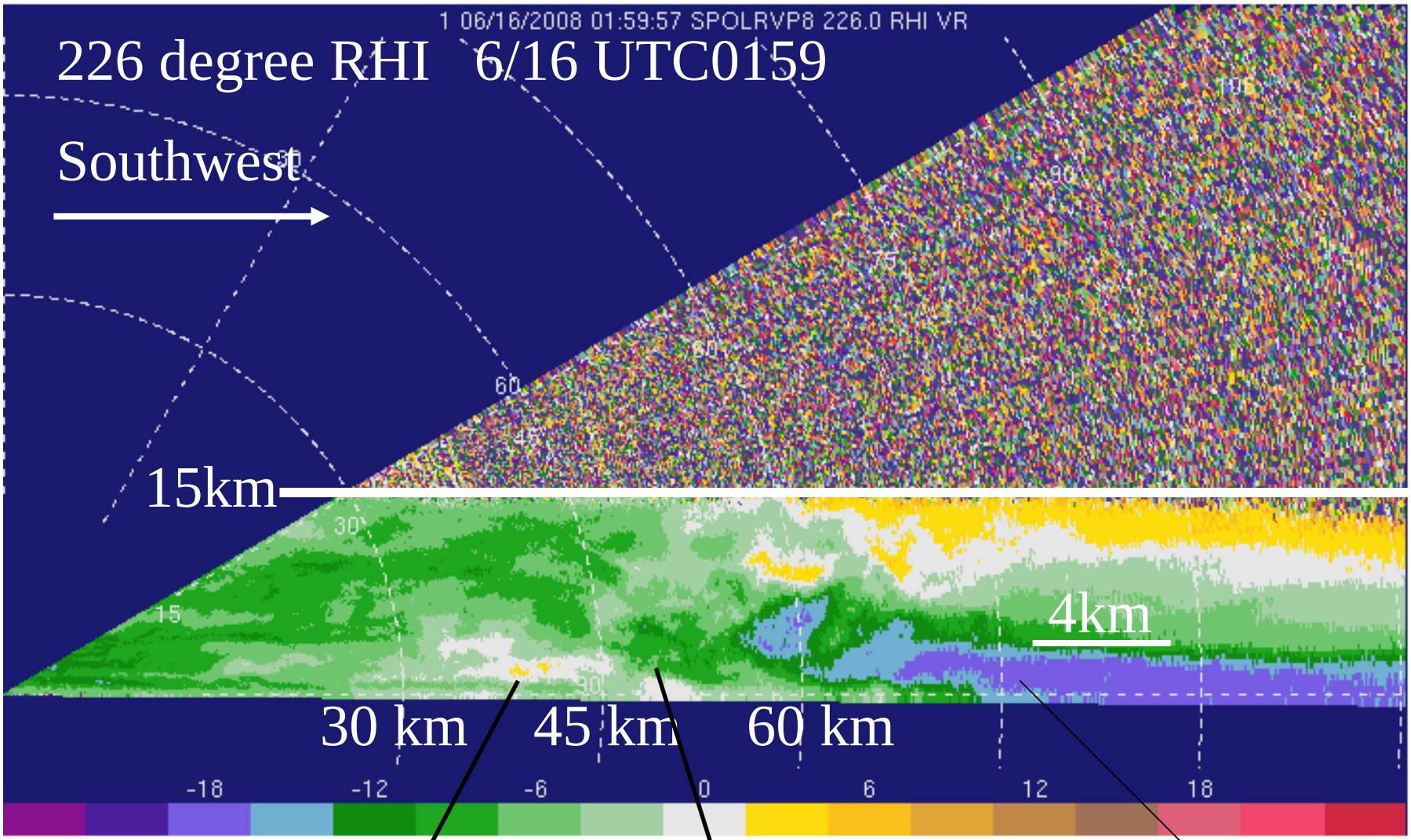


coast sounding 6/16 00Z



Upstream is unstable enough for deep convection,
and it is not favourable for convection over the island!

b. Evidence from radar : (SPOL radial velocity)

