Diurnal Cycles and their Regional Variations of Radar Echo Area near Vientiane, Lao

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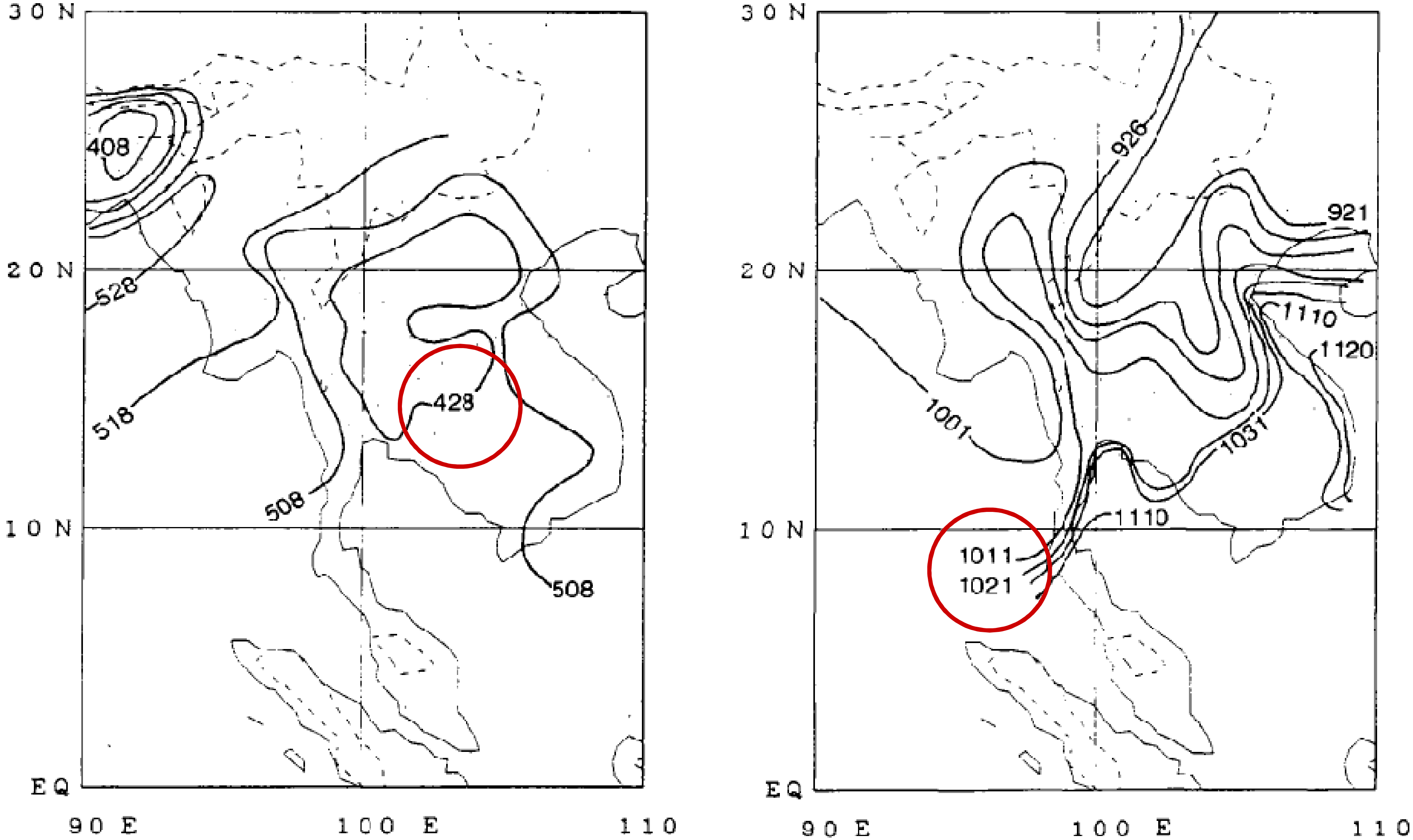
Workshop in Vietnam, 2009

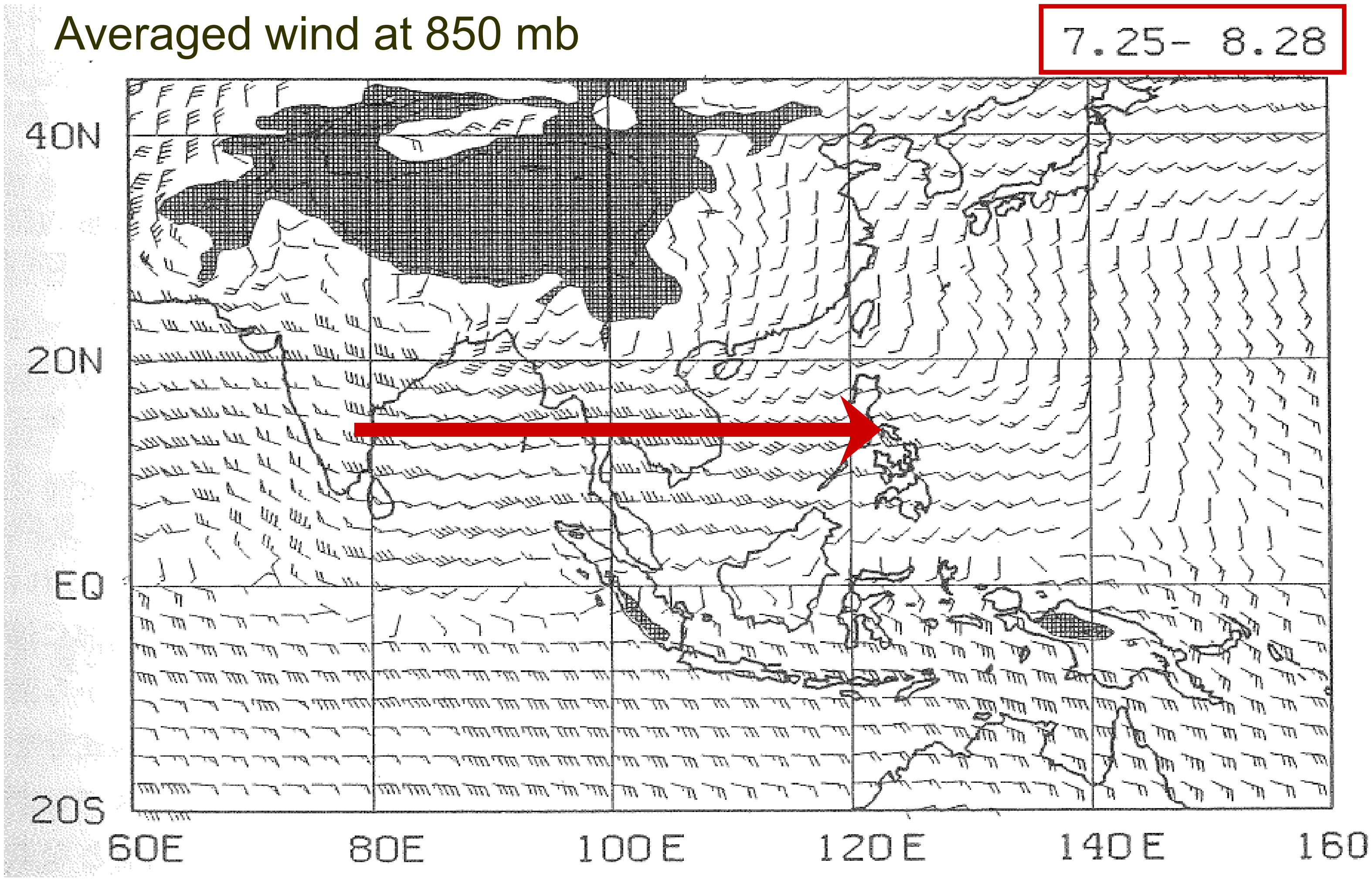
Onset and withdrawal of rainy season

Onset Offset



Matsumoto (1997)

Wind direction during rainy season



Southwesterly governs at 1000 mb (not shown)

Matsumoto (1992)

Diurnal variations of convective activity

Ohsawa et al. (2001) used GMS satellite data and investigated when the diurnal variations of convective activity have their peak over the Indochina Peninsula.
They defined

$$\Delta T_{BB} = T_{BB}(IR1) - T_{BB}(WV)$$

as an index. Where

$T_{BB}(IR1)$: the infrared-1 channel black body temperature
$T_{BB}(WV)$: the water vapor channel black body temperature

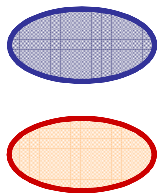
The convective activity gets strong when $\Delta T_{BB} \leq 3\,(\mathrm{K})$

Diurnal variations of convective activity

Time of maximum convective activity over Indochina Peninsula

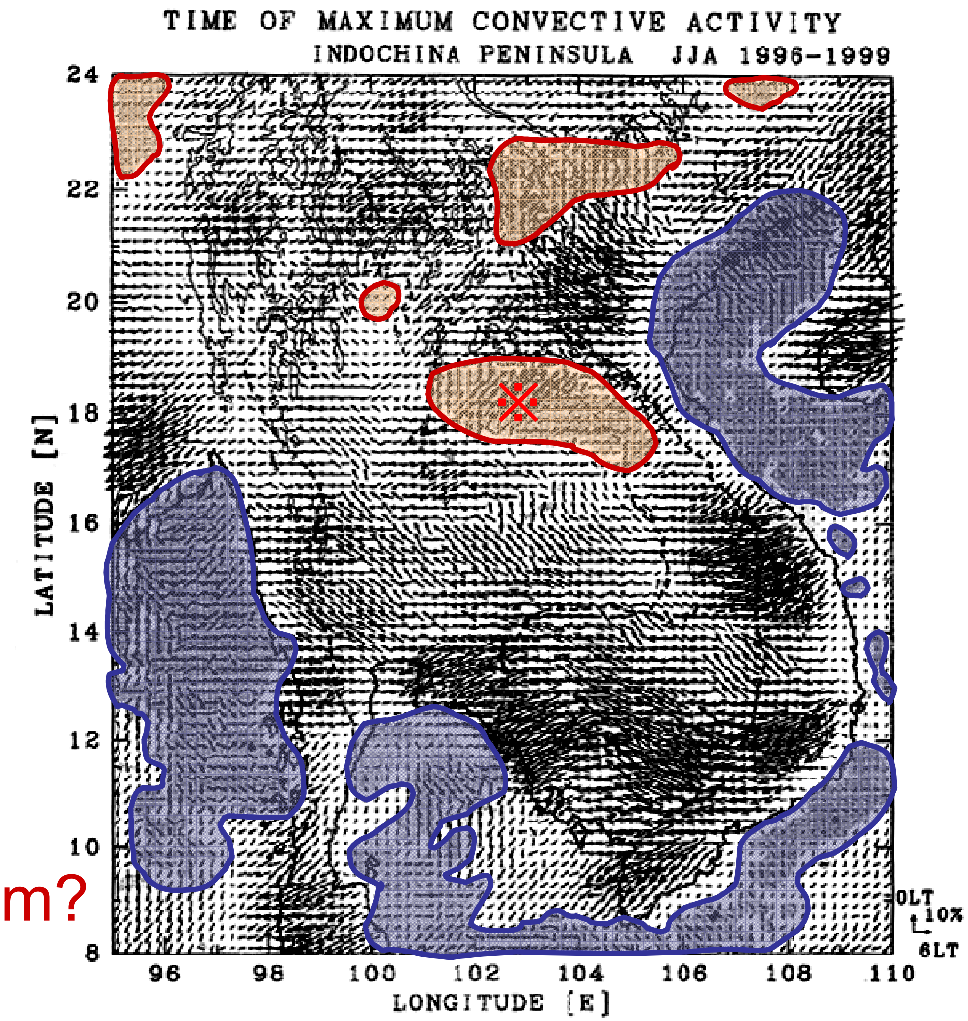
(averaged over JJA)

Late night-early morning maximum:



