

Numerical experiments on the diurnal variation of precipitation in the northeastern Bangladesh

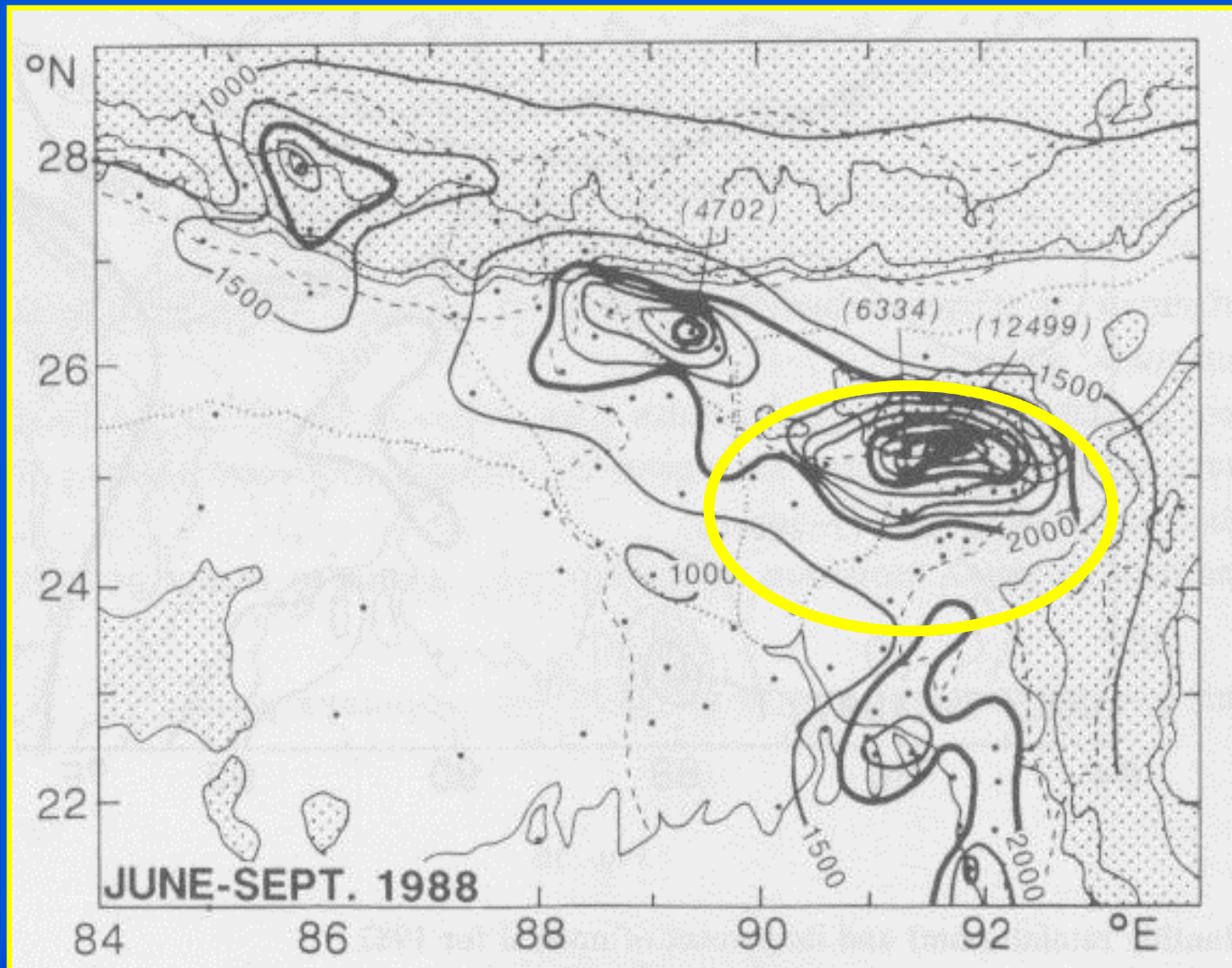
Aya KATAOKA and Takehiko
SATOMURA

Kyoto University

Observational Evidences

The World Record

(Aug. 1860 ~ July 1861 26461 mm)

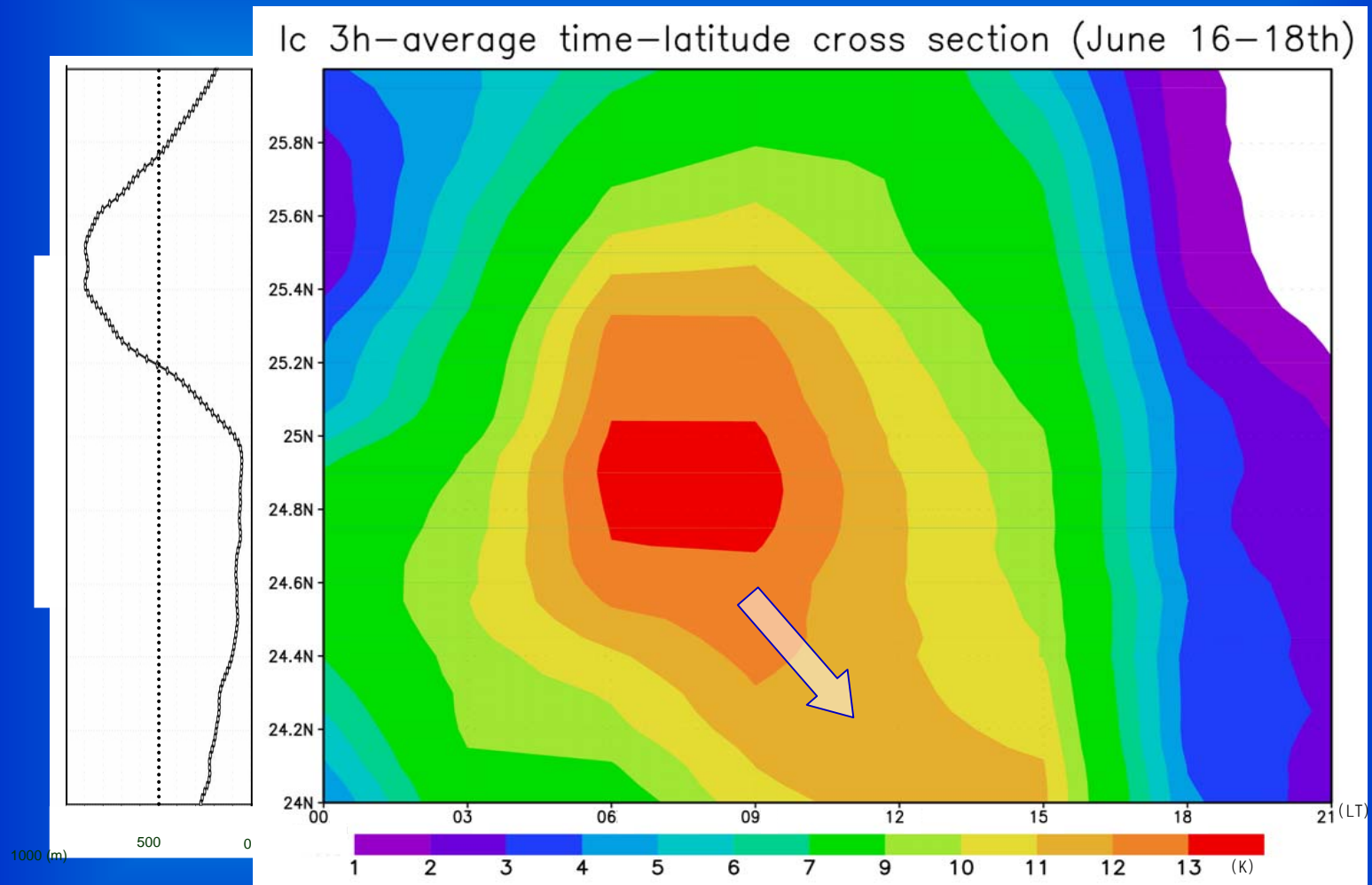


1988 June ~ Sep. Precipitation (mm)
(matsumoto et al., 1996)

Observational Evidences

$$I_c = \begin{cases} 230 - T_{bb} & (T_{bb} \leq 230K) \\ 0 & (T_{bb} > 230K) \end{cases}$$

Diurnal Variation of Convective Activity

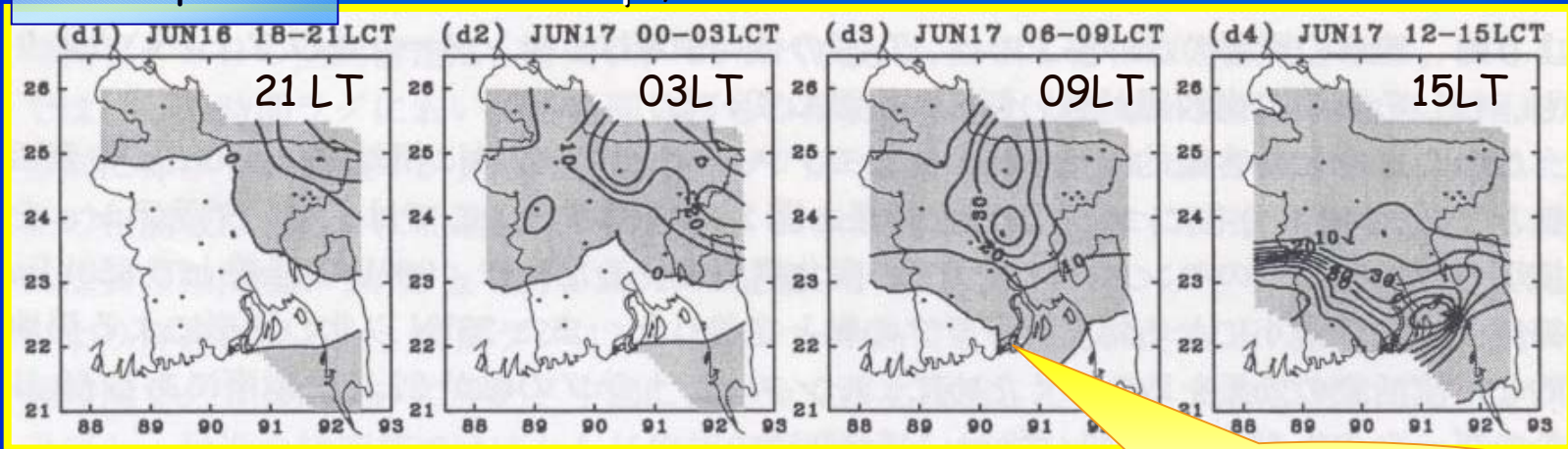


Precipitation maximum is observed in midnight to early morning (Ohsawa et al., 2000,2001; Terao et al., 2002;Islam et al., 2005)

Observational Evidences 1995 June 16-17 (Ohsawa et al., 2000)

3h Prep.

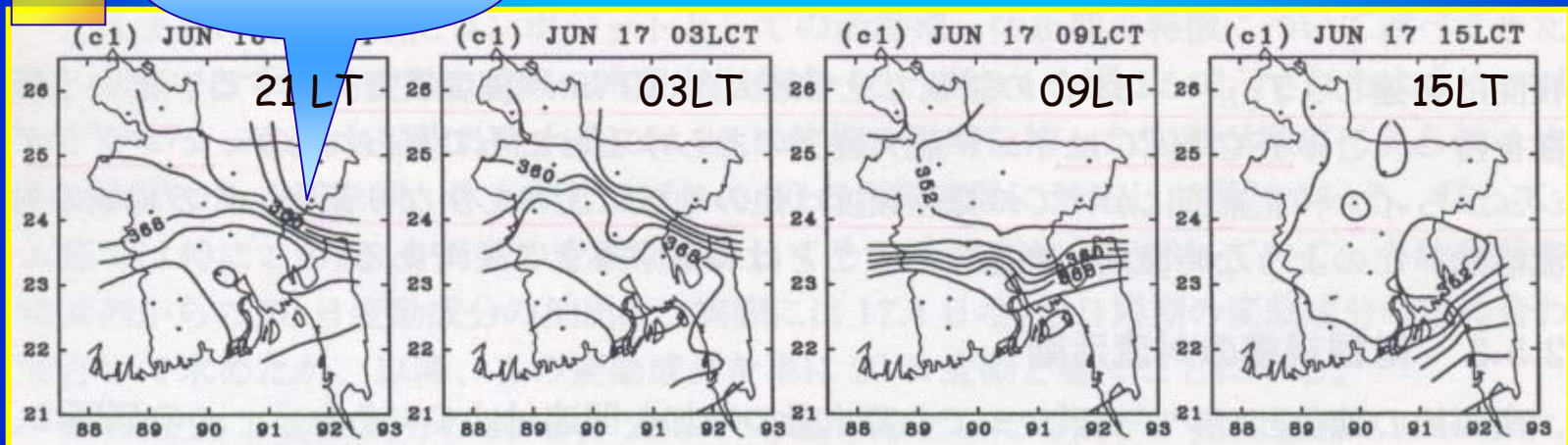
shade : Prep., contour : 10 mm/3h



θ_e

Front of θ_e

contour : 4 K



Purpose of this study

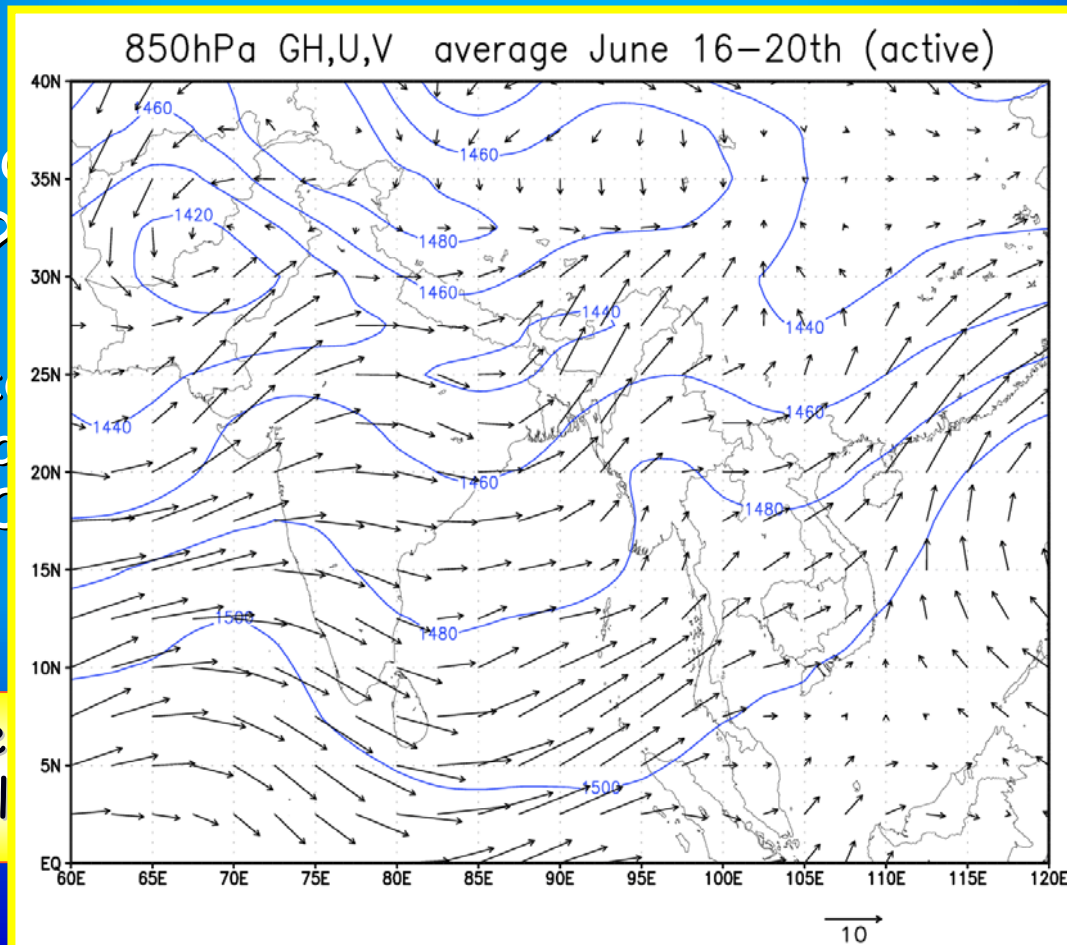
Q1. Why does the precipitation area expand southward?

