UNESCAP/WMO Typhoon Committee

United Nations ESCAP

WMO OMM

Typhoon Committee Roving Seminar 2011

Topic B(3) :

Operational QPE/QPF – Application to TC rainfall

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Petaling Jaya, Malaysia

UNESCAP/WMO
Typhoon Committee

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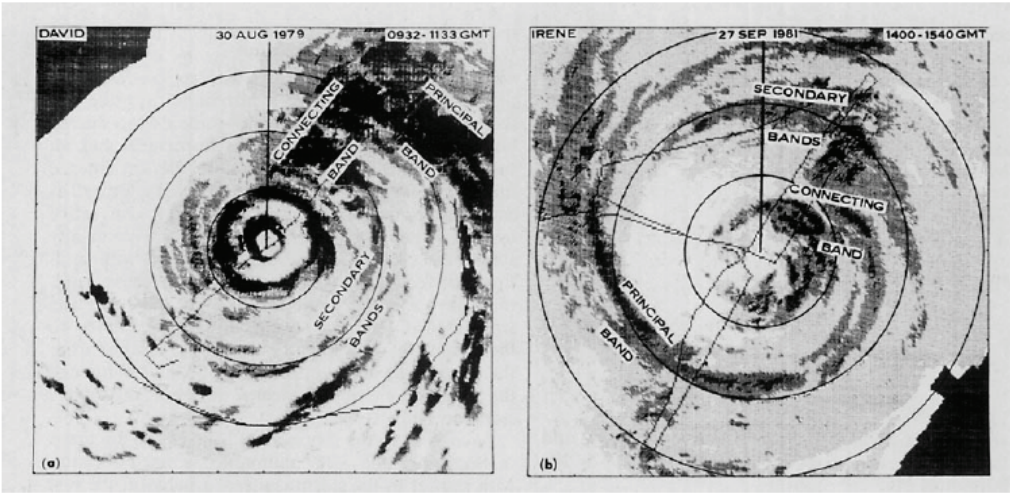
Tropical Cyclone Rainbands

Core & Primary Spiral Bands

Examples & Conceptual Model

- *H.E. Willoughby et al. 1984*



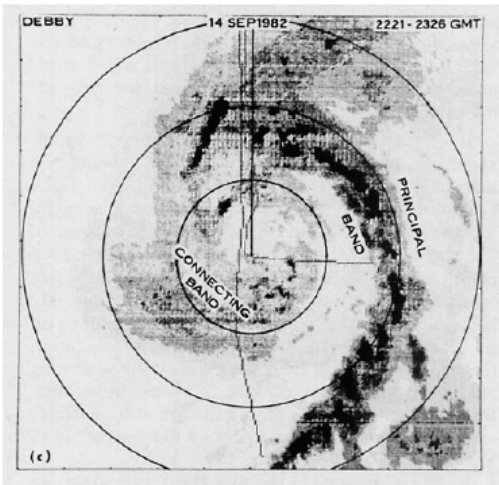


FIG. 2. Radar composites showing the stationary band complex in Hurricanes: (a) David between 0932 and 1133 GMT 30 August 1979, (b) Irene between 1400 and 1540 GMT 27 September 1981, and (c) Debby between 2221 GMT and 2326 GMT 14 September 1982. Successively darker shading indicates reflectivities ≥ 25, 30, 35, and 40 dB(Z) and cross hatching indicates areas not viewed by radar. In panel (a) the domain is 360 km square, in panels (b) and (c) 240 km square; in all three panels range rings appear at 40 km intervals.

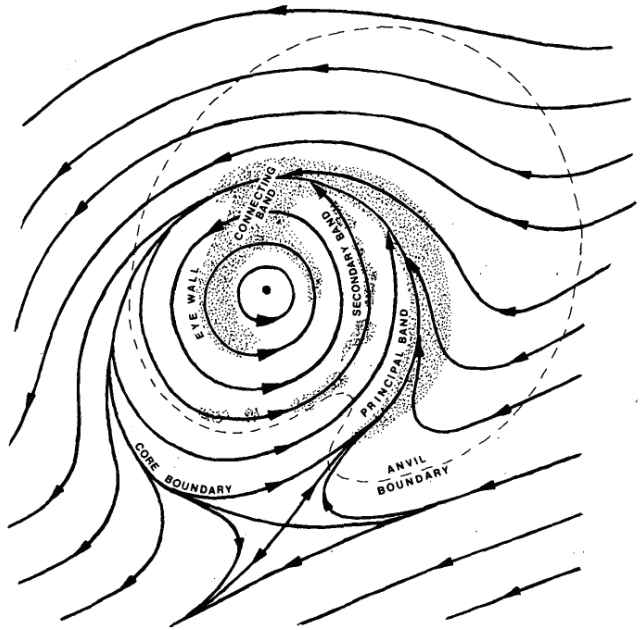
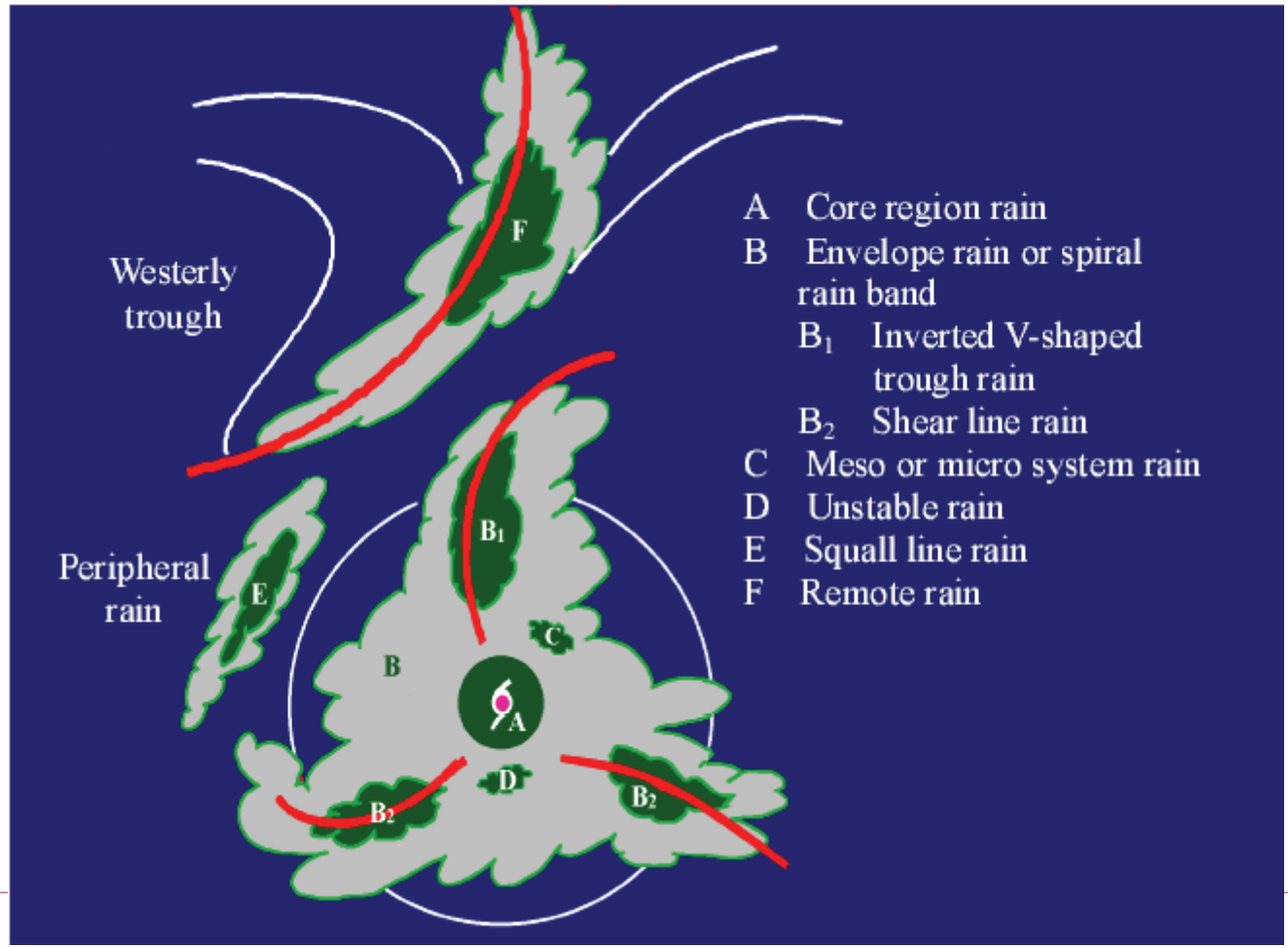


FIG. 18. Schematic representation of the stationary band complex, the entities that compose it and the flow in which it is embedded.

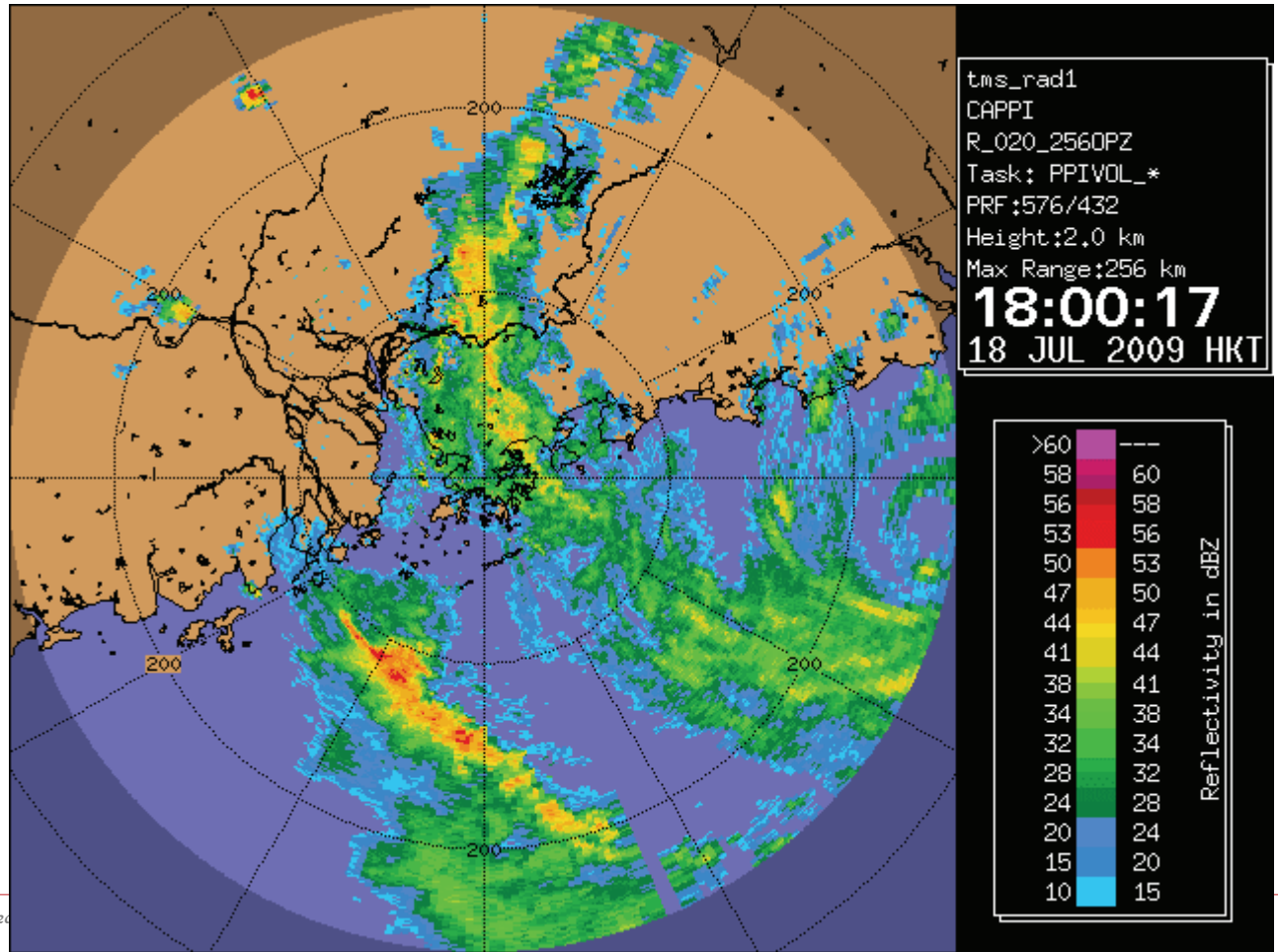
Outer rainbands and Environ. Inter.

- TC rainband classification
  - *L. Chen et al. 2010*



An Example in Hong Kong

- T. Molave (0906)
  - *both spiral and eyewall rainbands affected HK*

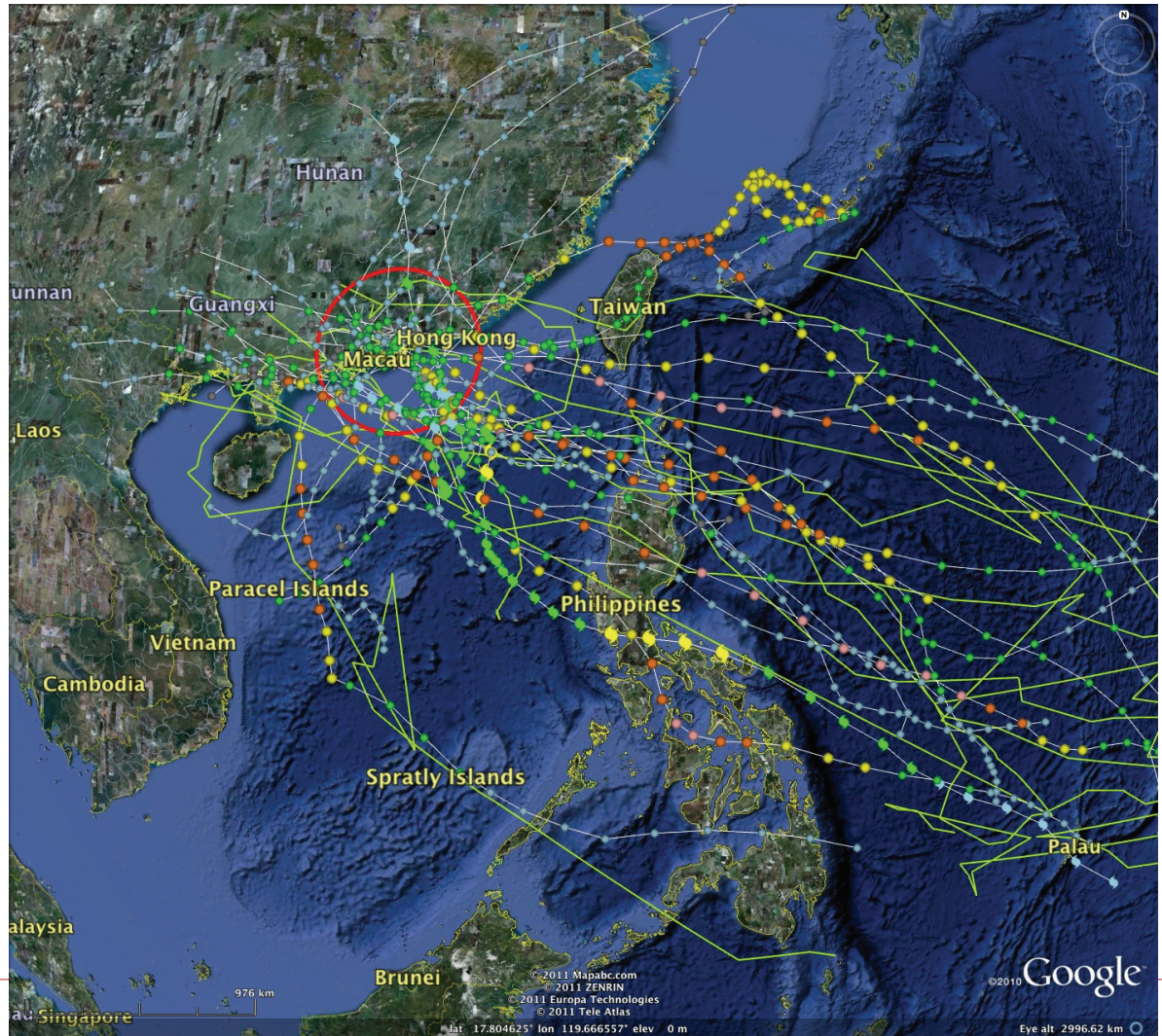


Rainstorms Related to TC

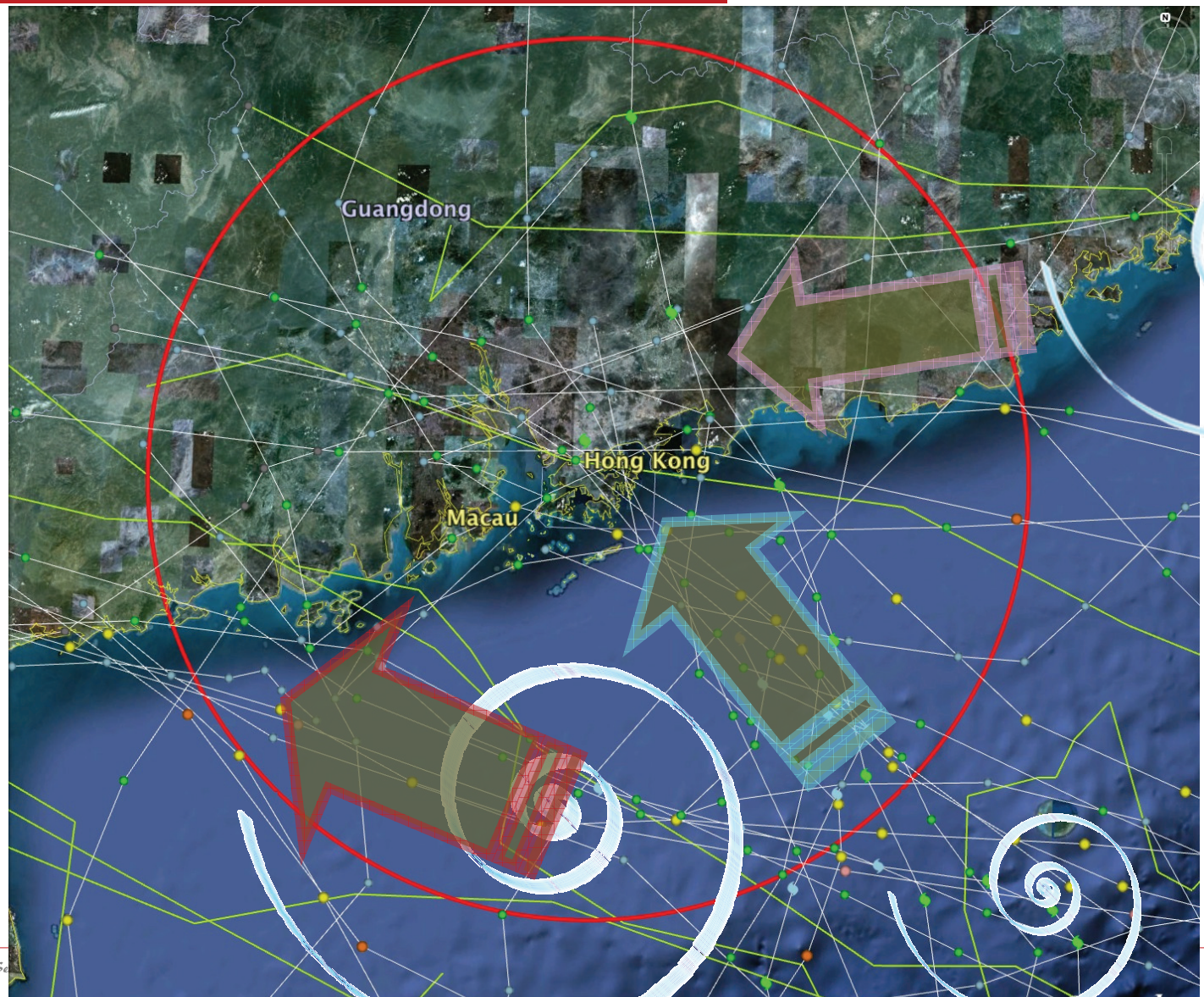
- **mechanisms seen in southern China coastal areas:**
  - *eyewall / core*
    - direct hit by TC
    - e.g. Molave, York, etc.
  - *spiral bands*
    - due to approaching TC
  - *active southwesterlies*
    - due to TC fallen onto the mainland
  - *southeasterly convergence*
    - TC departing to the west or southwest
    - tail S/SW'lies converging with SE'lies from Pacific ridge
  - *sea breeze convergence*
    - sea breeze convergence with N/N'lies of distant TC
    - known locally as evening thunderstorms