Near Vientiane: 3 LT

What brings this night maximum?
-> Not known yet



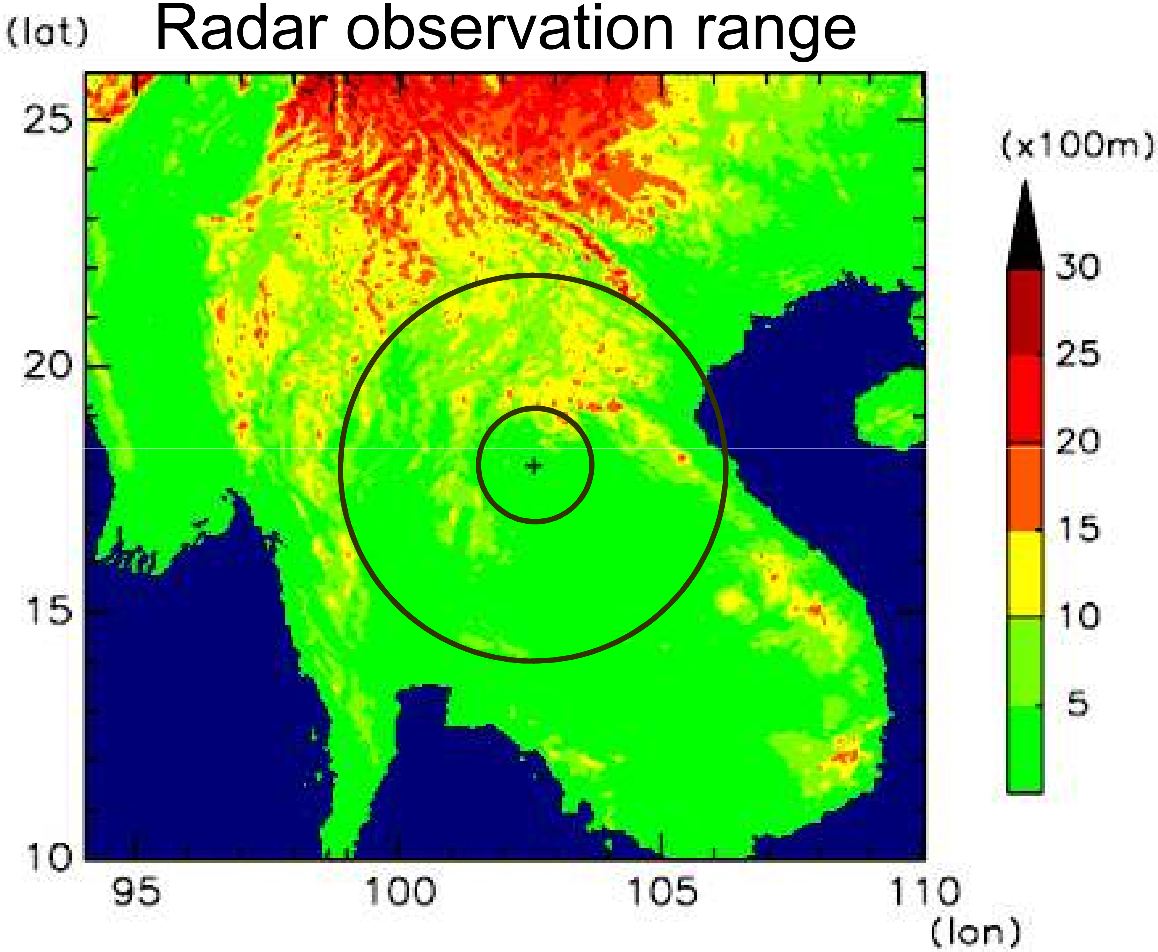
Ohsawa et al. (2001) ※ : Vientiane

Preface

+ Not enough ground-based observation has been done near Vientiane
  - -> Meteorological radar was built in 2007
  - -> Time has come!
+ In tropics, convective activity shows outstanding diurnal variation over the continent (Nitta and Sekine, 1994)
  - -> Analyzing the diurnal cycle of convective activity is on the top of the must-do list
+ Time of the maximum convective activity is around midnight near Vientiane (Ohsawa et al., 2001)
  - -> Mechanism is not known yet

> Meteorological radar located at Vientiane brings us 2-dimensional ground-based observation.
> Using this radar, diurnal cycles and their regional variations were analyzed.

Data



Outer circle : 400 km, inner circle : 120 km

400 km obs. twice
(elevation 0.5, 1.3 degree)

120 km obs. 12 times
(elevation 0.5 ～ 22.9 degree)

Interval: 7.5 minutes

Analysis period:
Apr 1 – Oct 23, 2008

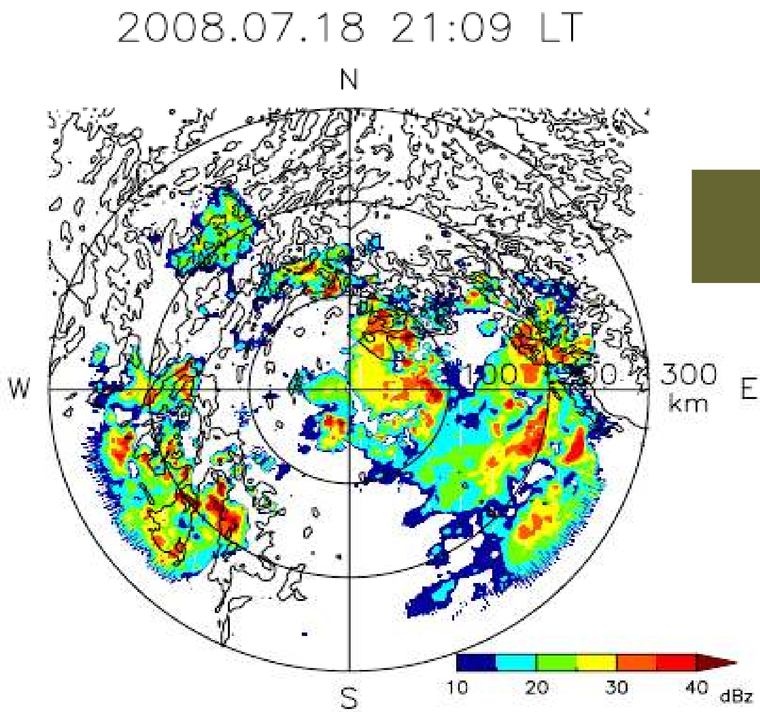
Spherical coordinate
↓Weighted interpolation
Cartesian coordinates

Data

After the interpolation, Constant Altitude PPI (CAPPI) was made at 3 km height

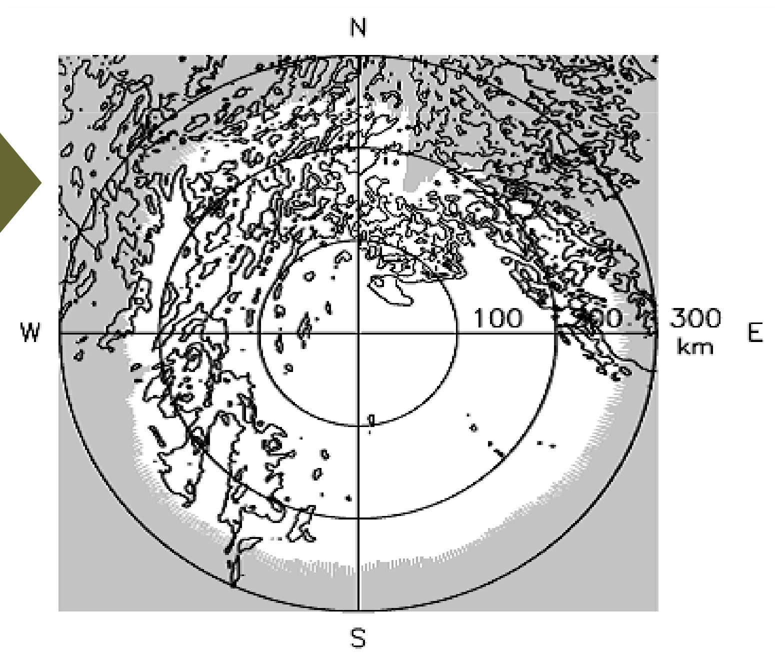
Analysis went through using this CAPPI

CAPPI (3 km height)



Blocked

Shadow



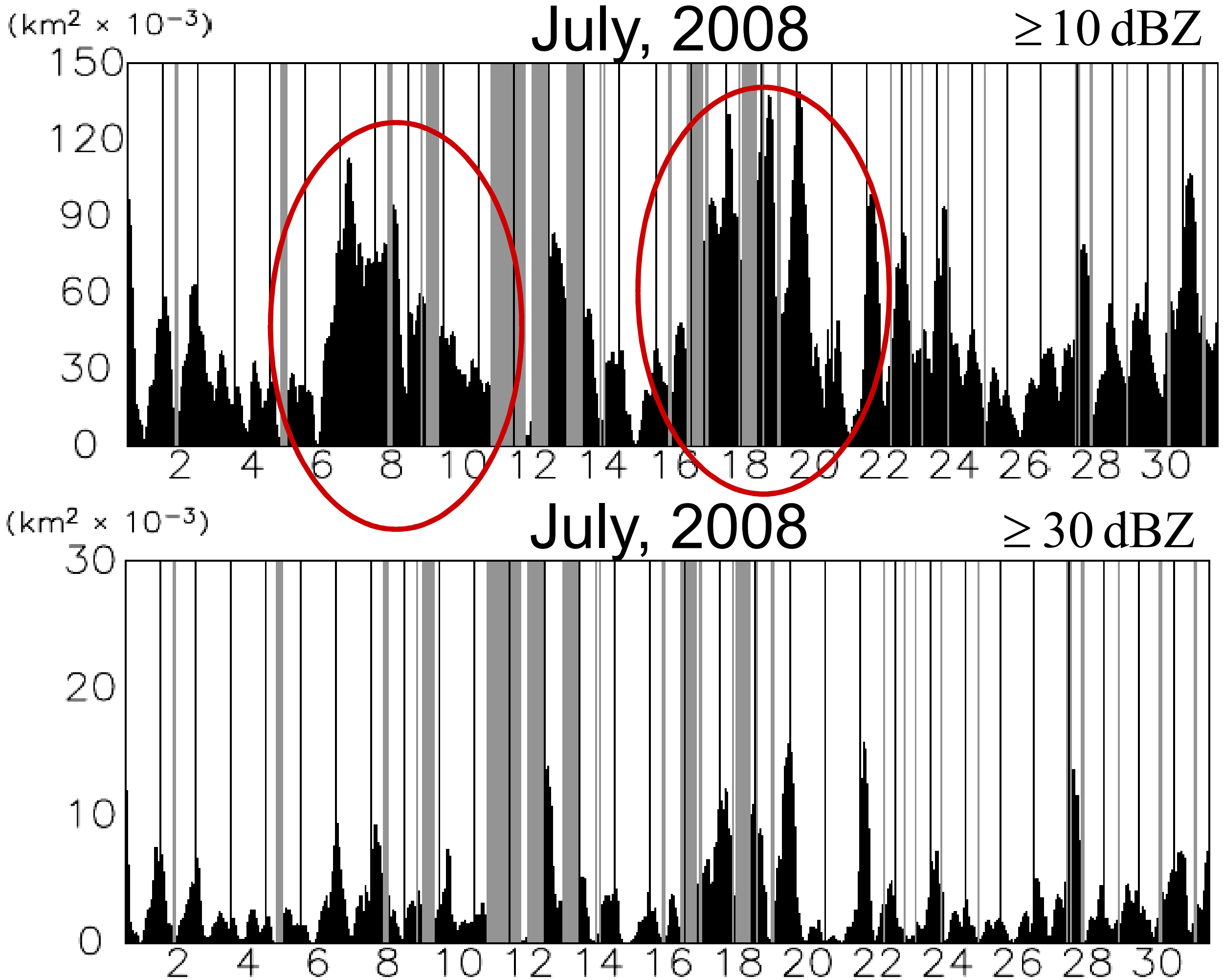
Contour: every 500 m

Time series variations of radar echo area

Horizontal axis: Day
black solid line: 0 LT

Grey tone: missing obs.

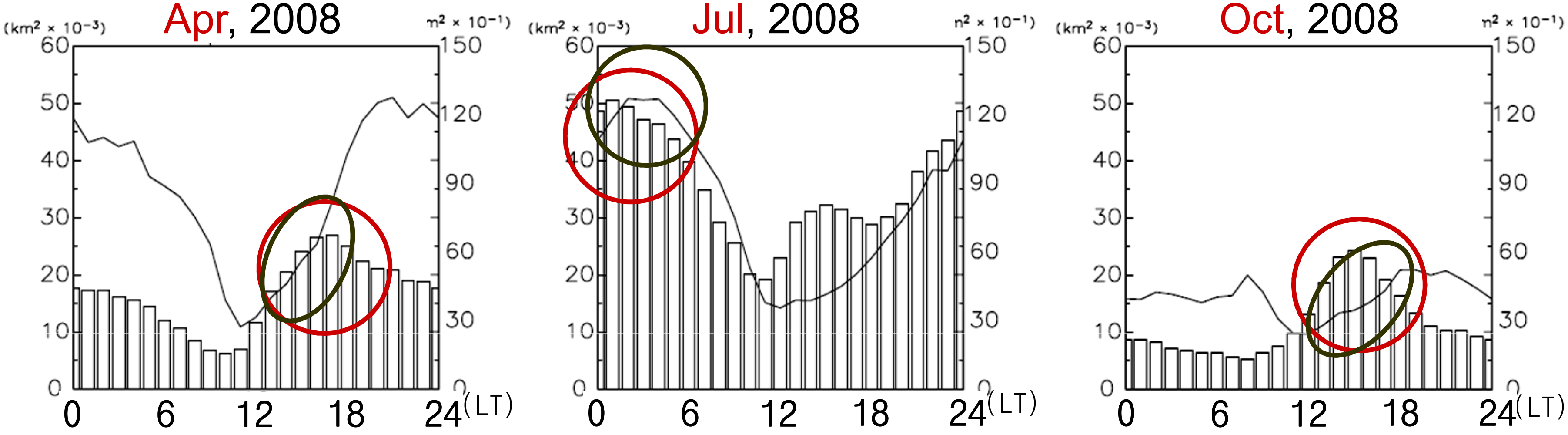
Above: over 10 dBZ
Below : over 30 dBZ



Over 10 dBZ: there exists long life precipitation
Both figures: night time precipitation is outstanding in July

Diurnal cycles of radar echo area

Onset — Apr, 2008 | Middle of rainy season — Jul, 2008 | Offset — Oct, 2008



Bar graph: radar echo area of the intensity of over 10 dBZ
(left vertical axis)