The direction is against the SW

Q2. Why is the precipitation maximum?

It is caused by the katabatic wind (e.g., C)

This means that the precipitation is available



urnal

sturnal
monsoon

ata

Model

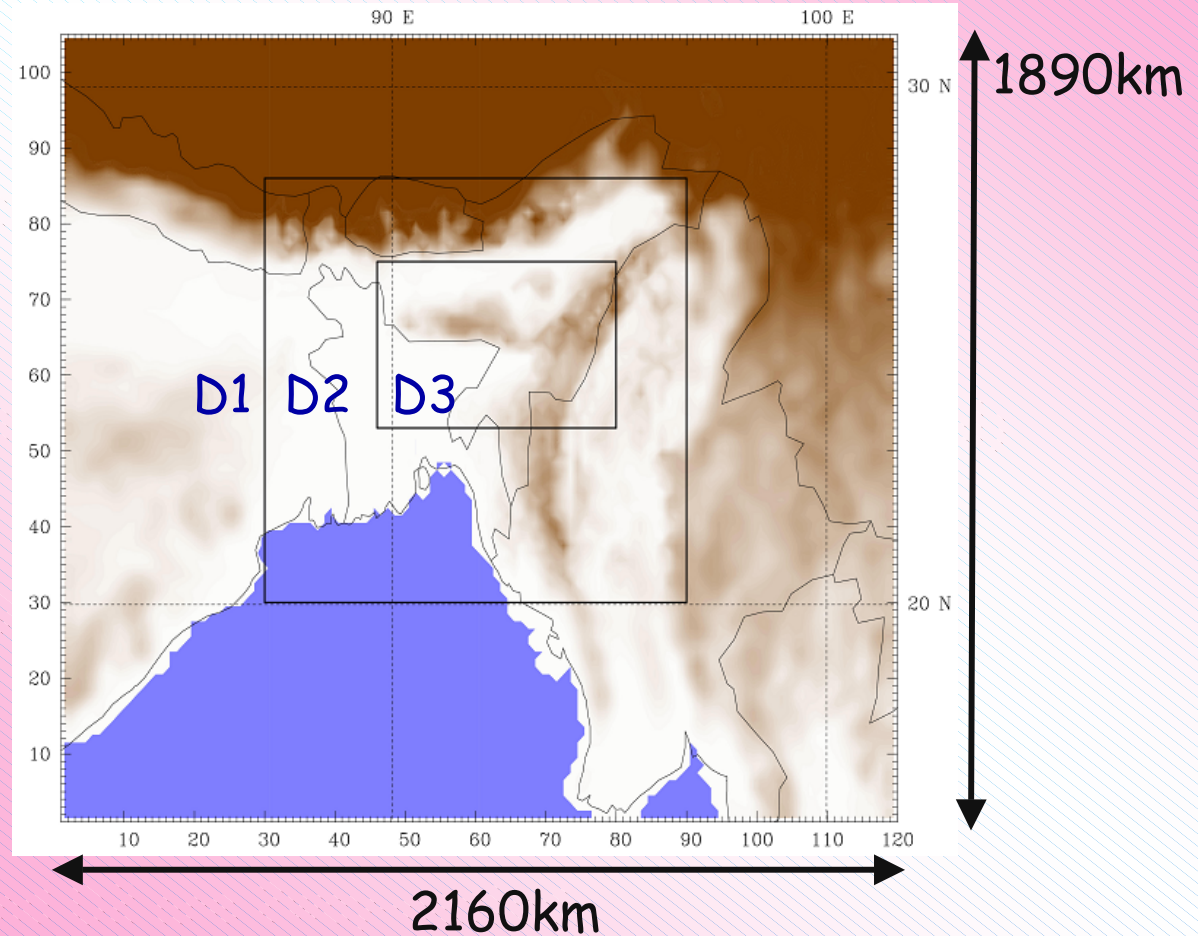
PSU/NCAR Me

• Input data:

• Period : 19

• Domains :

D1 c

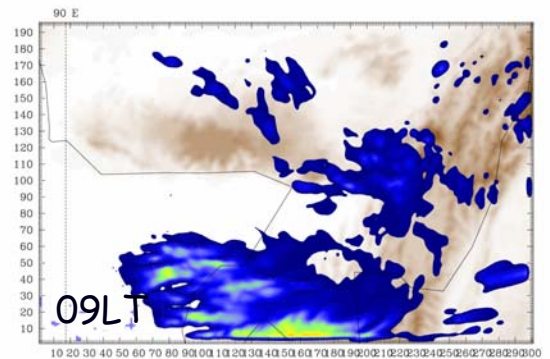
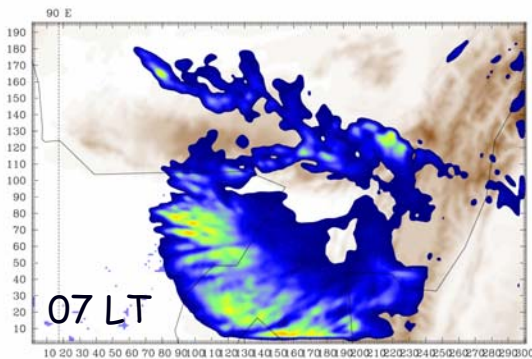
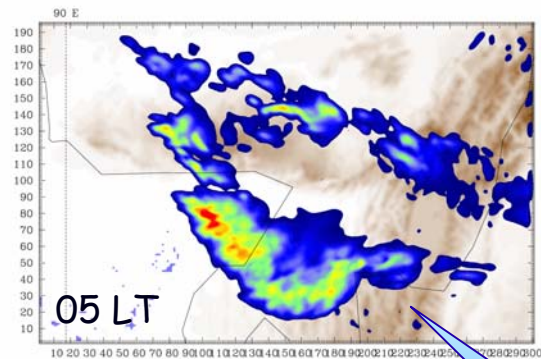
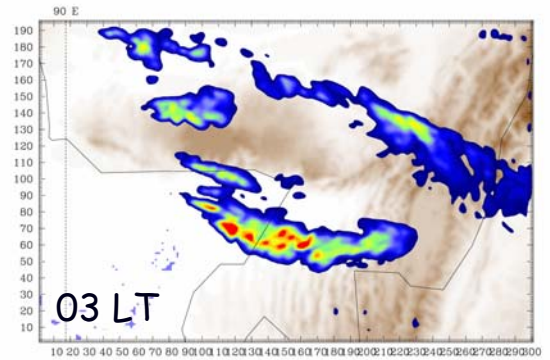
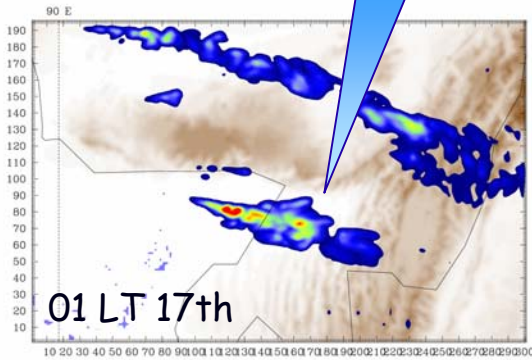
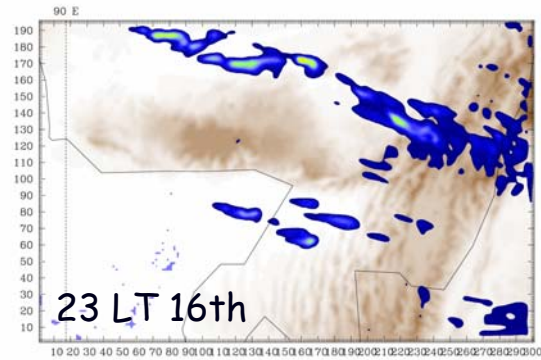


D3 is one-way nested in D2

1 hour precipitation

Domain 3

Line shape



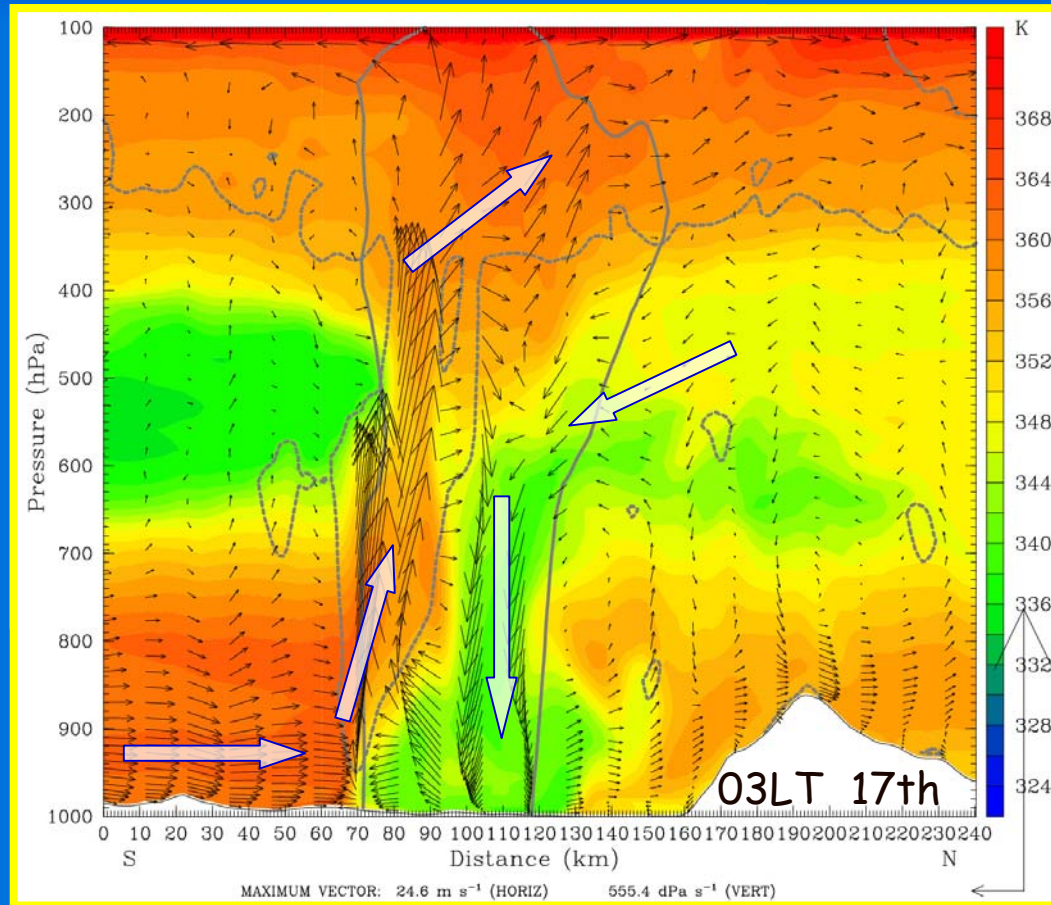
Expands southward

Q1. Why does prep. area expand southward?

100 hPa →

500 hPa →

900 hPa →

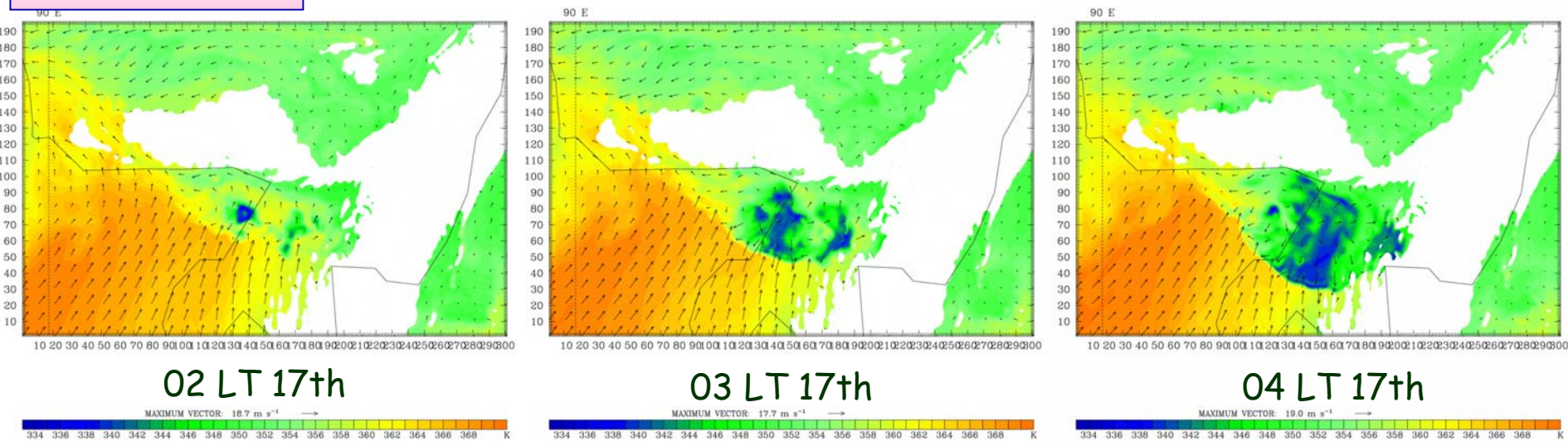


- color
equiv. pot. temp
- dashed line
cloud (0.1g/kg)
- solid line
rain (1 g/kg)
- vector
wind

555.4 dPa/s

24.6 m/s

θ_e on 950 hPa



Concave
topography



Favorable to forming strong cold pool



Southward propagation speed is
estimated as 4 ~ 18 m/s

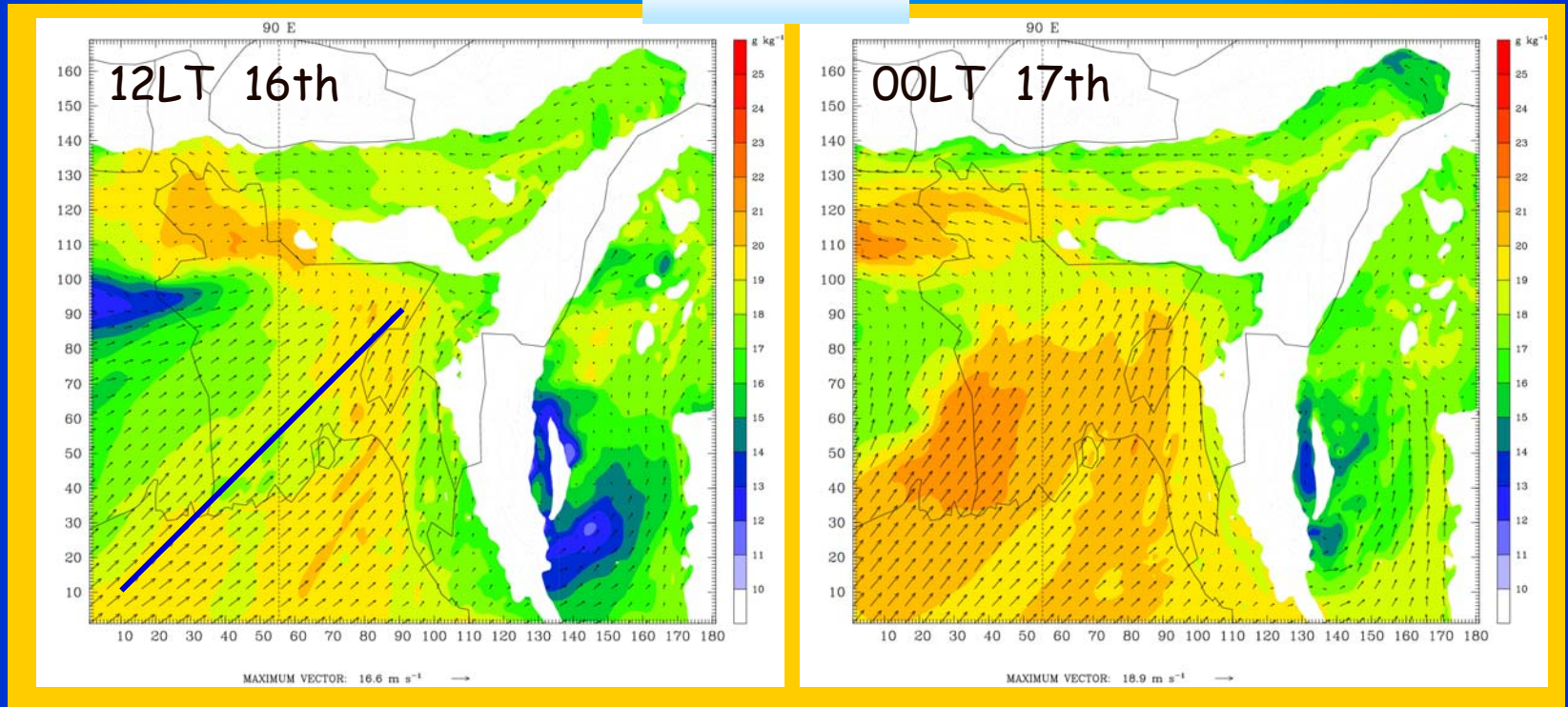
Experiments without mountains support this effect.

