7 June 2024: STIPMEX
@IITM, Pune, Maharashtra, India

SOHMON

AsiaPEX

GEWEX

Asian summer monsoon circulation and precipitation in view of high moist static energy airmass

Toru Terao (Kagawa Univ.)

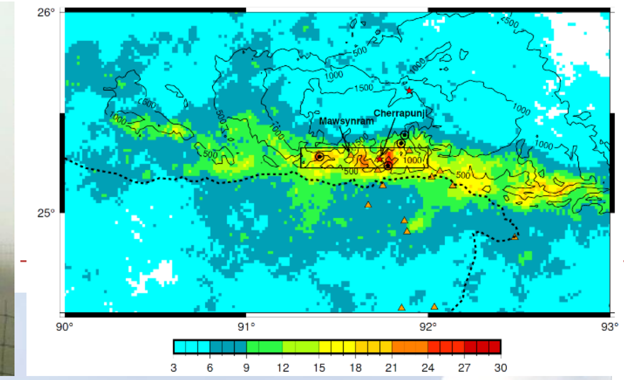
Self introduction

SOHMON

Self introduction

SOHMON Project

New Disdrometers in Bangladesh
(already installed over the Meghalaya Plateau)

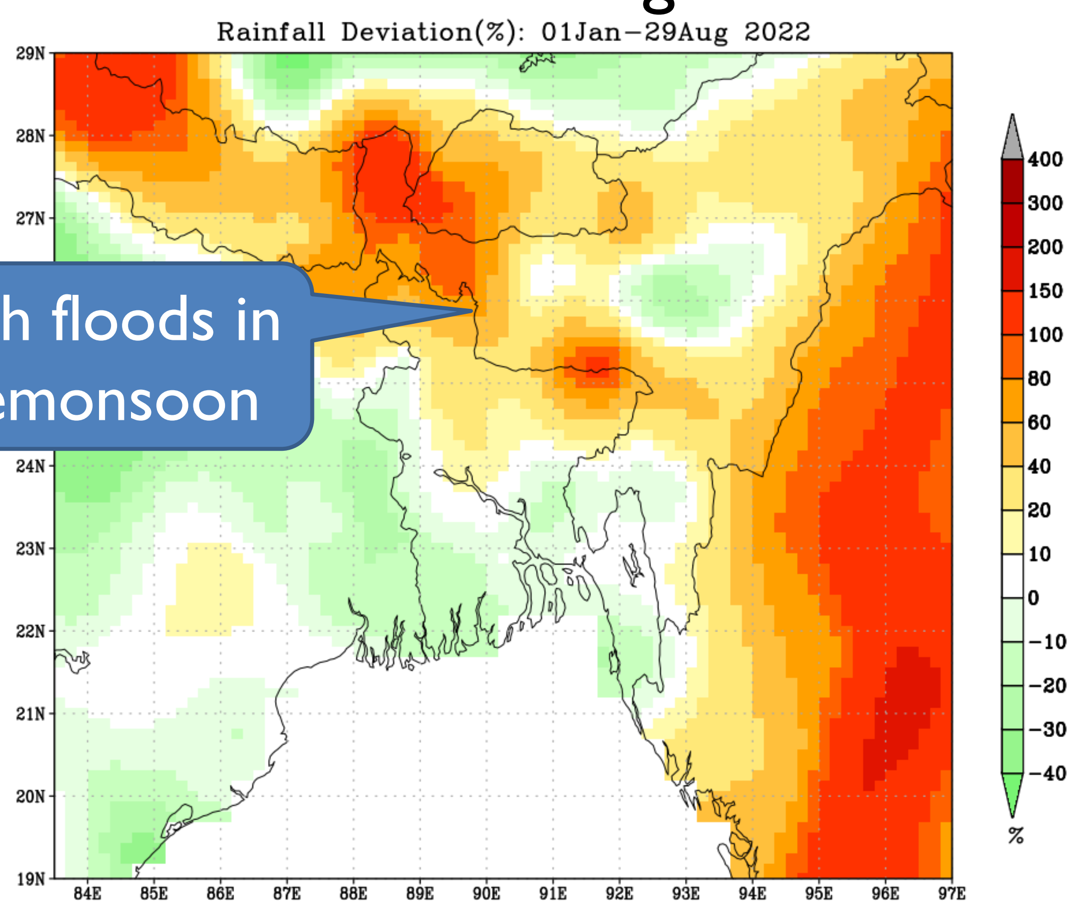


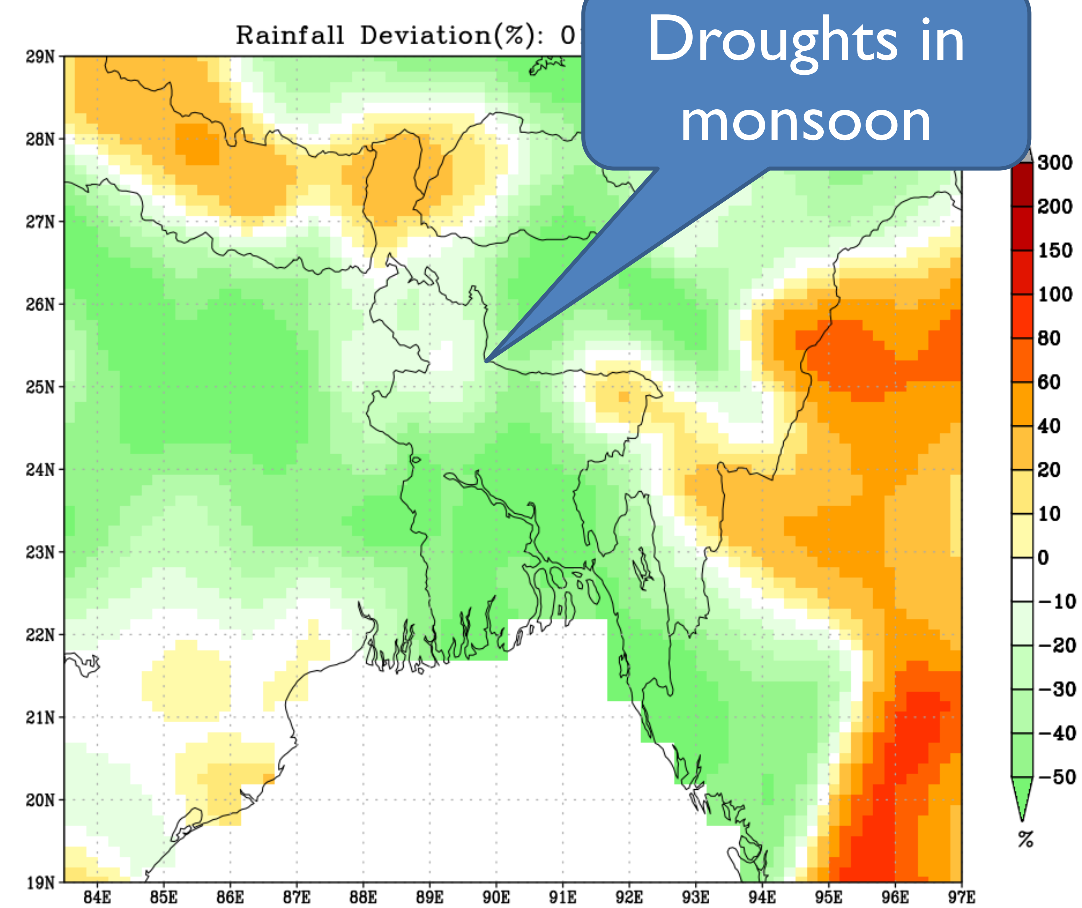
Sylhet

Murata et al. (2020)

2022 Premonsoon, Monsoon
NE India+Bangladesh Flood & Drought

- In the first three weeks of June, Assam recorded 528.5 mm of rainfall in excess of 109 per cent. Meghalaya recorded 1215.5mm an excess of 185 per cent.
- Flooding has been reported in 33 of the 35 district, Close to half a million people have been affected while almost 300,000 people have been relocated according to the Assam





By courtecy of Dr. A. Mannan, BMD and Dr. R. Mahanta, Cotton Univ.

Change in seasonality of rainfall?