S

H

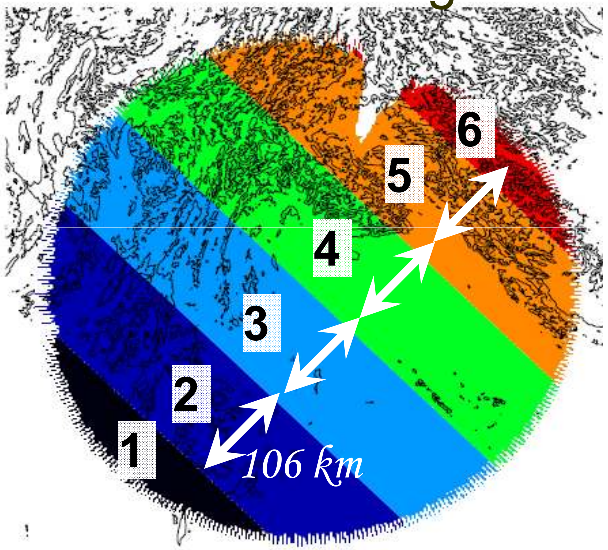
Radar echo area maximum in the afternoon:
contribution of numbers of small convective systems

Radar echo area maximum at night in July:
contribution of some large convective systems

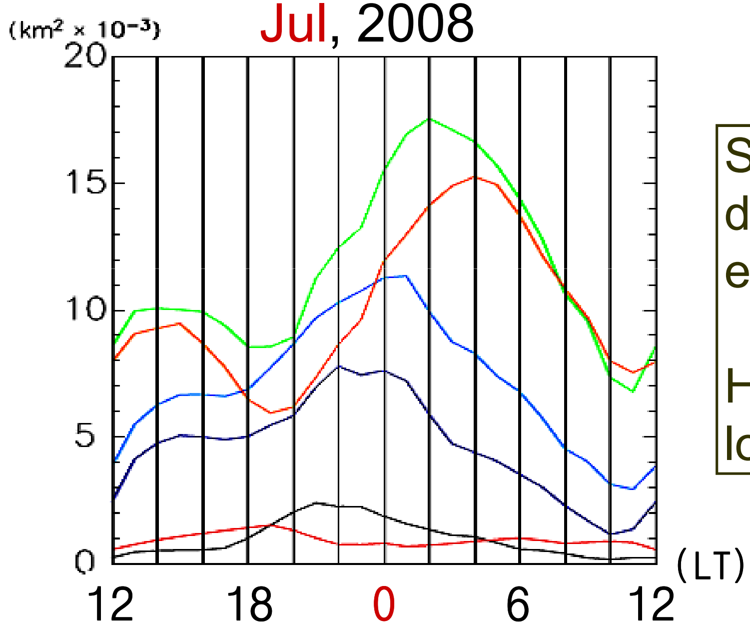
Regional differences of diurnal cycles

The phase of the diurnal cycles shifts over the downstream of mountains.

divided into 6 regions



Jul, 2008



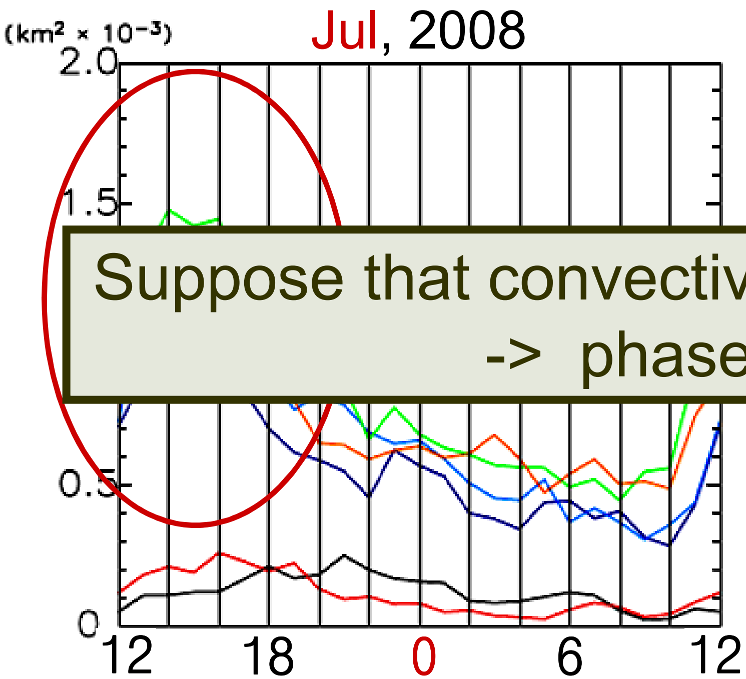
Solid lines: diurnal cycles of echo area

Horizontal axis: local time

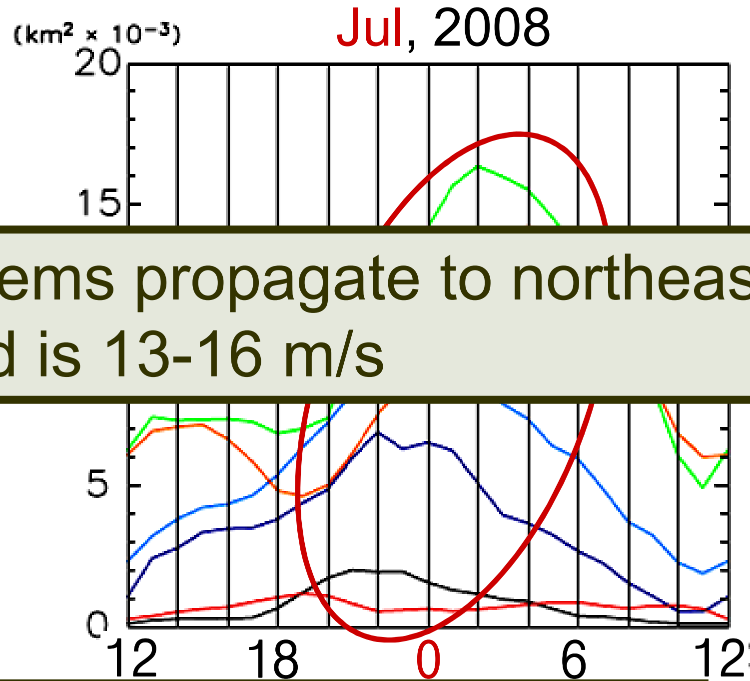
See the results of two cases:
1) consider small systems only.
2) consider large systems only. Threshold: $800\,\mathrm{km}^2$

Regional differences of diurnal cycles

Small systems only $(< 800\,\mathrm{km}^2)$



Large systems only $(\geq 800\,\mathrm{km}^2)$



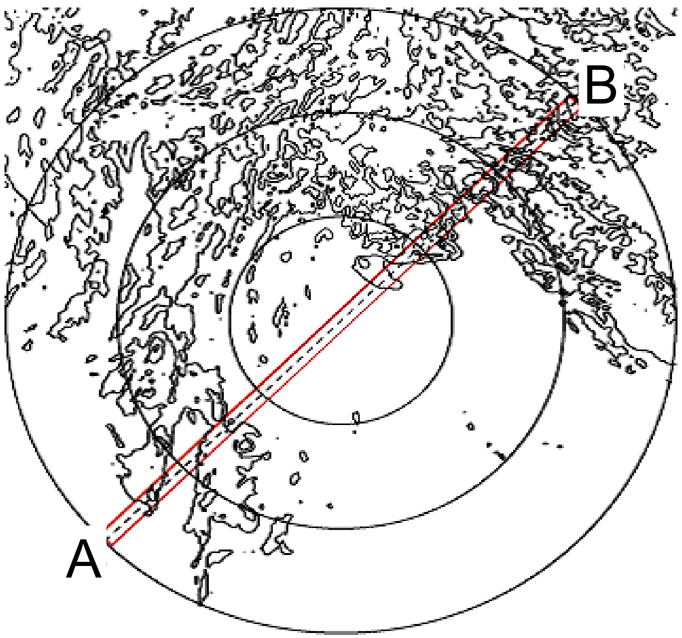
Suppose that convective systems propagate to northeast
-> phase speed is 13-16 m/s

The phase shift of diurnal cycles cannot be seen
Time
-> sm
sh

Time of the maximum gets late as it goes to northeast
-> This result indicates the existence of northeastward convective systems

Ratio of radar echo existence

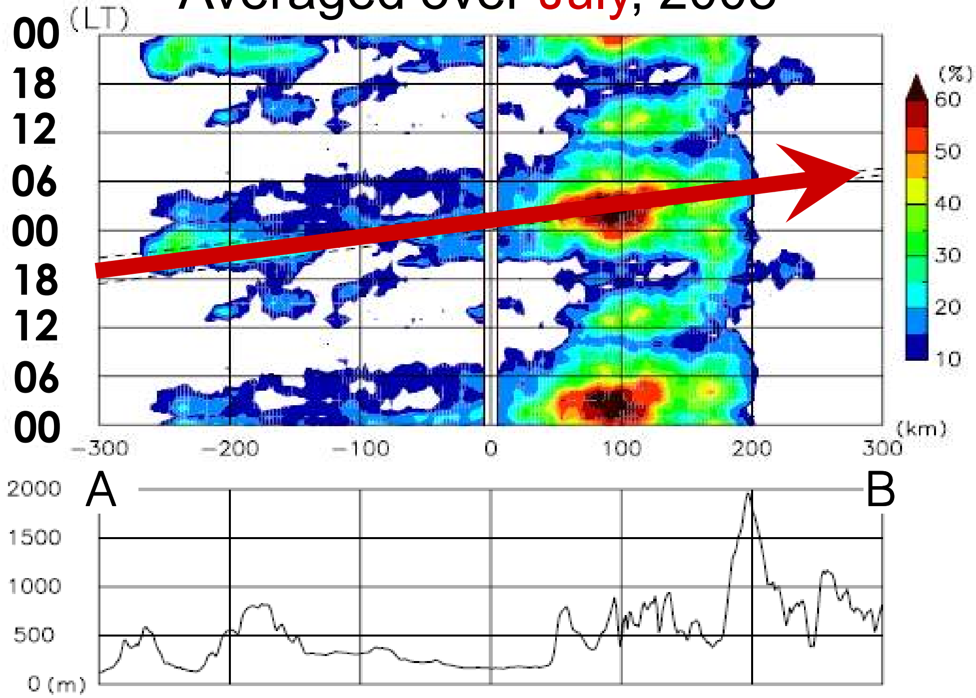
Domain: 600 km x 20 km



Circles: 100 km, 200 km, 300 km
Contour: every 500 m

Time-Distance cross section

Averaged over July, 2008



Above
Tone : diurnal cycles of the ratio of echo existence in the domain Horizontal axis : distance
Vertical axis : LT (diurnal cycle twice)

al axis : distance
xis : averaged elevation in the domain

Echo propagates northeastward speed: 12-15 m/s

Conclusions

+ Diurnal cycles

Apr and Oct: in the afternoon -> numbers of small systems

Jul: around 1 LT

+ Night time precipitaion in July

Large convective systems:
It appears that there exists northeastward convective systems

Phase speed / traveling speed: 12-16 m/s
Similar to the phase speed of cloud streaks observed in East Asia (Wang et al., 2004) and North Africa (Laing et al., 2008); 10-25 m/s.

It suggests that northeastward convective systems bring the night time rain near Vientiane.
Consider the speed, squall line would have a part in the mechanism.

ຂອບໃຈ ຫຼາຍໆ!

Fin.