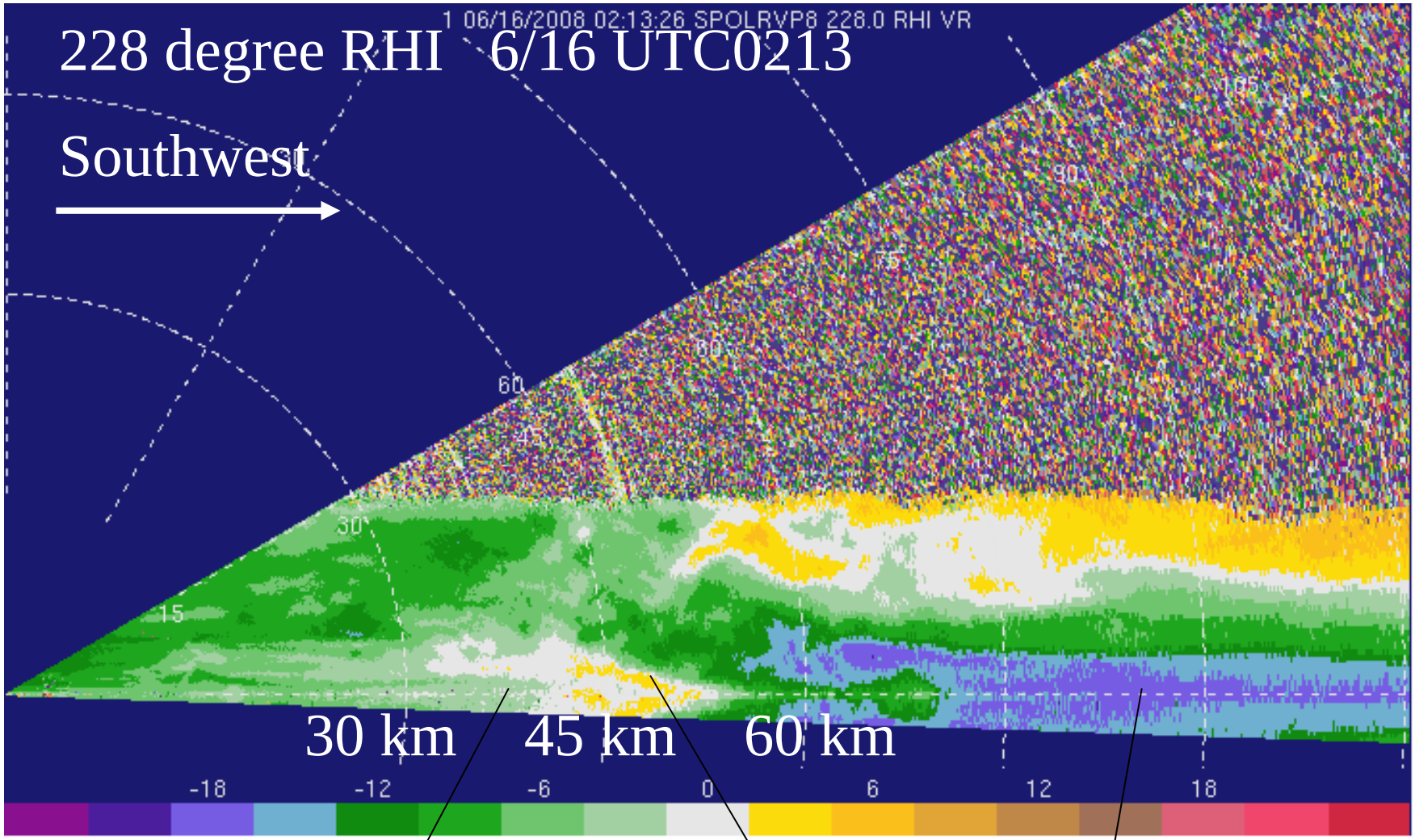


light wind in the "cold pool"?

wind boundary 45-50 km

low level jet

b. Evidence from radar : (SPOL radial velocity)