Q2. Why the nocturnal maximum precipitation

q_v

Domain 2

950 hPa

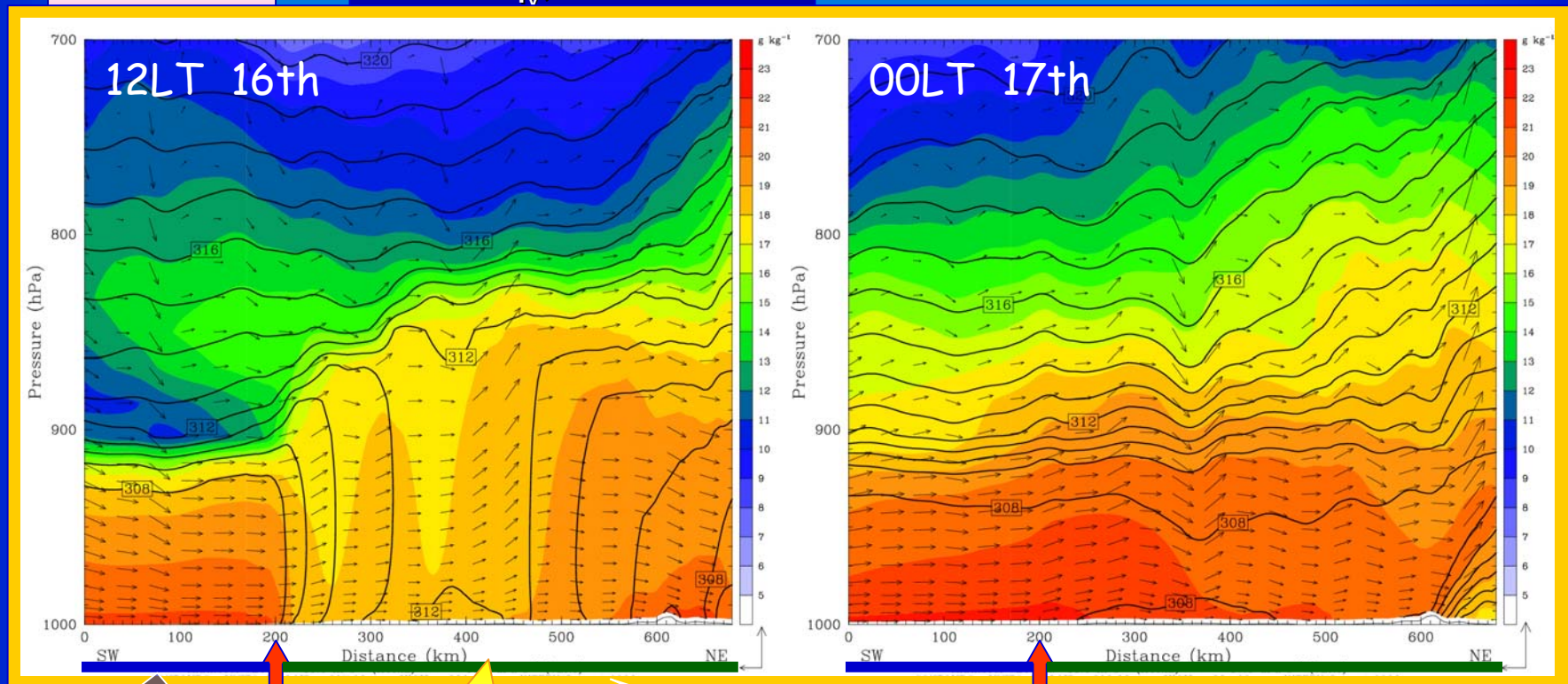


The low level atmosphere has more moisture and more unstable in the night than in daytime.

q_v

Domain 2

color : q_v , contour :



Bay of Bengal

coast

land

coast

Deep mixed layer over land which dilutes the moisture.

No mixing, easy to penetrate to inland

Summary

Q1. Southward expansion problem



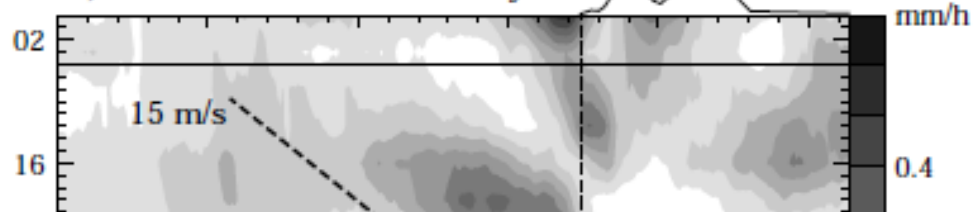
- It is the southward propagation of squall line
- Strong cold pool is formed in the concave topography.

Q2. Nocturnal precipitation maximum problem



- Water vapor flux in low-level from the Bay of Bengal is larger in the nighttime than in the daytime. Thus, the atmosphere is more unstable in the nighttime than in the daytime.
- No evidence of convergence between mountain wind (katabatic down-slope wind) and SW monsoon

a) 3N-7N GPI mean diurnal cycle

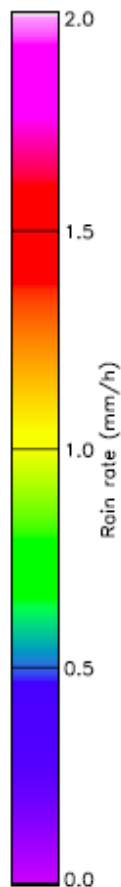
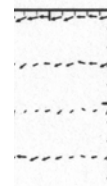
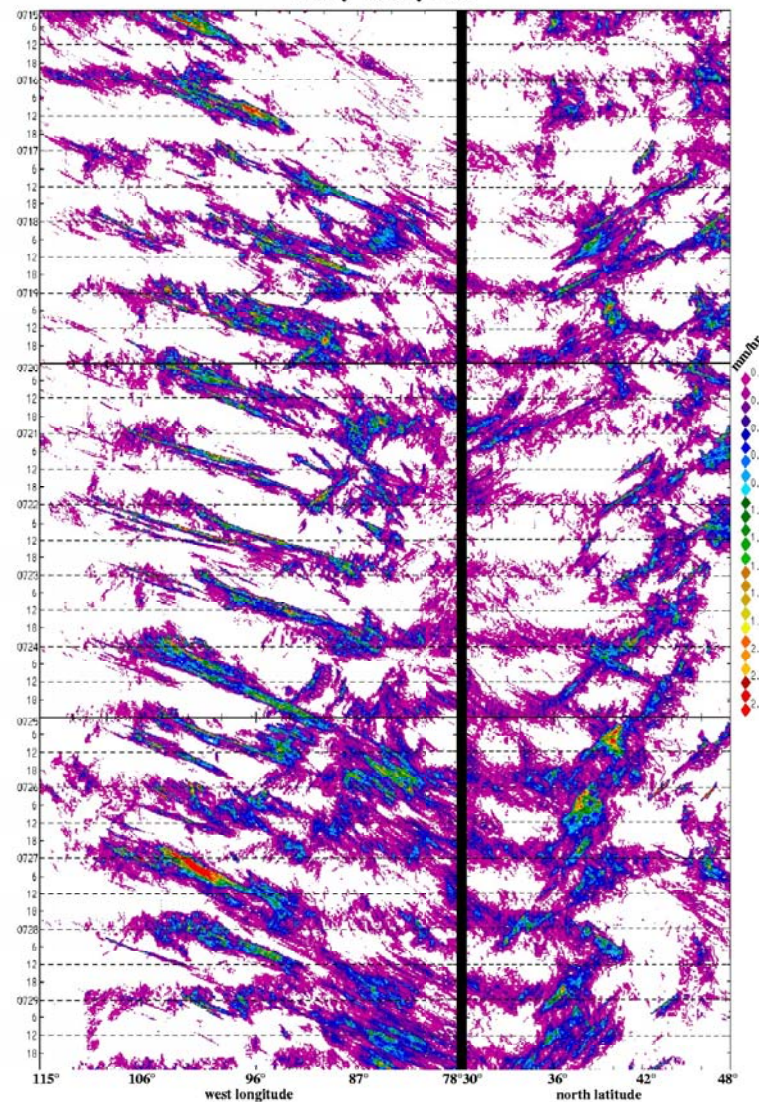
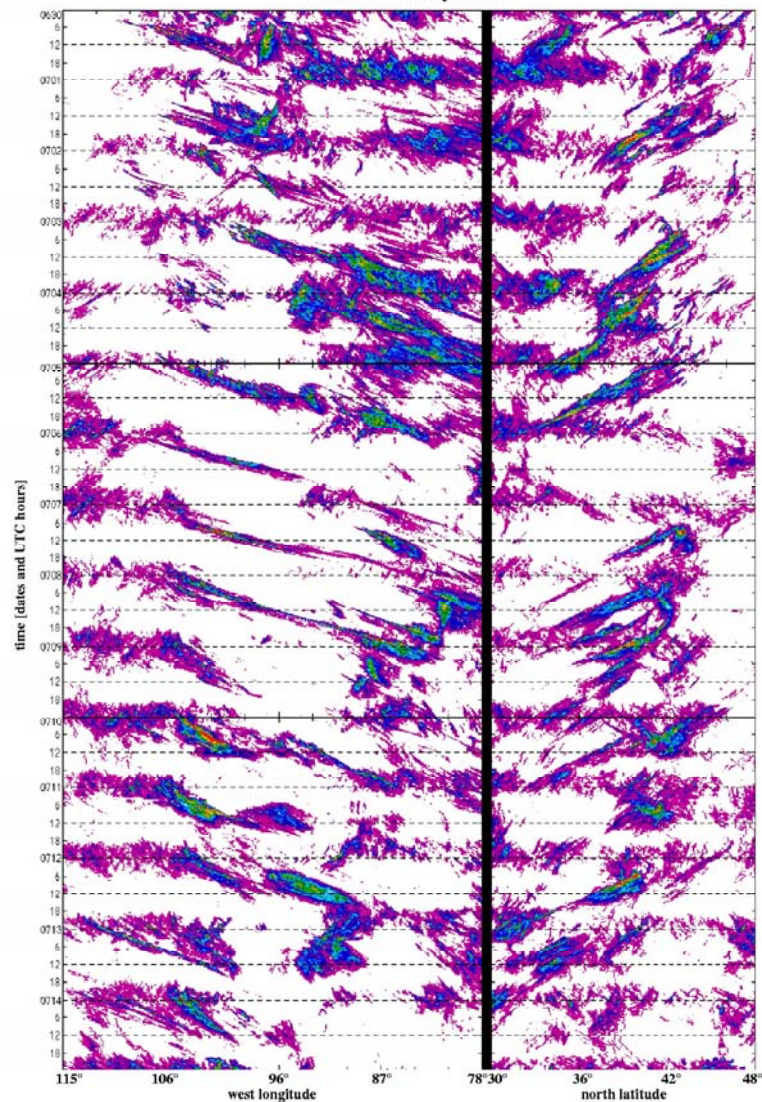


the world

Local hour

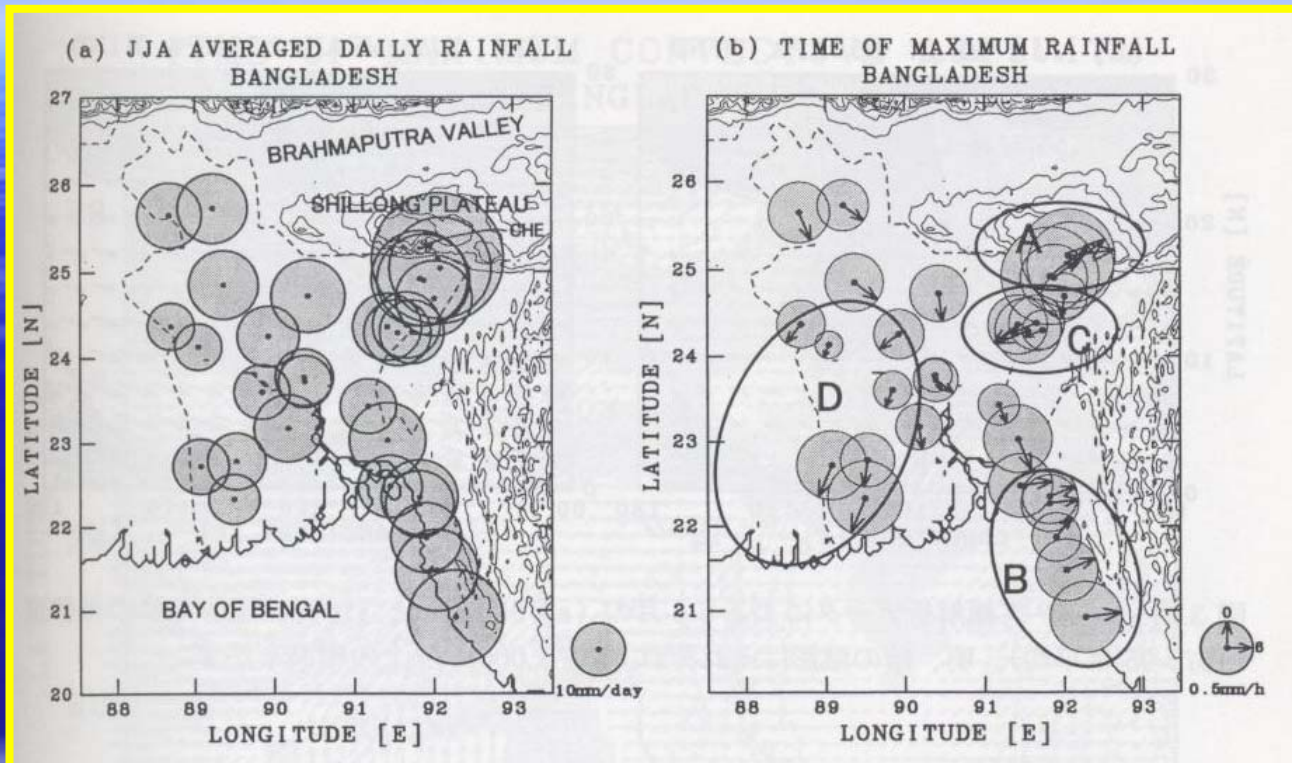
30 June - 14 July 2001

15 July - 29 July 2001





過去の研究



(左図) Bangladeshの31観測点における1995年6～8月の平均日降水量 (mm)。

(右図) 降水量が極大となる時間 (矢印)