Proximate TC 1999-2010

- within the 256-km range of HKO's radarscope



Proximate TC Tracks ~ HK



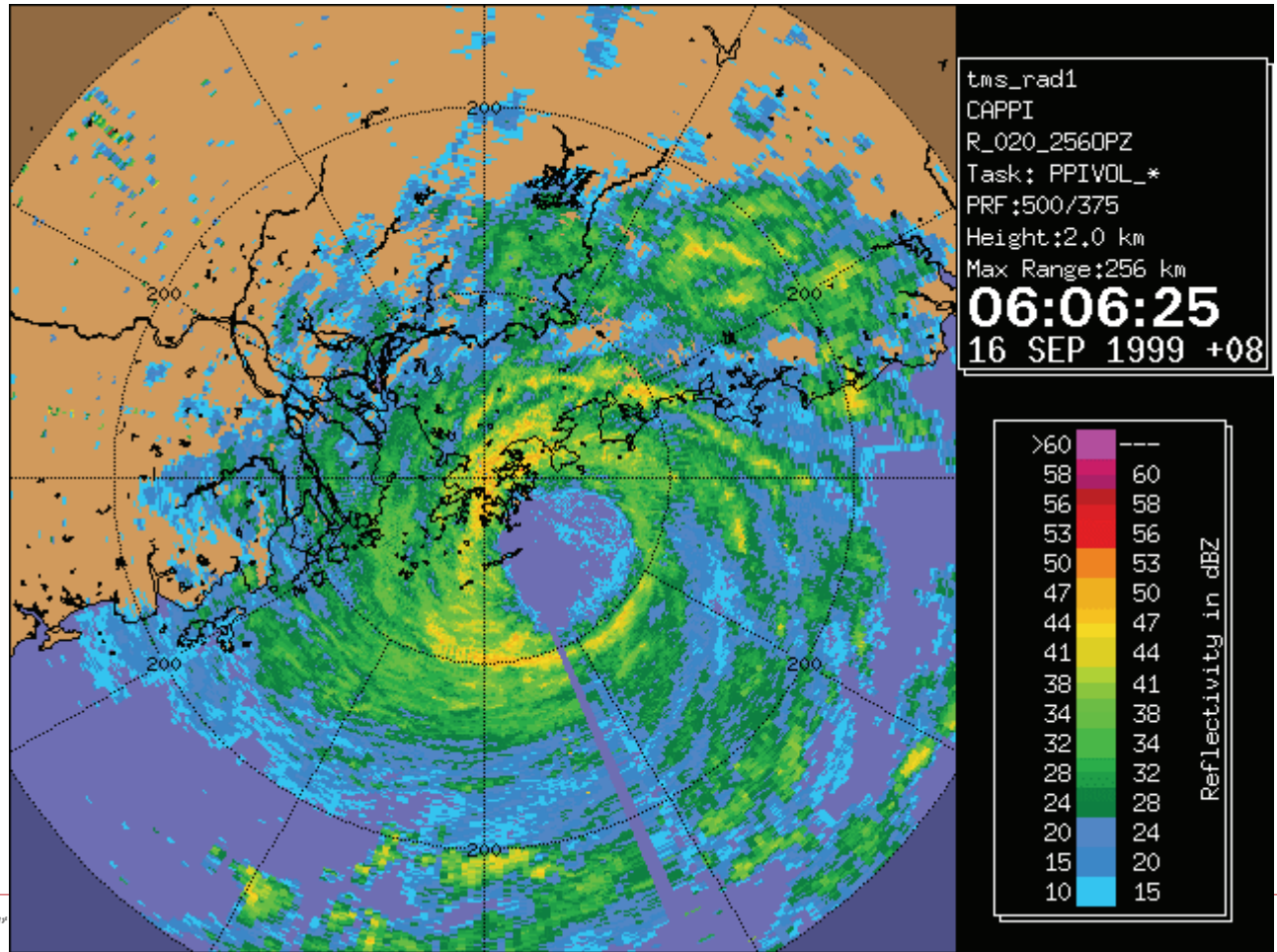
Examples of TC Rainstorms

Table I – Z-R parameters for the five TCs that produce serious rainstorms in Hong Kong during their passages.

TC			Wind Regime	Z-R Parameter	
Name	I.D.	Intensity	(rainstorm)	*a*	*b*
York	9915	Typhoon	N to NE	107.25	1.55
Unnamed storm in Sep 2006	-	Tropical Depression	E	231.05	1.40
Neoguri	0801	Typhoon	S to SE	274.66	1.35
Fengshen	0806	Typhoon	SW	250.16	1.36
Molave	0906	Typhoon	W to SW	267.67	1.52

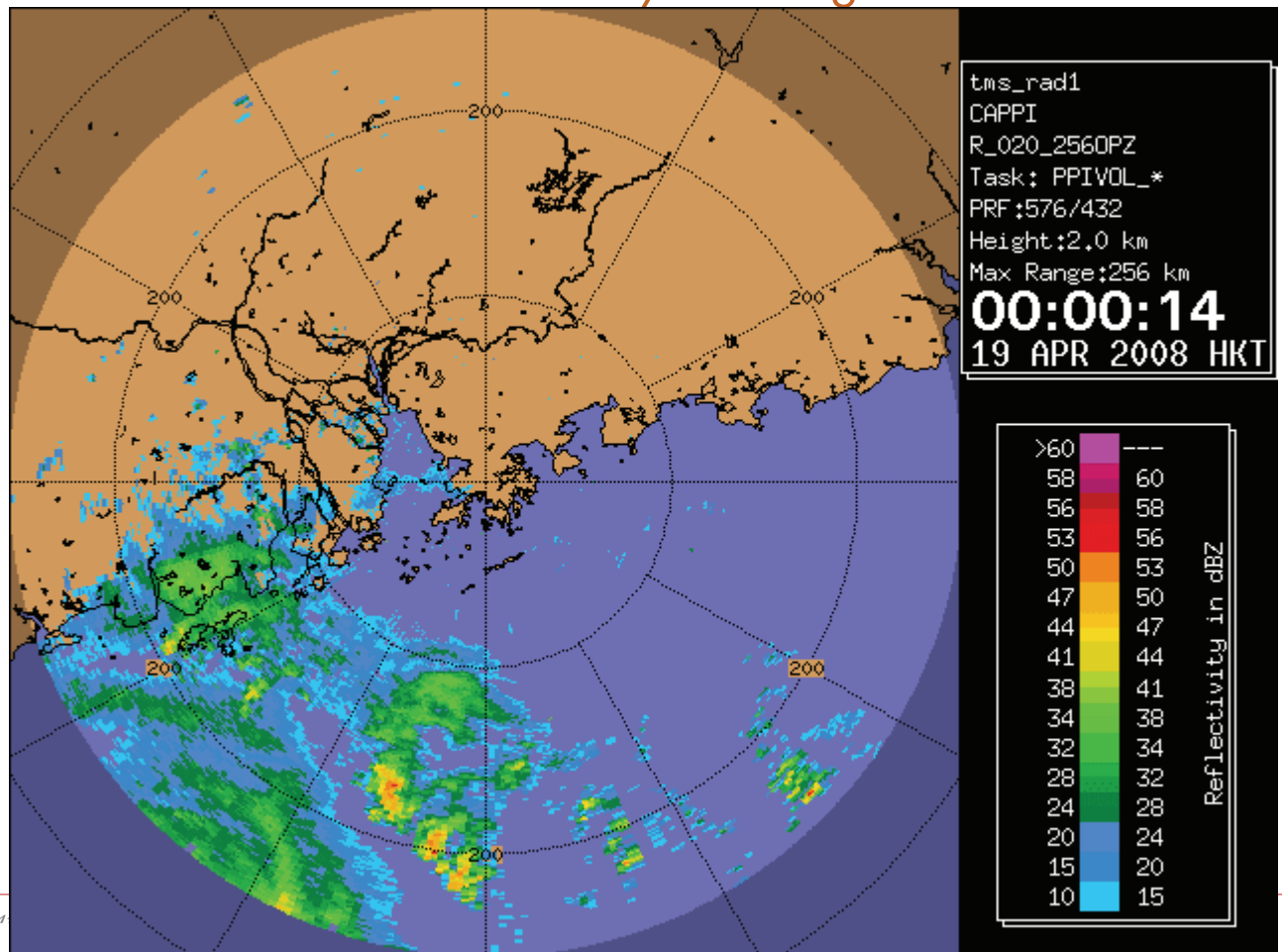
Typhoon York (9915)

- **Red Rainstorm (hourly rainfall ≥ 50 mm)**
  - *eyewall rainbands affected HK for a prolonged period*

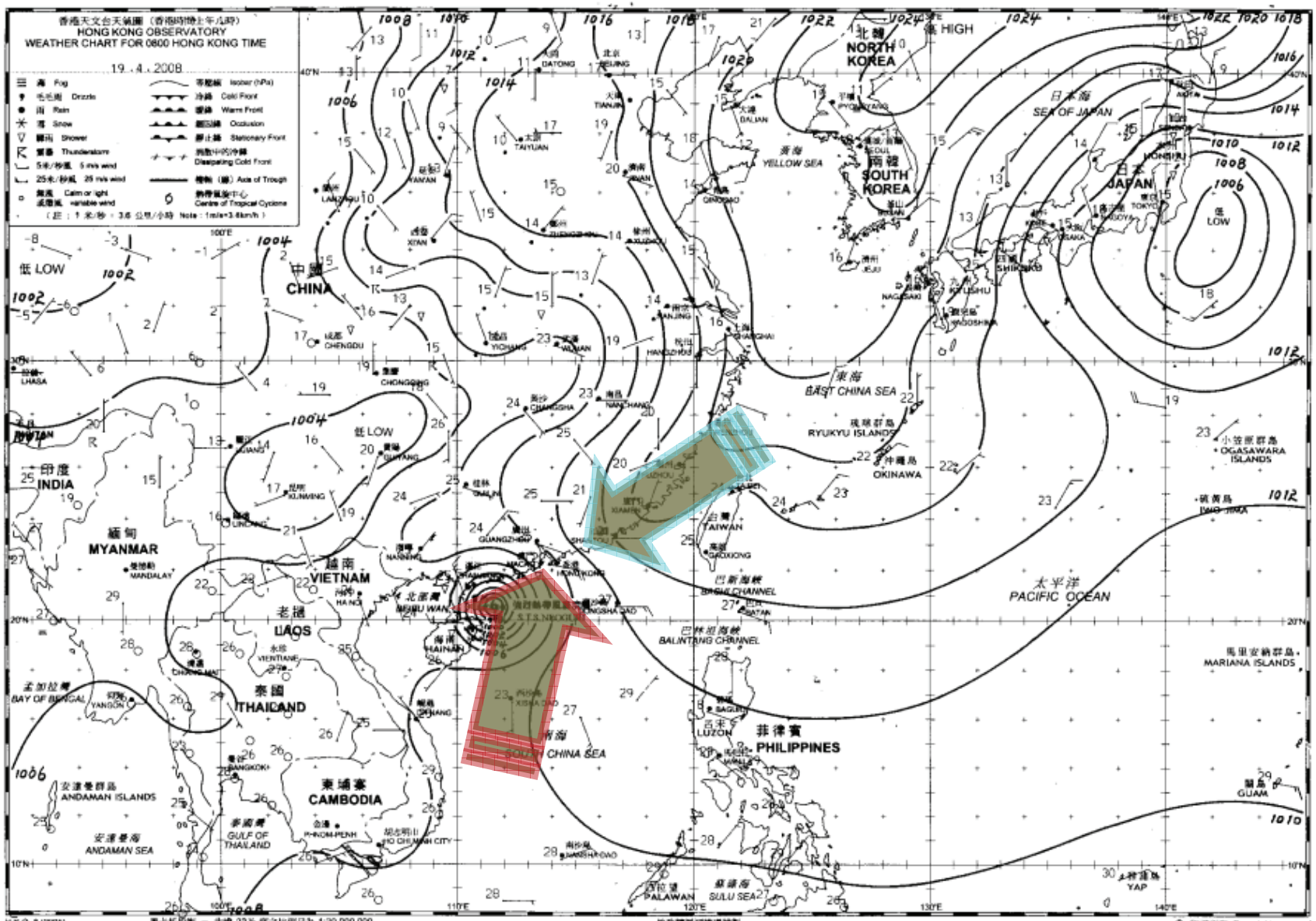


Typhoon Neoguri (0801)

- **Black Rainstorm**
  - *widespread hourly rainfall ≥ 70 mm*
  - *core rainbands enhanced by convergence with NE monsoon*