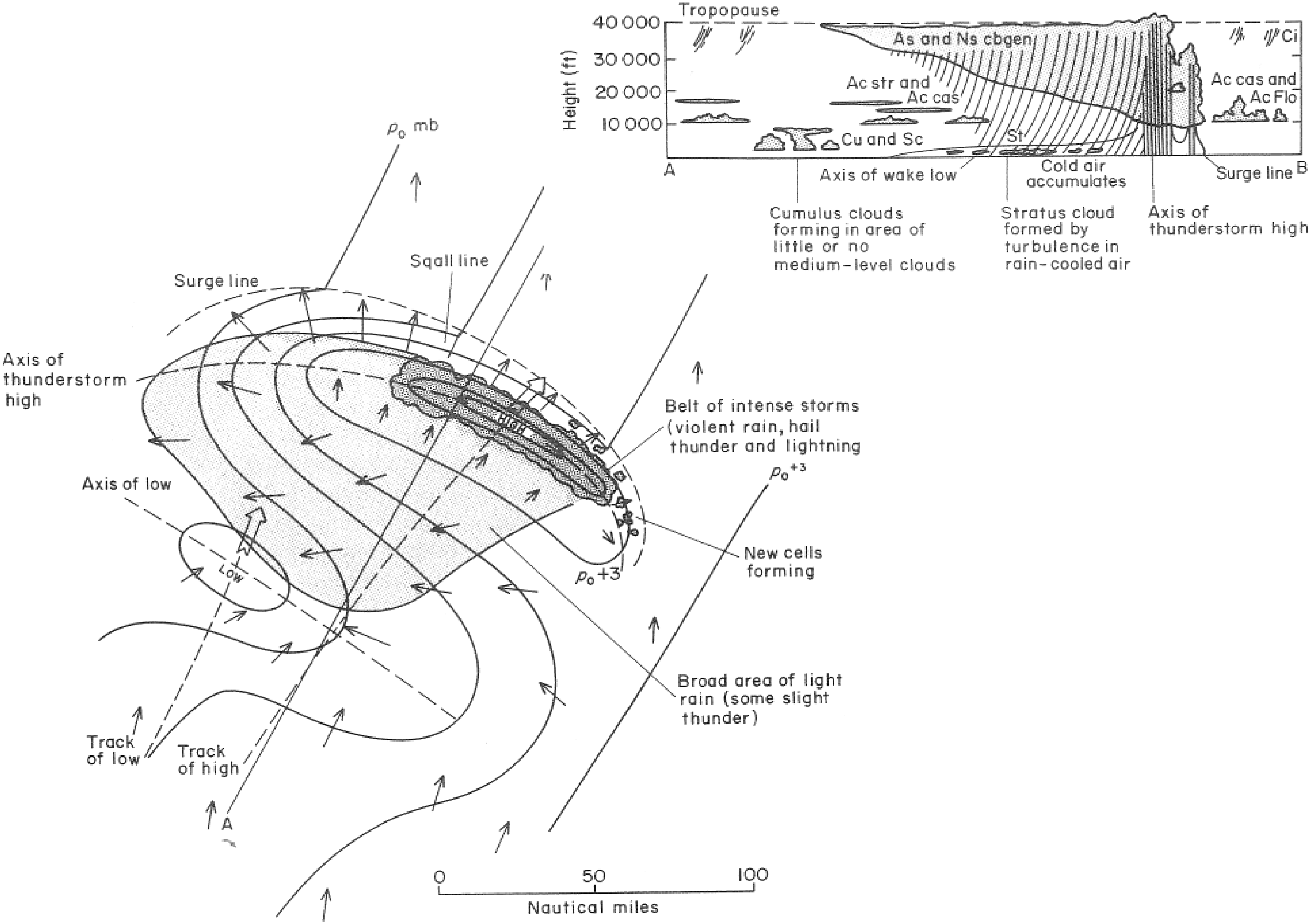
squall line

スコールライン型
中層(850 hPa-550 hPa) の相当温位が低く、対流不安定性強い
ラインの先端部に活発な積乱雲が並ぶ convective region
背後に中層から上層にかけてメソスケールに広がった stratiform region がある(100 km の範囲になることもしばしば)

ストームの前面からストーム内に空気は流入

メソ気象＆Zipser 1982

squall line


Tropopause
40 000
30 000
20 000
10 000
Height (ft)
As and Ns cbgen
Ci
Ac str and
Ac cas
Ac cas and
Ac Flo
Cu and Sc
St
A
B
Axis of wake low
Cold air
accumulates
Surge line
Cumulus clouds
forming in area of
little or no
medium-level clouds
Stratus cloud
formed by
turbulence in
rain-cooled air
Axis of
thunderstorm high
p_0 mb
Sqall line
Surge line
Axis of
thunderstorm
high
Belt of intense storms
(violent rain, hail
thunder and lightning
High
p_0+3
Axis of low
Low
New cells
forming
p_0+3
Broad area of light
rain (some slight
thunder)
Track
of low
Track
of high
A
0
50
100
Nautical miles

squall line

スコールライン型

中層(850 hPa-550 hPa) の相当温位が低く、対流不安定性強い

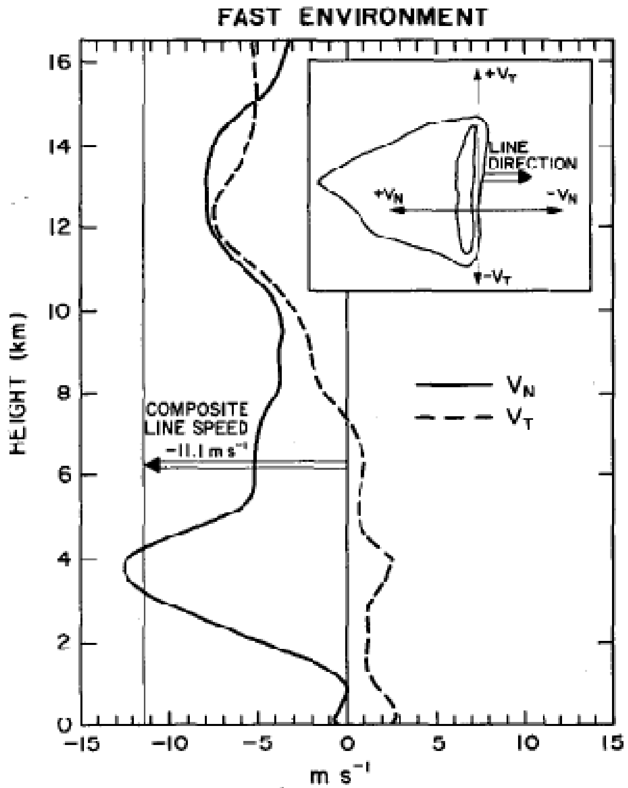


FIG. 7. Composite profile of the wind component normal (V_N, solid) and parallel (V_T, dashed) to the leading edge of a squall line for the environment. The mean line speed is shown by a thin vertical line.

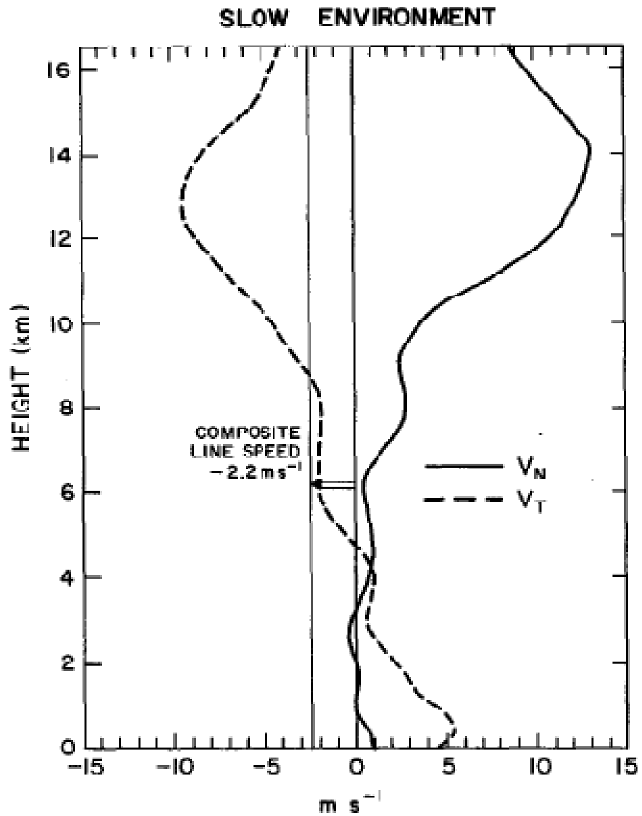
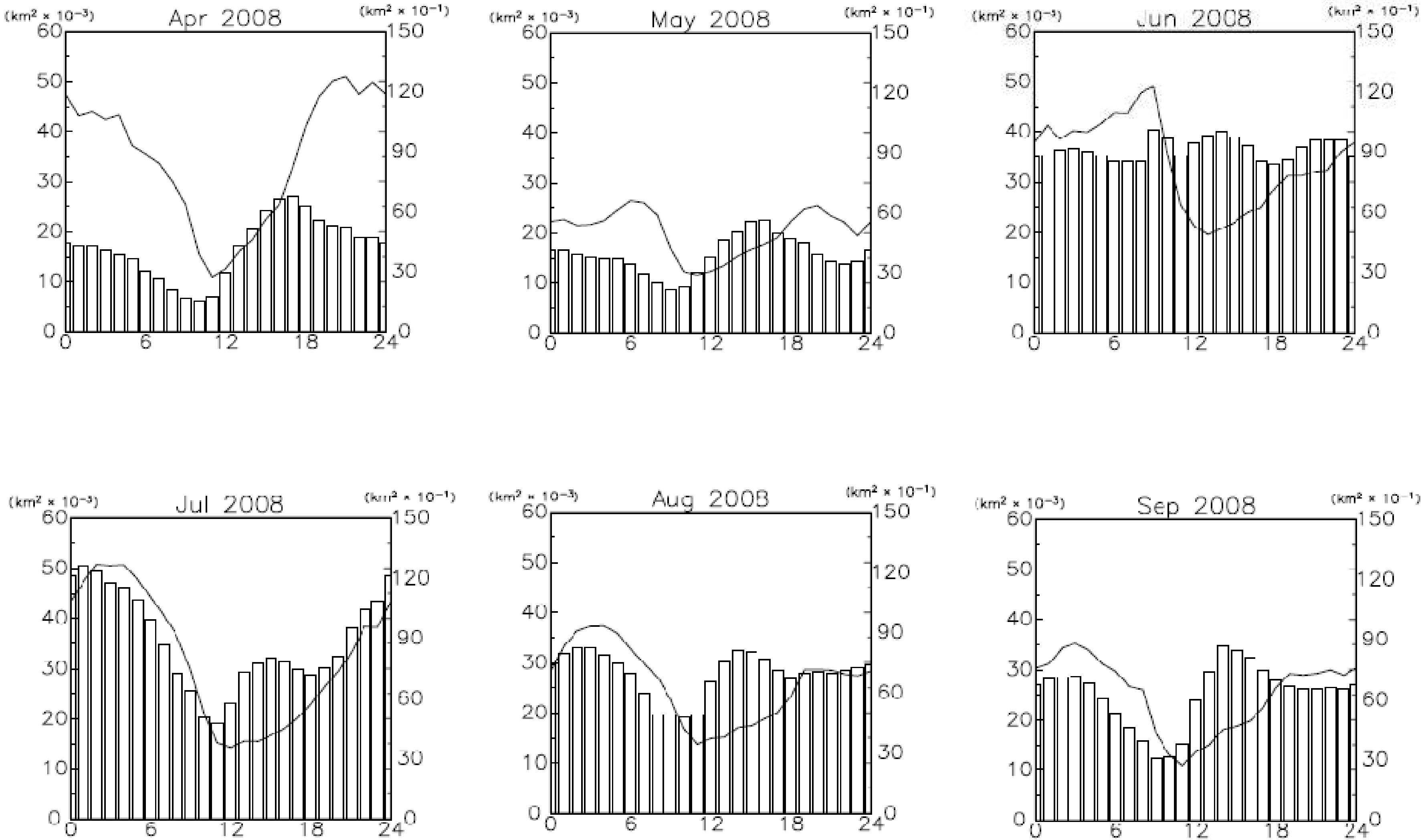


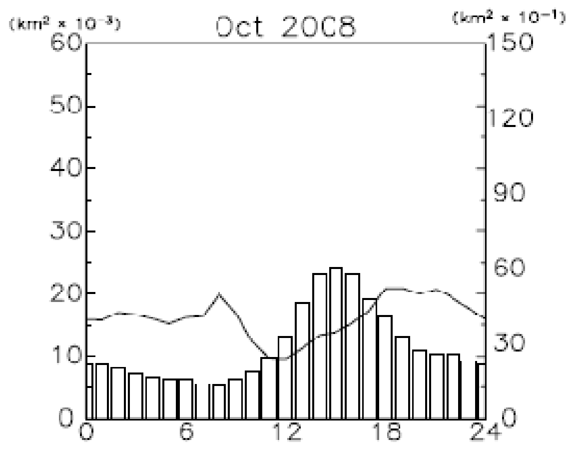
FIG. 8. As in Fig. 7 but for the slow-moving cloud line.

squall line

メソ対流系ー団塊状ー組織化されていないマルチセル型
（気団性雷雨）
ー組織化されたマルチセル型
－スーパーセル型
－メソスケール対流複合体（ＭＣＣ）
－線状ースコールライン型
（急行型：鉛直シアに直交型）15 m/s
－非スコールライン型
（鈍行型：鉛直シアに平行型）
（降雨バンド型）

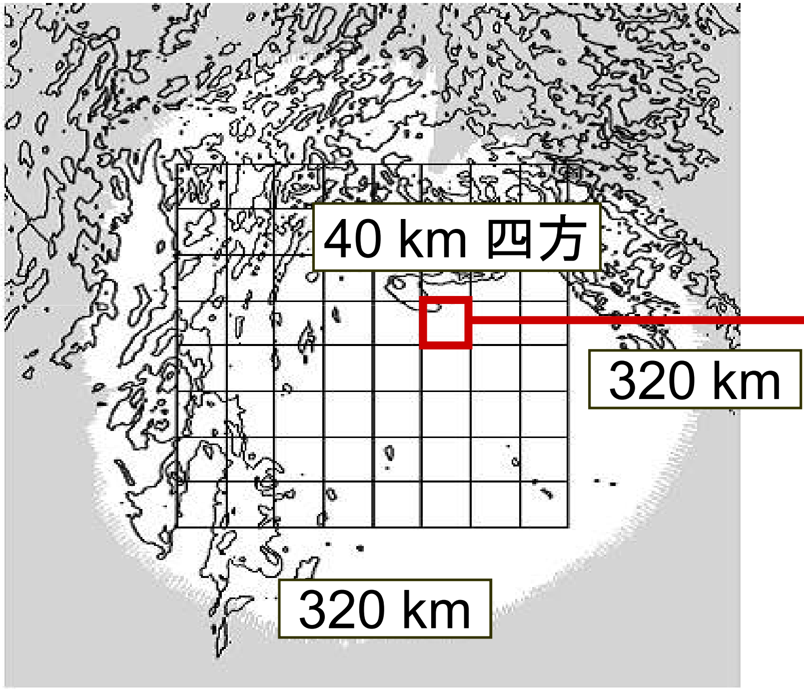
MCS は 20 km - 500 km 水平あれば affirmative


Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
(km^2 × 10^{-3})
(km^2 × 10^{-1})
0 10 20 30 40 50 60
0 30 60 90 120 150
0 6 12 18 24