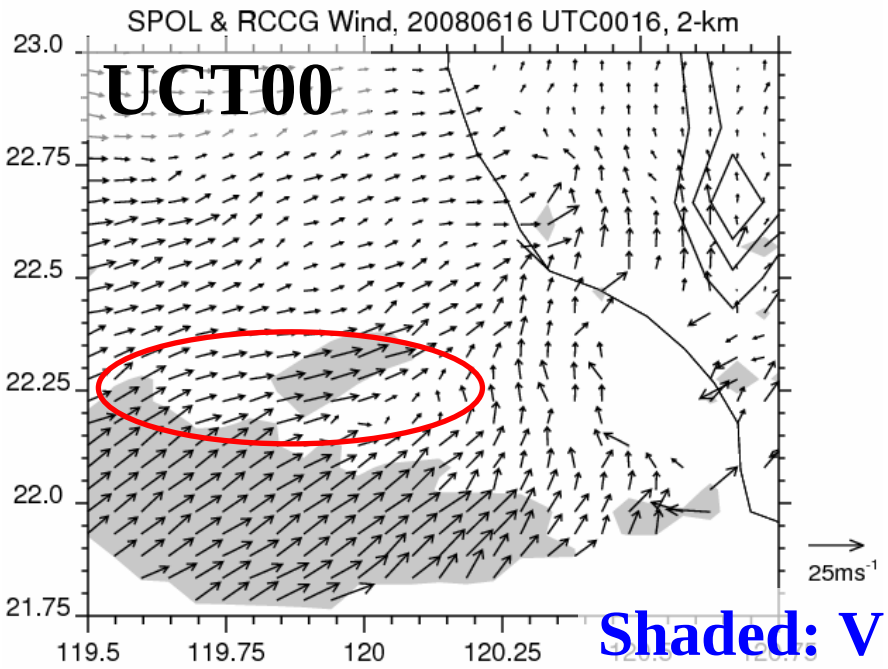


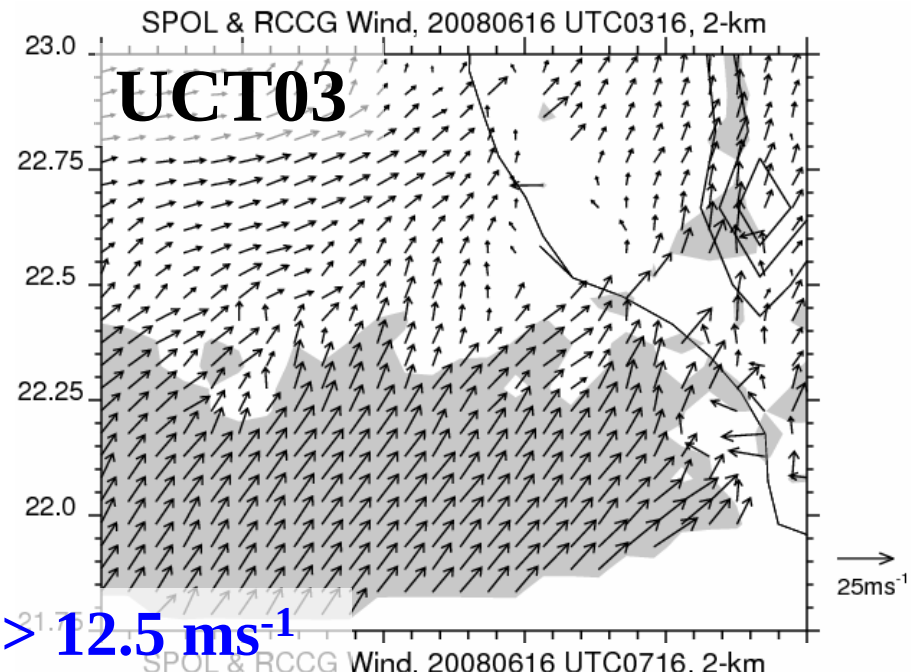
light wind in the "cold pool"?