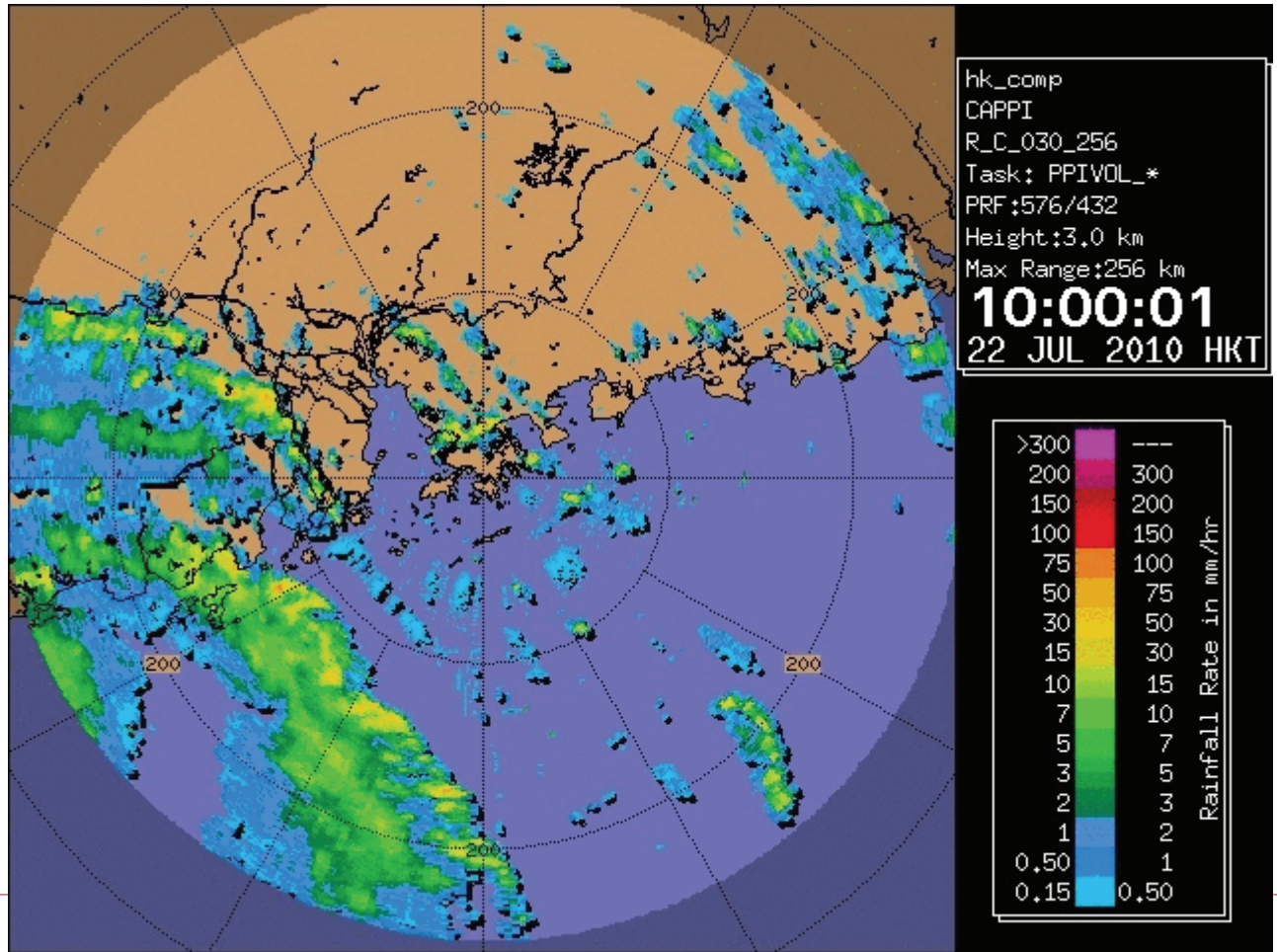


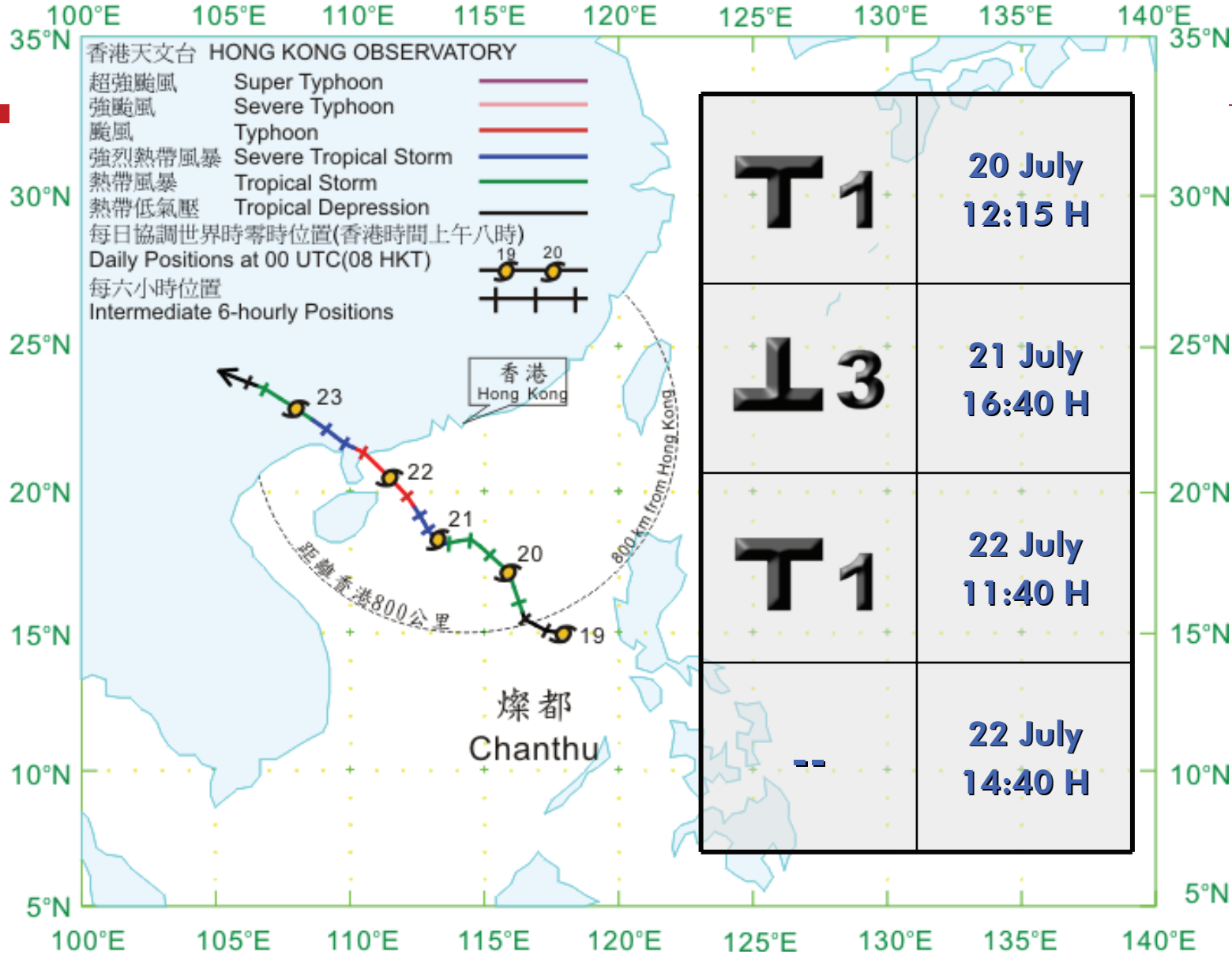
Interaction with NE Monsoon



TC Interacting with Pacific Ridge

- outer circulation of Typhoon Chanthu converging with SE'lies from the Pacific Ridge



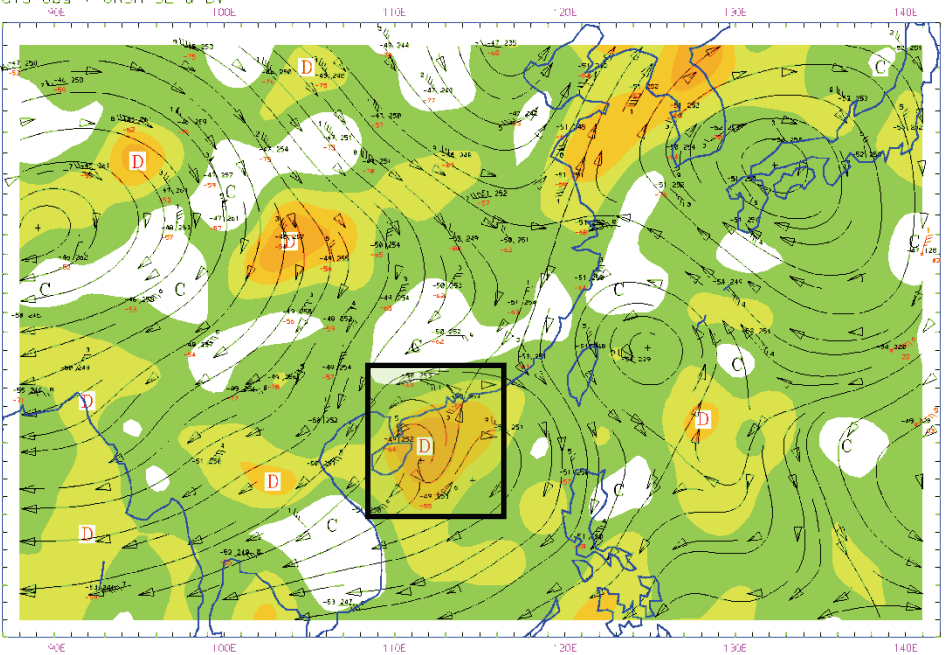


T1	20 July 12:15 H
⊥3	21 July 16:40 H
T1	22 July 11:40 H
--	22 July 14:40 H

UPPER AIR 200 HPA
GTS obs + ORSM SL & DV

THU 201007 2200 UTC

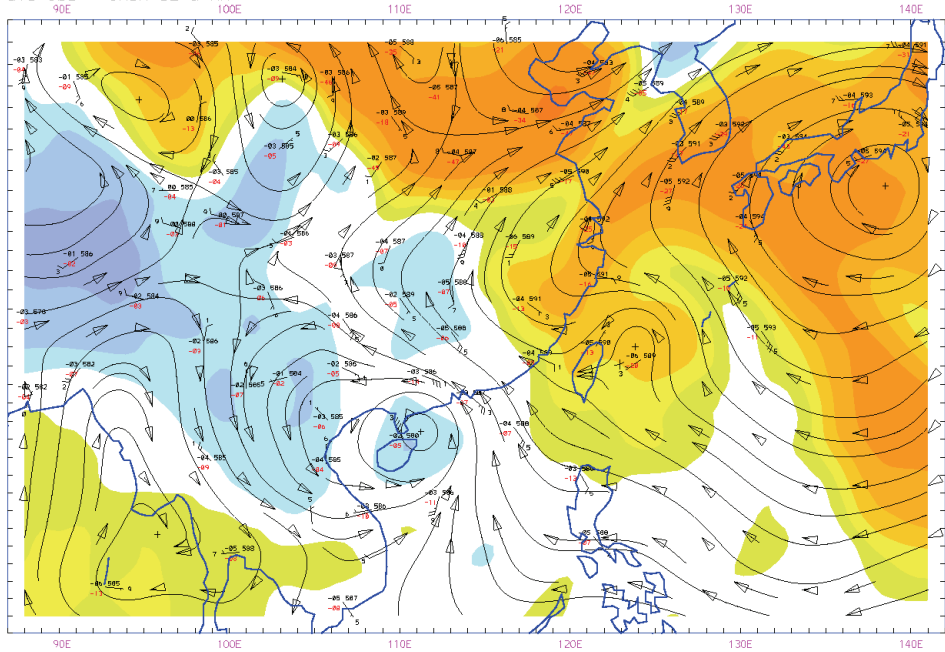
010-040N / 088- 141E
Prepared at 201007 221241



UPPER AIR 500 HPA
GTS obs + ORSM SL & RH

THU 201007 2200 UTC

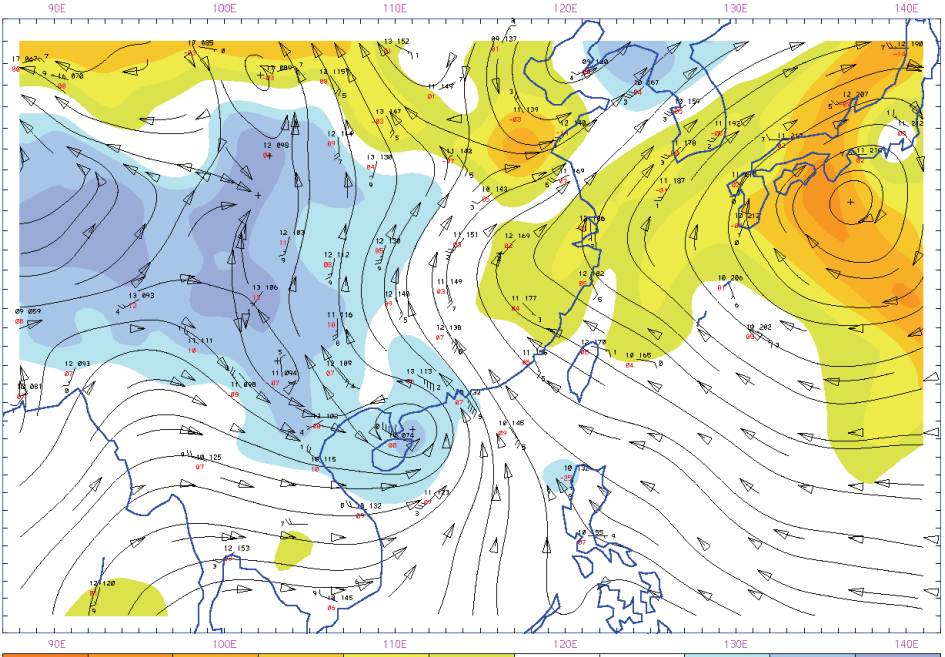
010-040N / 088- 141E
Prepared at 201007 221240



UPPER AIR 700 HPA
GTS obs + ORSM SL & RH

THU 201007 2200 UTC

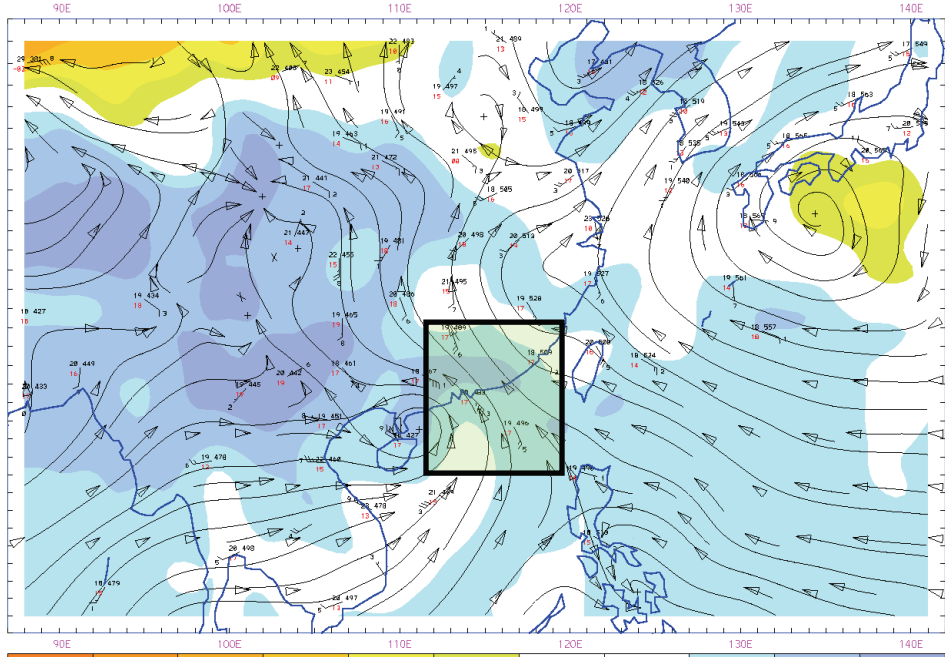
010-040N / 088- 141E
Prepared at 201007 221240



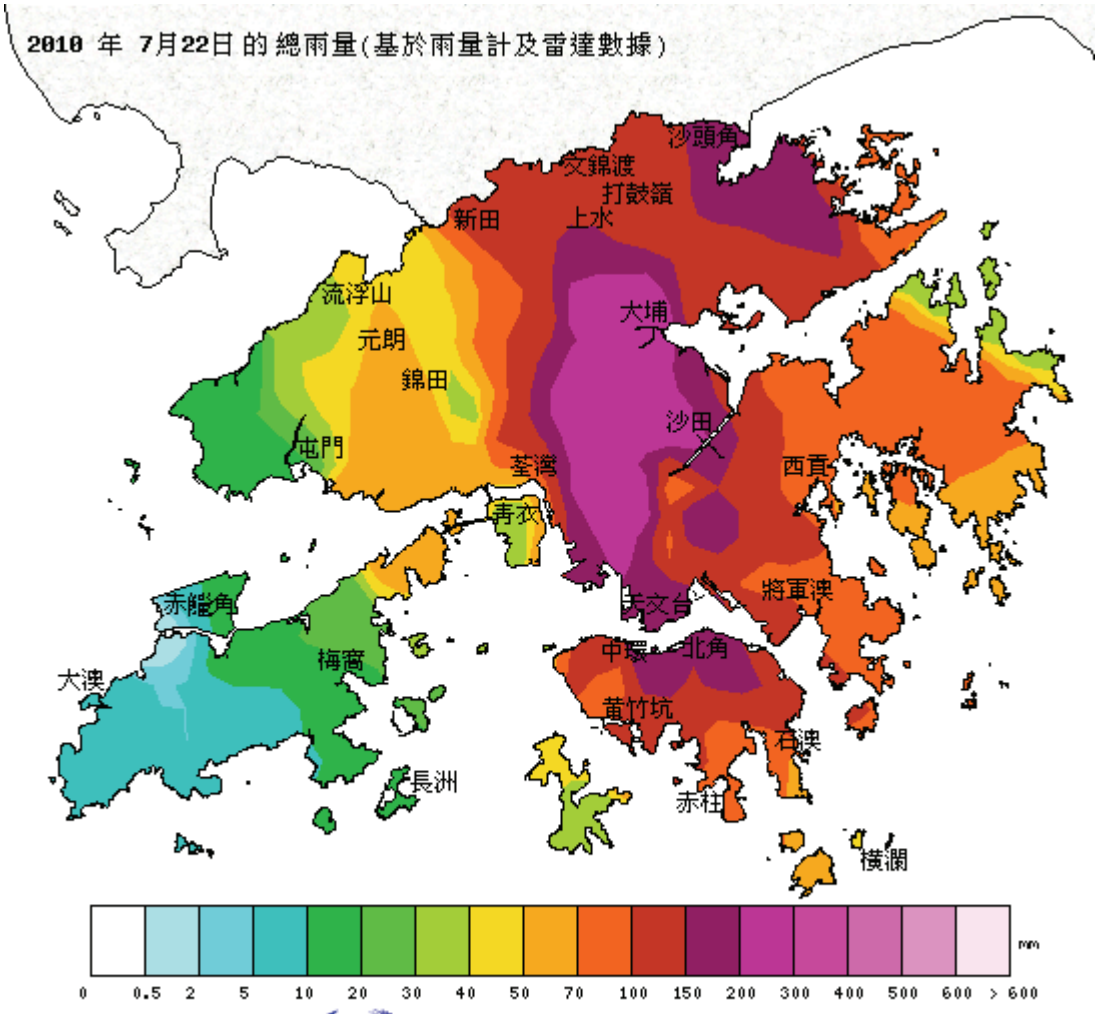
UPPER AIR 850 HPA
GTS obs + ORSM SL & RH

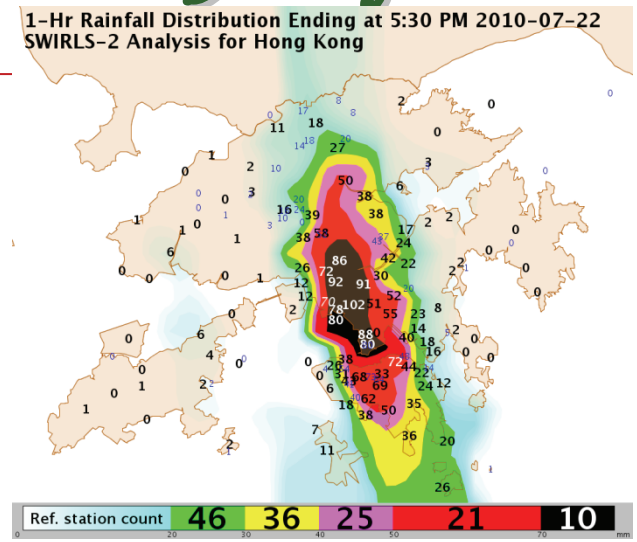
THU 201007 2200 UTC

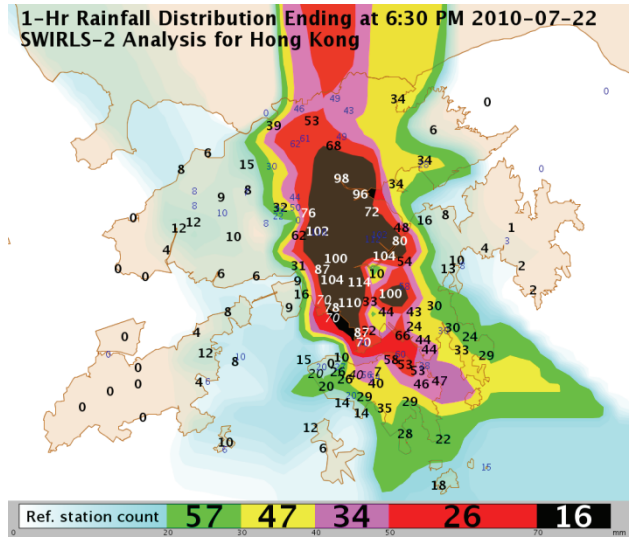
010-040N / 088- 141E
Prepared at 201007 221239