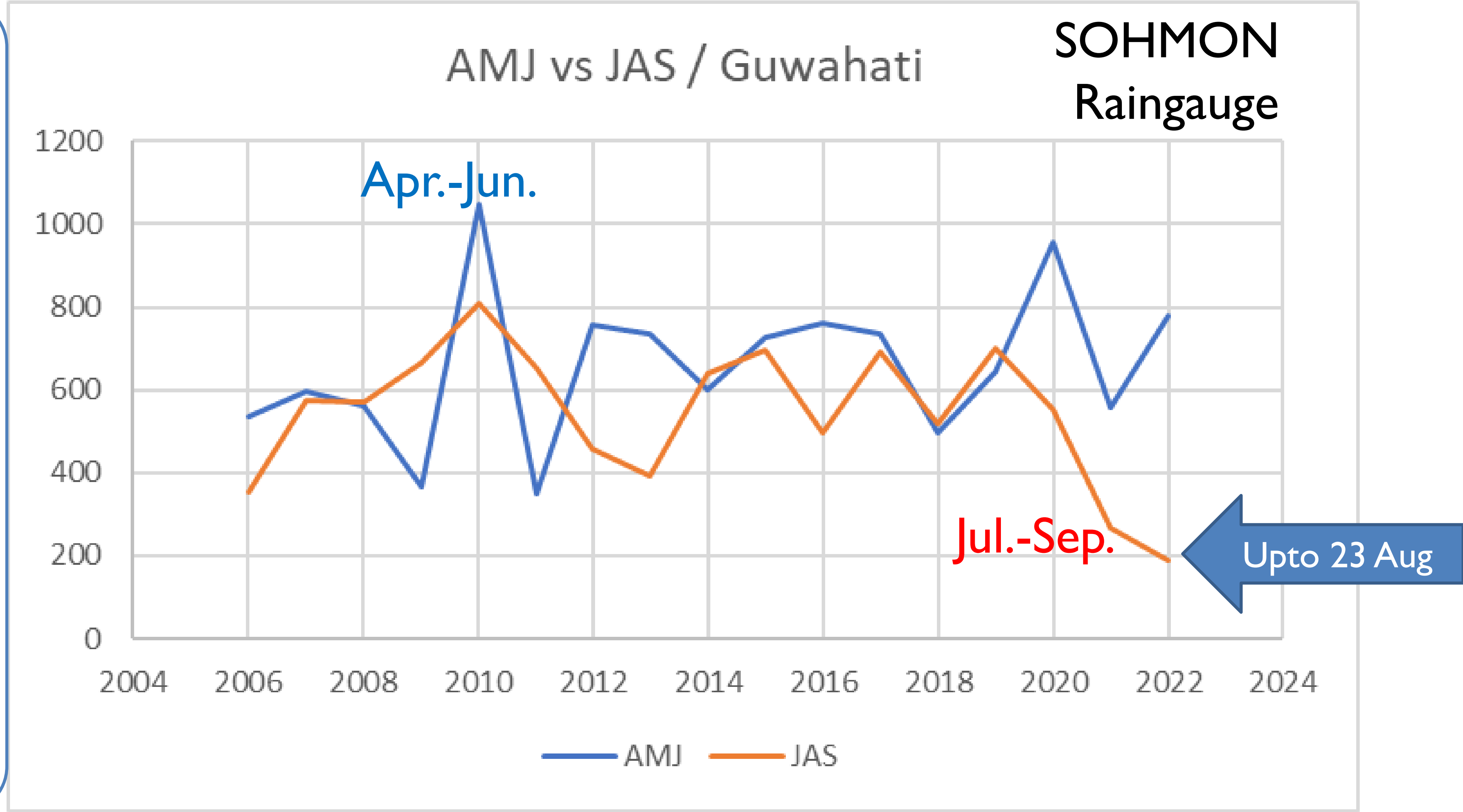
- I heard same story in many places --- What is going on??
  - Premonsoon rain is increasing / Flush floods in Assam / Bangla.
  - Monsoon rain is decreasing / Special irrigation in Bangladesh