日平均時間降水量からの偏差 (円の大きさ)。

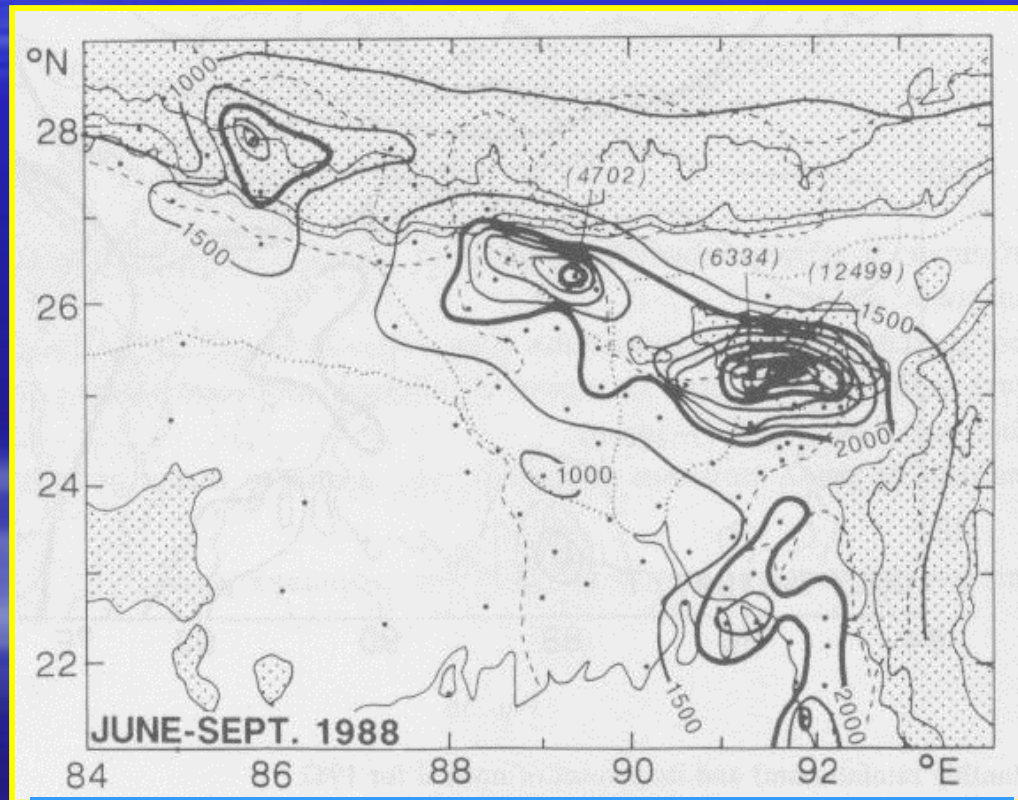
(Ohsawa et al., 2001)

過去の研究

monsoon期には年間降水量の75～80%が集中する。

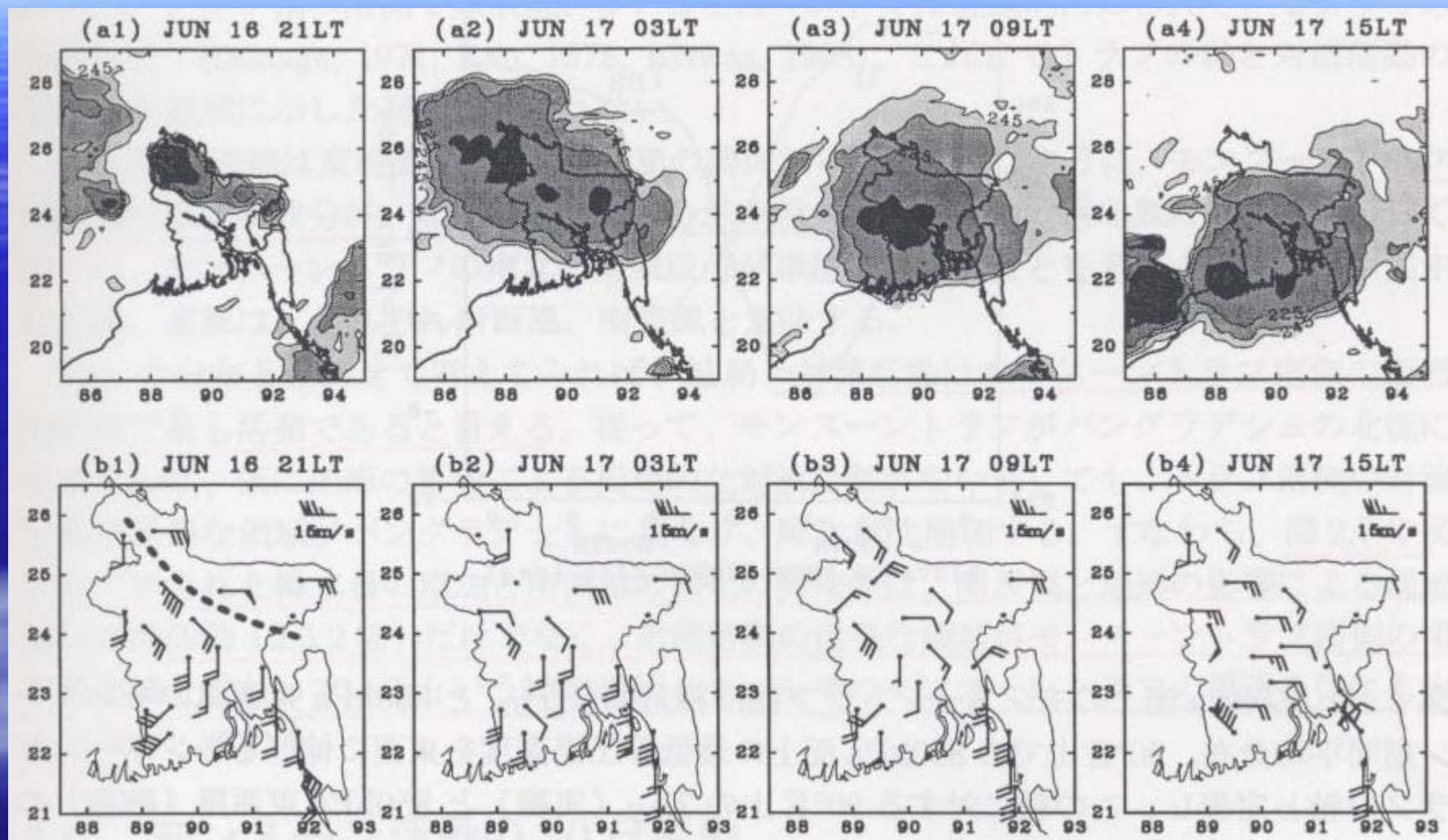
(Ahmed and Karmakar, 1993)

災害・・・サイクロン・洪水



1988年6月～9月の総降水量(mm)
(matsumoto et al., 1996)

過去の研究 ~ 事例解析1995年6月16日-17日 (Ohsawa et al., 2000) ~



用いるモデル

MM5 (Fifth-Generation Mesoscale Model)

- ・ 米国大気研究所 (NCAR) とペンシルバニア州立大学が共同開発
- ・ 非静力学・完全圧縮性モデル
- ・ two-way nesting 可能
- ・ 4次元データ同化 可能
- ・ 鉛直座標系 p - 座標
- ・ 空間格子配置



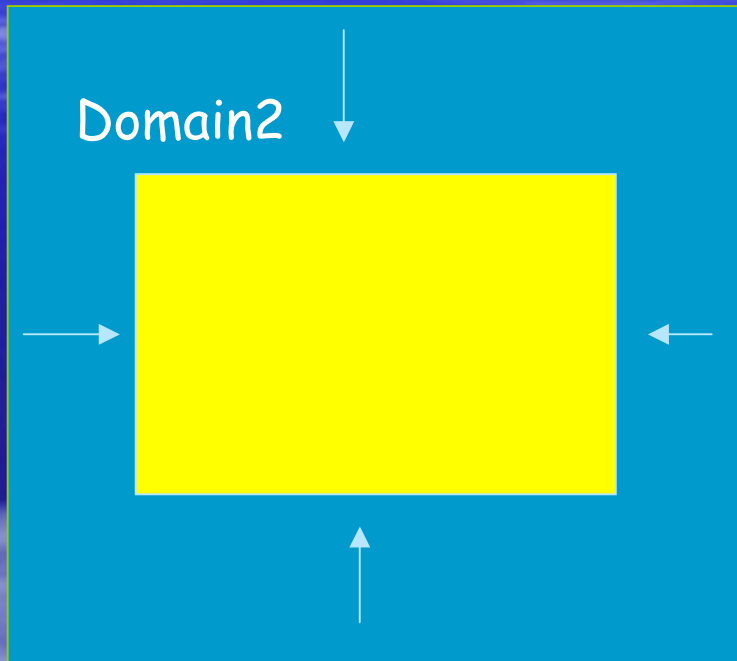
水平



鉛直

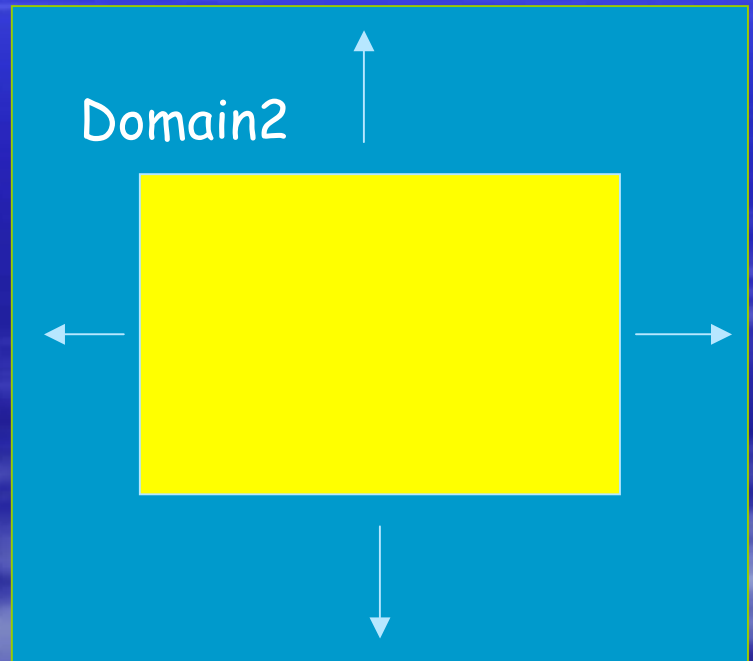
Two-way nesting

Domain1



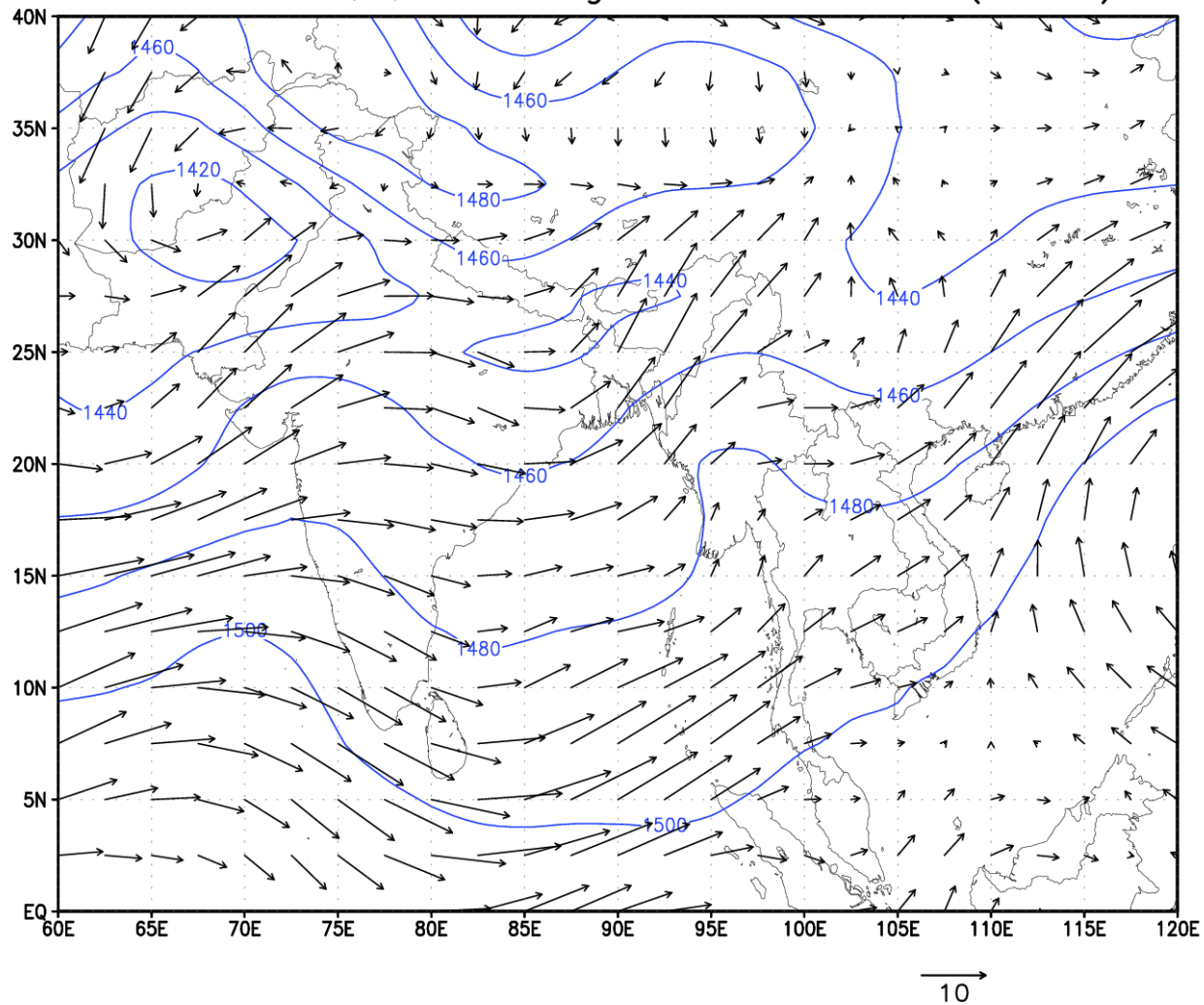
境界条件のみ与えられる

Domain1



子領域の結果が戻される

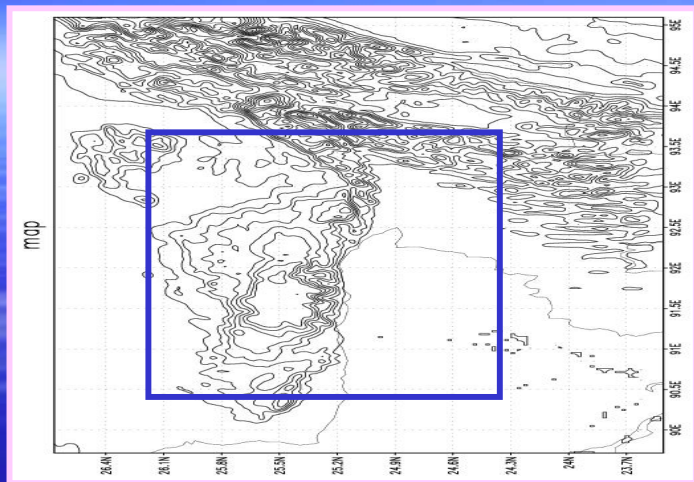
850hPa GH,U,V average June 16–20th (active)