Rainfall Distribution on 22 July 2010







香港天文台
HONG KONG OBSERVATORY

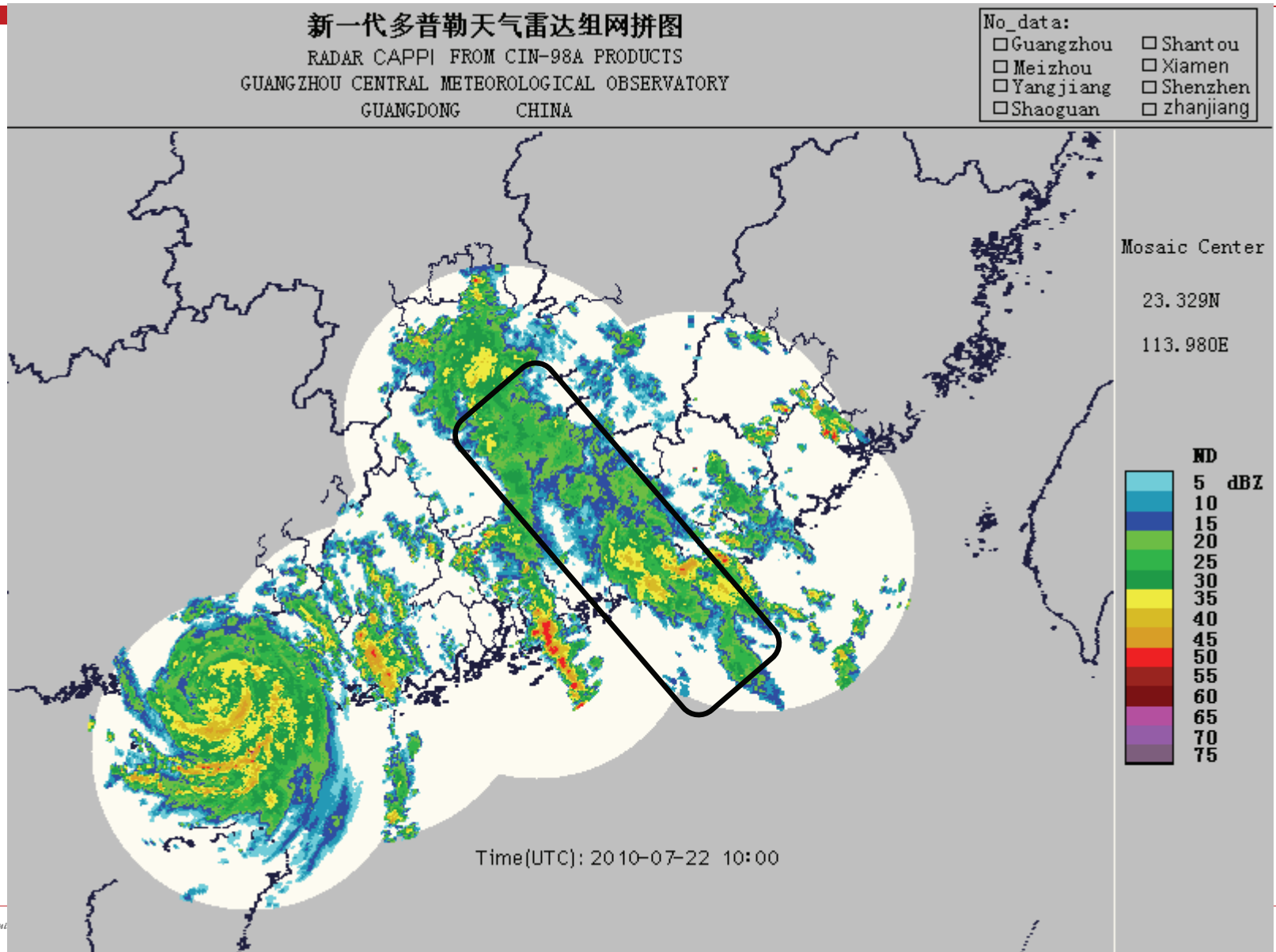
Weather Impacts

Amber 黃	16:35
Red 紅	17:20
Black 黑	17:30
Amber 黃	19:50
--	21:00

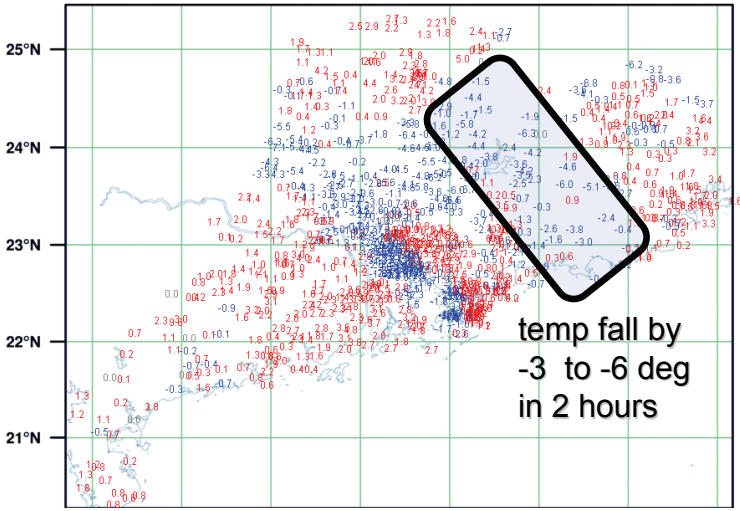
	Start	End
雷暴 Thunderstorm	22 July 09:40	23 July 01:45
	22 July 17:40	23 July 01:00
	22 July 18:10	23 July 04:35

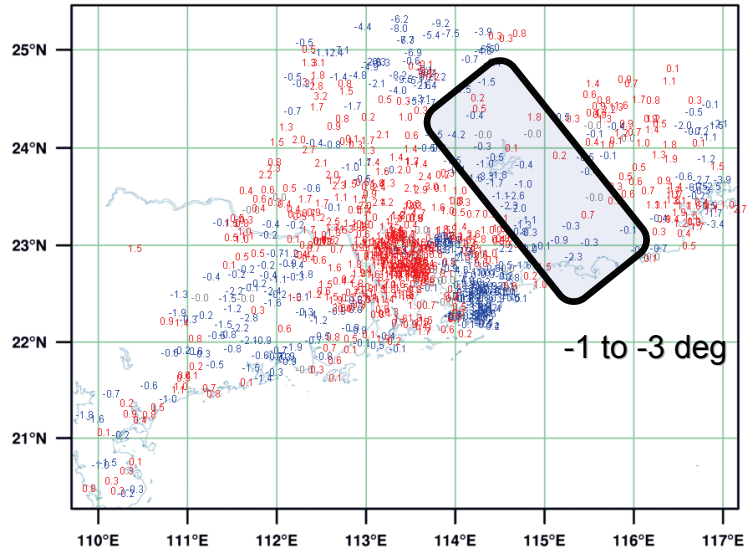
- flash floods and casualty in the evening of 22 July 2010

Radar Mosaic of Guangdong

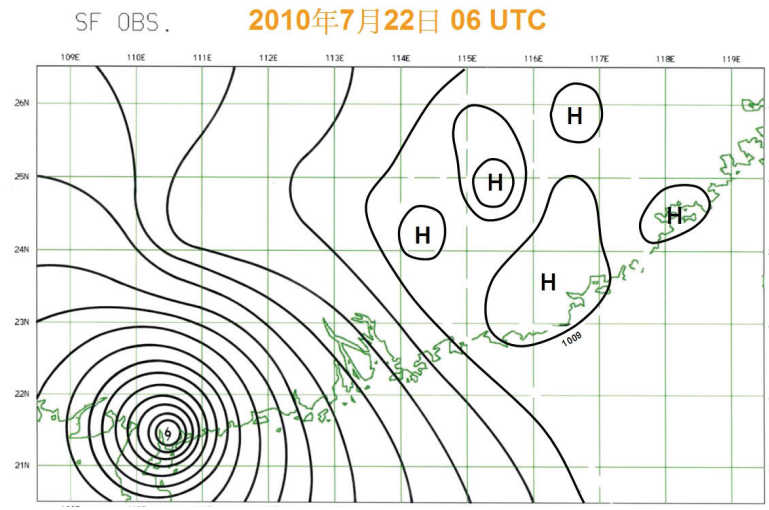


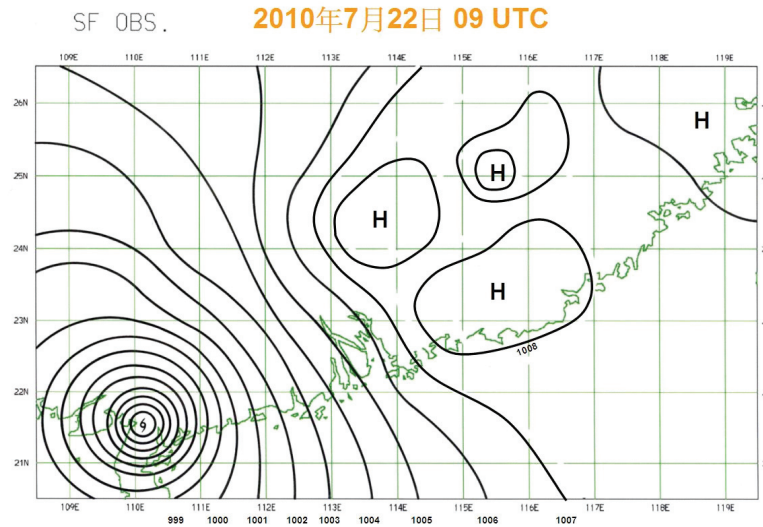
Mesoscale Enhancement



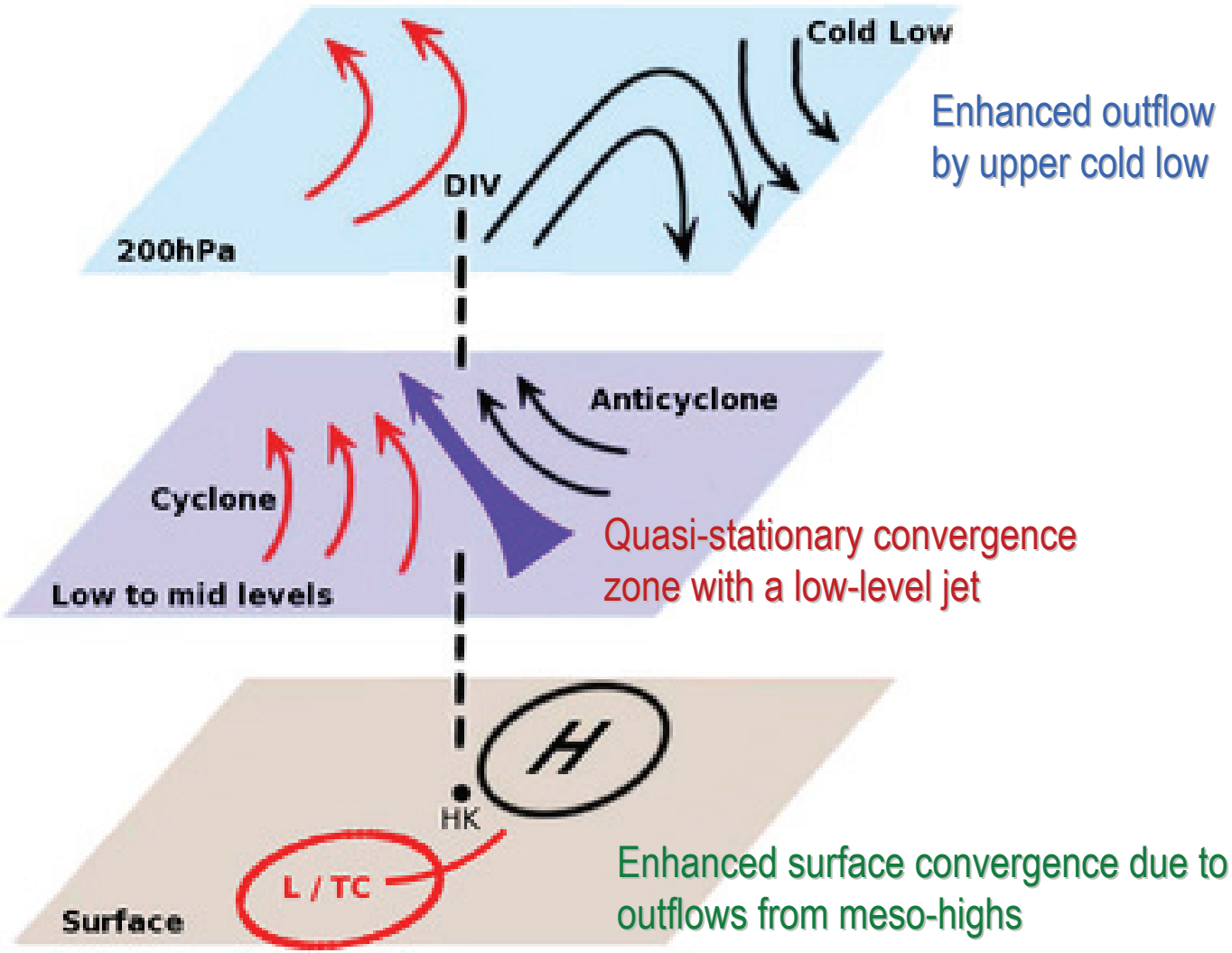


red: temp rise blue: temp fall





A Simple Conceptual Model



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Challenges in TC RPE/RPF

Uniqueness of TC Rainbands

- **nowcasting range**
  - *radar QPE*
    - Z-R relation calibrations for tropical cyclone rainbands?
  - *radar tracking of TC rainbands*
    - multi-scale motions of spiral bands and large scale translation of the whole system
  - *orographic enhancement by land-falling TCs*
    - where and how much?
- **very short to short range**
  - *mesoscale interactions and enhancement*
    - radar data assimilation by mesoscale NWP model?
- **medium range**
  - *TC track and intensity predictions*
    - large errors and un-realistic rainfall distribution in the mesoscale

Radar QPE for TC Rainfall

- the *b* parameter in Z-R relation generally smaller than 1.6:

TC			Wind Regime	Z-R Parameter	
Name	I.D.	Intensity	(rainstorm)	*a*	*b*
York	9915	Typhoon	N to NE	107.25	1.55
Unnamed storm in Sep 2006	-	Tropical Depression	E	231.05	1.40
Neoguri	0801	Typhoon	S to SE	274.66	1.35
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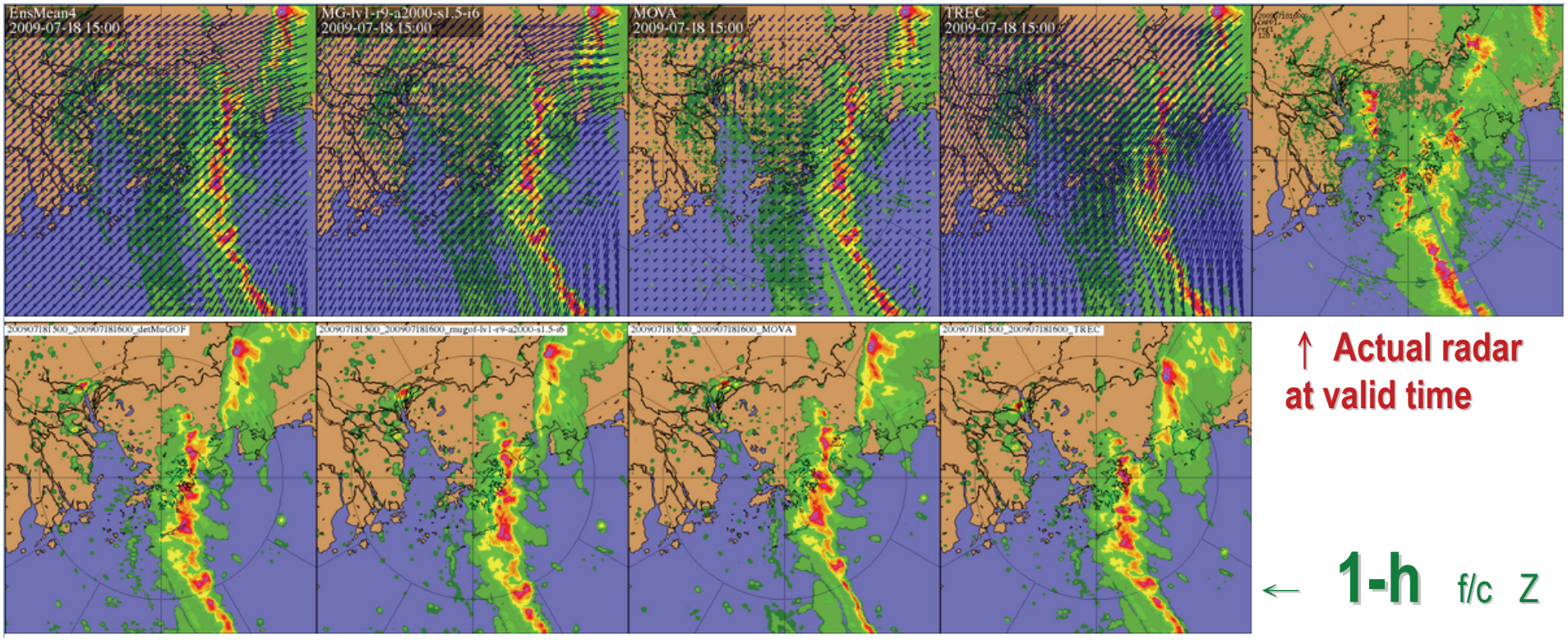
Molave	0906	Typhoon	W to SW	267.67	1.52

- climatological Z-R determined for HK using 36 proximate TCs in 1999-2010:
  - *a = 228.82 and b = 1.33*
- flow dependent?