wind boundary 45-50 km

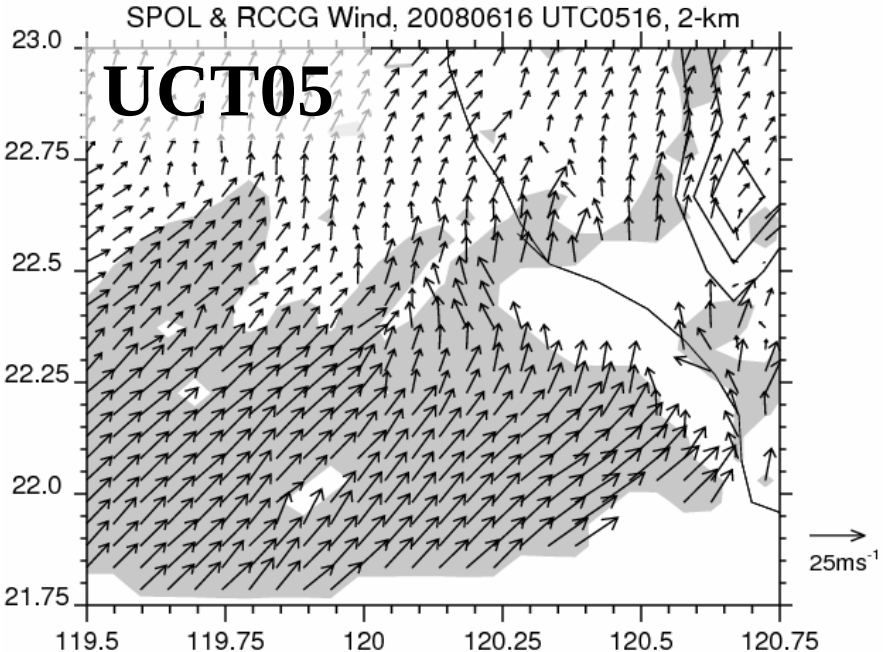
low level jet

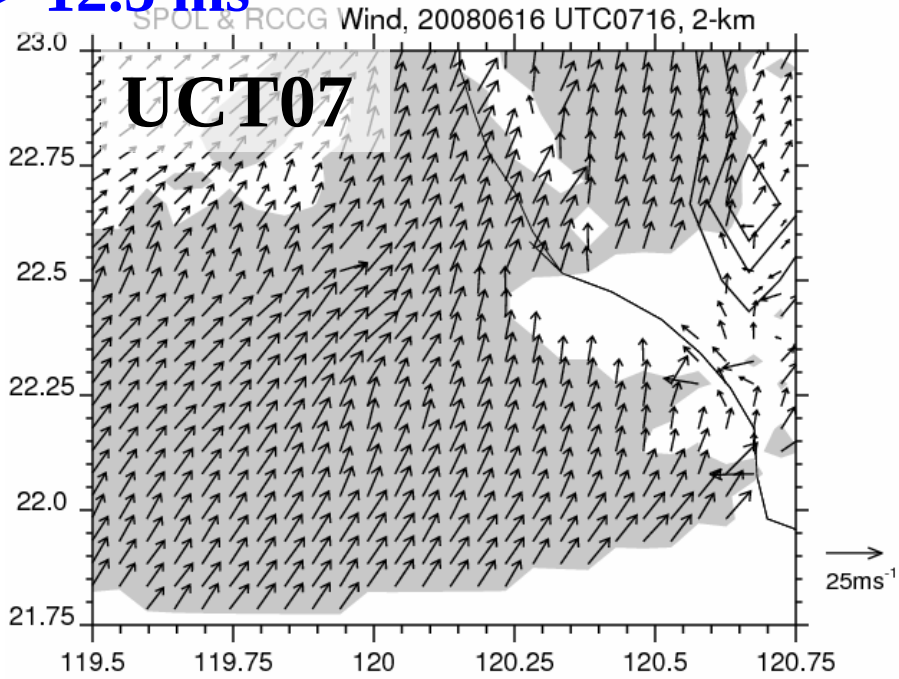
b. Evidence: progression of the LLJ (e.g., 2-km)