Collaboration in NE Indian Subcontinent

Cotton Univ, IITM, IMD Guwahati, NESAC, IMD HQ

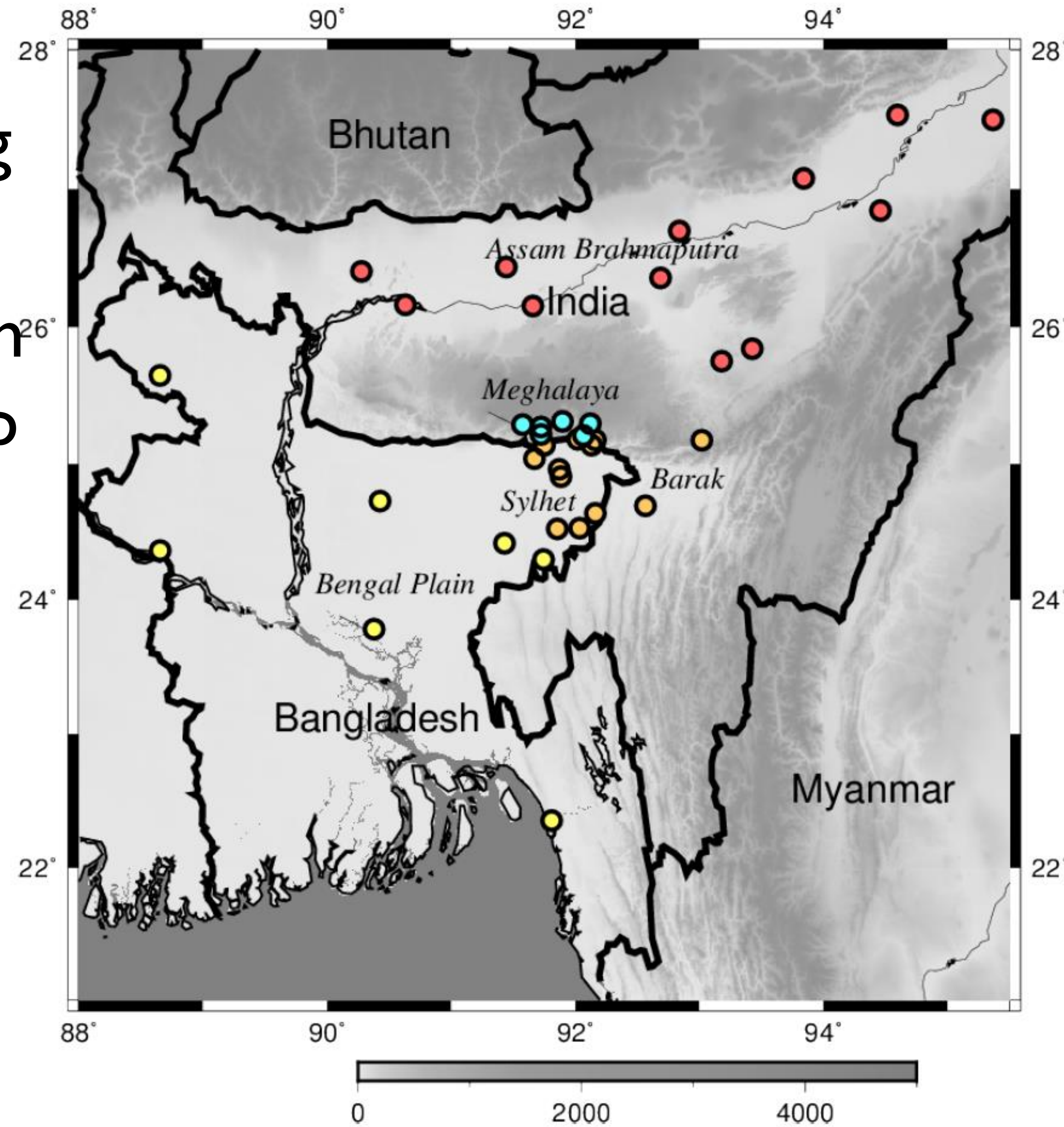
SOHMON/Jp

Univ. of Dhaka, BUET, BMD, BWDB JU, …



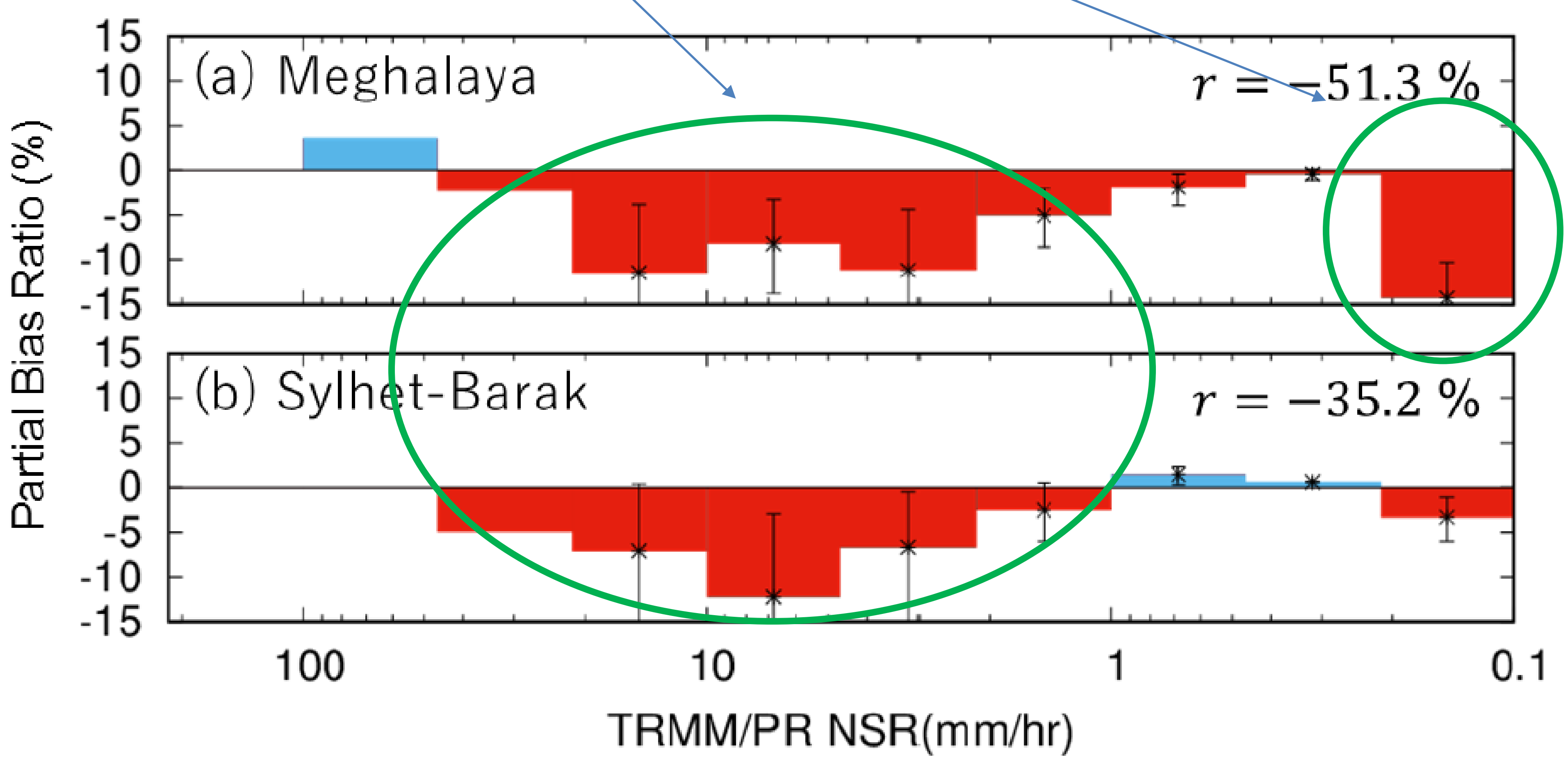
RG network in NE Indian subcontinent

- We conducted direct TRMM validation using 37 raingauges.
- They are Installed from 2004 and continued up to now.
- We obtained 29,172 matchups including 2,245 rainy cases.



Underestimation of TRMM/PR

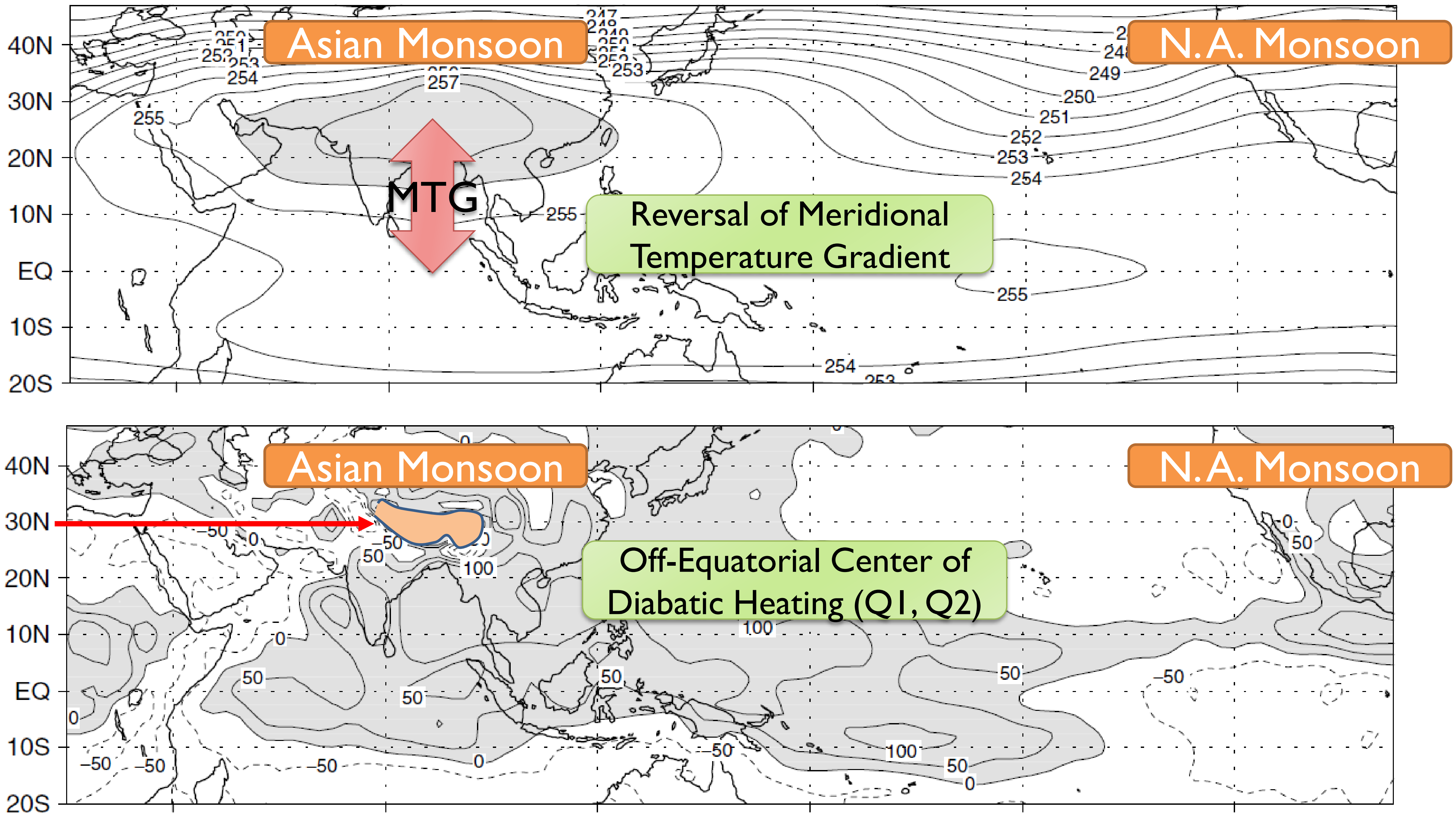
- Bias Ratio: Meghalaya: -51.3%, Sylhet-Barak: -35.2%
  - Significant at 99% Confidence Level
  - 2-20 mm/h (TRMM/PR)
  - Weak rainfall (especially for Meghalaya)