Tracking of TC Rainbands

- First example from the case of T. Molave (0906)
  - *2009-07-18 15:30H (base time)*
    - tracking and 1-hour extrapolation of a fast moving outer band



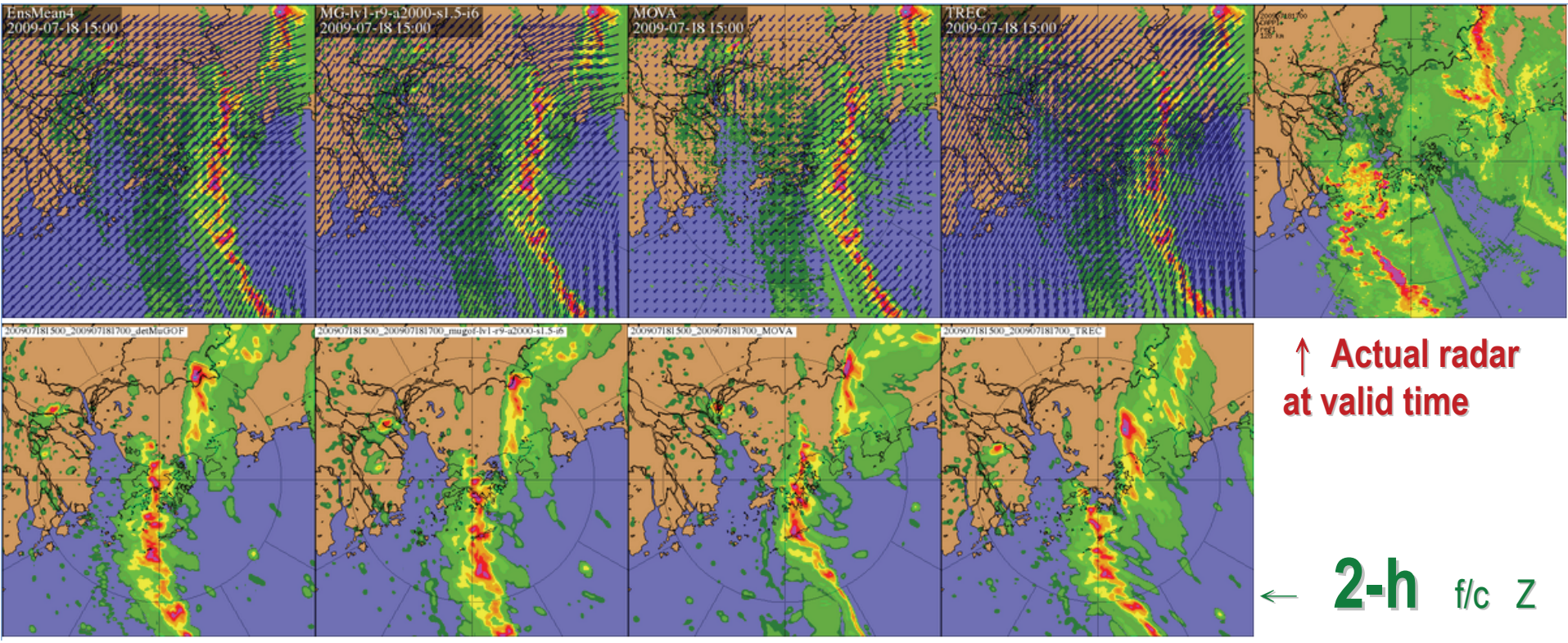
↑ Actual radar at valid time

← 1-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

Tracking of TC Rainbands

- First example from the case of T. Molave (0906)
  - *2009-07-18 15:30H (base time)*
    - tracking and 2-hour extrapolation of a fast moving outer band



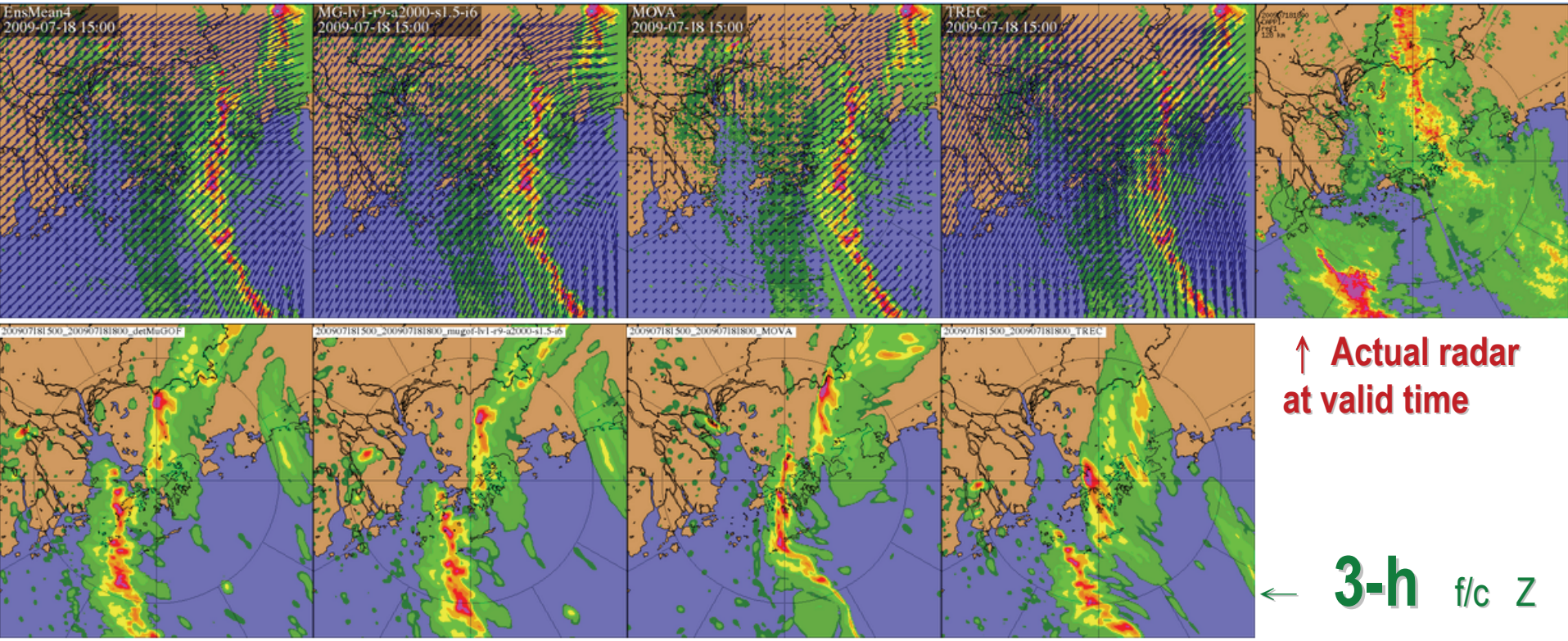
↑ Actual radar at valid time

← 2-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

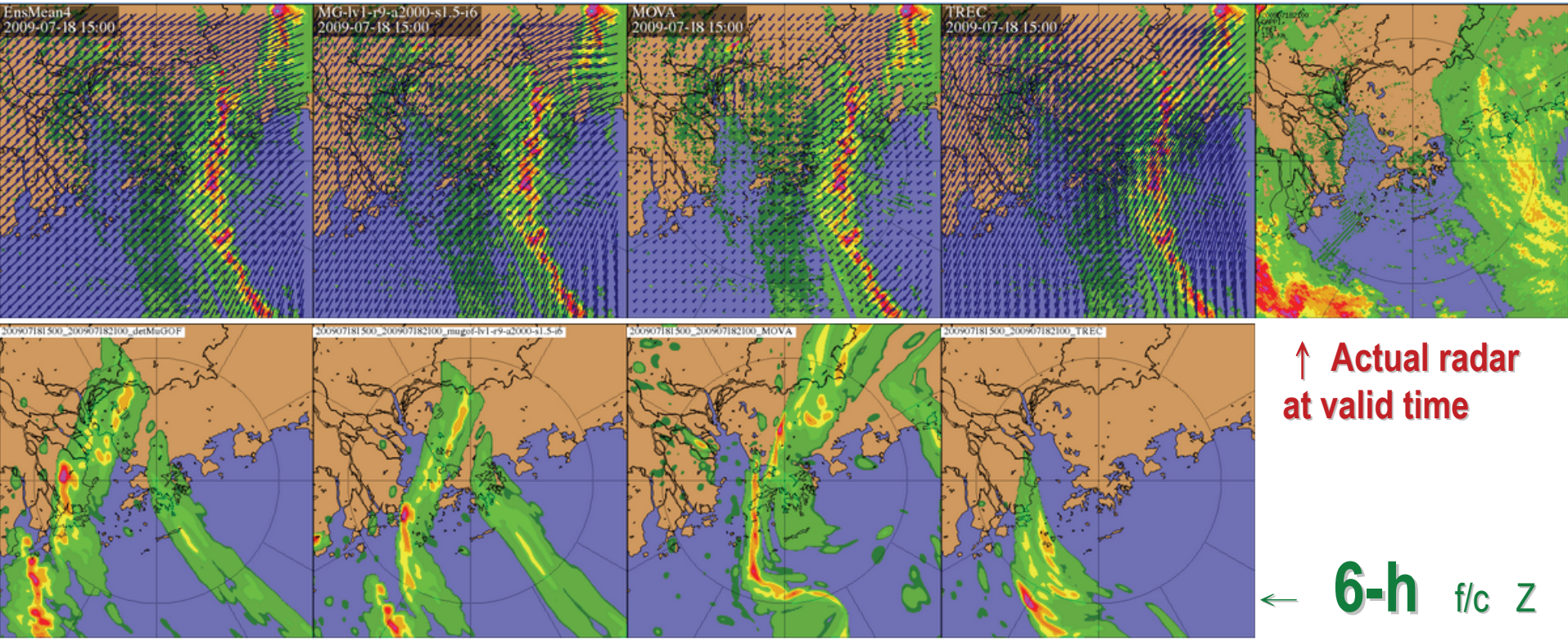
Tracking of TC Rainbands

- First example from the case of T. Molave (0906)
  - *2009-07-18 15:30H (base time)*
    - tracking and 3-hour extrapolation of a fast moving outer band



Tracking of TC Rainbands

- First example from the case of T. Molave (0906)
  - *2009-07-18 15:30H (base time)*
    - tracking and 6-hour extrapolation of a fast moving outer band



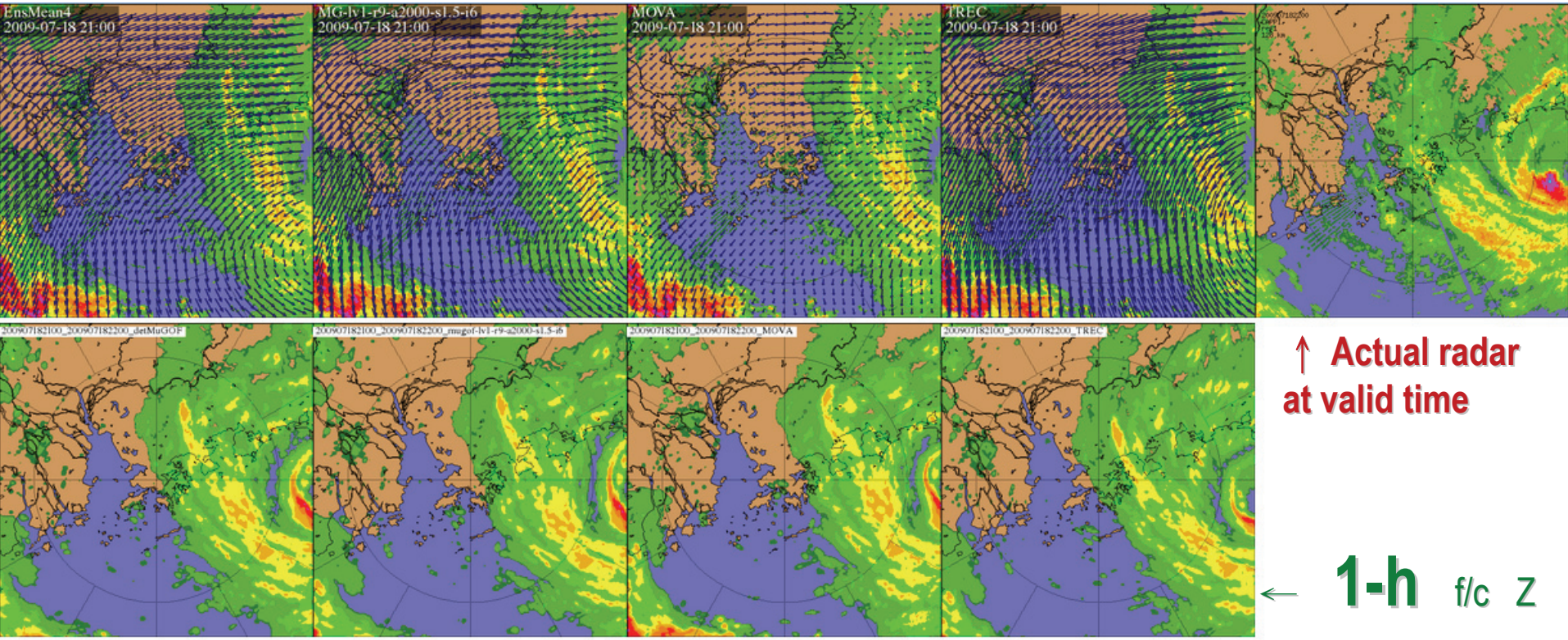
↑ Actual radar at valid time

← 6-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

Tracking of TC Rainbands

- Second example from the case of T. Molave (0906)
  - *2009-07-18 21:00H (base time)*
    - tracking and 1-hour extrapolation of an inner spiral band



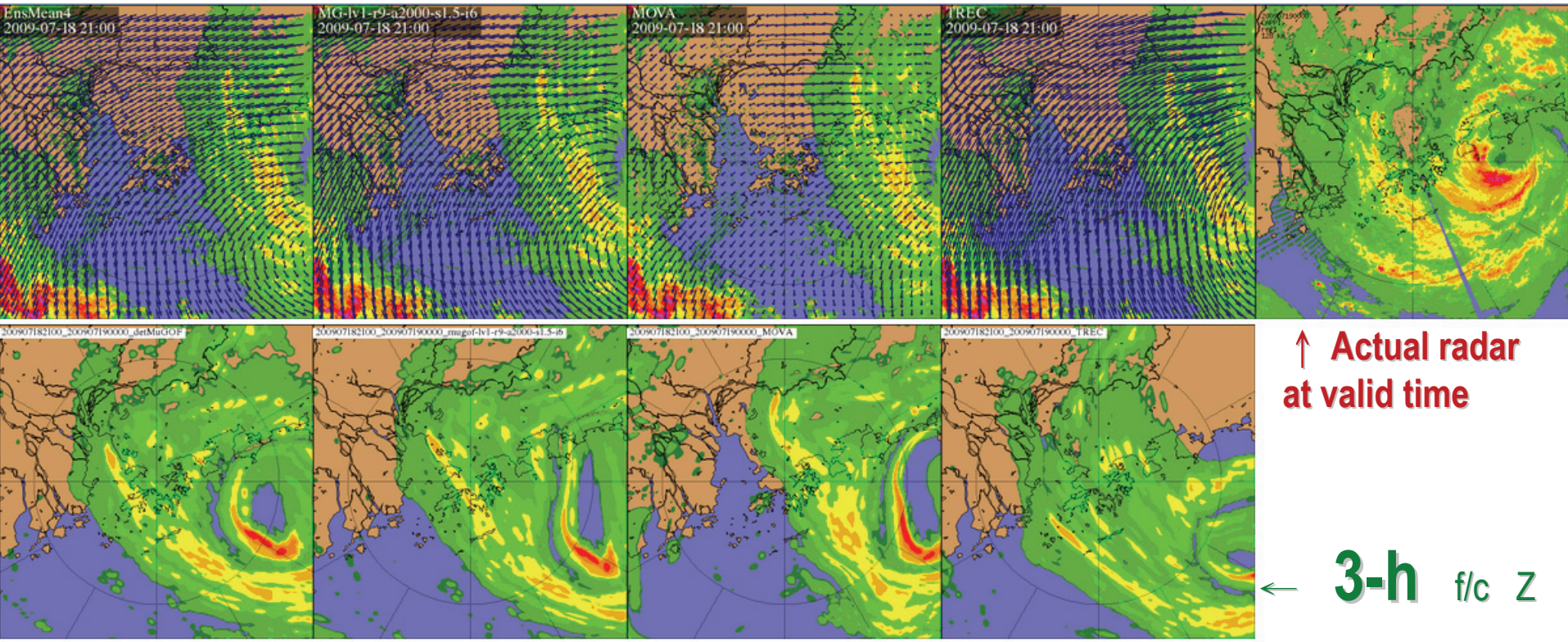
↑ Actual radar at valid time

← 1-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

Tracking of TC Rainbands

- Second example from the case of T. Molave (0906)
  - *2009-07-18 21:00H (base time)*
    - tracking and 3-hour extrapolation of an inner spiral band