Based on Japanese criteria
10 dBZ -> 0.15 mm/hr   don't need an umbrella
20 dBZ -> 1.5 mm/hr   may need an umbrella
30 dBZ -> 2.7 mm/hr   need an umbrella
40 dBZ -> 11.5 mm/hr   strong rain
45 dBZ -> 23.7 mm/hr   rain cats and dogs
50 dBZ -> 100 mm/hr   fear the rain

エコー面積の移動方向と大規模風の風向

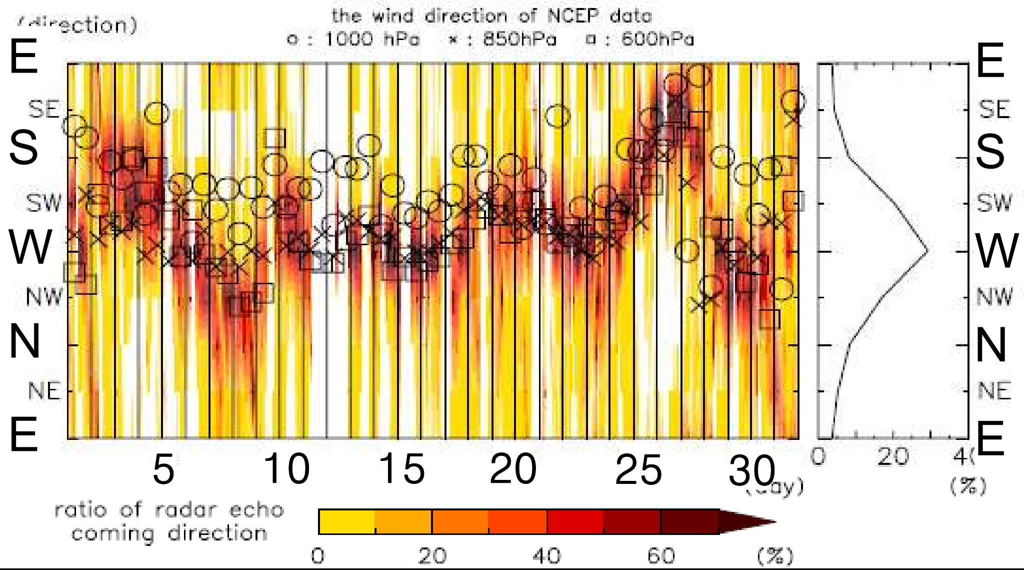


64 個の各小領域に存在するエコーが次のタイムステップでどの方角に移動したか

相互相関係数（水越・里村, 1999）を用いて調べ、
移動ベクトル 64 個を算出

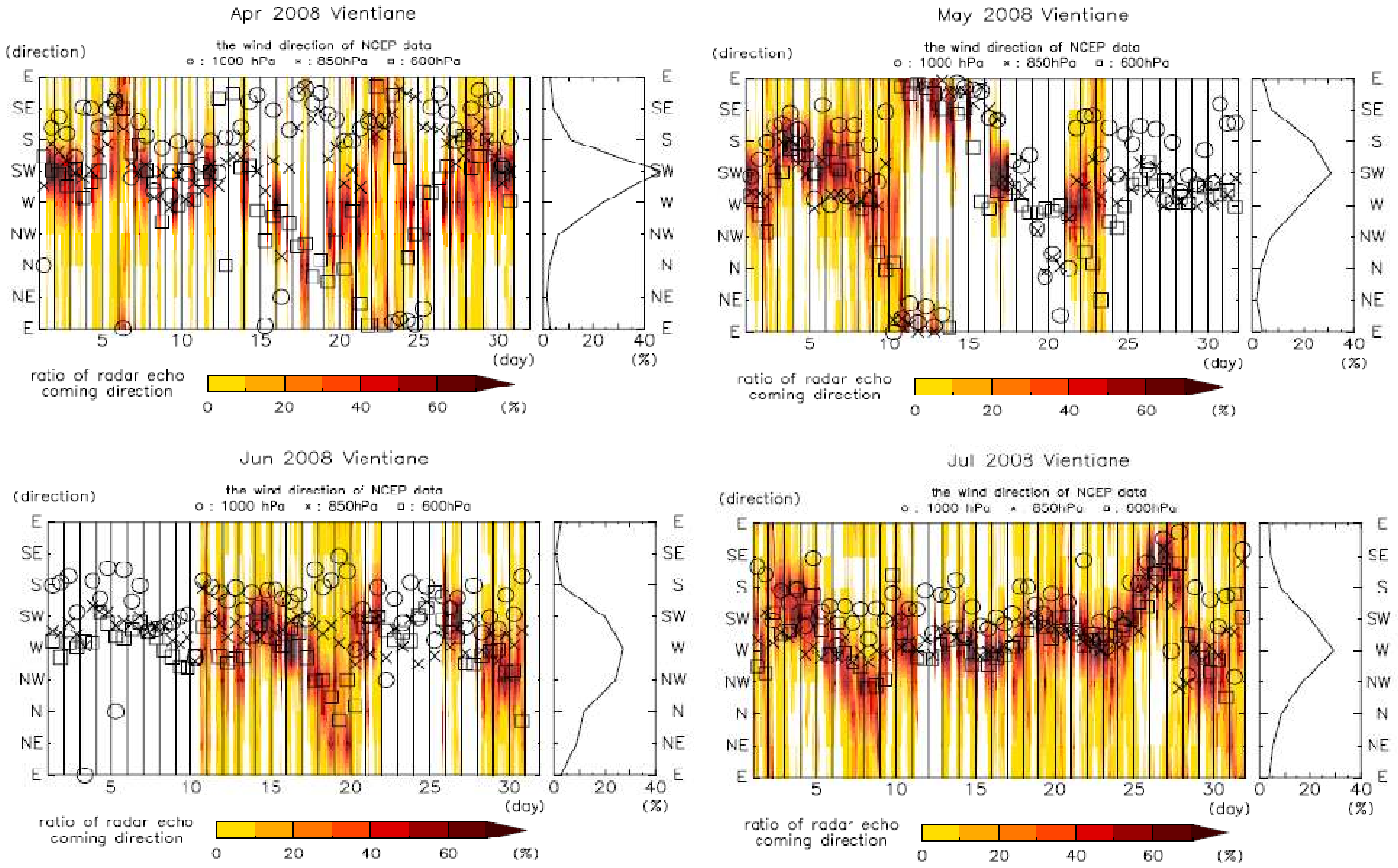
Radar echo coming direction

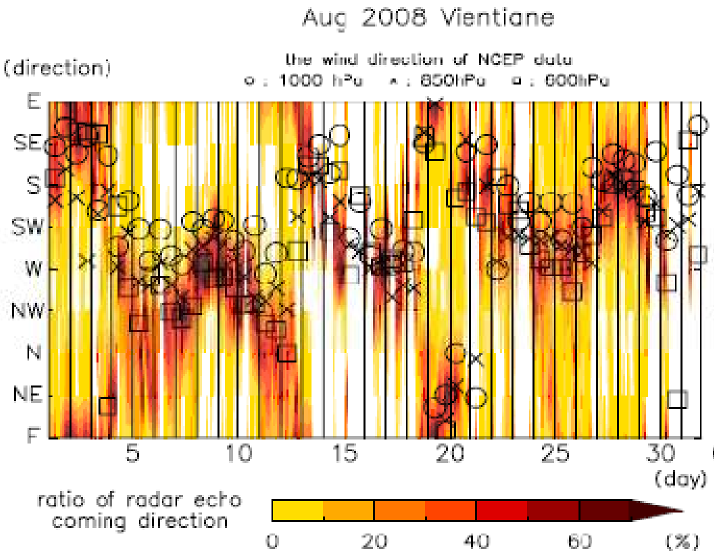
Jul, 2008

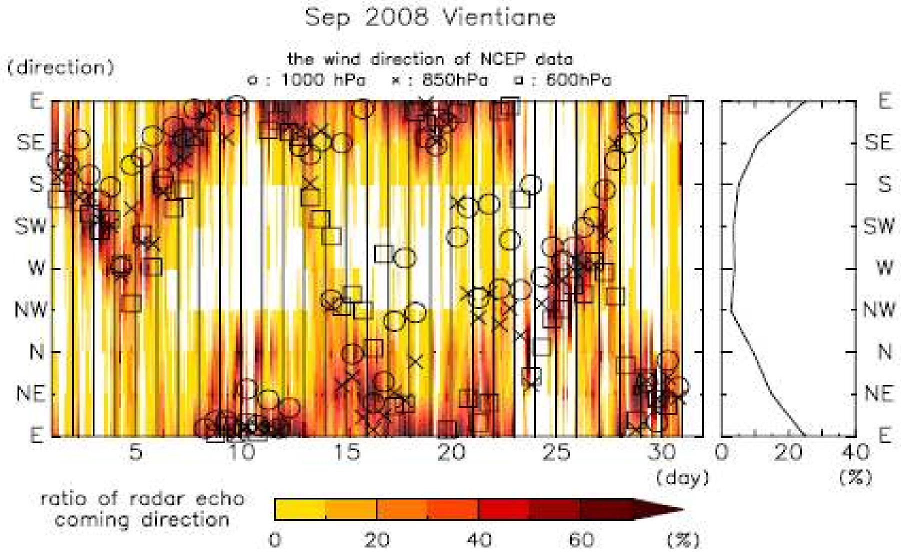


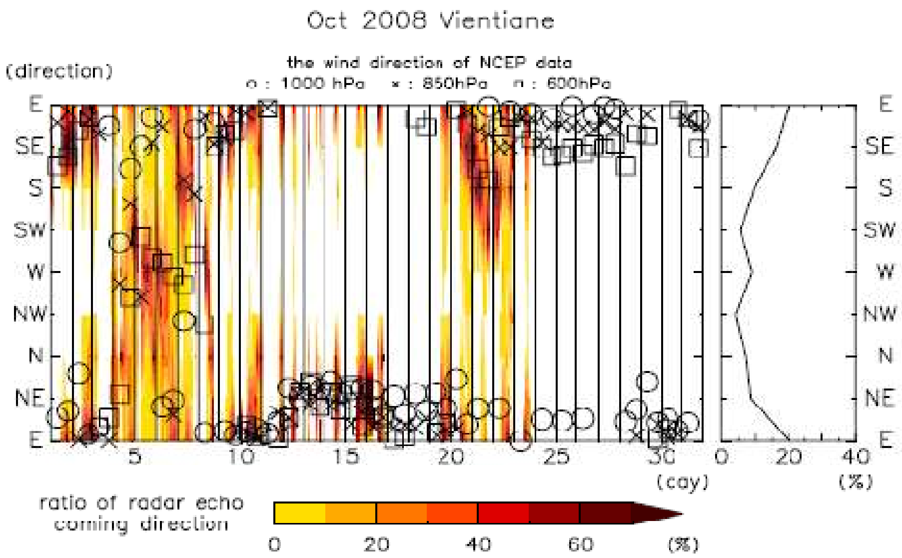
Left Horizontal axis : Day (black solid lines: 0 LT)
Tone: ratio of radar echo coming direction
Marks: NCEP Reanalysis data
○ : 1000 hPa, × : 850 hPa, □ : 600 hPa

7 月について:
1000 hPa 面では大規模風は南西風
高度 3 km CAPPI 上のエコーは 850 hPa ー 600 hPa の
中層の大規模風の風向(西・南西・北西)に沿ってやってくる


Apr 2008 Vientiane
May 2008 Vientiane
Jun 2008 Vientiane
Jul 2008 Vientiane
(direction)
the wind direction of NCEP data
o : 1000 hPa × : 850hPa □ : 600hPa
E
SE
S
SW
W
NW
N
NE
E
5
10
15
20
25
30
(day)
0
20
40
(%)
ratio of radar echo coming direction
0
20
40
60
(%)

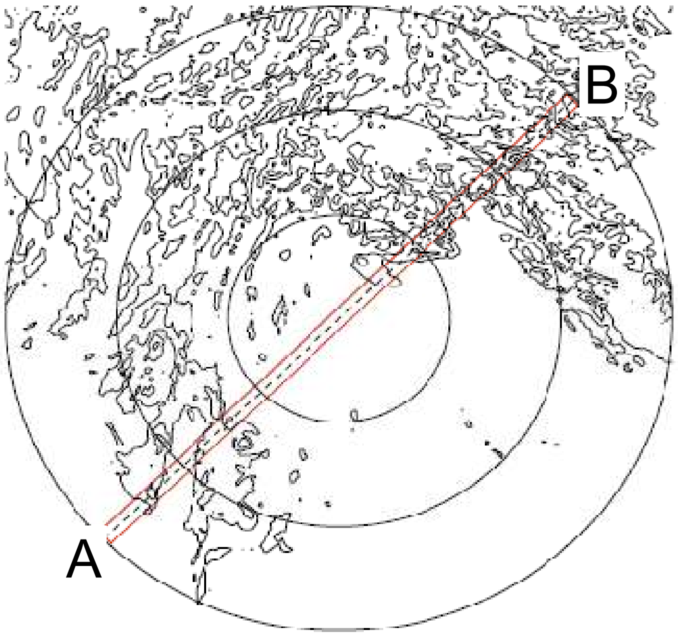

Aug 2008 Vientiane
(direction)
the wind direction of NCEP data
o : 1000 hPa × : 850hPa □ : 600hPa
E
SE
S
SW
W
NW
N
NE
E
5
10
15
20
25
30
(day)
0
20
40
(%)
ratio of radar echo coming direction
0
20
40
60
(%)