Q_1-Q_2 view

Heating Impact on the Asian monsoon

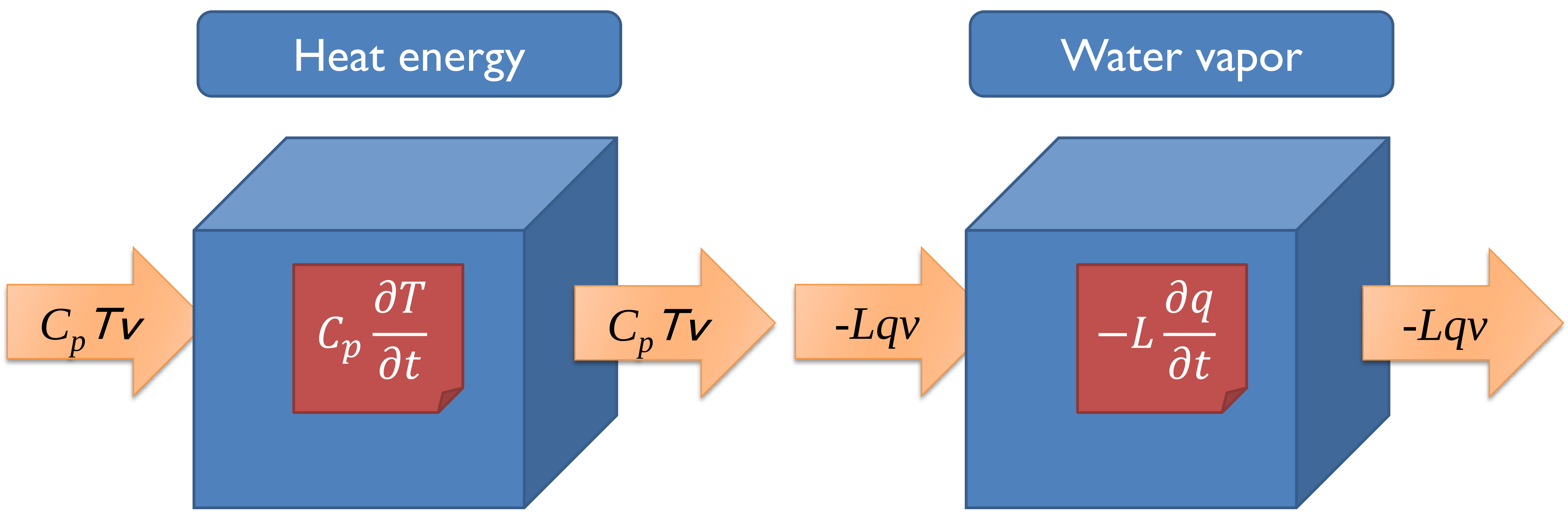
- Response to the off-equatorial heating center



Xavier et al. (2007)

Q1, Q2?

- Heat energy and water vapor mass must be conserved.
- From the budget calculation of heat energy (*CpT*) and water vapor (*q*), we can estimate additional heating/water vapor missing due to unconservative processes.



Q1: Apparent Heat Source
Total diabatic heating

Q2: Apparent Moisture Sink
Latent heating (P-E)

Definitions of Q1, Q2

- Q1: Apparent Heat Source

$$Q_1 = C_p \left(\frac{p}{p_0}\right)^{\kappa} \left(\frac{\partial \theta}{\partial t} + \mathbf{V}\cdot\nabla\theta + \omega\frac{\partial \theta}{\partial p}\right)$$

- Q2: Apparent Moisture Sink

$$Q_2 = -L\left(\frac{\partial q}{\partial t} + \mathbf{V}\cdot\nabla q + \omega\frac{\partial q}{\partial p}\right)$$

- Vertical integral and unconservative process

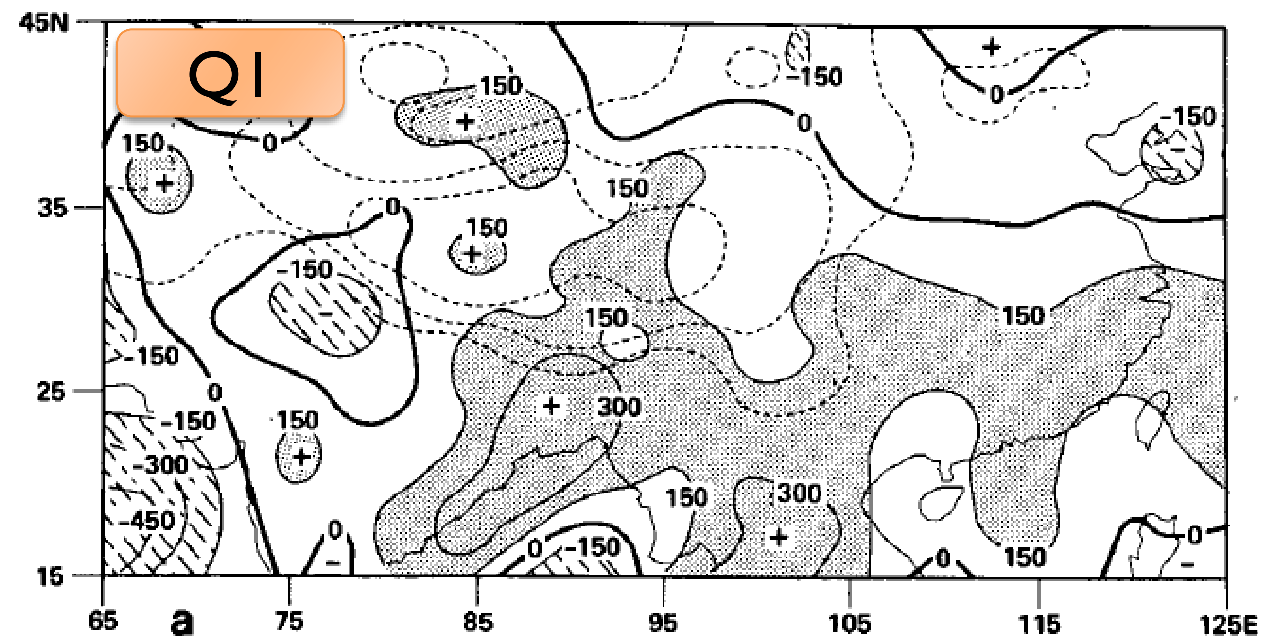
$$\langle Q_1\rangle = \langle Q_R\rangle + LP + S$$