Tracking of TC Rainbands

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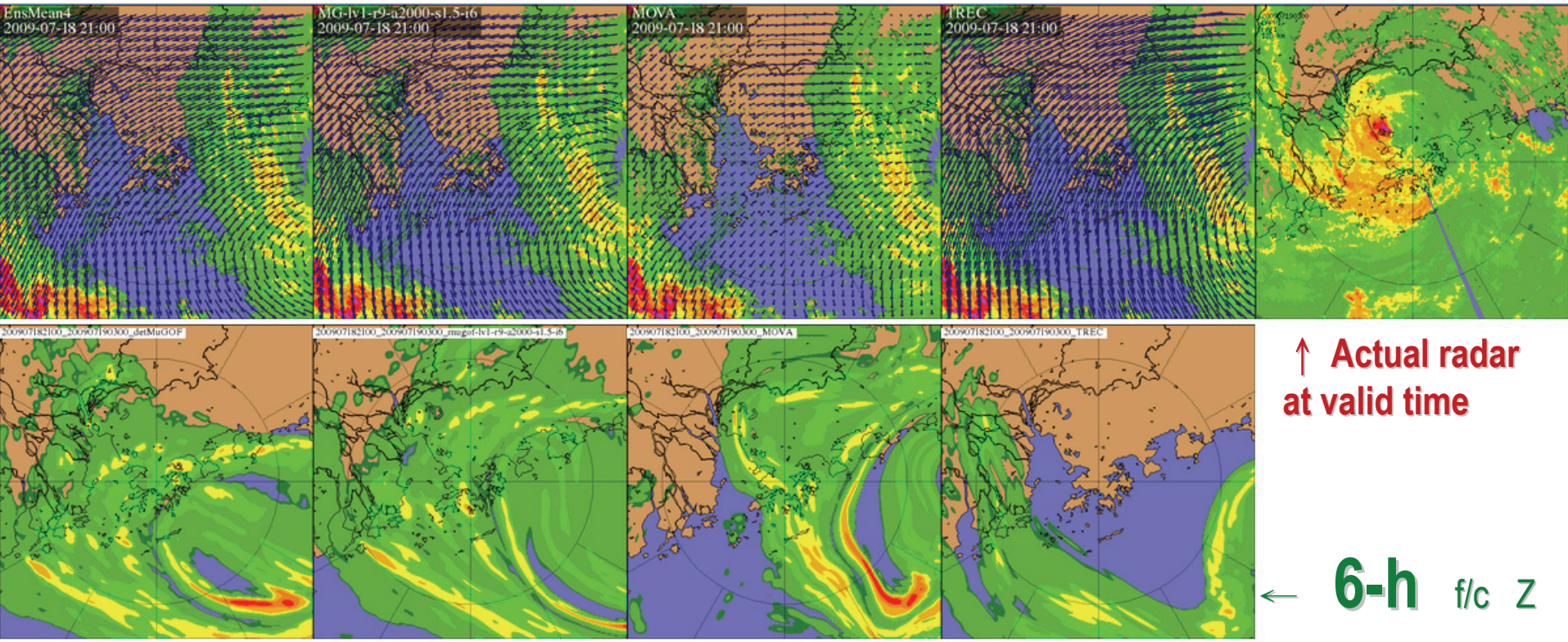
    - tracking and 6-hour extrapolation of an inner spiral band



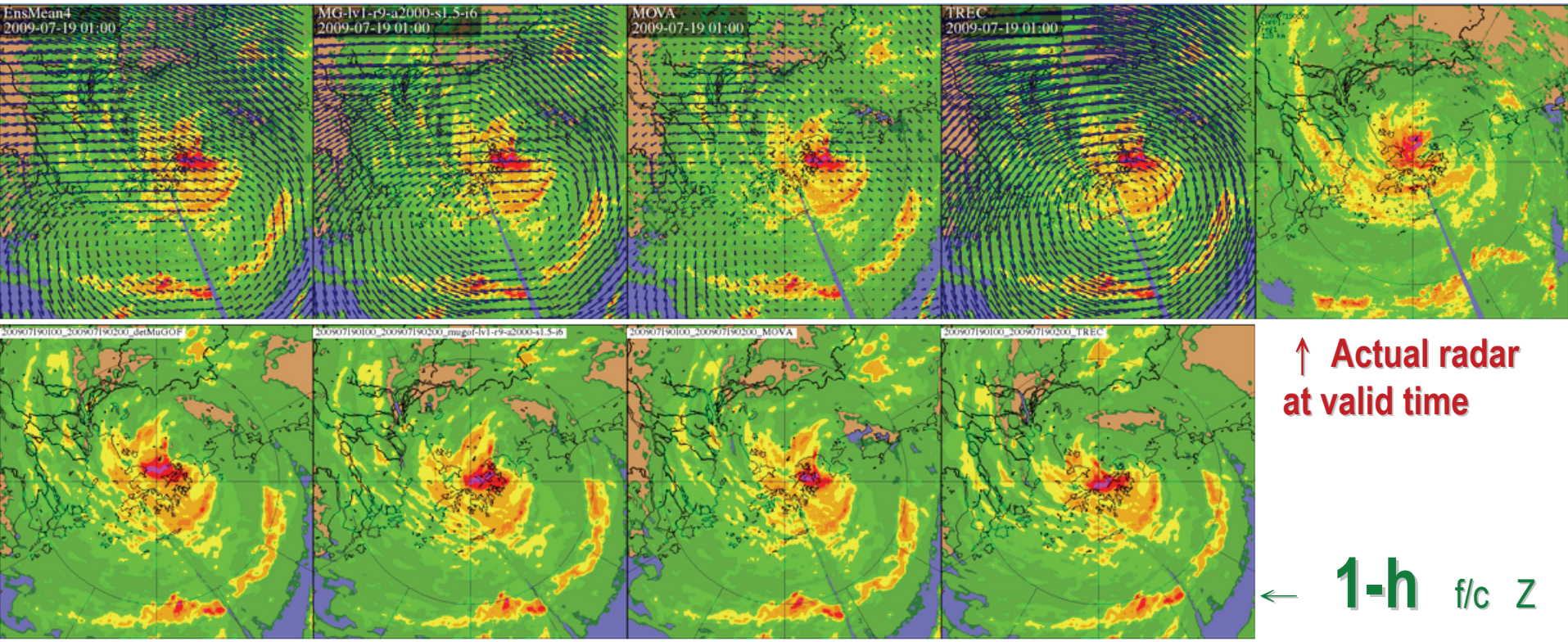
↑ Actual radar at valid time

← 6-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

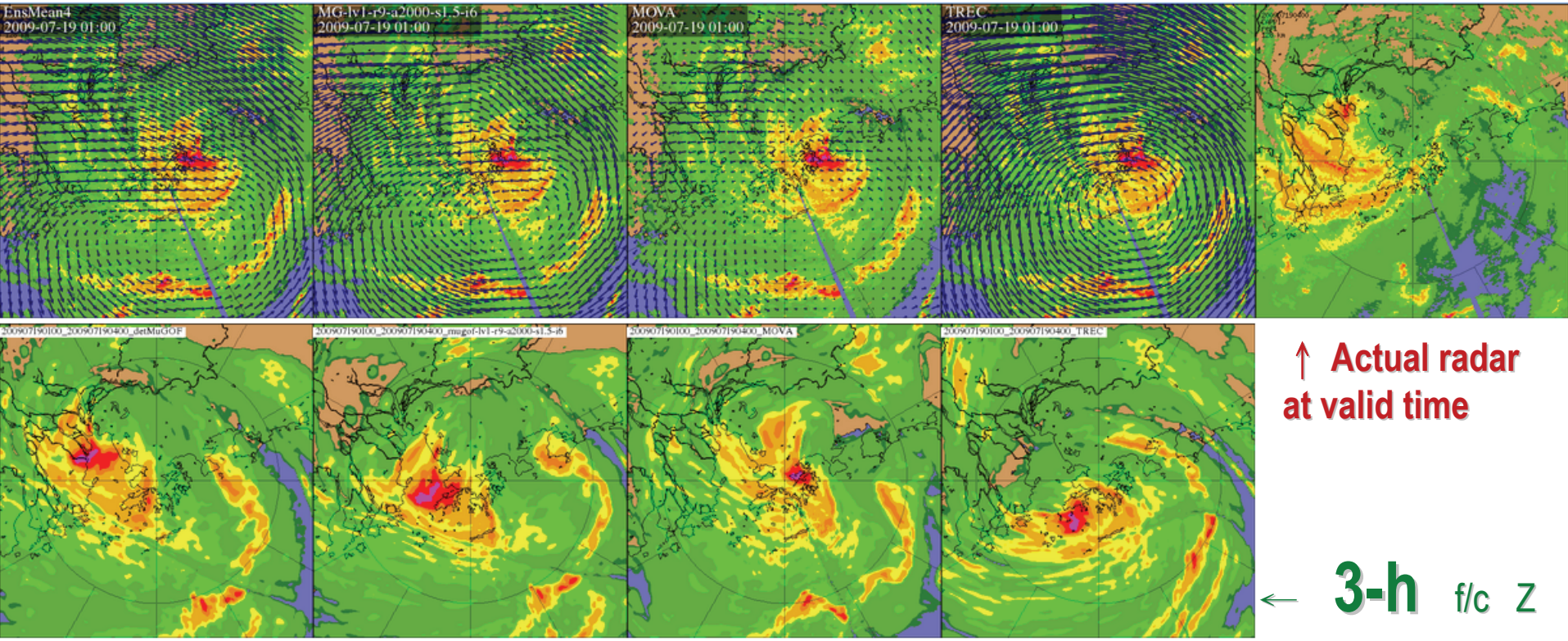
Tracking of TC Rainbands

- Third example from the case of T. Molave (0906)
  - *2009-07-19 01:00H (base time)*
    - tracking and 1-hour extrapolation of the rotating and translating core



Tracking of TC Rainbands

- Third example from the case of T. Molave (0906)
  - *2009-07-19 01:00H (base time)*
    - tracking and 3-hour extrapolation of the rotating and translating core



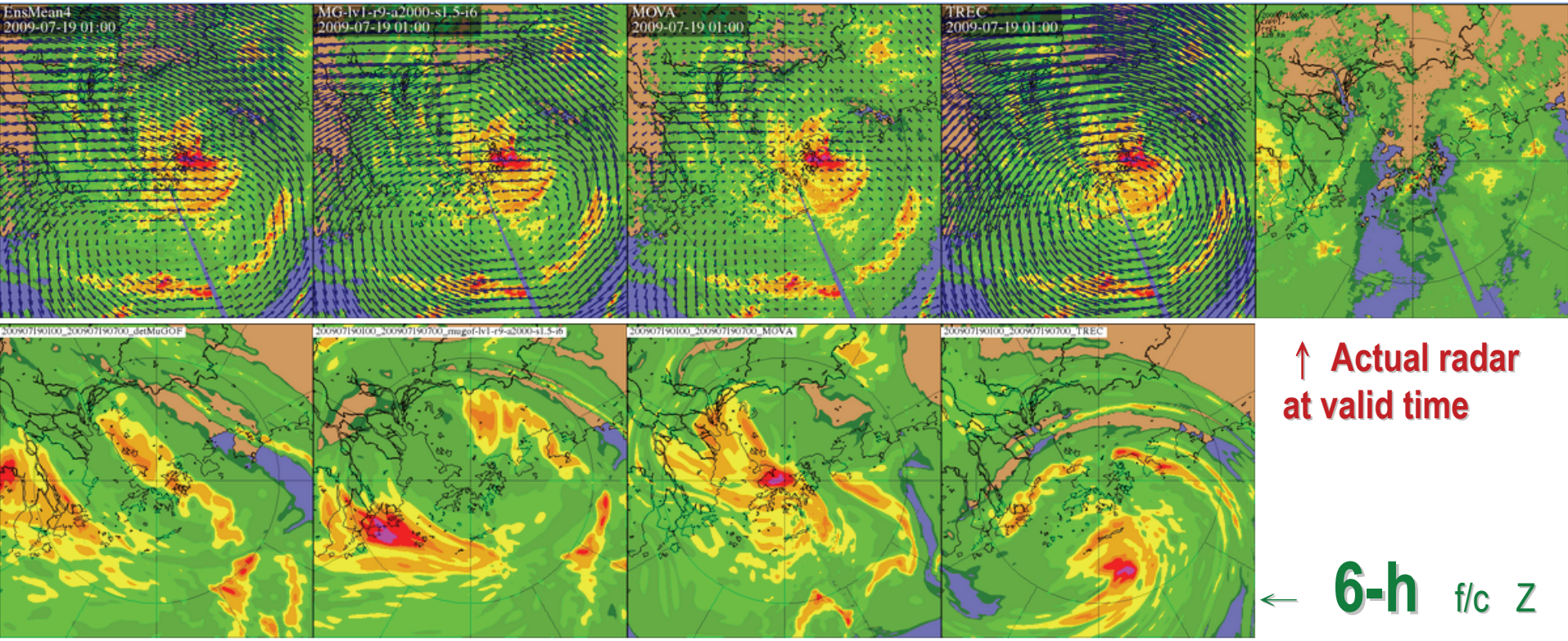
↑ Actual radar at valid time

← 3-h f/c Z

4M-Ens.Mean MuGOF MOVA TREC

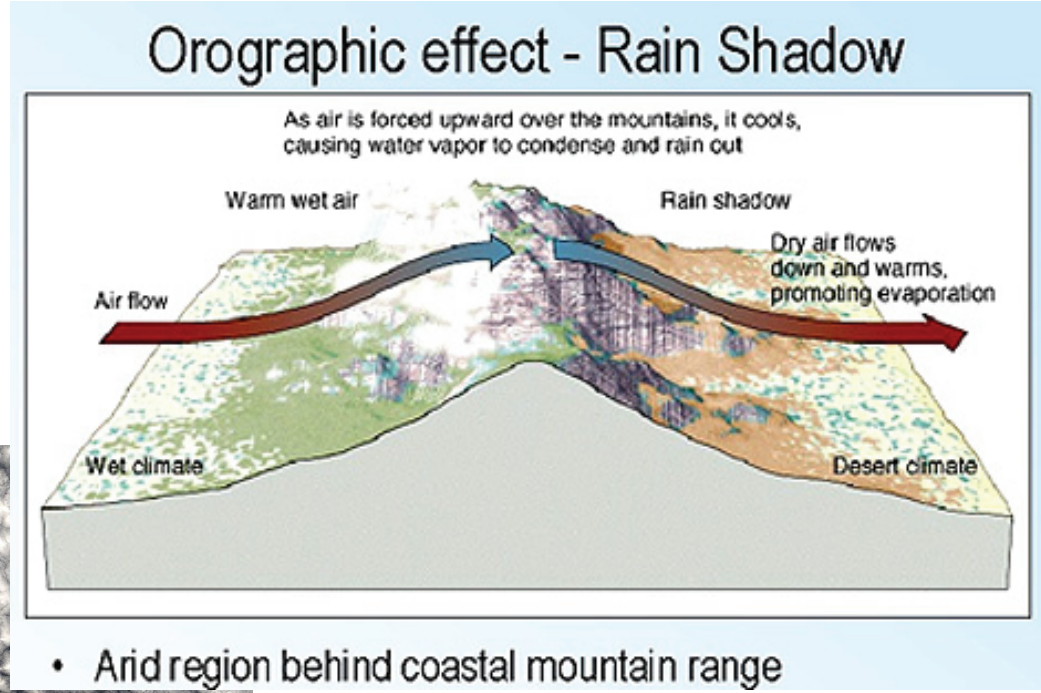
Tracking of TC Rainbands

- Third example from the case of T. Molave (0906)
  - *2009-07-19 01:00H (base time)*
    - tracking and 6-hour extrapolation of the rotating and translating core

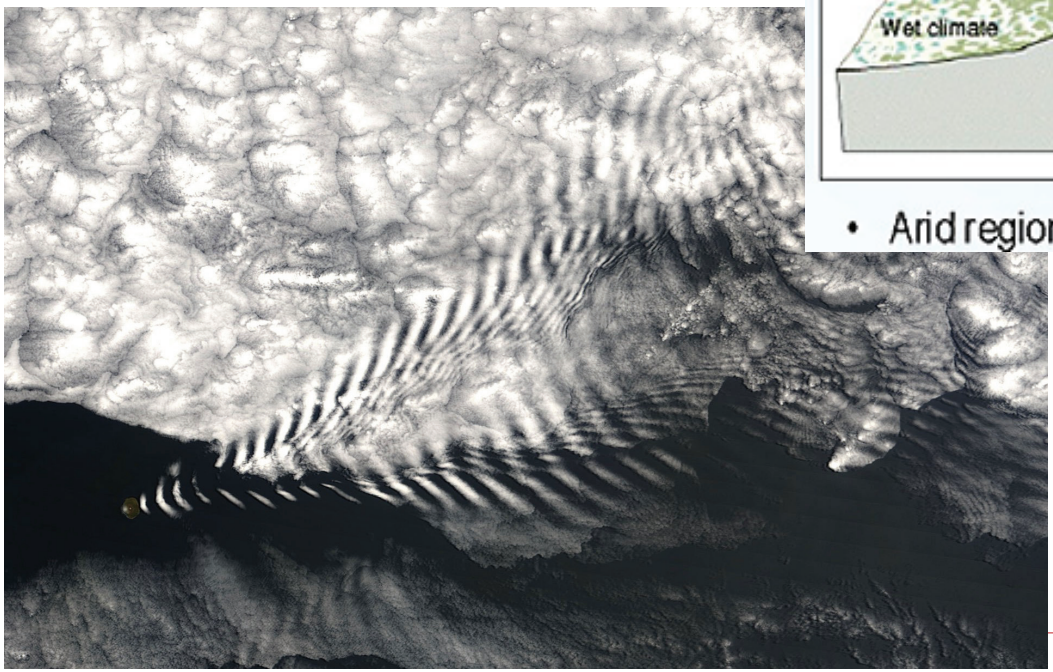


Orographic Enhancement

- Possible effects in general situations:



mountain lee waves



↑ enhanced rainfall on windward slop and

rain shadow on the lee side

Orographic Effect by TCs

- **World-record rainfall during TC Gamede (Feb 2007)**
  - *over La Reunion Island in South Indian Ocean*

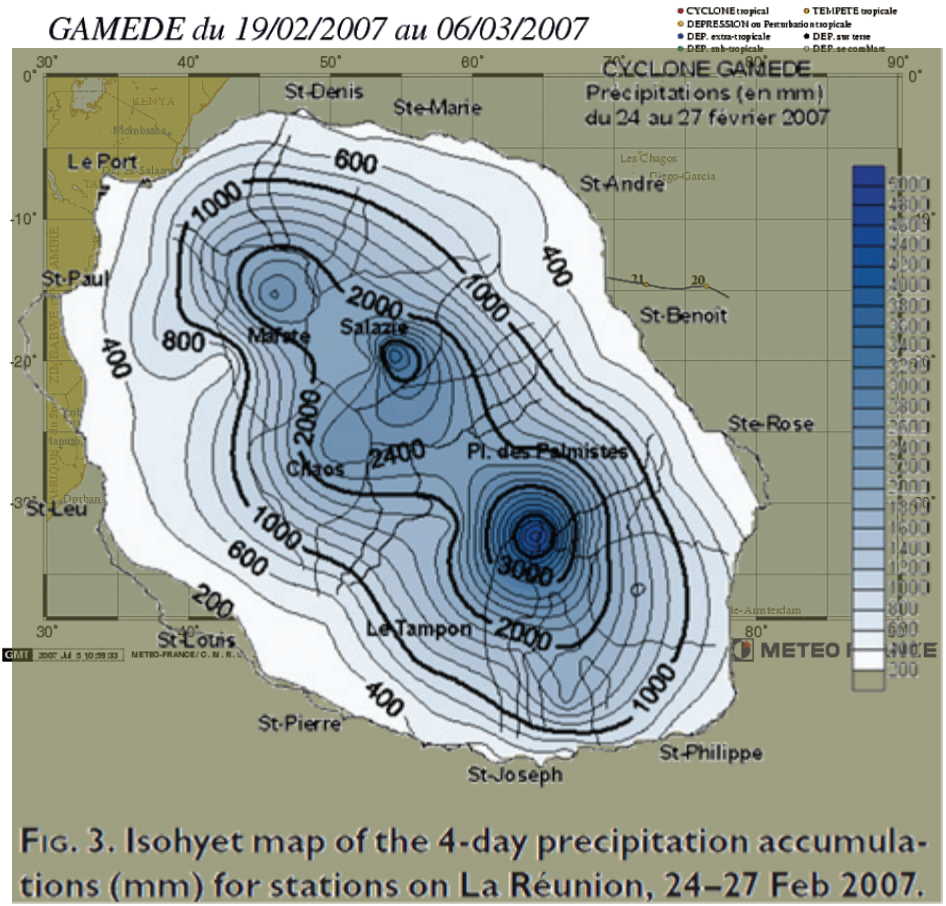


FIG. 3. Isohyet map of the 4-day precipitation accumulations (mm) for stations on La Réunion, 24–27 Feb 2007.