Sep 2008 Vientiane
(direction)
the wind direction of NCEP data
o : 1000 hPa × : 850hPa □ : 600hPa
E
SE
S
SW
W
NW
N
NE
E
5
10
15
20
25
30
(day)
0
20
40
(%)
ratio of radar echo coming direction
0
20
40
60
(%)


Oct 2008 Vientiane
(direction)
the wind direction of NCEP data
o : 1000 hPa × : 850hPa □ : 600hPa
E
SE
S
SW
W
NW
N
NE
E
5
10
15
20
25
30
(day)
0
20
40
(%)
ratio of radar echo coming direction
0
20
40
60
(%)

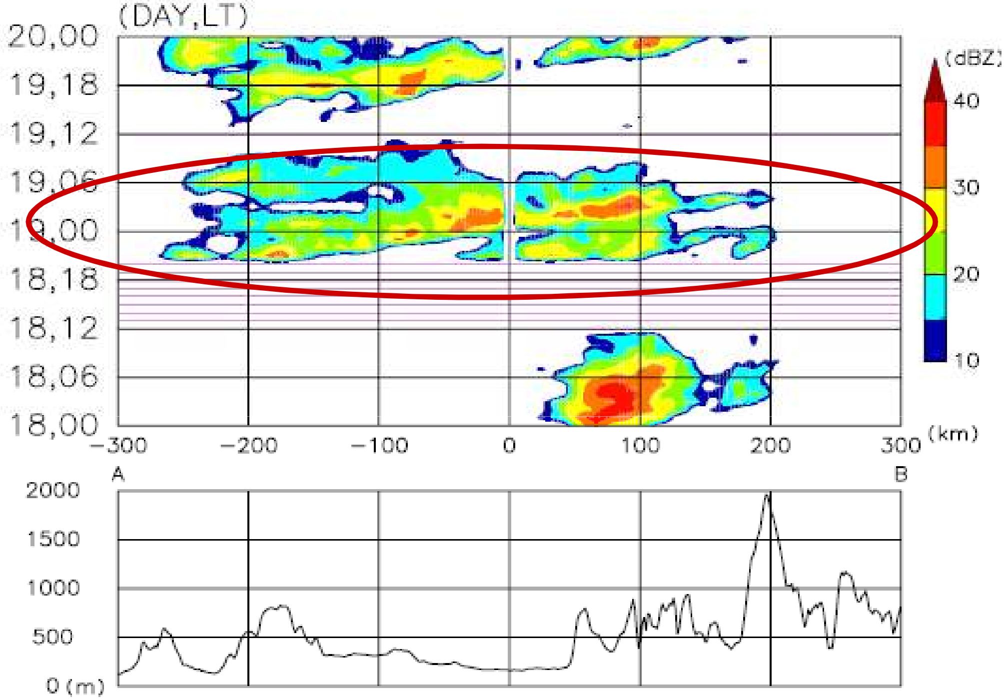
エコー反射強度の時間－距離断面図

南西ー北東に細長い 600 km x 20 km の領域



円：内側から 100km, 200km, 300km

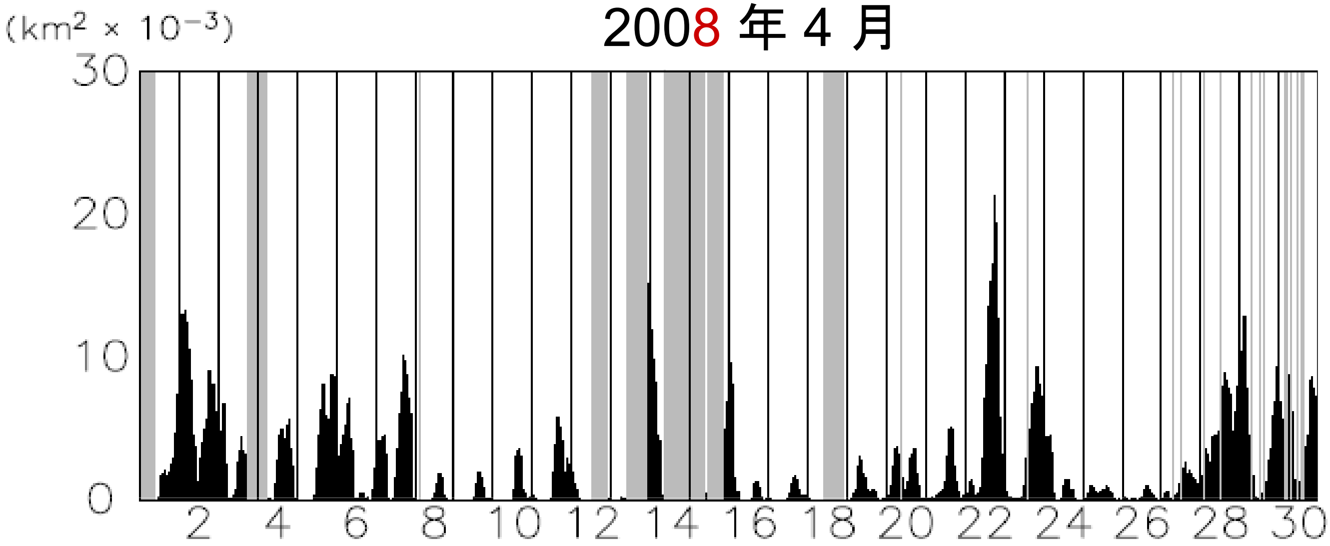
2008 年 7 月 18 日 ー 20 日



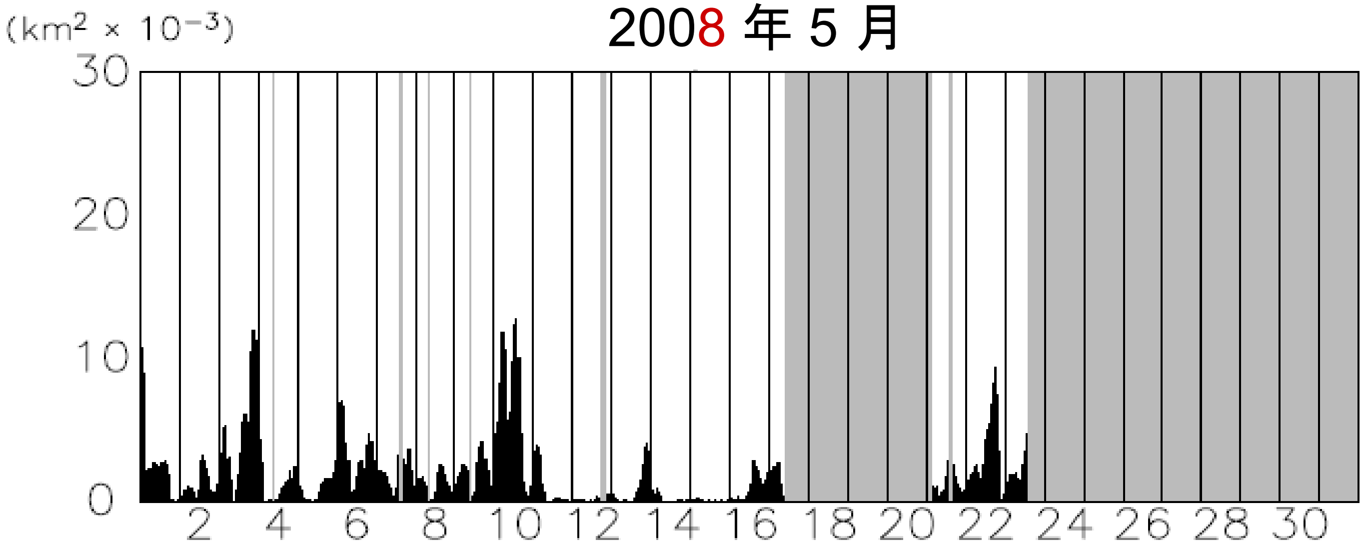
上
トーン：AB の領域内でのエコー反射強度
横軸：距離
縦軸：現地時刻 （横縞線：欠測期間）
下
横軸：距離
縦軸：AB の領域内の平均標高