計算条件

	DOMAIN1	DOMAIN2	DOMAIN3
* 計算時間	1995, Jun 14 18LT ~ 21 18LT	1995, Jun 15 6LT ~ 21 18LT	1995, Jun 15 6LT ~ 21 03LT
grid間隔 grid数	18km 120 × 105	6km 181 × 169	2km 301 × 196
タイムステップ	18秒	6秒	2秒
鉛直座標	42層	42層	42層
nesting	Mother domain	D1と2way-nesting	D2と1way-nesting
雲の微物理過程	Goddard Microphysics	Goddard Microphysics	Goddard Microphysics
積雲パラメタリゼー ション	Kain-Fritsch	Kain-Fritsch	None
境界層スキーム	MRF	MRF	MRF
放射過程	Cloud-radiation scheme	Cloud-radiation scheme	Cloud-radiation scheme
Land surface model	Noah LSM	Noah LSM	Noah LSM

結果の信頼性



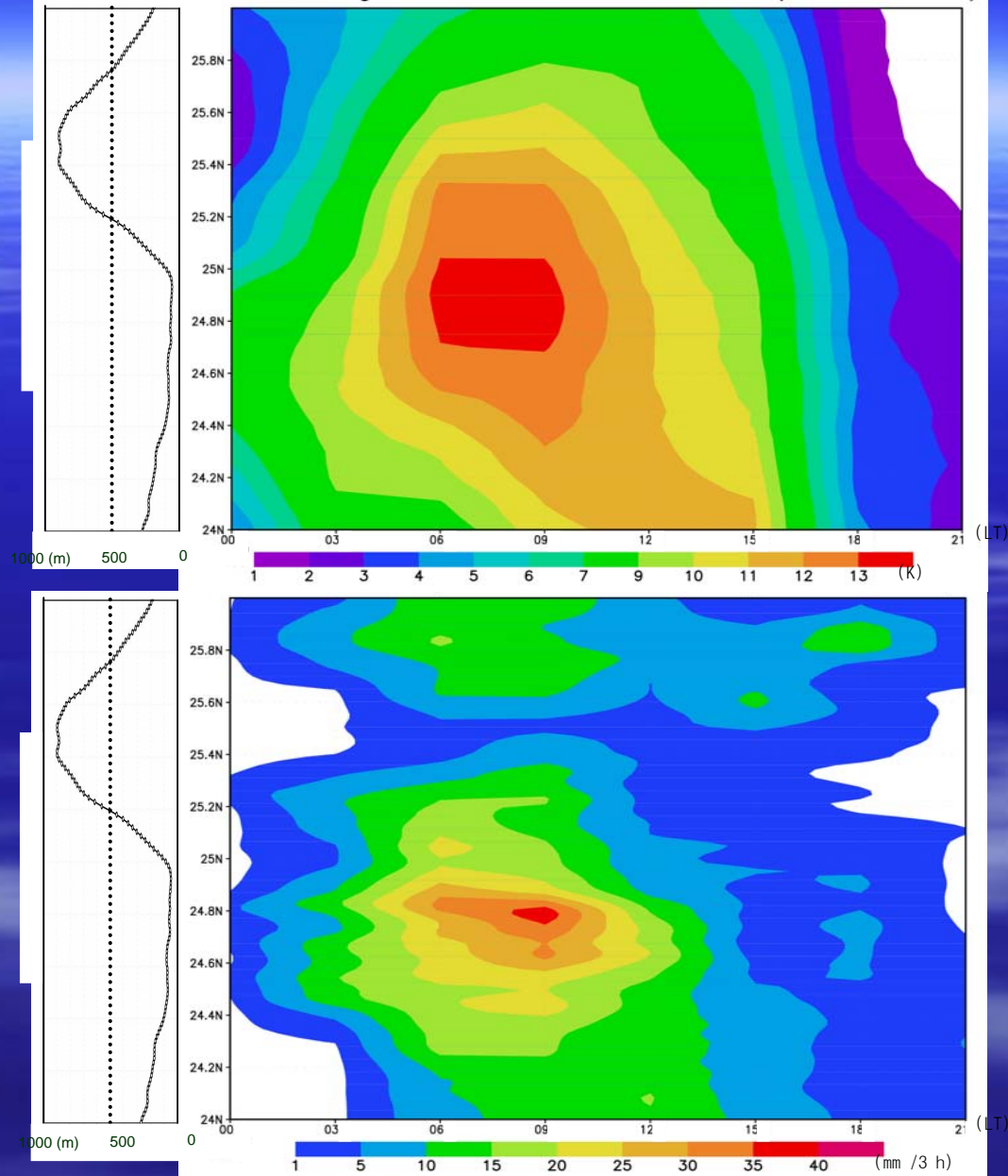
対流活動Index

$$I_c = \begin{cases} 230 - T_{bb} & (T_{bb} \leq 230K) \\ 0 & (T_{bb} > 230K) \end{cases}$$

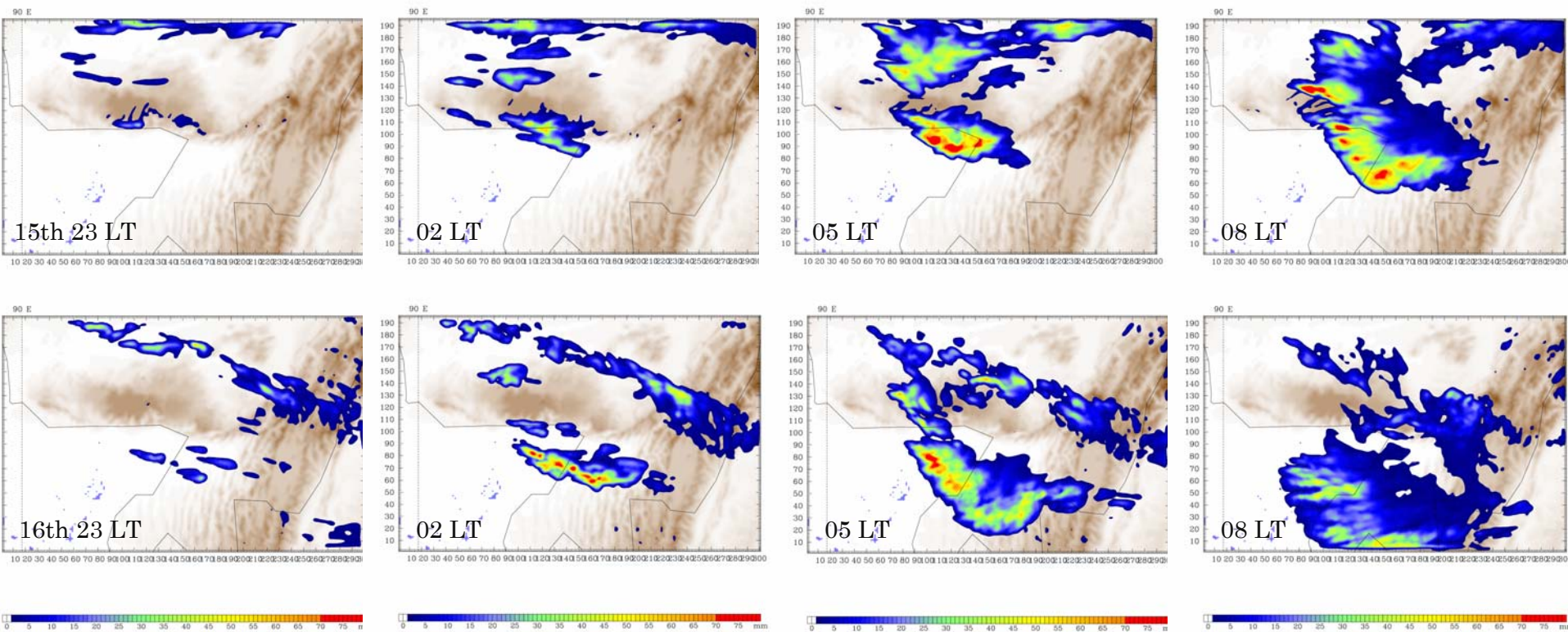
T_{bb} はGMS5 (IR1)より・・・

1時間ごとの I_c を、3時間平均し、
(17日03LTの I_c は、17日01, 02,
03LTの値の平均) 3時間ごとの期間
平均 (1995 Jun 16 ~ 21) を計算した。
それを経度 $90.5^\circ \sim 93.5^\circ$ で平均した。

lc 3h-average time-latitude cross section (June 16-18th)

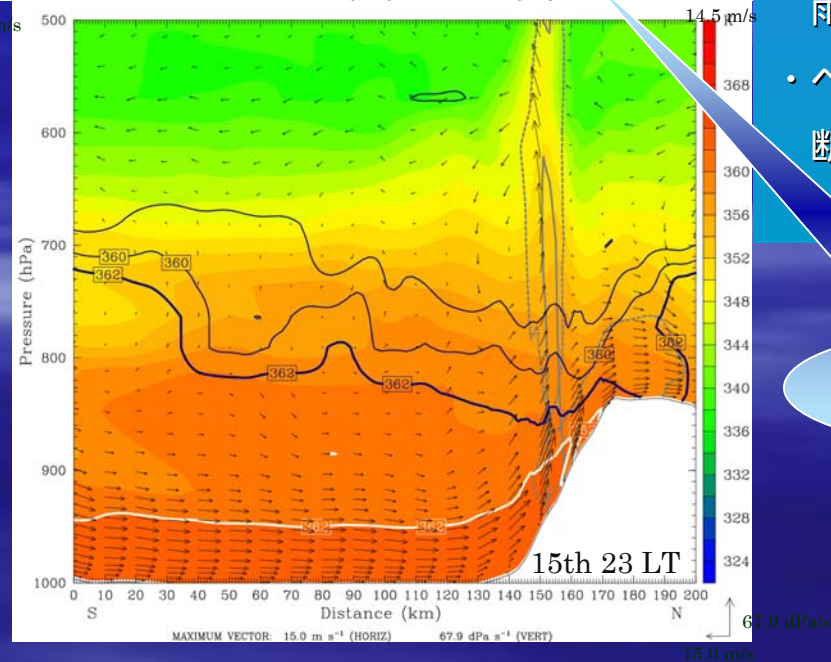
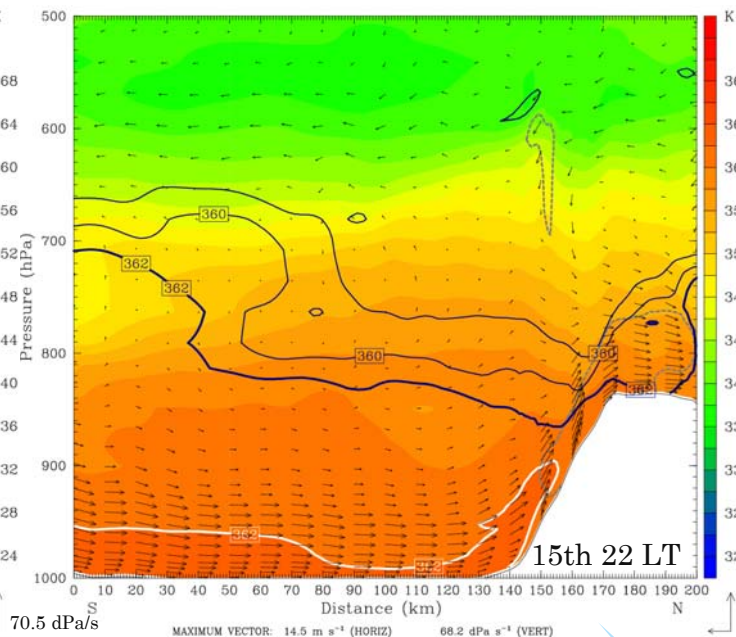
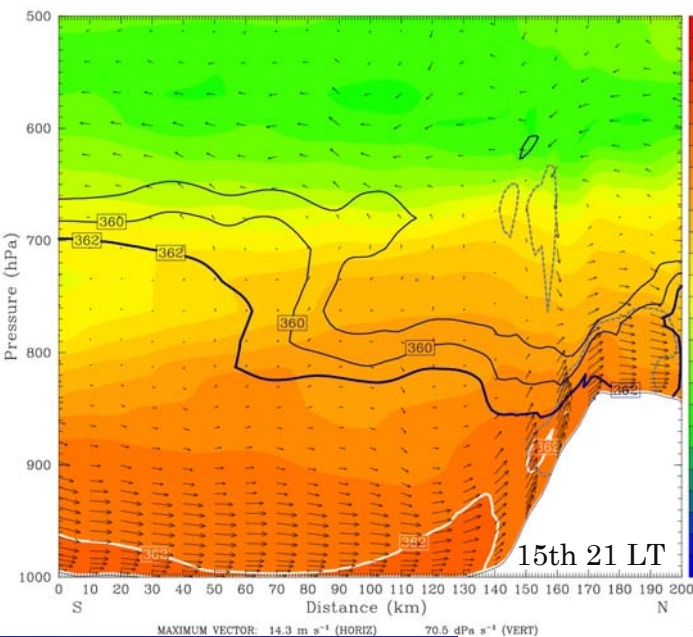


結果 ~ 1時間降水量 ~



シロン高地南麓、もしくは南麓から数十キロ離れた位置で降水が開始。夜中にかけて線状に発達し、早朝南下する。

結果 ～ 降水開始のトリガー～

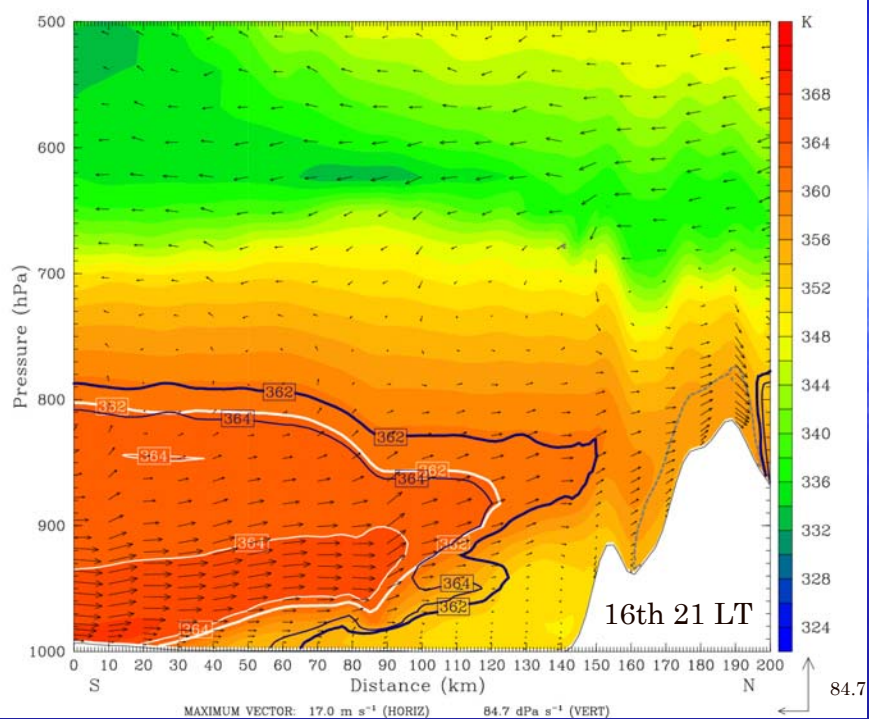


- ・ カラー
相当温位
- ・ 白線
相当温位362 K
- ・ 濃紺線 (太線)
飽和相当温位362 K
- ・ 破線
雲水混合比 (0.1 g/kg)
- ・ 実線
雨水混合比 (1 g/kg)
- ・ ベクトル
断面に平行な風