Source: H. Quetelard *et al.*, 2009: BAMS, May 2009, p603-607.

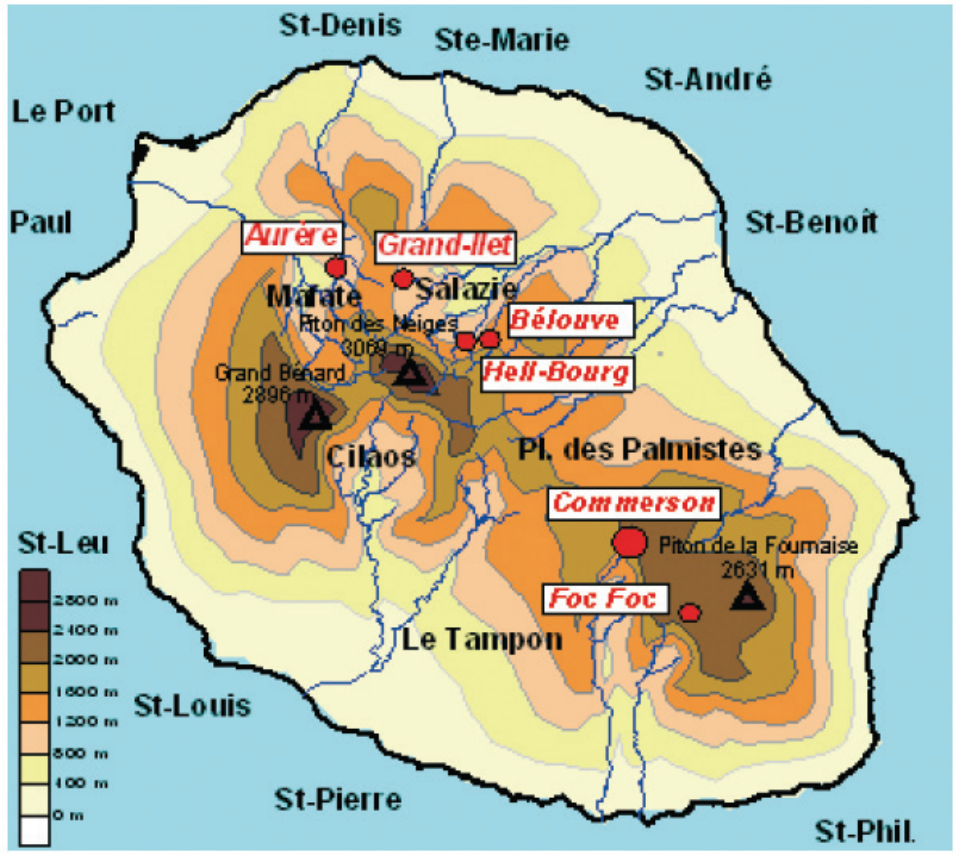
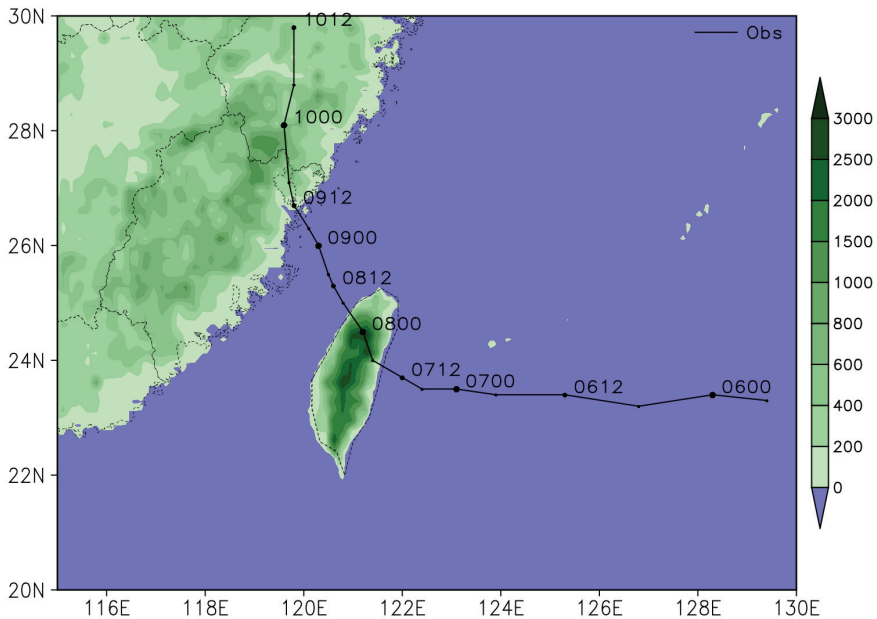
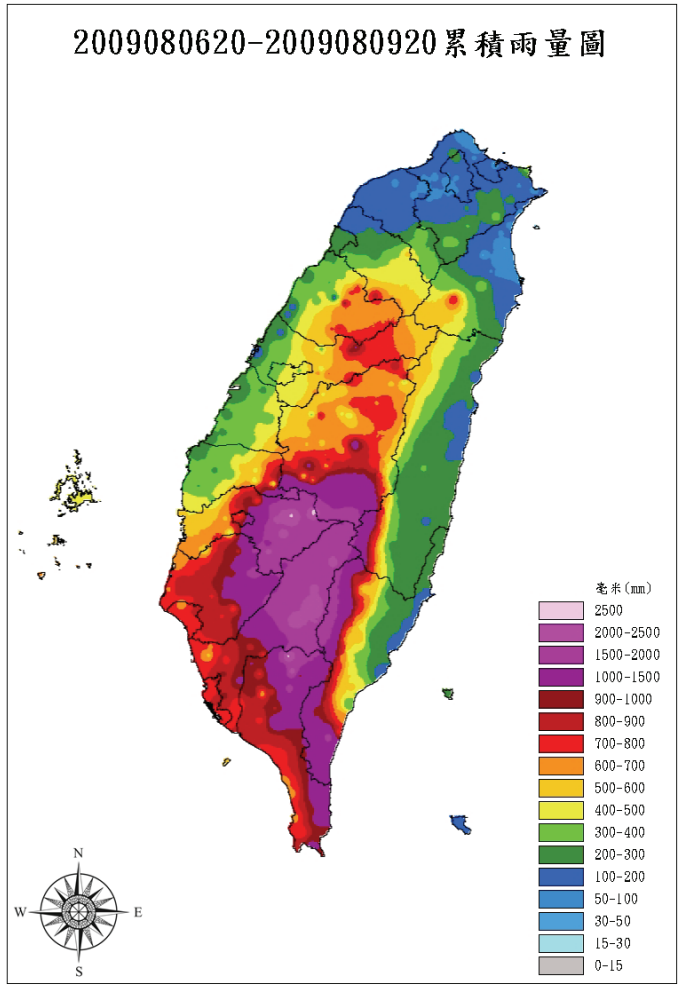


FIG. 2. Topographic map of La Réunion Island.

Extreme R/f in by T. Morakot (0908)



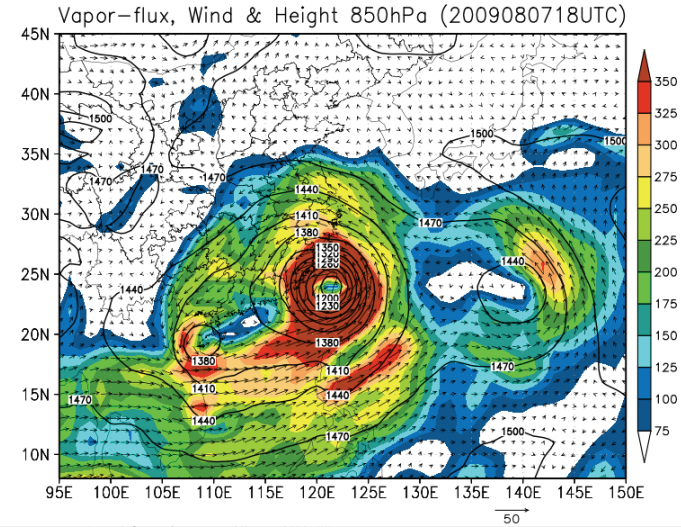


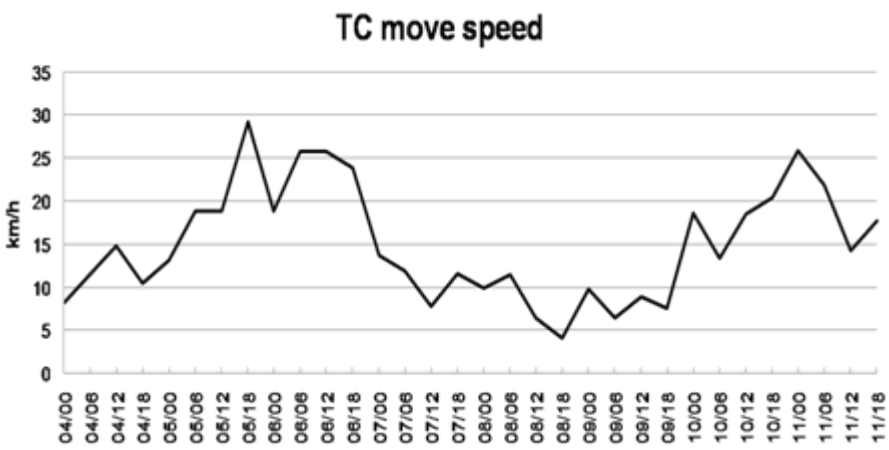
- Maximum total rainfall: 3059.5 mm (Alishan)
- 24-h & 48-h accumulated rainfall: 1623.5 mm & 2361.0 mm @Alishan (world record 1825 & 2467 mm resp.)
- Return period > 200 years
- Deadliest TY in Taiwan – 620 dead, 80 missing

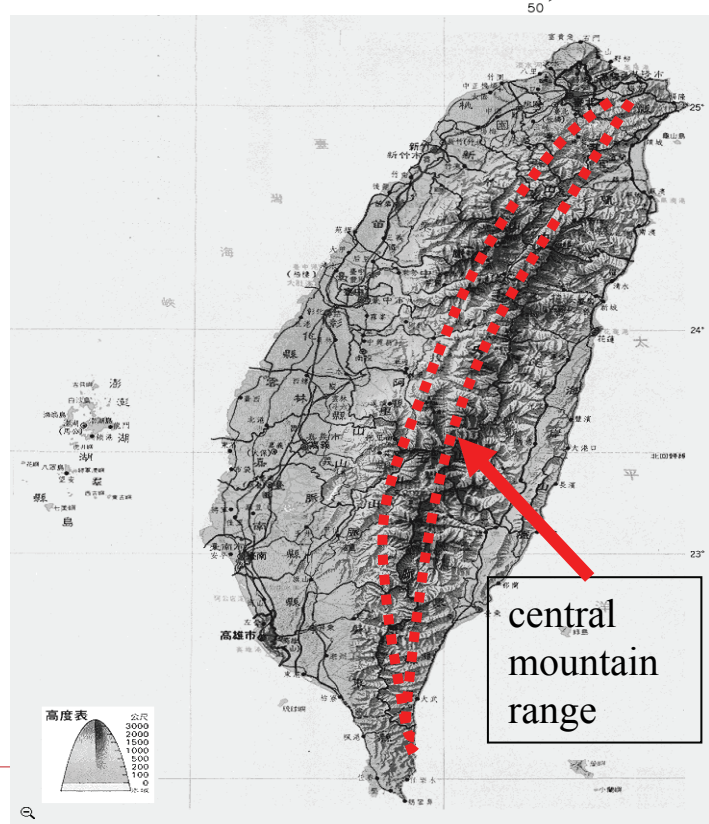
(From CWB, Taiwan)

T. Morakot

- **Possible reasons for the extreme rainfall**
  - *Slow TC movement*
  - *Large circulation*
  - *Steep topography of Central Mountain Range (>2,500 m)*
  - *Strong SW monsoon for abundant moisture supply*

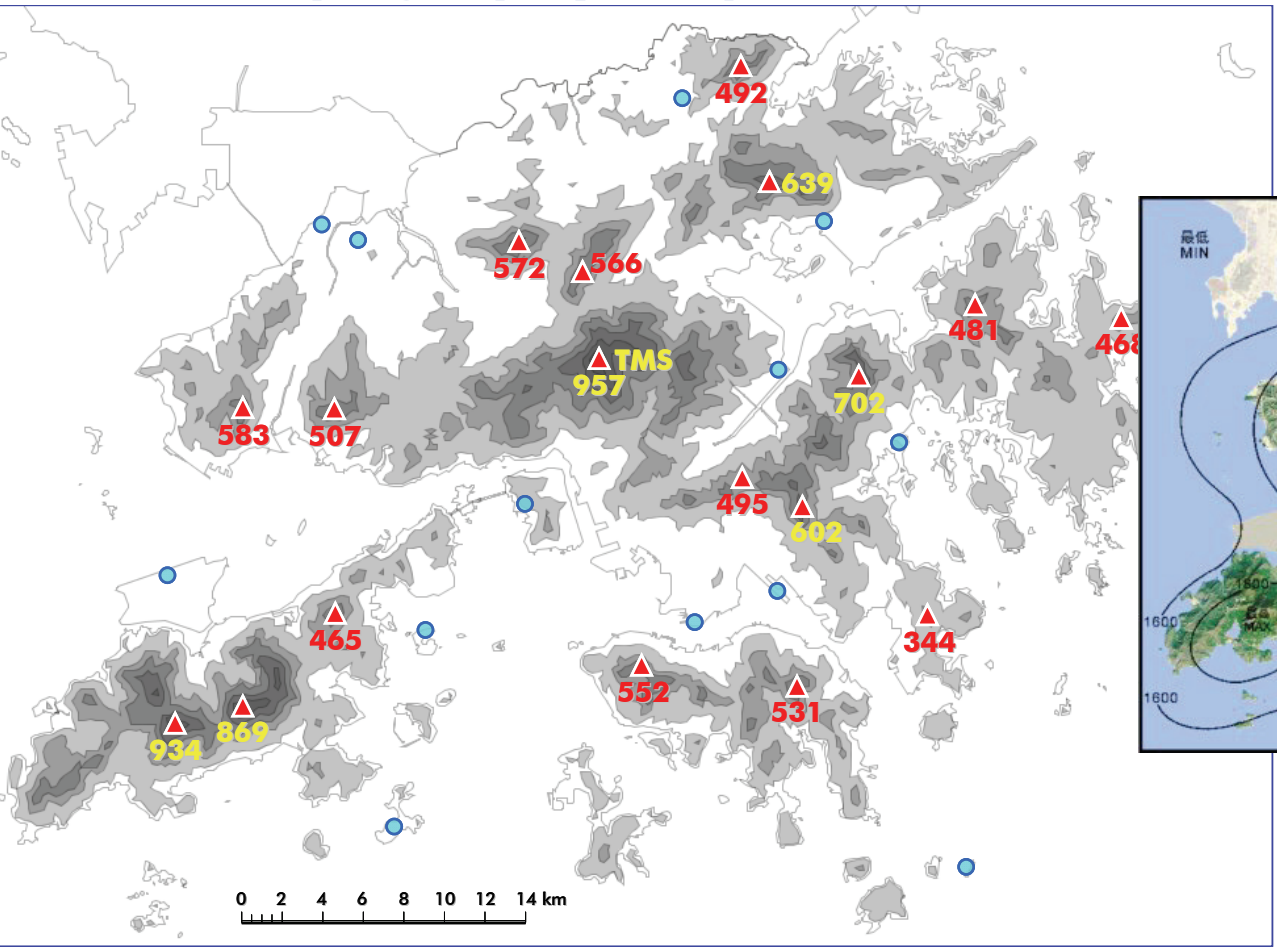


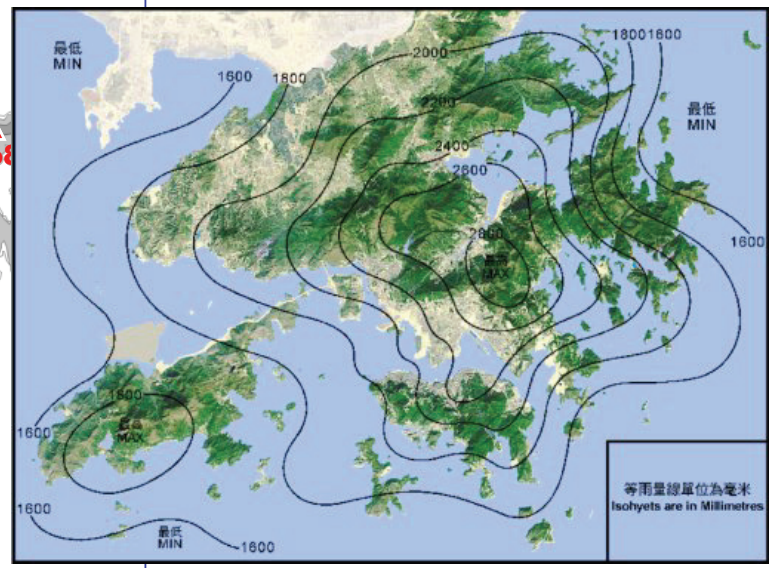




Orographic Enhancement in HK

- Topography map and rainfall climatology

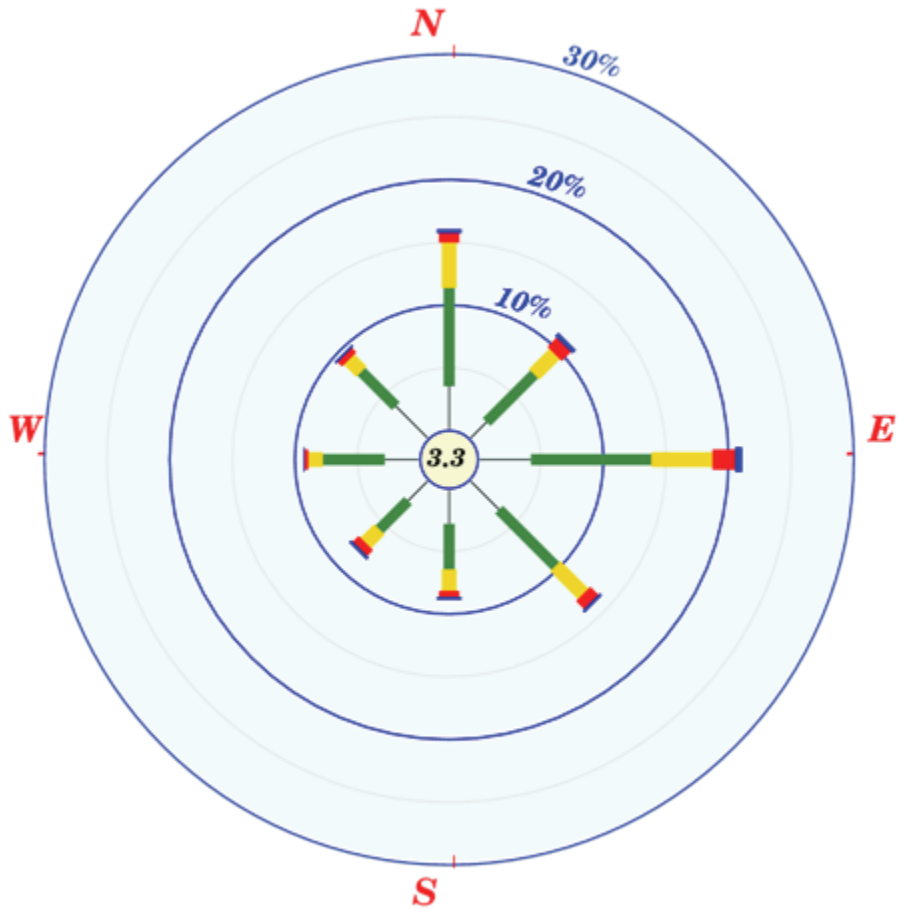




Mean annual rainfall of Hong Kong (1971-2000)