欠測頻度

2008 年 4 月

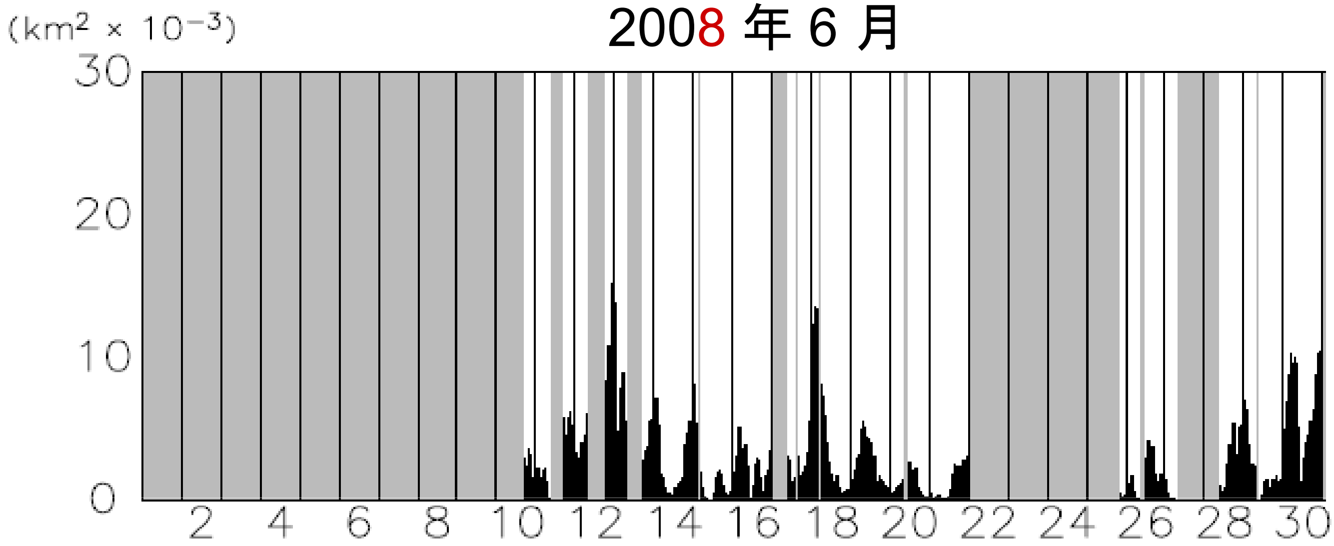


2008 年 5 月

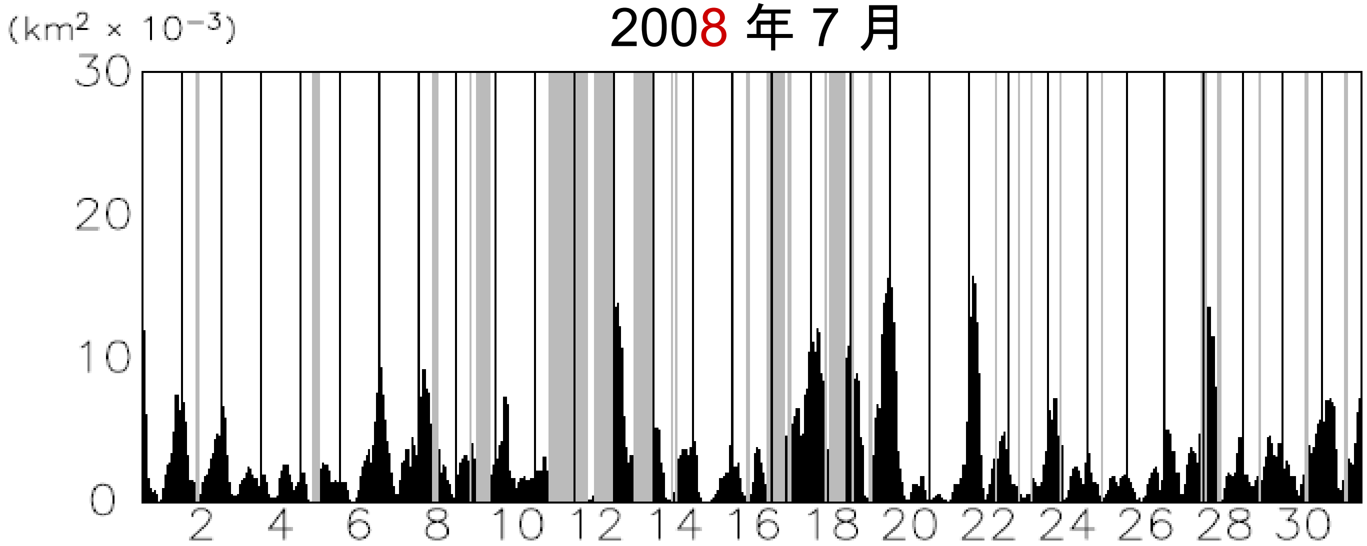


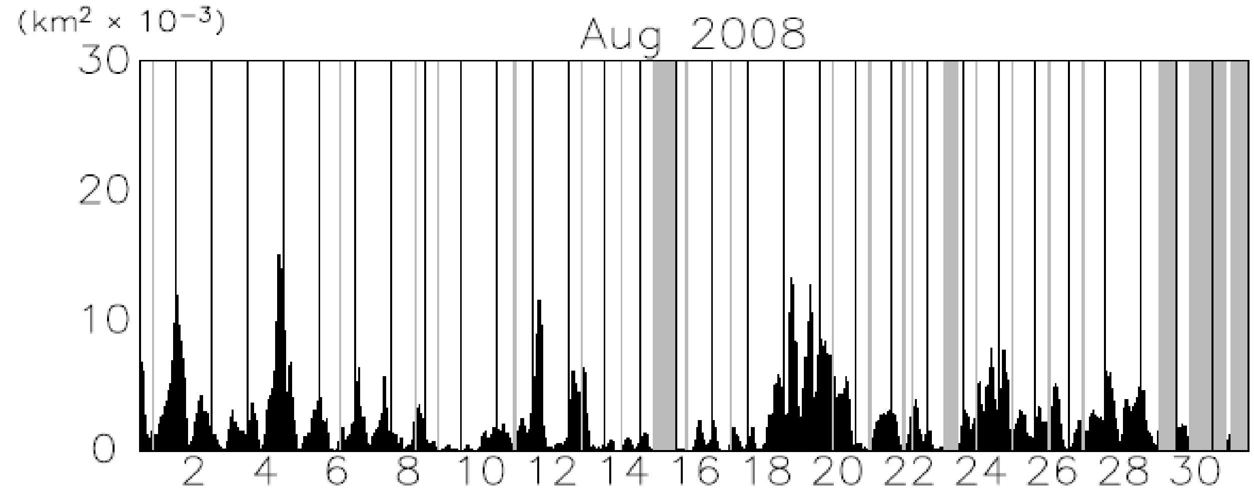
欠測頻度

2008 年 6 月

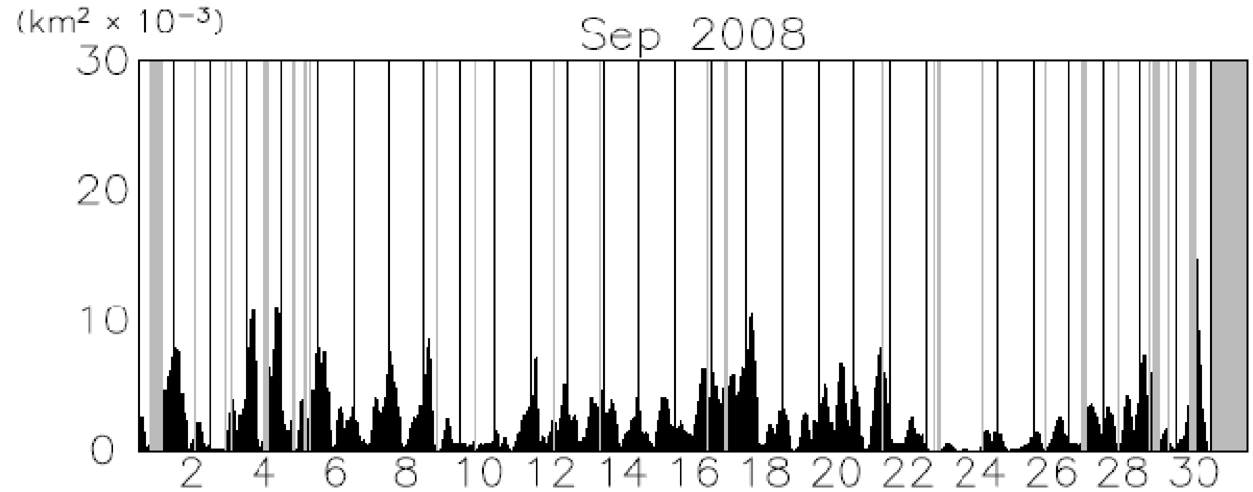


2008 年 7 月

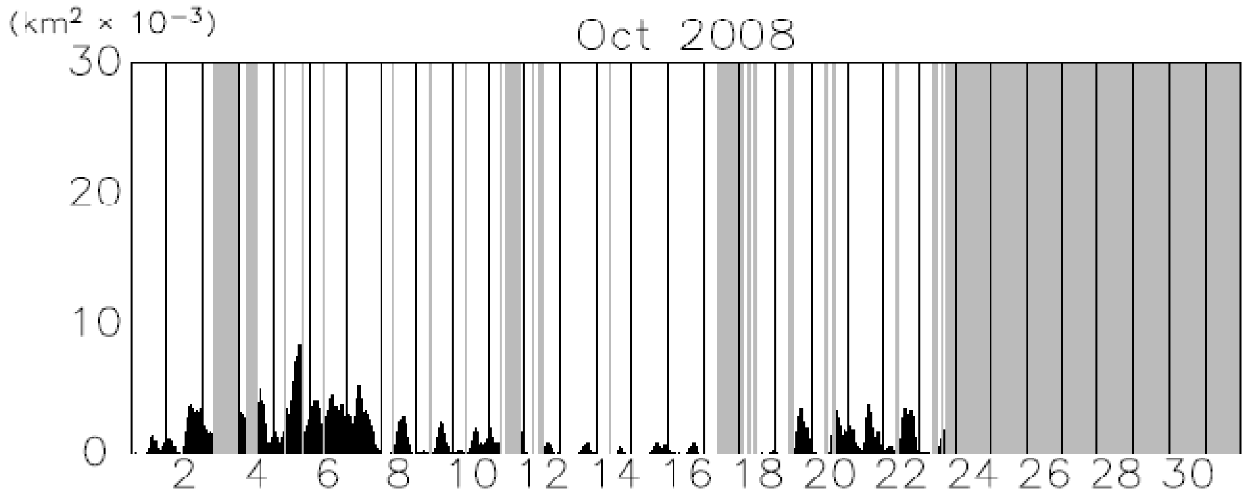




(km² × 10⁻³)
Aug 2008
30
20
10
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

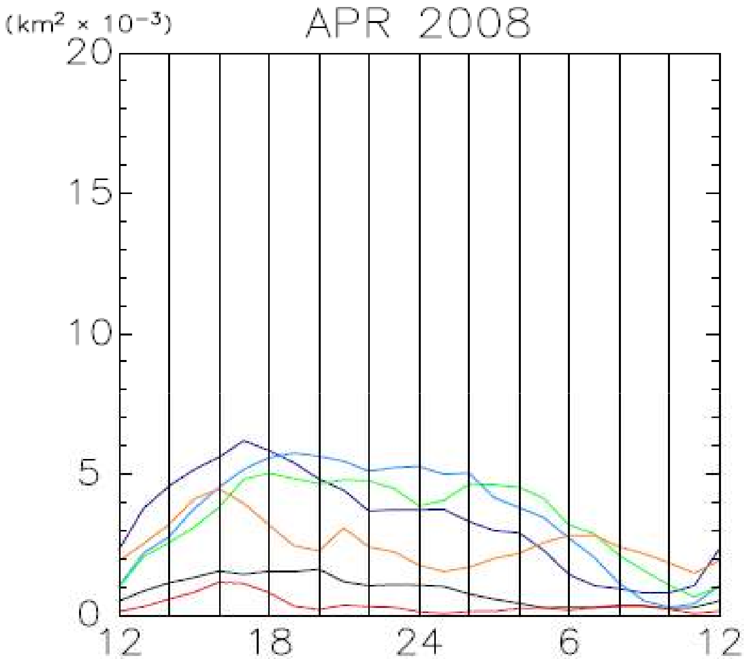


(km² × 10⁻³)
Sep 2008
30
20
10
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

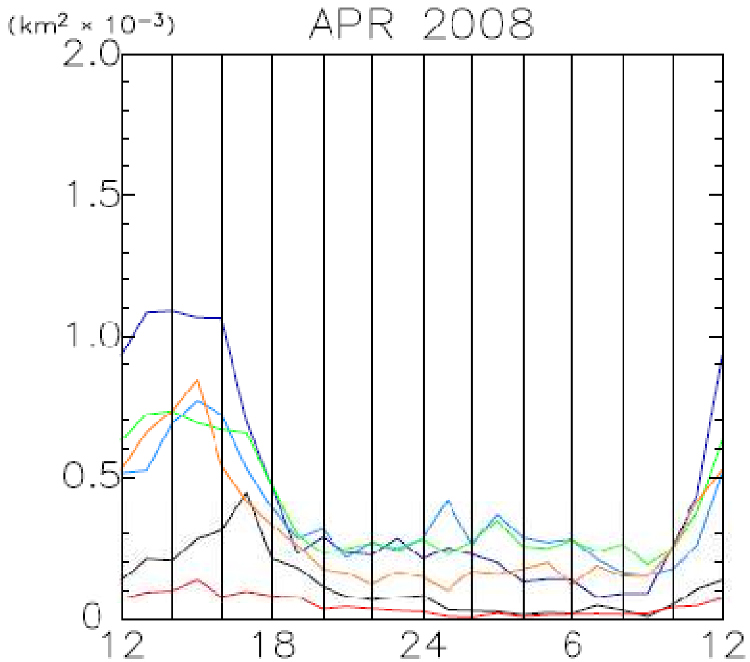


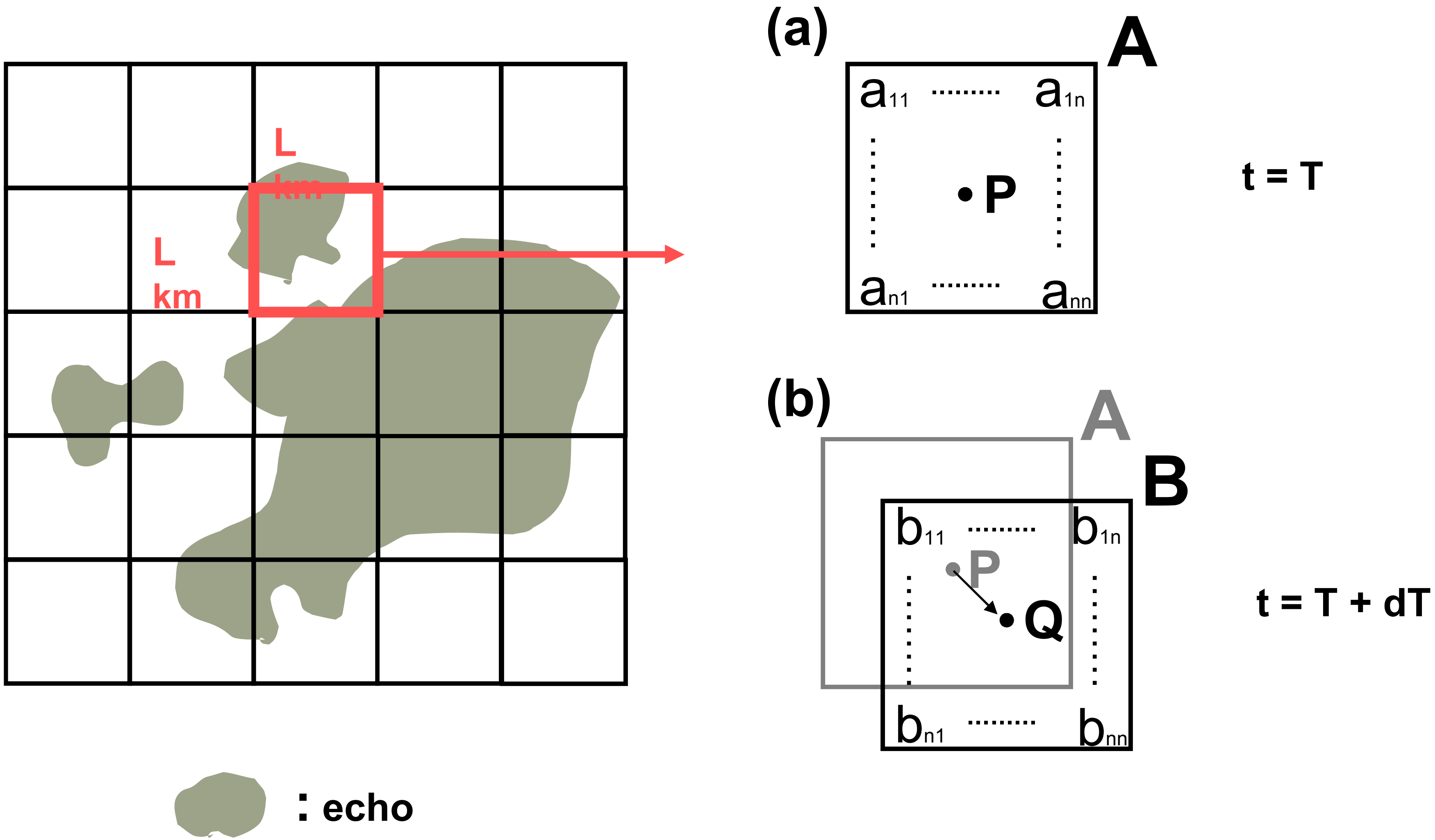
(km^2 × 10^{-3})
Oct 2008
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

大きい対流システム (≥ 800 km²)