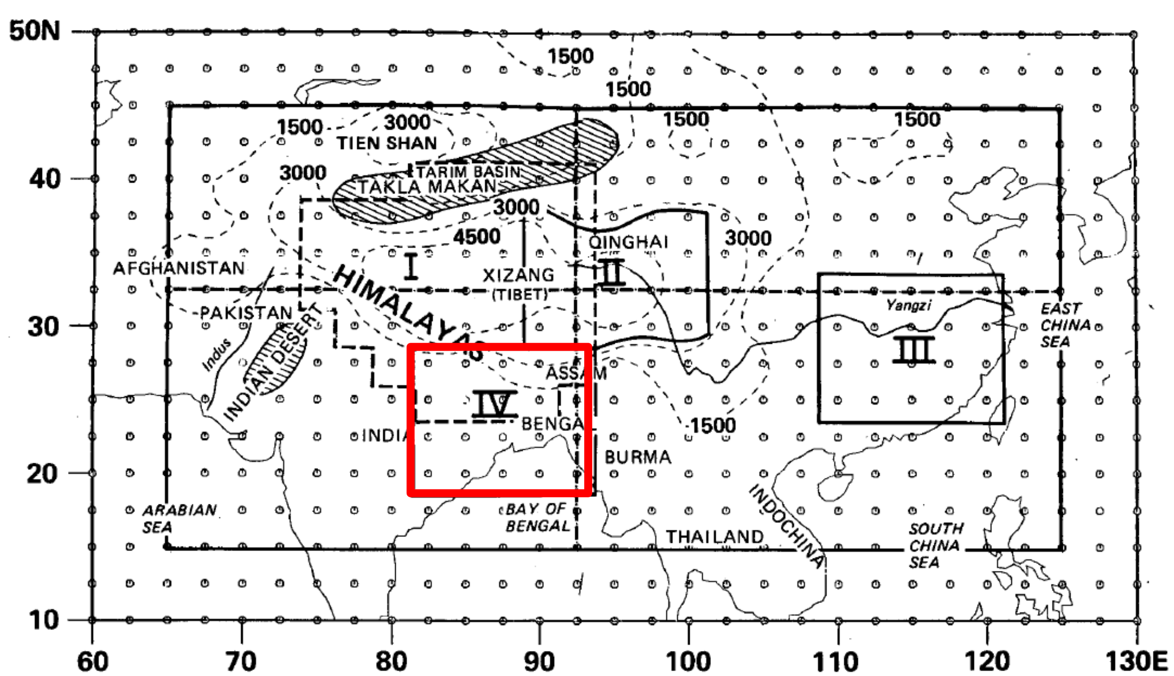
$$\langle Q_2\rangle = L(P - E)$$

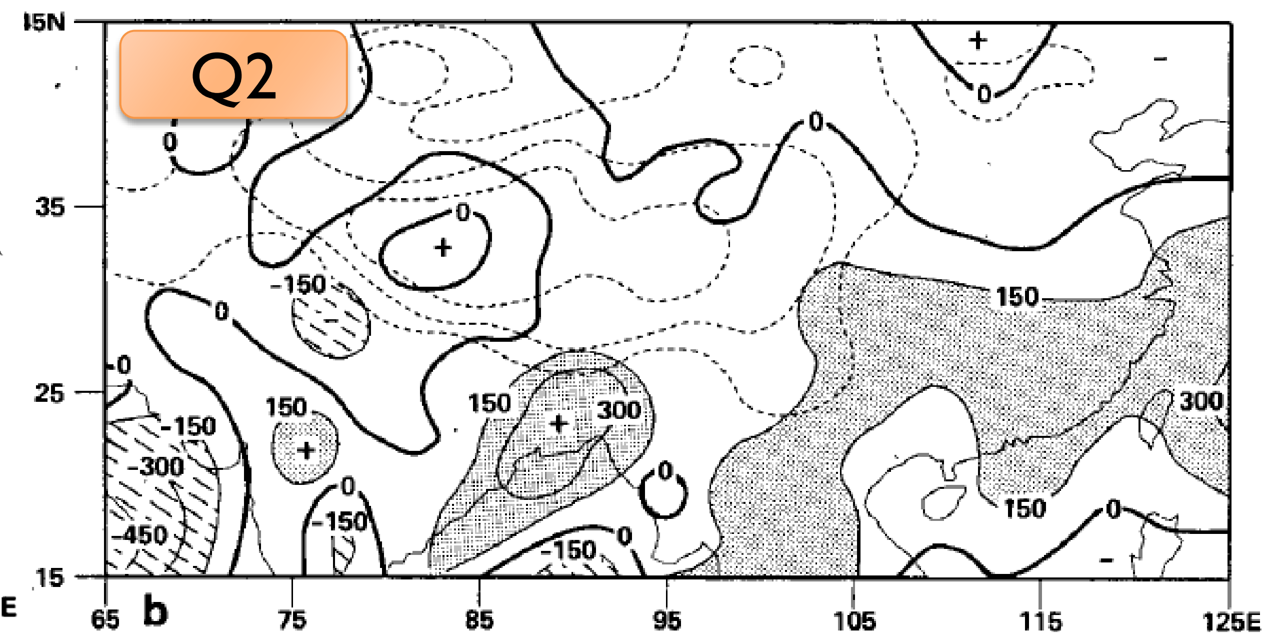
(Xavier et al. 2007)

Diabatic Heating near Tibetan Plateau

- Q1, Q2 around T-P.(Luo and Yanai 1984)
  - FGGE (1979)
  - Around Onset
    - 26 May - 4 July
  - 4 reg., 92.5E/32.5N Section