TC Climatology 1999-2010

- 36 TCs within the 256-km proximity of HK
  - *Wind rose of TC wind distribution:*



ANNUAL
NO. OF OBSERVATIONS = 778599
NO. OF VARIABLE WINDS= 23035 (2.960 %)
NO. OF CALM WINDS = 2584 (0.330 %)

0 10 20 30

PERCENTAGE FREQUENCY

The number in the inner circle is the percentage frequency of occurrence of calm and variable winds

(F1)	(F2)	(F3)	(F4)	(F5)
0.1-3.2	3.3-8.2	8.3-14.2	14.3-20.7	>20.7 m/s
1-2	3-4	5-6	7-8	>8 Beaufort force

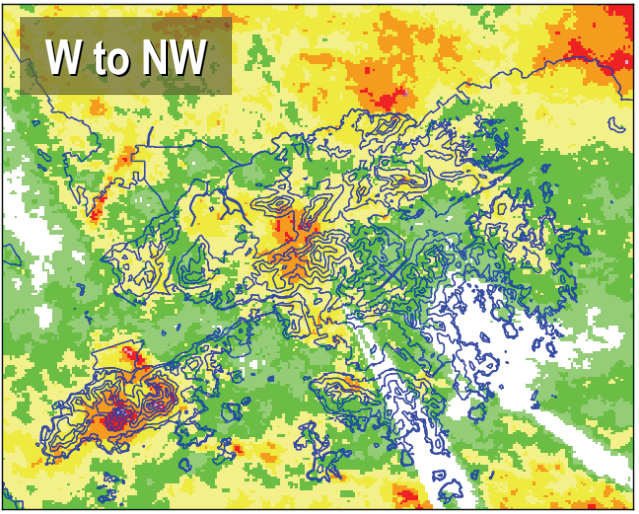
WIND SPEED

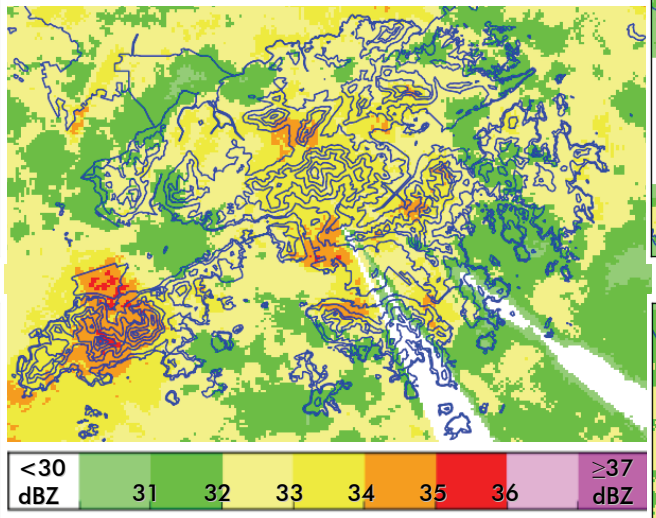
	023-067	068-112	113-157	158-202	203-247	248-292
F1	1.790	4.080	3.190	2.680	2.190	2.690
F2	5.370	9.610	6.360	3.610	3.230	4.950
F3	2.300	4.890	3.150	1.730	1.540	1.160
F4	1.040	1.790	0.890	0.470	0.650	0.300
F5	0.360	0.550	0.220	0.210	0.240	0.070
	10.860	20.920	13.810	8.700	7.850	9.170

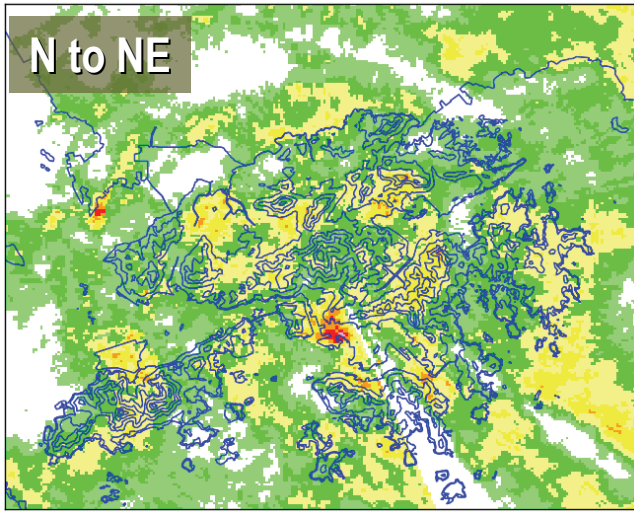
	293-337	338-022	Total
F1	3.570	3.400	23.590
F2	3.890	7.820	44.840
F3	1.390	3.630	19.790
F4	0.490	0.750	6.380
F5	0.170	0.300	2.120
	9.510	15.900	96.720

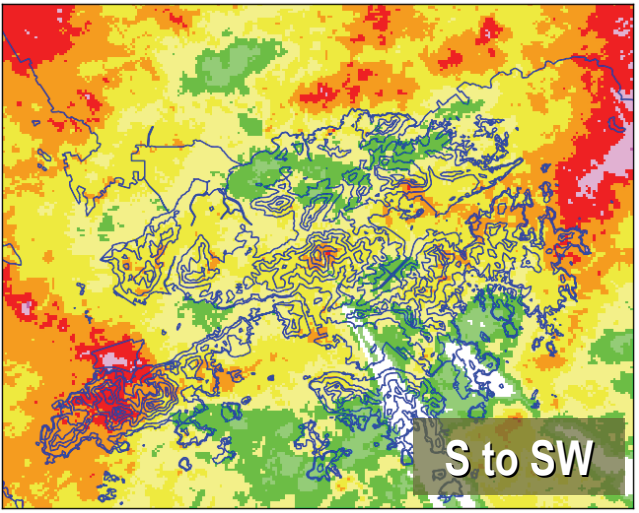
FREQUENCY TABLE

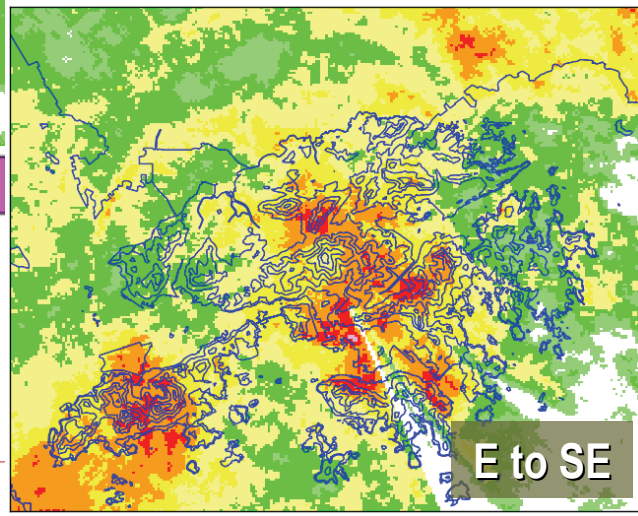
Averaged Radar Reflectivity





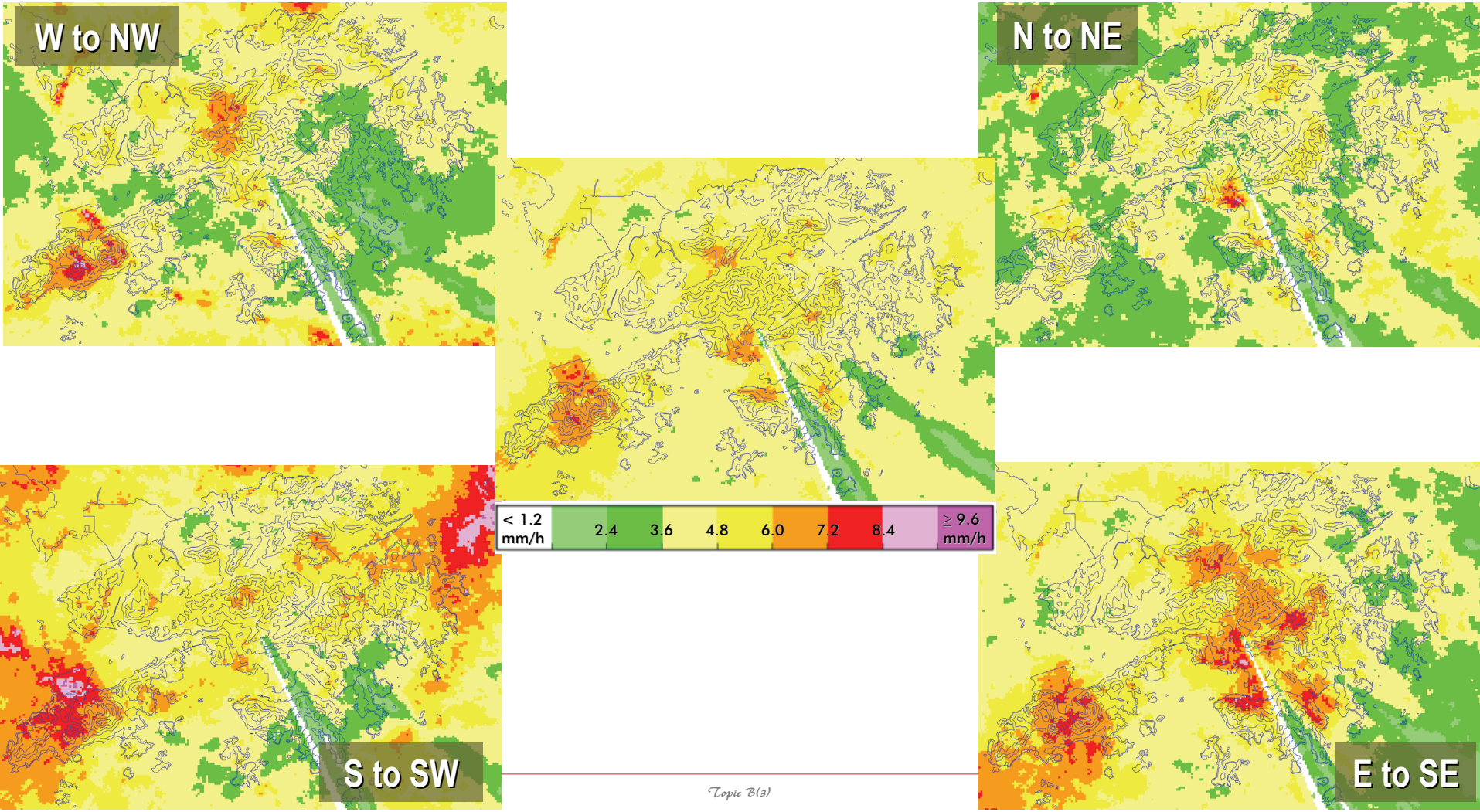






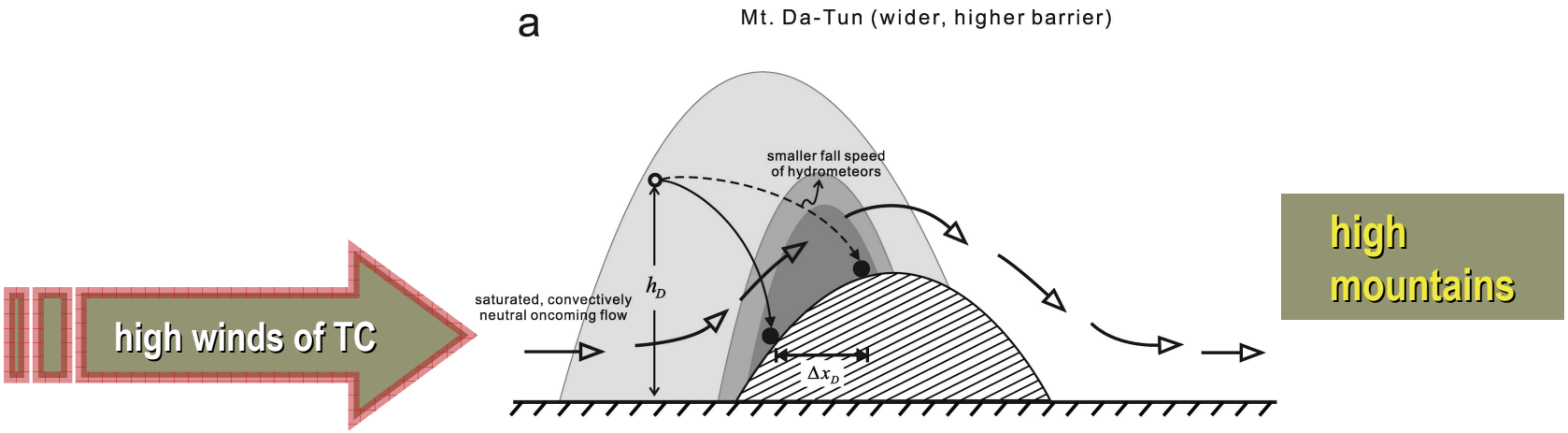
Averaged Rainfall Rate

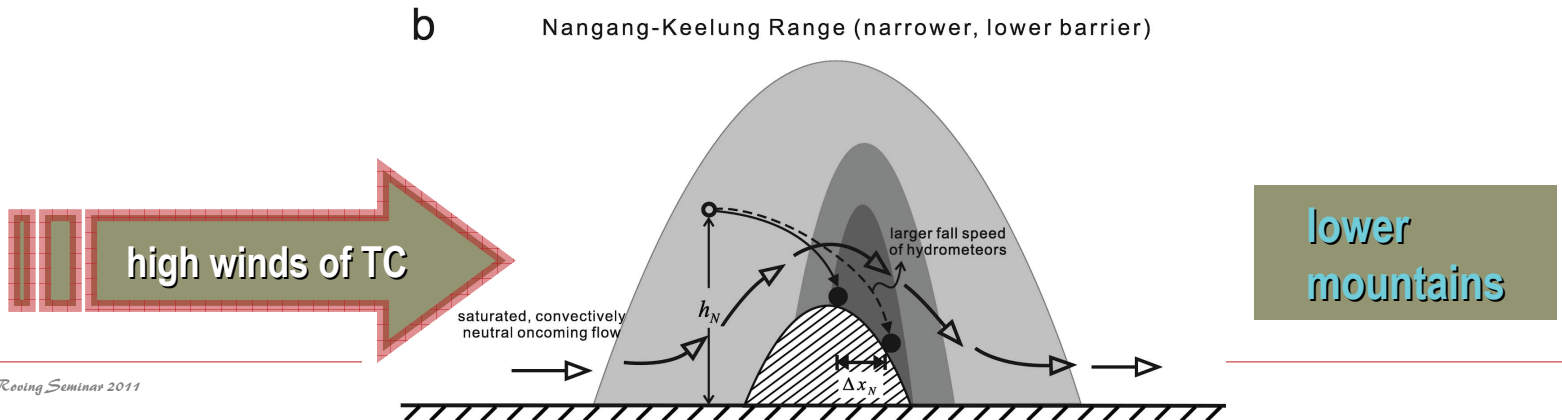
- converted from average Z using $Z = 228.82\ R^{1.33}$



Orographic Enhancement on R/F in HK

- possible mechanism for both windward and lee side enhancement:
  - *Yu & Cheng 2008, Mon. Wea. Rev., 136, 497-521*





Summary

- **TC rainbands are unique and difficult to analyze and forecast**
- **for nowcasting, various challenges to overcome:**
  - *Z-R relations more representative of TC for better QPE*
  - *detailed orographic enhancement by land-falling TCs*
  - *sophisticated radar tracking methods to deal with complicated motion of TC rainbands for better QPF*
- **for longer ranges, further improvements pending:**
  - *convections and mesoscale interactions to be correctly handled by sophisticated high resolution NWP models*
  - *TC track, intensity and local winds to be accurately predicted before QPF from global models can be used effectively*

UNESCAP/WMO
Typhoon Committee

United Nations
ESCAP

WMO OMM

~ End ~