小さい対流システム (< 800 km²)




L
km
L
km
: echo
(a)
A
a11
a1n
P
an1
ann
t = T
(b)
A
B
b11
b1n
P
Q
bn1
bnn
t = T + dT

対流活動の日変化の位相のずれ

Riley et al. (1987) はロッキー山脈とその東側の平野に設置された雨量計を用いて降水の日変化を調べた

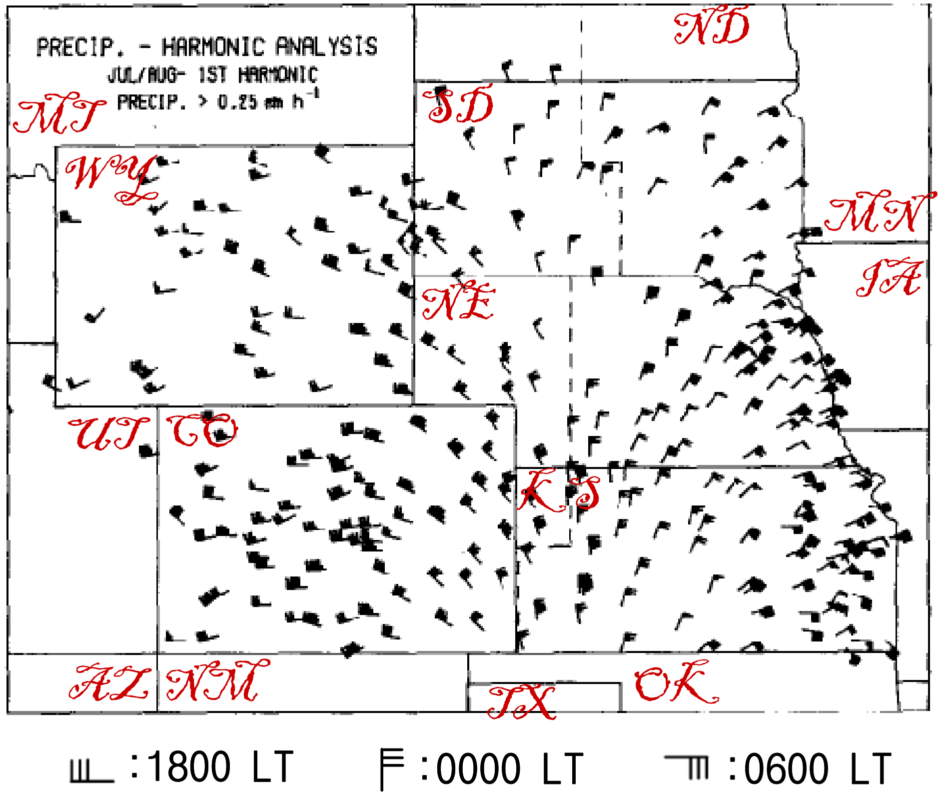
日変化の極大時刻 (LT) を表したのが右図 (解析期間: JUL/AUG; 1948-1983)

→極大時刻が東にいくほど遅い

Tripoli and Cotton (1989) は二次元数値実験を行い、コロラド州山岳域で発生したメソスケール対流システム (MCS) が東進し、東の平野で夜に雨をもたらすことを再現

また、彼らは MCS の形成に南西モンスーンが重要であることを示唆

JUL/AUG



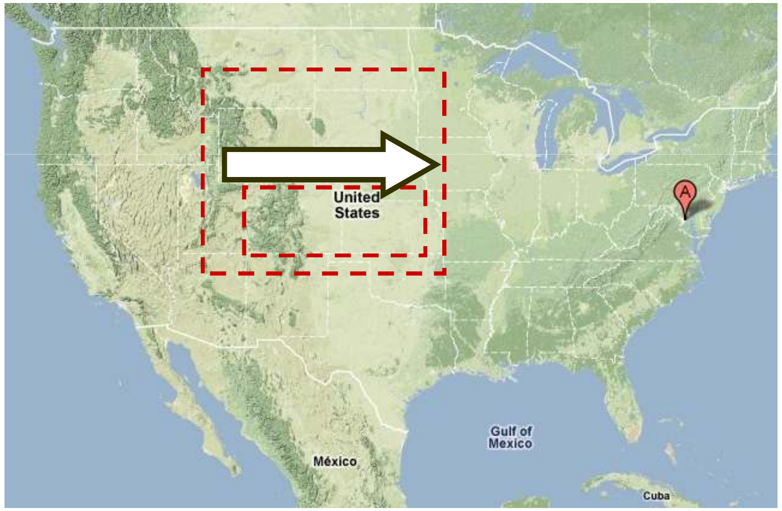
Riley et al. (1987)

対流活動の日変化の位相のずれ

夜雨が顕著 → 中緯度では夏期における Great Plains が知られている

Riley et al. (1987) はロッキー山脈とその東側の平野に設置された雨量計を用いて降水の日変化を調べた

→ 日変化の極大時刻が東にいくほど遅い



Google map

Tripoli and Cotton (1989) は二次元数値実験を行い、コロラド州山岳域で発生したメソスケール対流システム (MCS) が東進し、夜に東の平野に到達することを再現

また、彼らは MCS の形成には季節風である南西モンスーンが重要であることを示唆

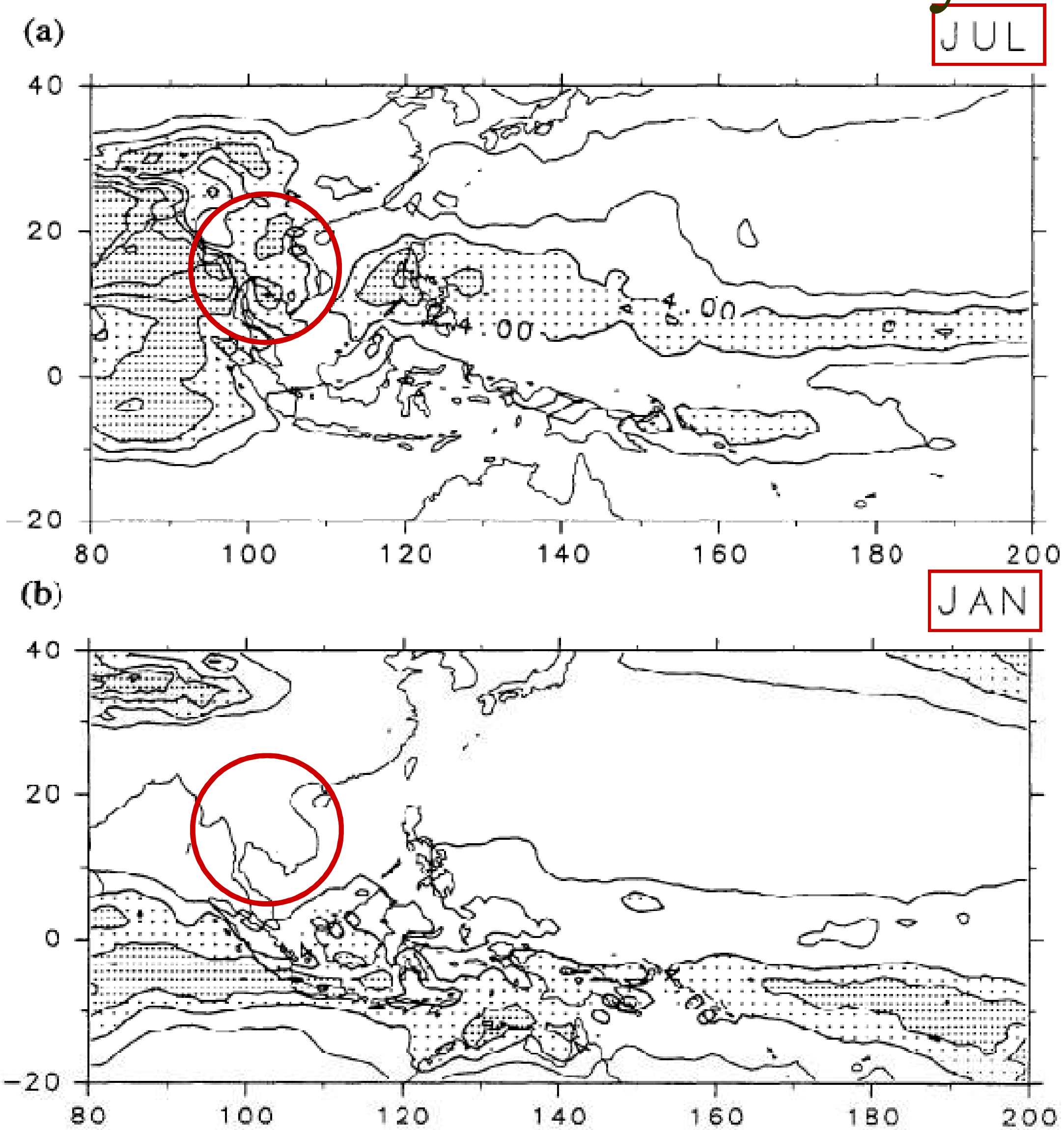
Horizontal distribution of convective activity

Nitta and Sekine (1994) defined I_c as follows

$$I_c = 250 - T_{BB}, \ (T_{BB} < 250(K))$$
$$= 0, \ (T_{BB} \geq 250(K))$$

T_{BB} : black body temperature

The activity is outstanding during July over the Indochina Peninsula



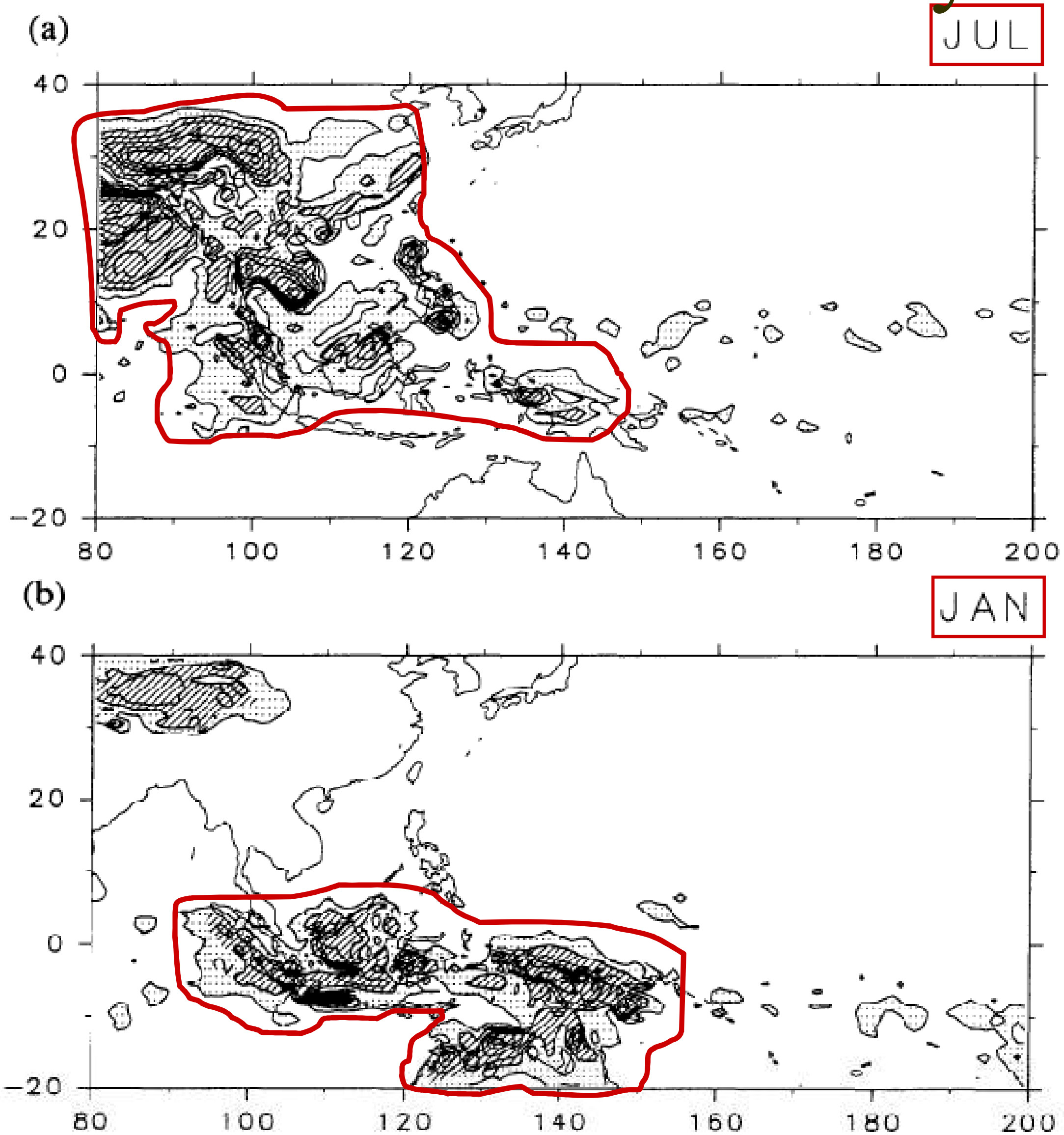
Nitta and Sekine (1994)

Horizontal distribution of convective activity

Amplitudes of diurnal components of I_c

Large diurnal variations:
- -> over the continent
- -> near large islands

Understanding diurnal variations is of the essence



Nitta and Sekine (1994)