Shaded: V > 12.5 ms^{-1}

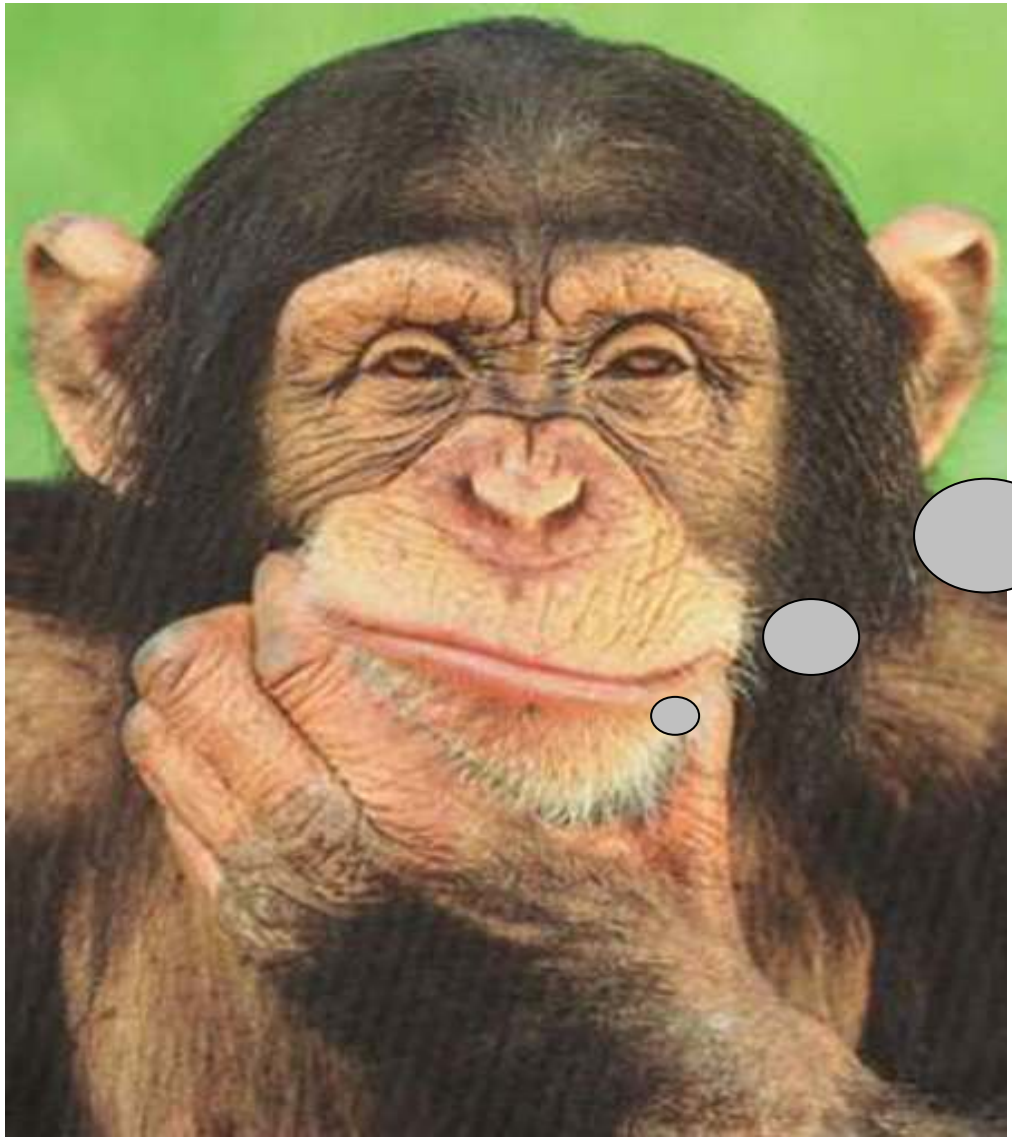




Summary

- On June 16, new convection “redevelops” SW off shore, forms MCSs for ~18 hrs; but convection decays or dies close to the island;
- Hypothesis: Old “cold pool” forms partial barrier to low-level moist SW airflow;
- Sea-air flux partially restores the warm, moist air upstream of Taiwan and destabilizes the atmosphere;
- Convection is triggered upstream of the “cold pool” boundary; but the “cold pool” over the island stops the convection to develop;

Thanks! Questions?



Hum, What's that figure talking about??