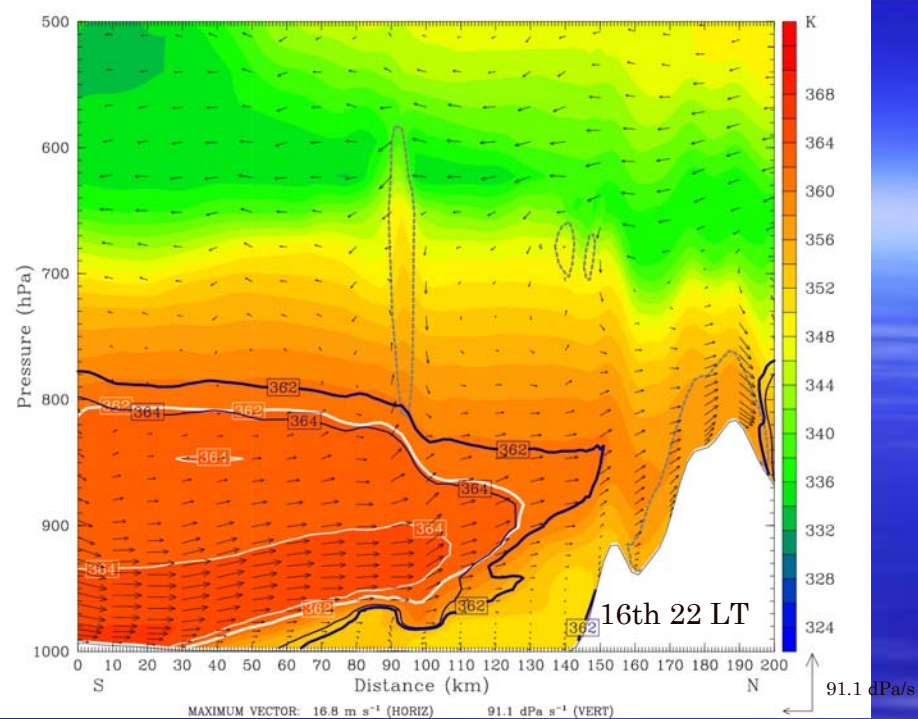
・ 相当温位の高い領域がシロン高地の斜面にそって上昇し、同じ値の飽和相当温位(LFC)の高度に近づいている様子が分かる。

・ 山の斜面を吹き降ろすような風向の風は見られない。

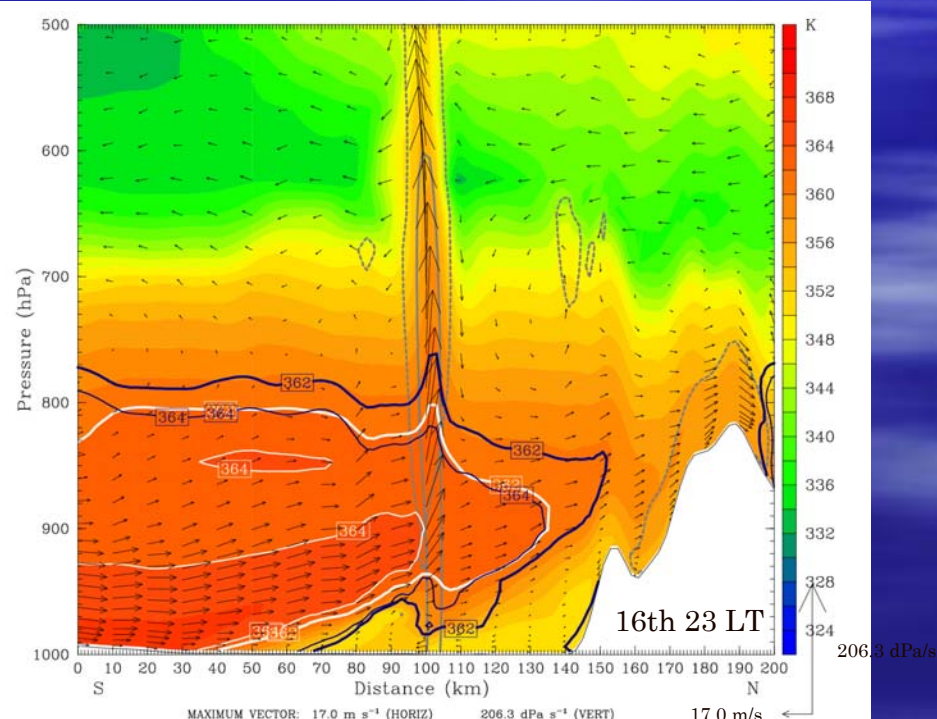
降水開始



17.0 m/s



91.1 dPa/s

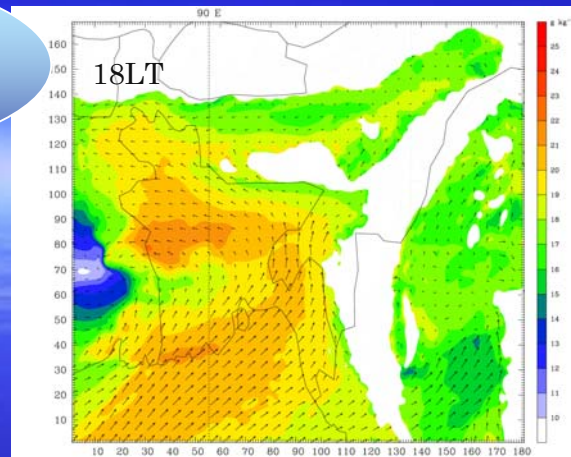


206.3 dPa/s

水蒸気の輸送

950 hPa面での
混合比の日変化

混合比の大きい領域が、正午過ぎから次第に、ベンガル湾や、インドの方からバングラデシュ国内へと輸送され、夜にバングラデシュ北部に到達している。



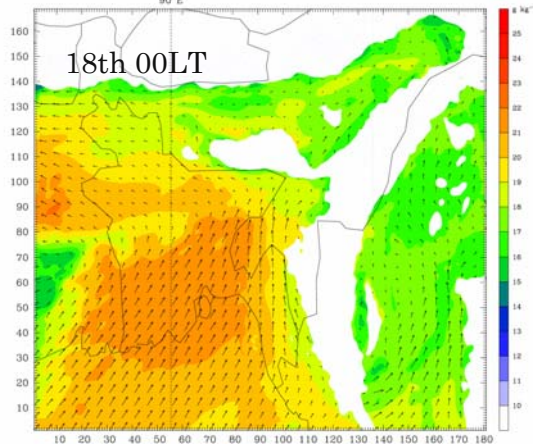
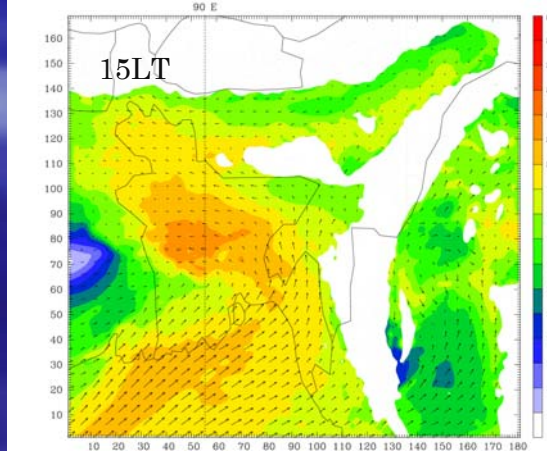
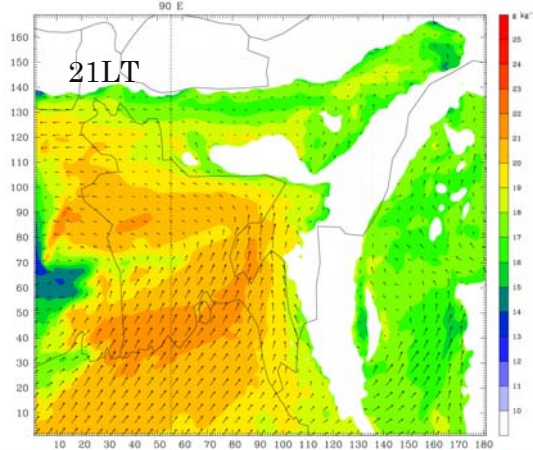
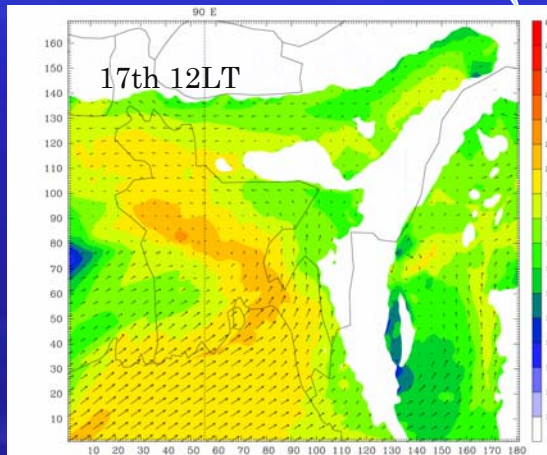
風速の日変化