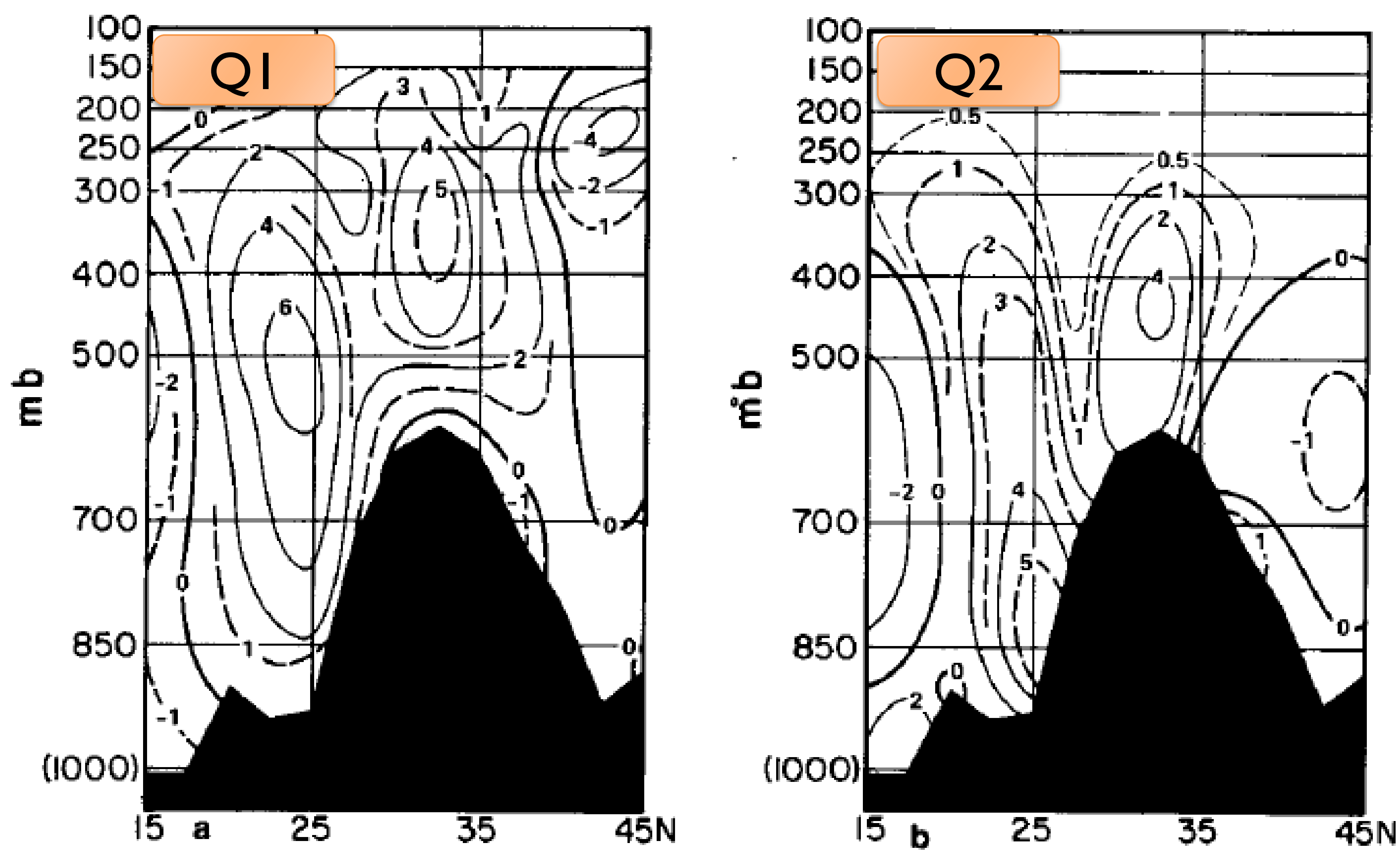






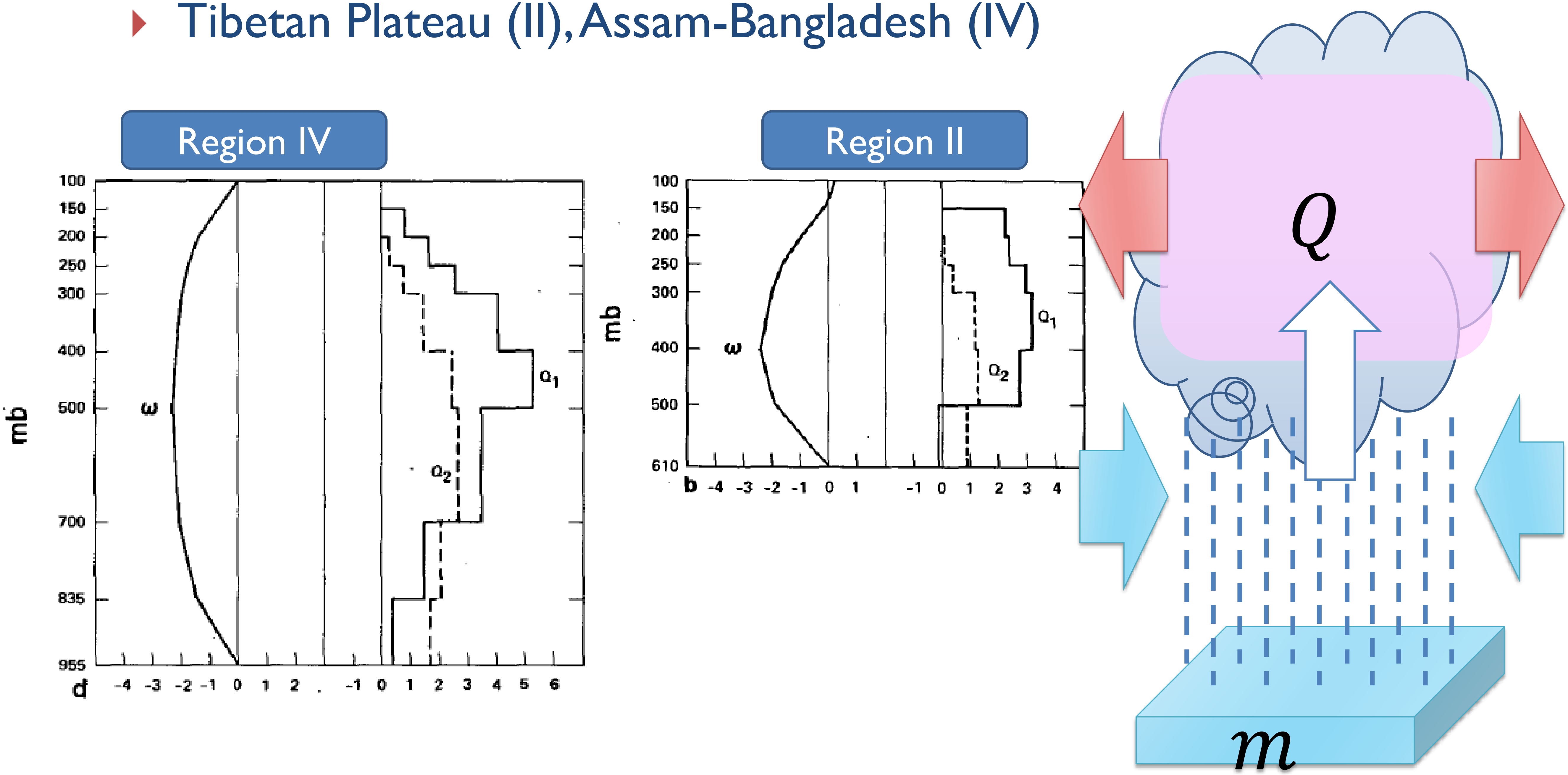
Heating Distribution

- Along 92.5E (Luo and Yanai 1984)
  - Two Separated Heating (Tibetan Plateau, Assam-Bangladesh)



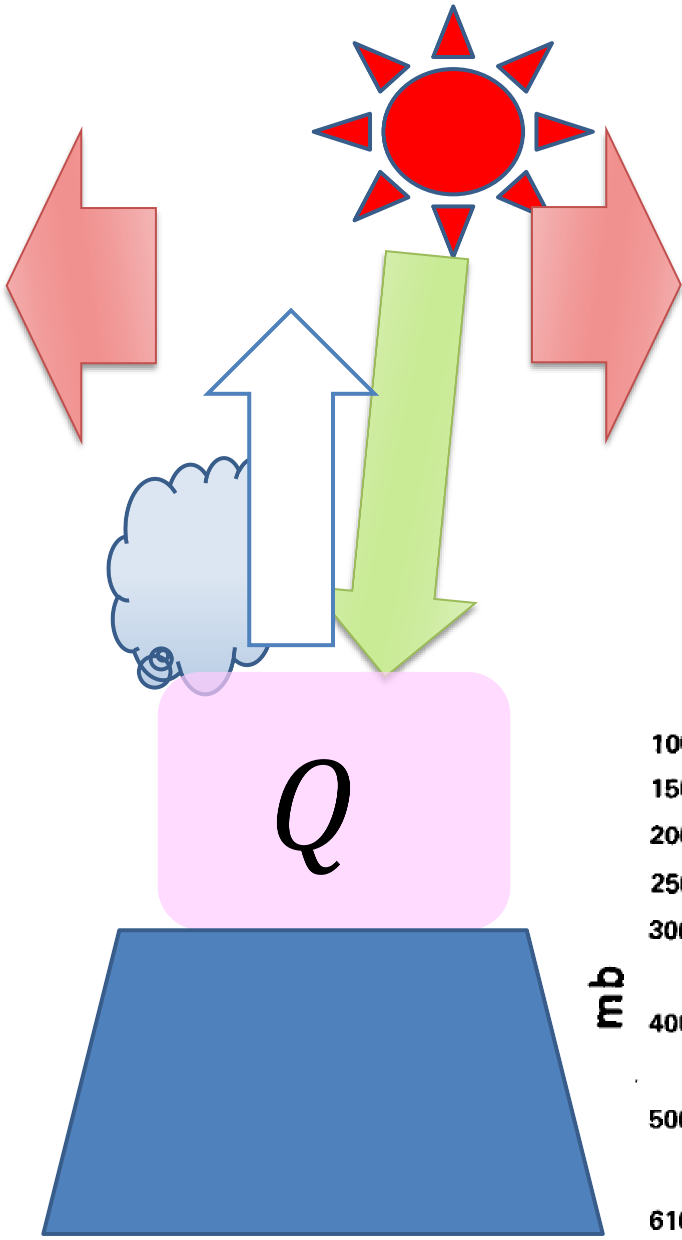
Vertical Profiles of Q1, Q2 (1/2)

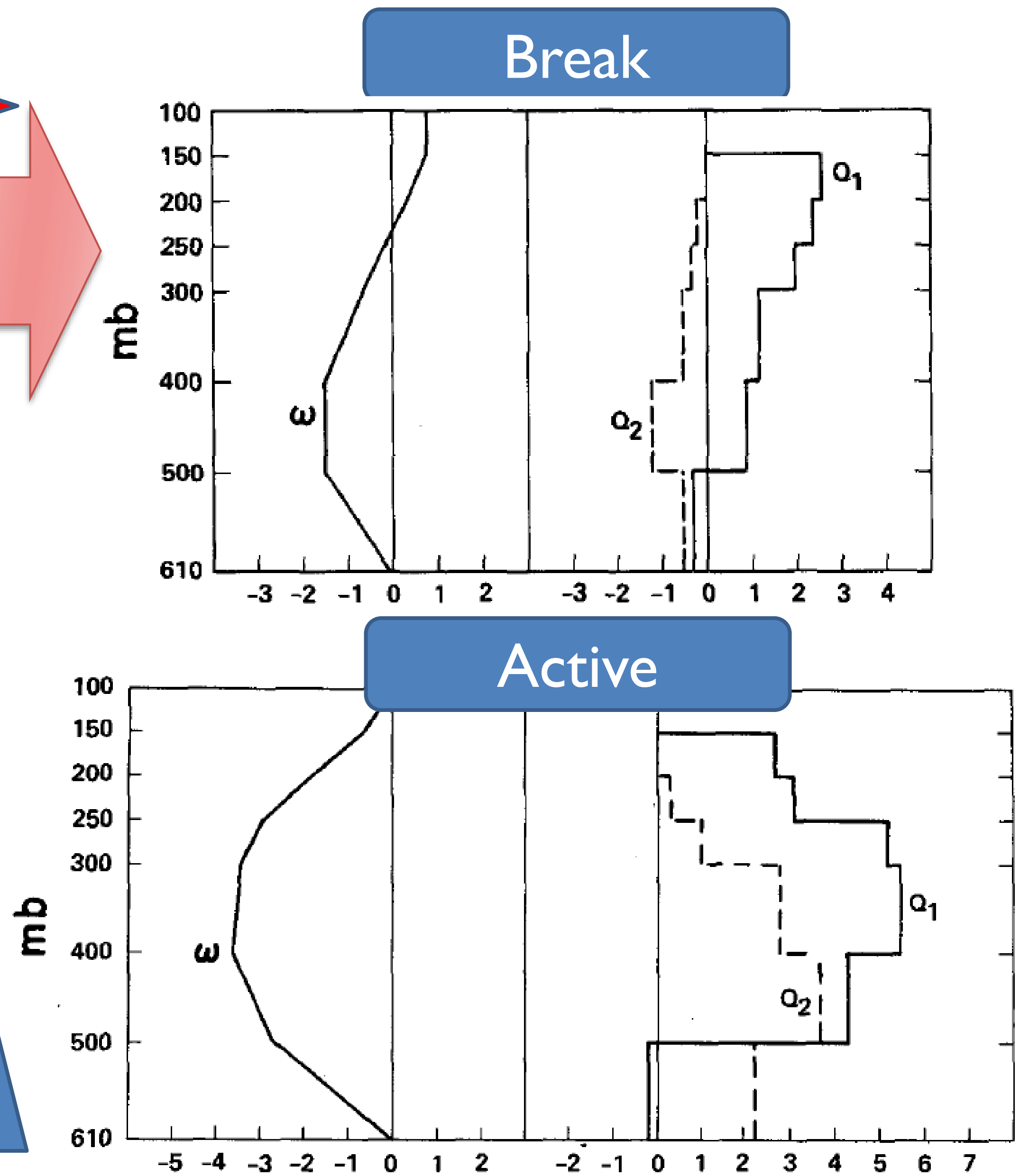
- Q1, Q2 for Regions II, IV (Luo and Yanai 1984)
  - Tibetan Plateau (II), Assam-Bangladesh (IV)