渦運動量輸送の指標となる摩擦速度と、下層の風速の日変化には、負の相関が見られた。

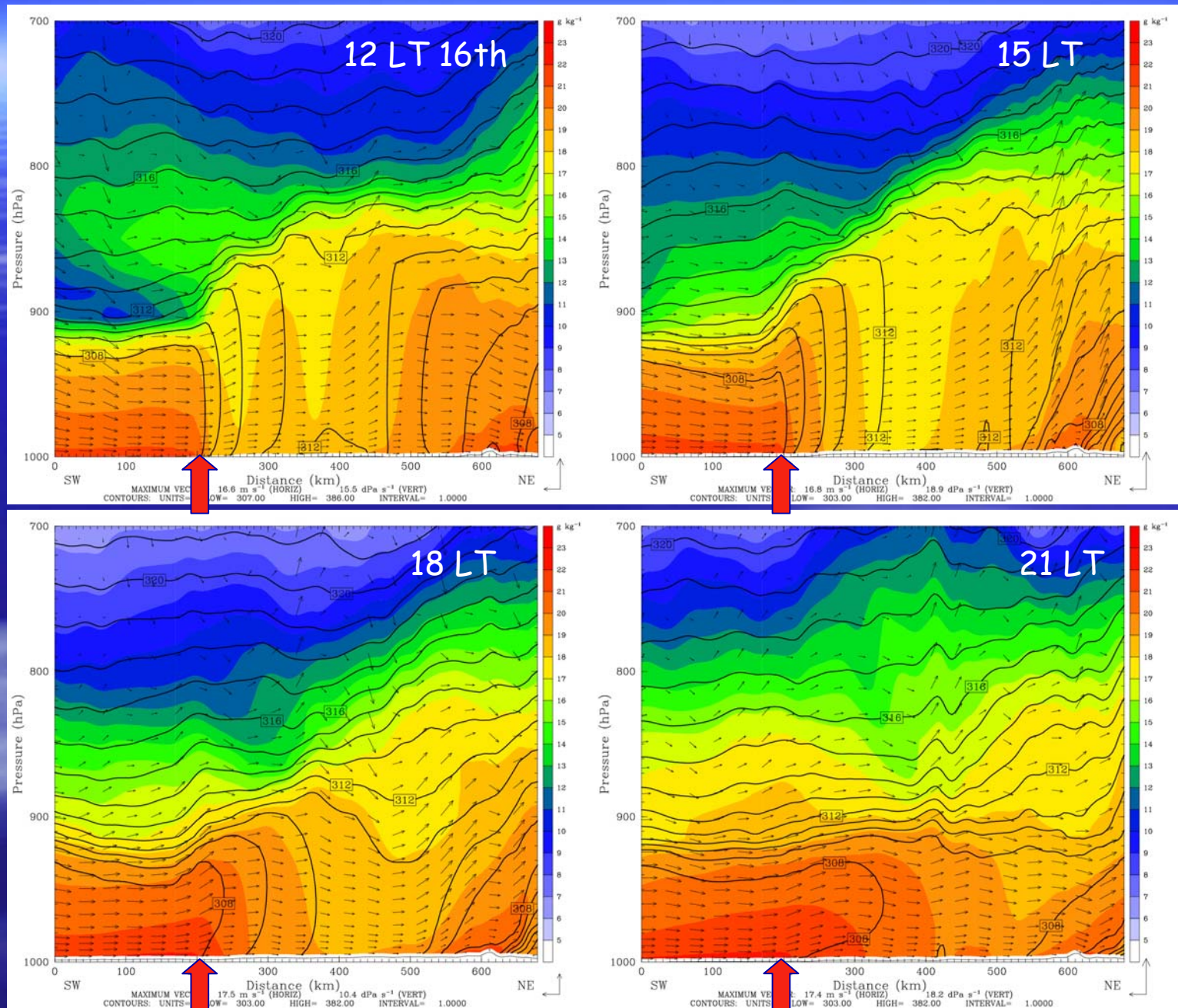


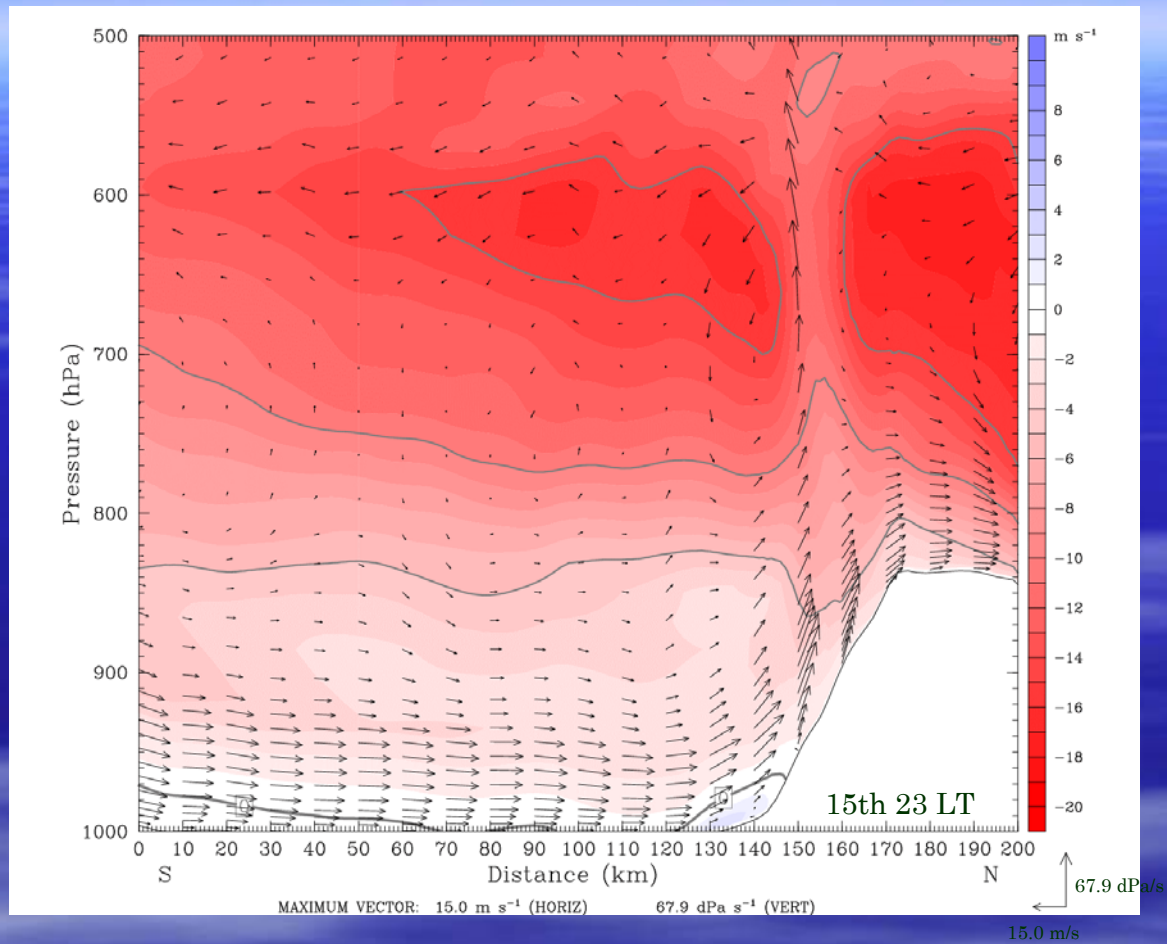
夜間ジェットの特徴に一致する。

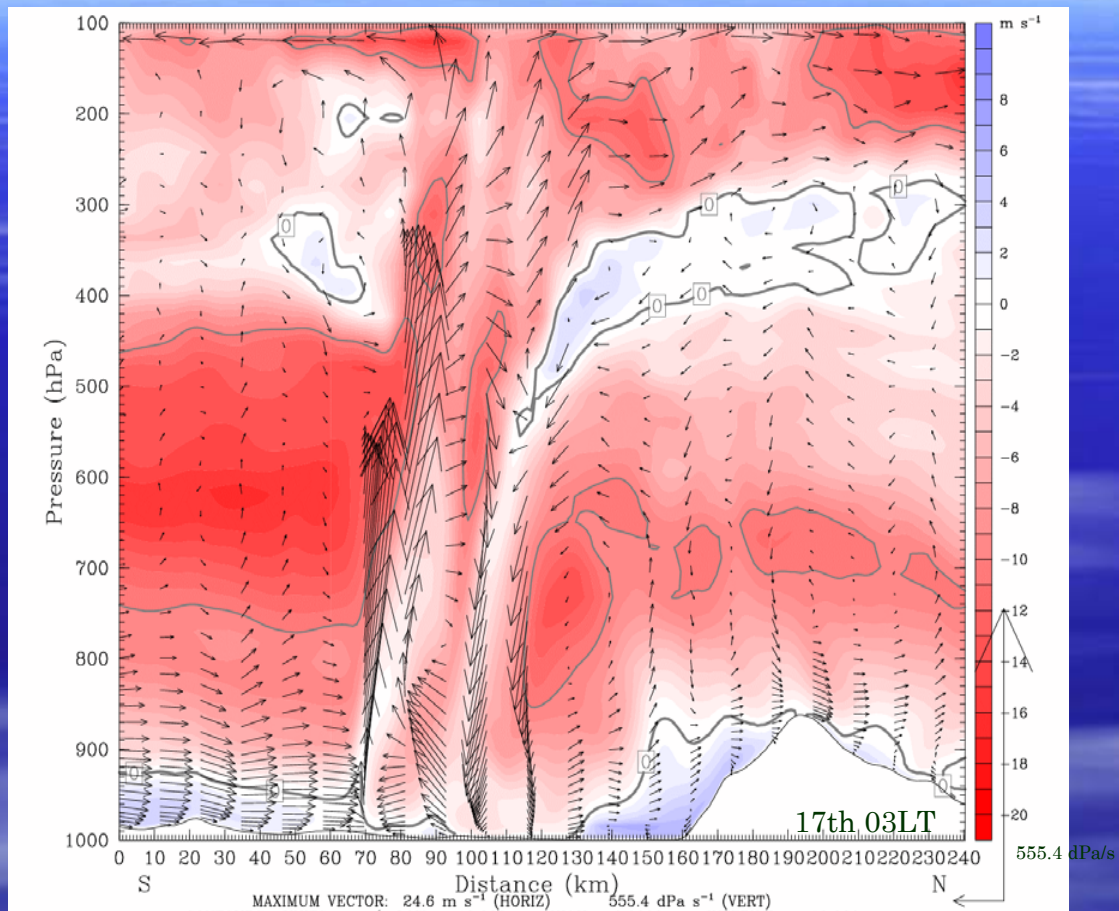
摩擦速度：
$$u_*^2 = \left| \overline{(u'w')}_s \right|$$

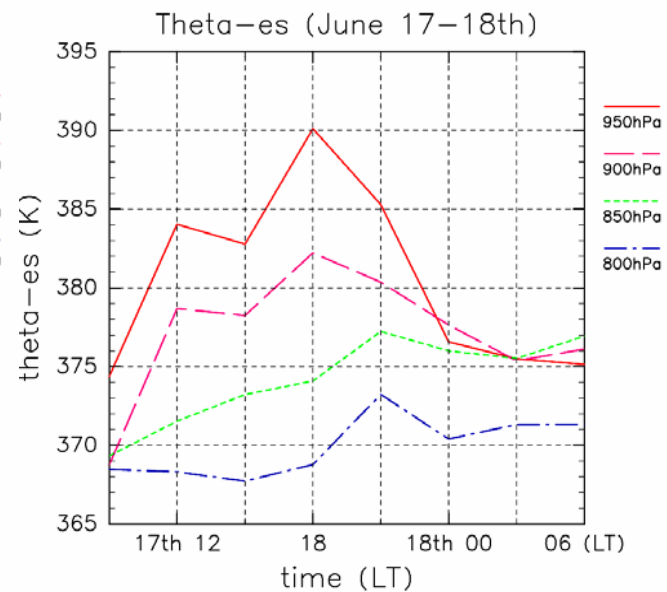
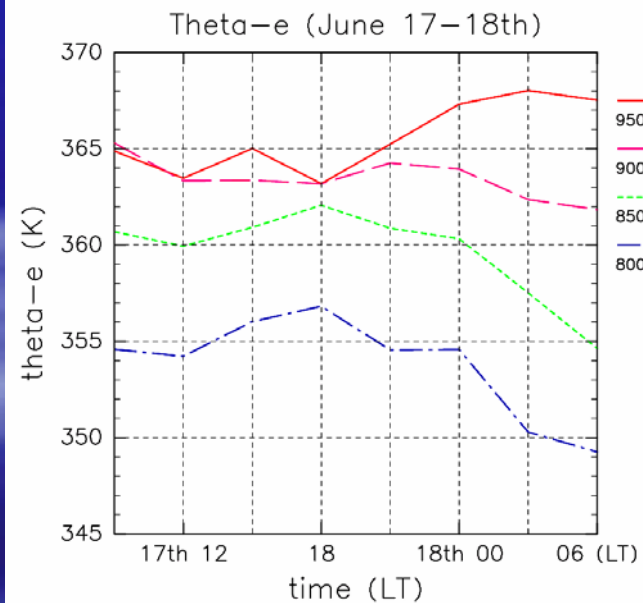
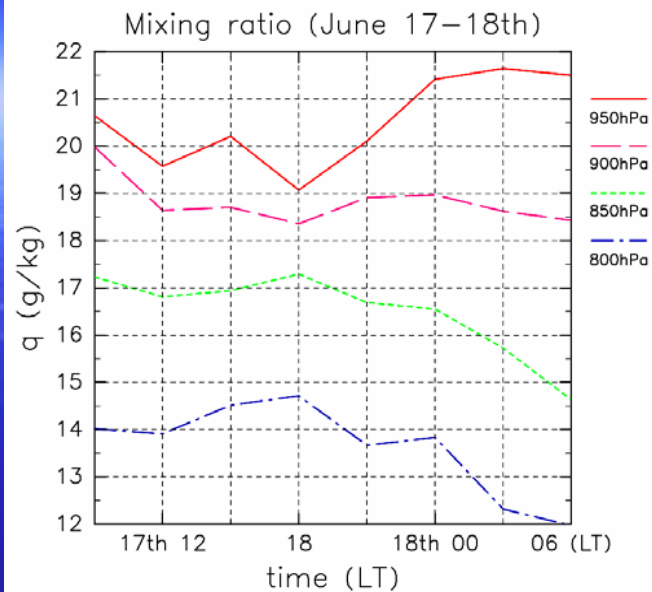
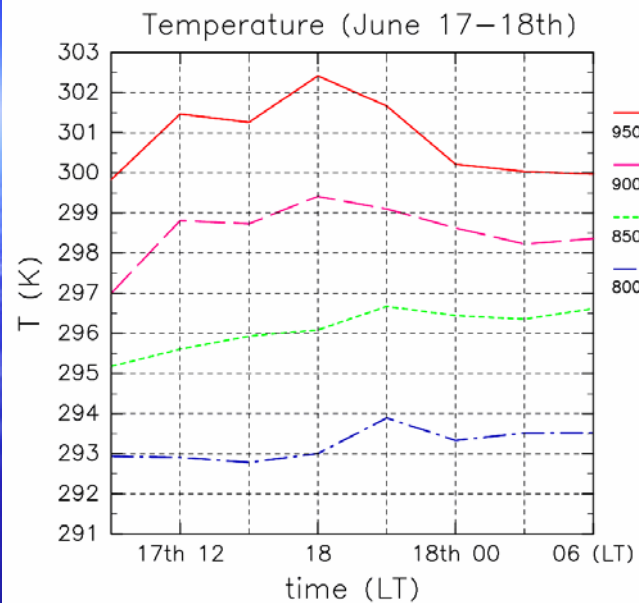


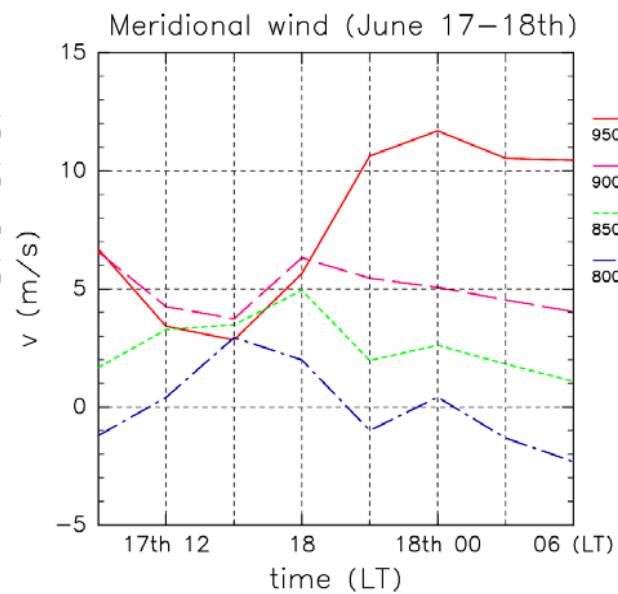
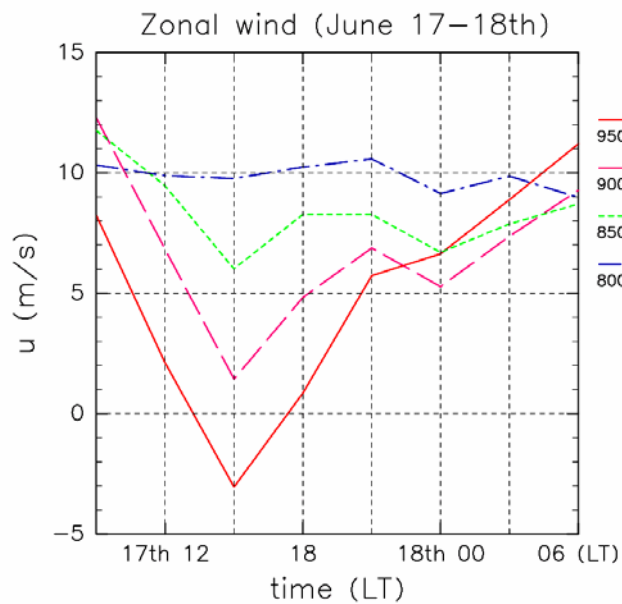
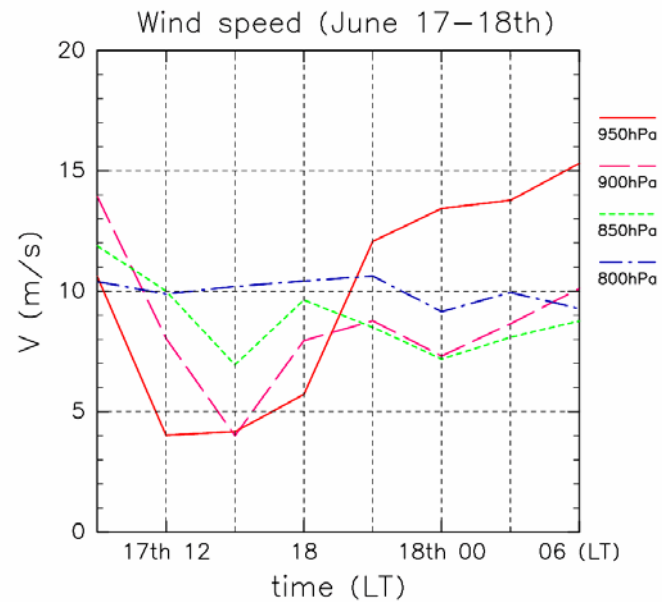
水蒸気の混合比