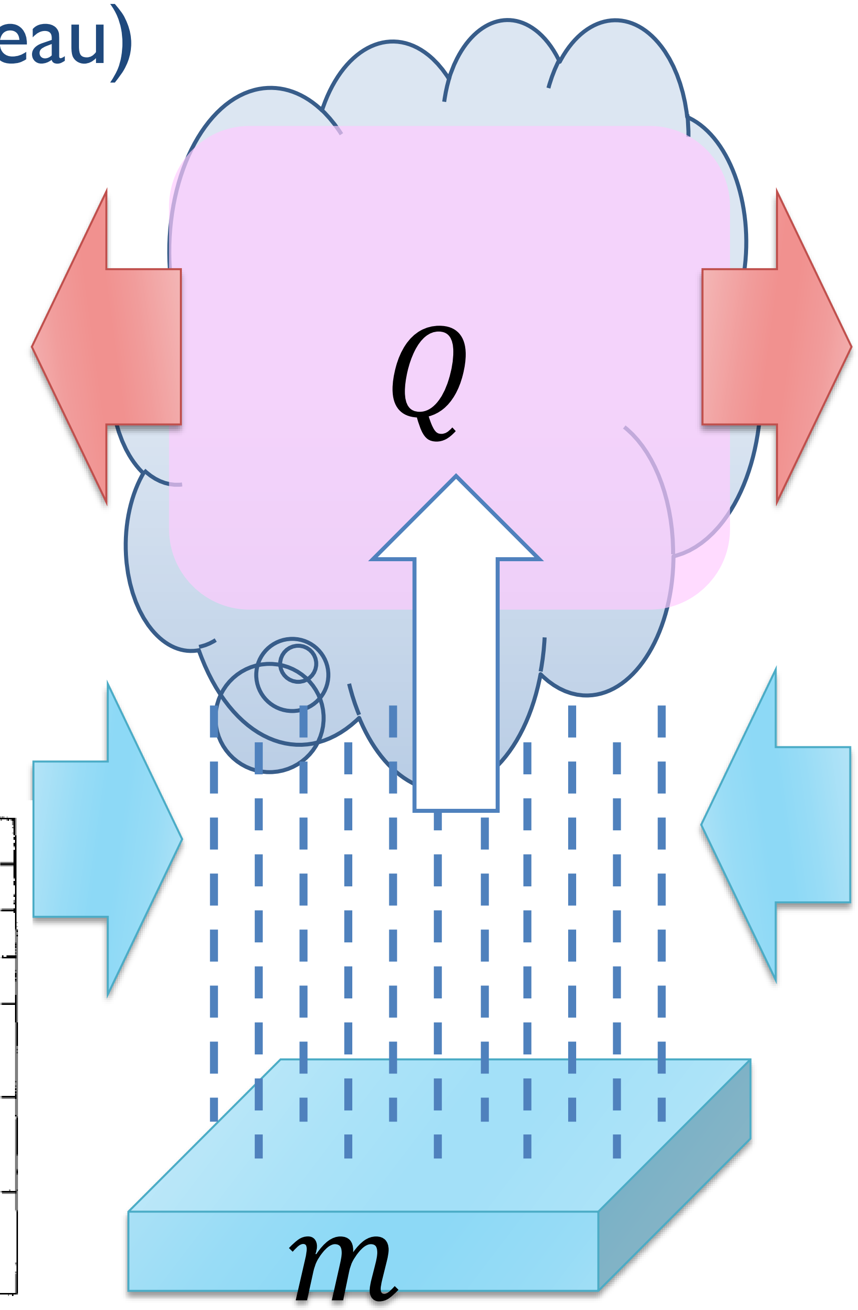


Vertical Profiles of Q1, Q2 (2/2)

- Q1, Q2 for Regions II (Luo and Yanai 1984)
  - Break Phase and Active Phase (Tibetan Plateau)







Summary of Luo and Yanai (1984)

- Around the Bay of Bengal, Bengal Plain
  - Q1~Q2: LH by convective activity dominates
- Eastern Tibetan Plateau
  - Q1>Q2: SH by dry convection also play important roles
  - Active phase, convective activity prevails
- Western Tibetan Plateau
  - Q1>>Q2: SH by dry convection from elevated ground surface dominates

Global distribution of <Q1> and <Q2>

Li and Yanai (1996)

- Center of heating is around the Bay of Bengal and the Tibetan Plateau
- Much larger than North American monsoon
- Q2~Q1. LH plays important roles globally.