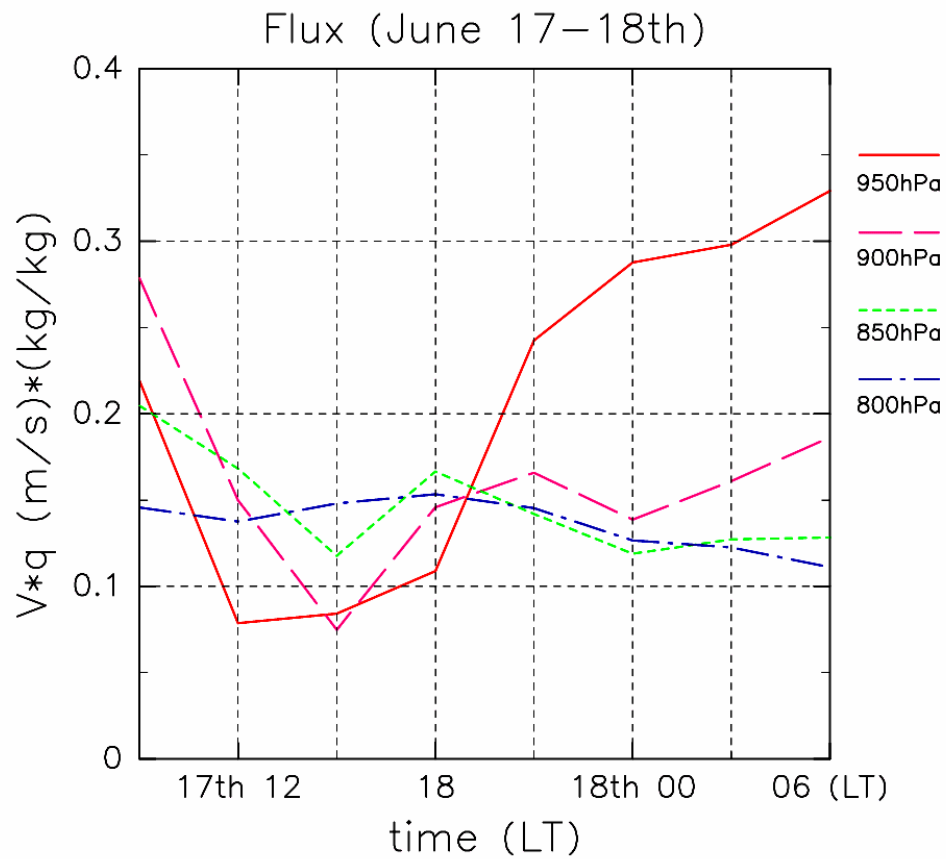




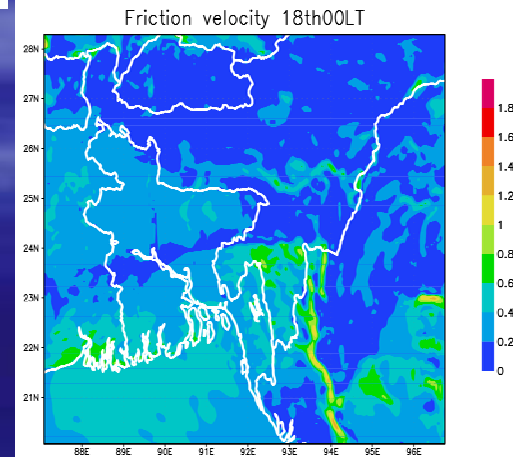
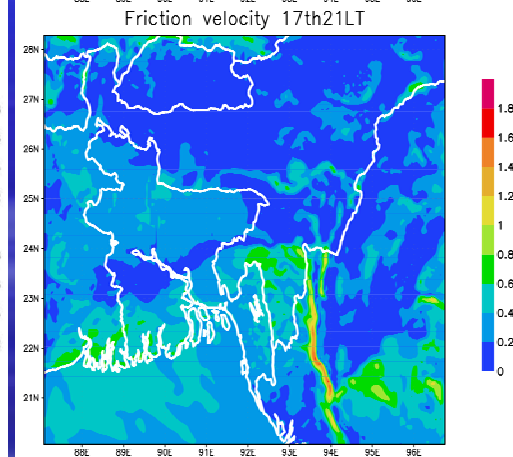
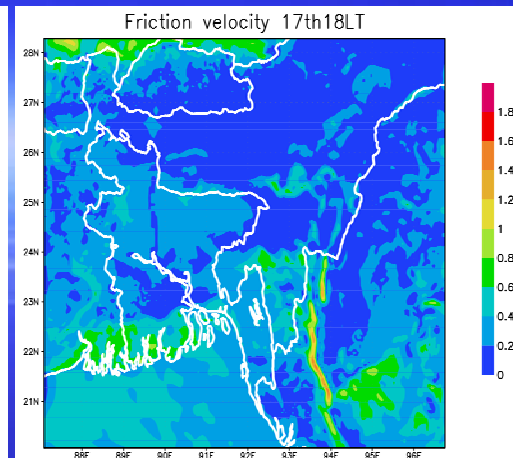
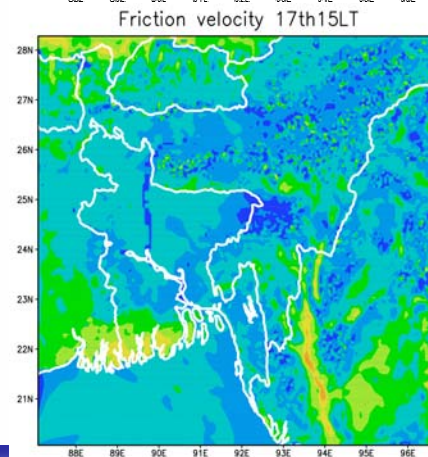
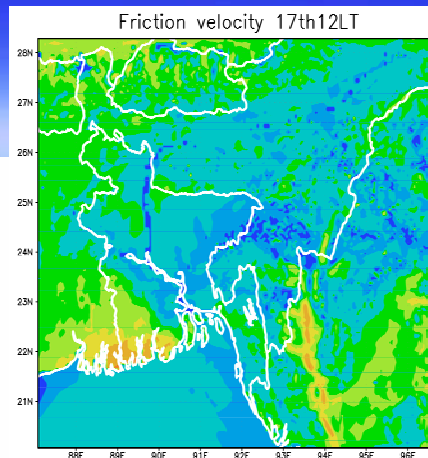
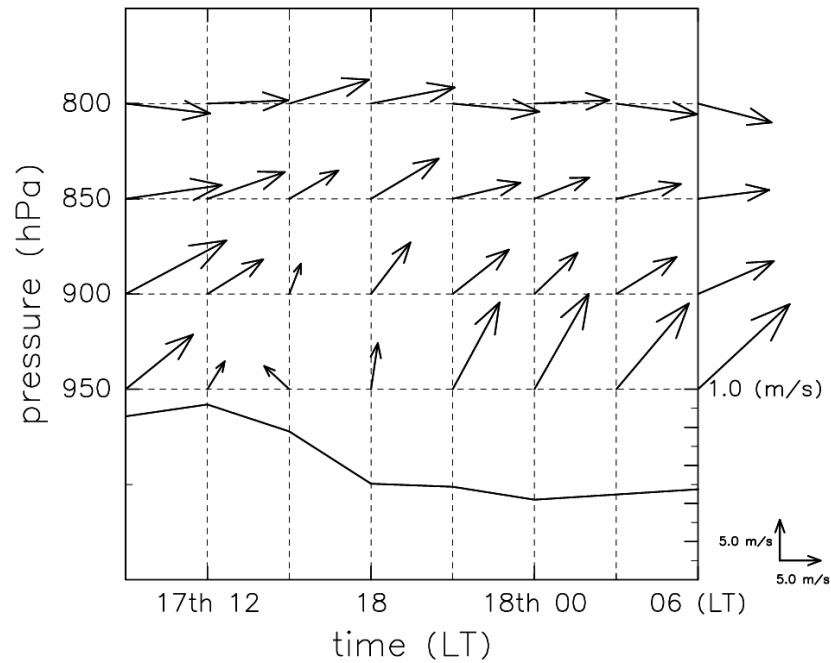


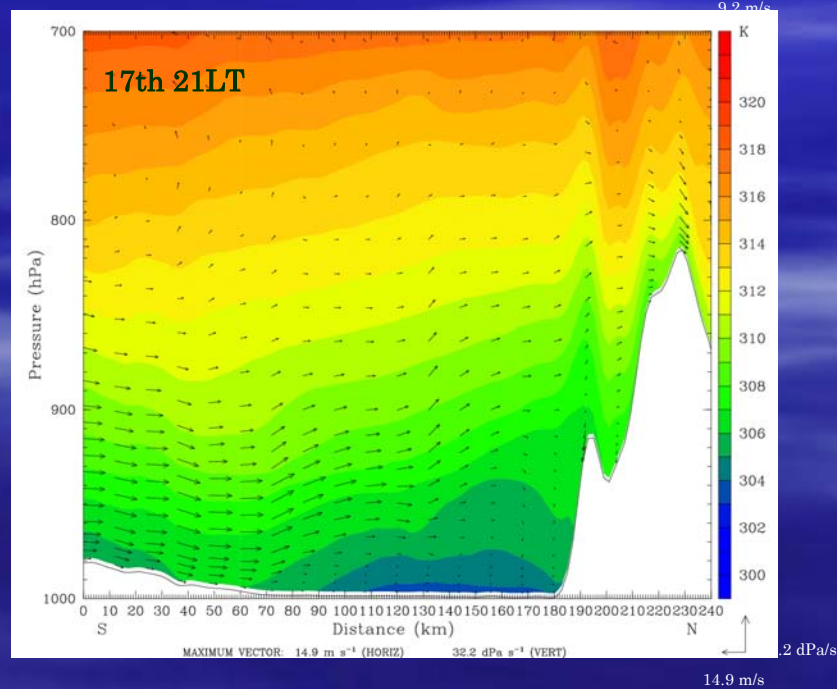
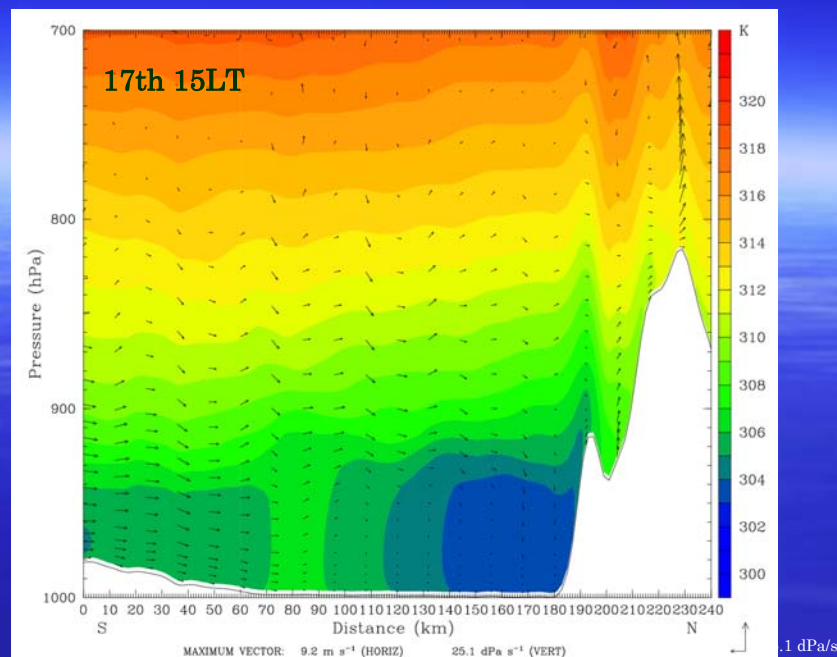
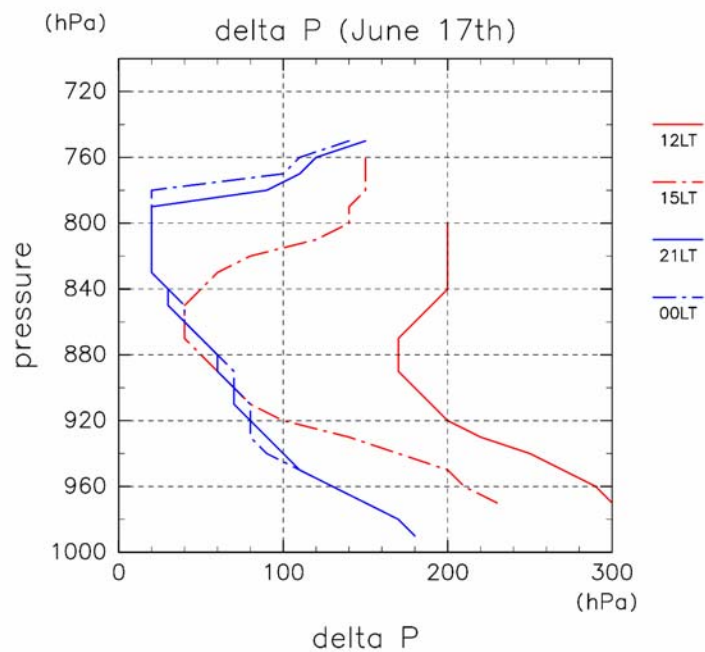


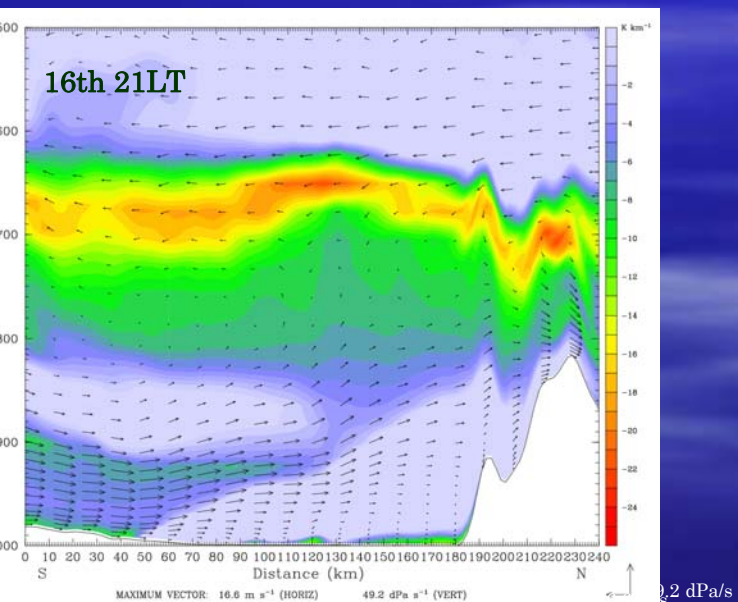
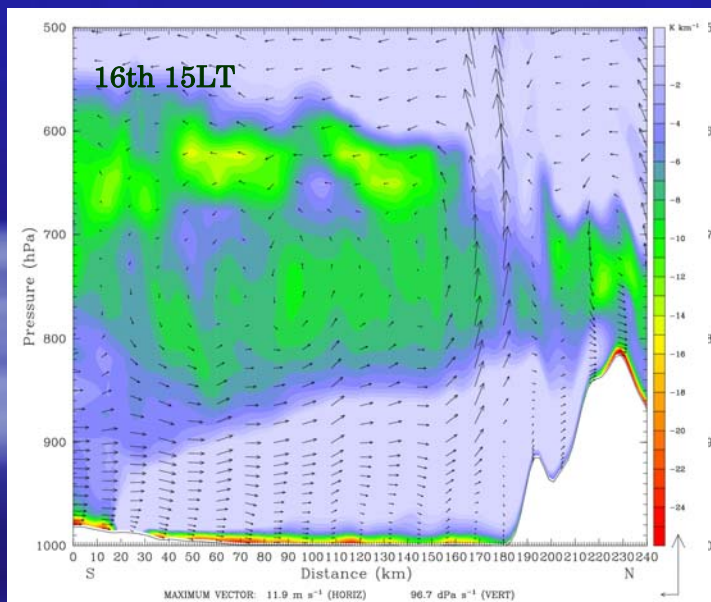
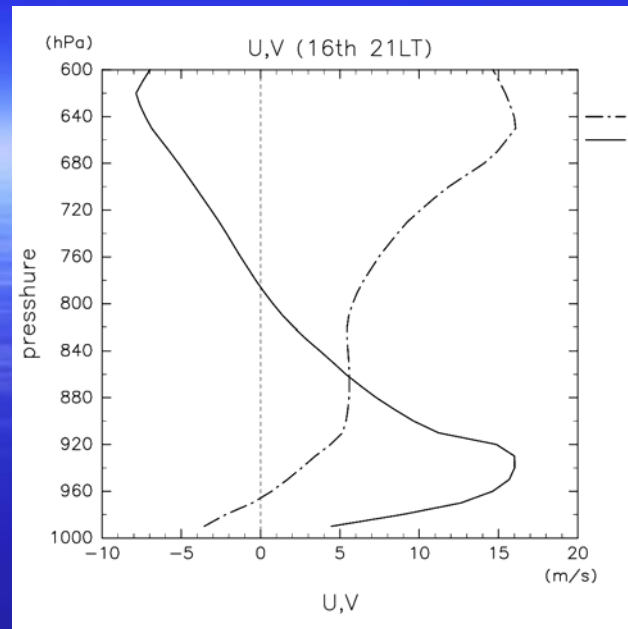
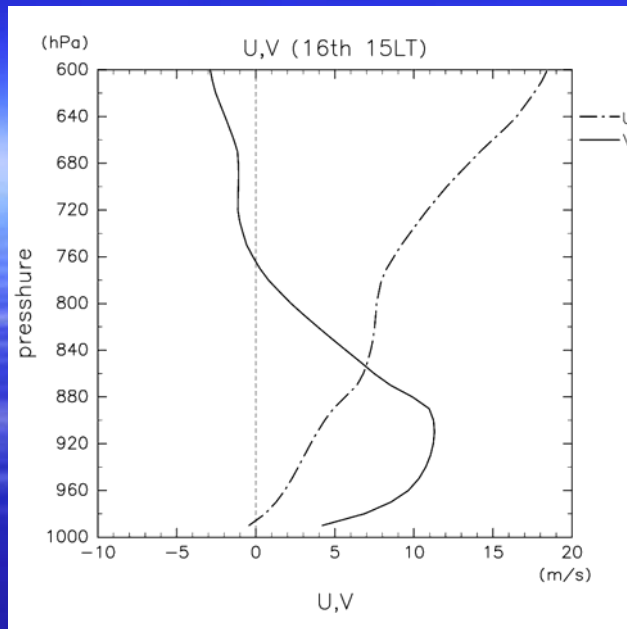




Wind and friction velocity (June 17–18th)







11.9 m/s

16.6 m/s