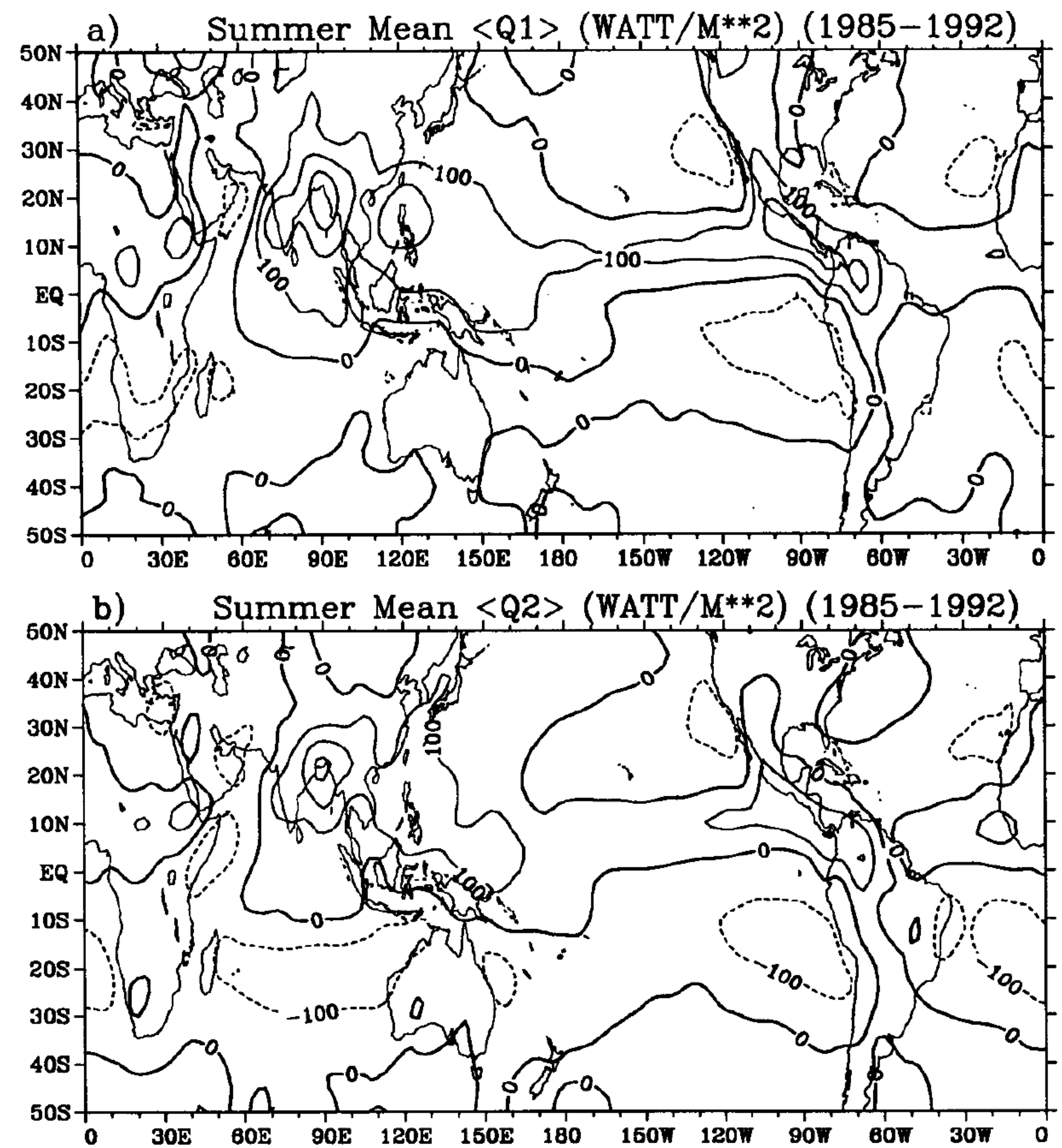
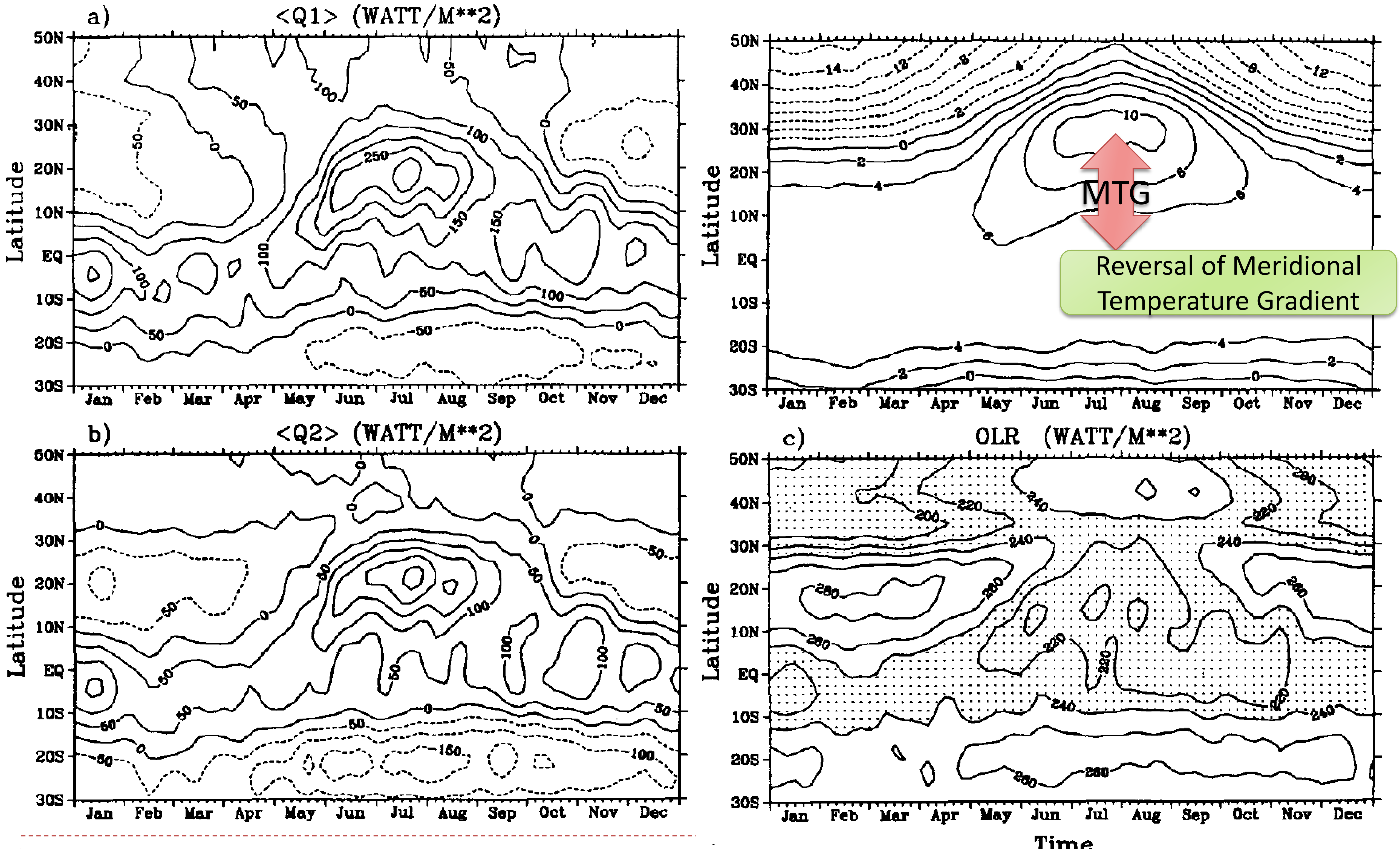


FIG. 5. (a) The vertically integrated heat source $\langle Q_1 \rangle$, and (b) the vertically integrated moisture sink $\langle Q_2 \rangle$ for summer, averaged over 8 years (1985–1992). Contour interval is 100 W m^{-2}.

Monsoon Onset and MTG, <Q1> and <Q2>

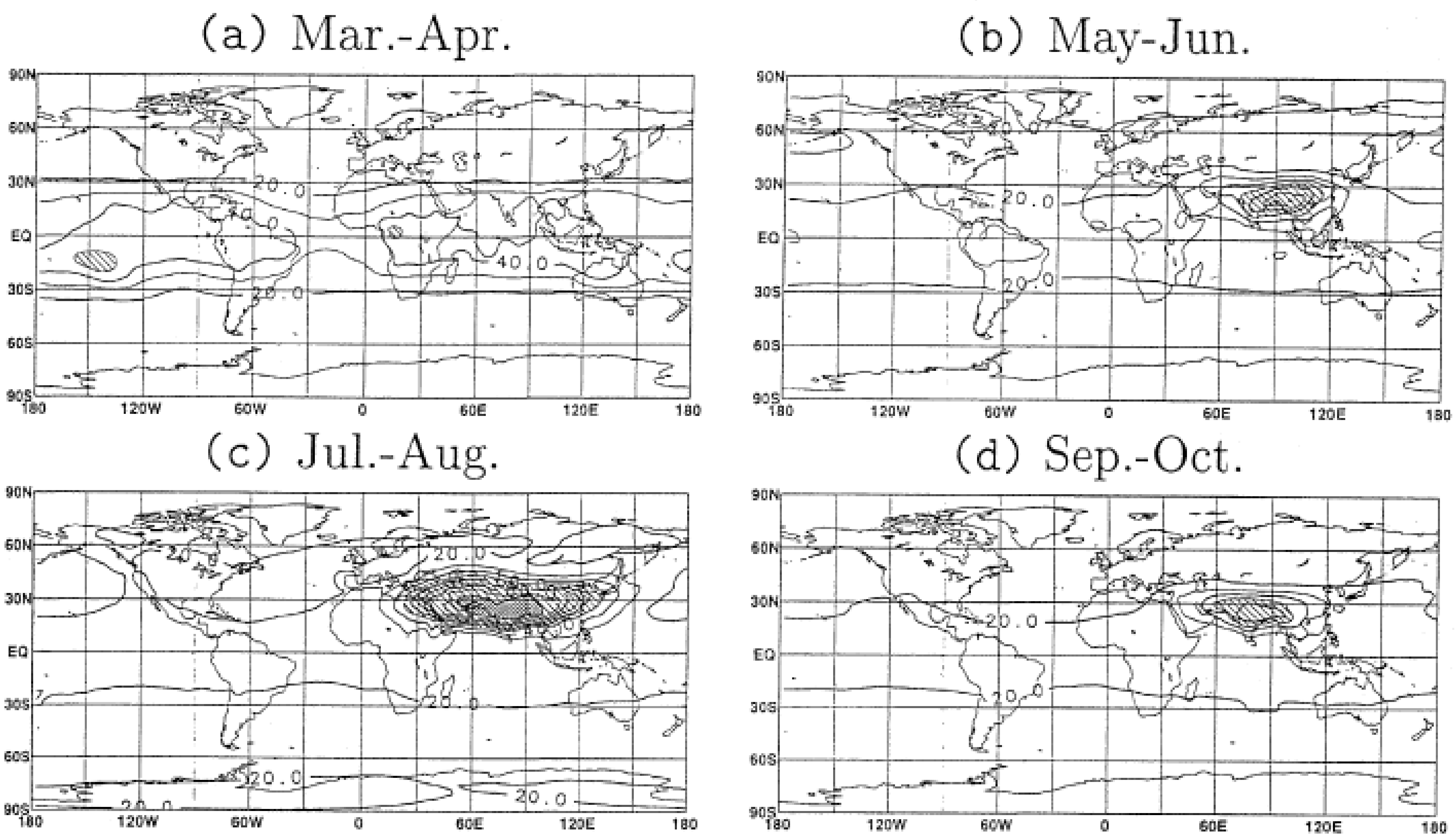


Li and Yanai (1996)

HMSEA/HDSEA view

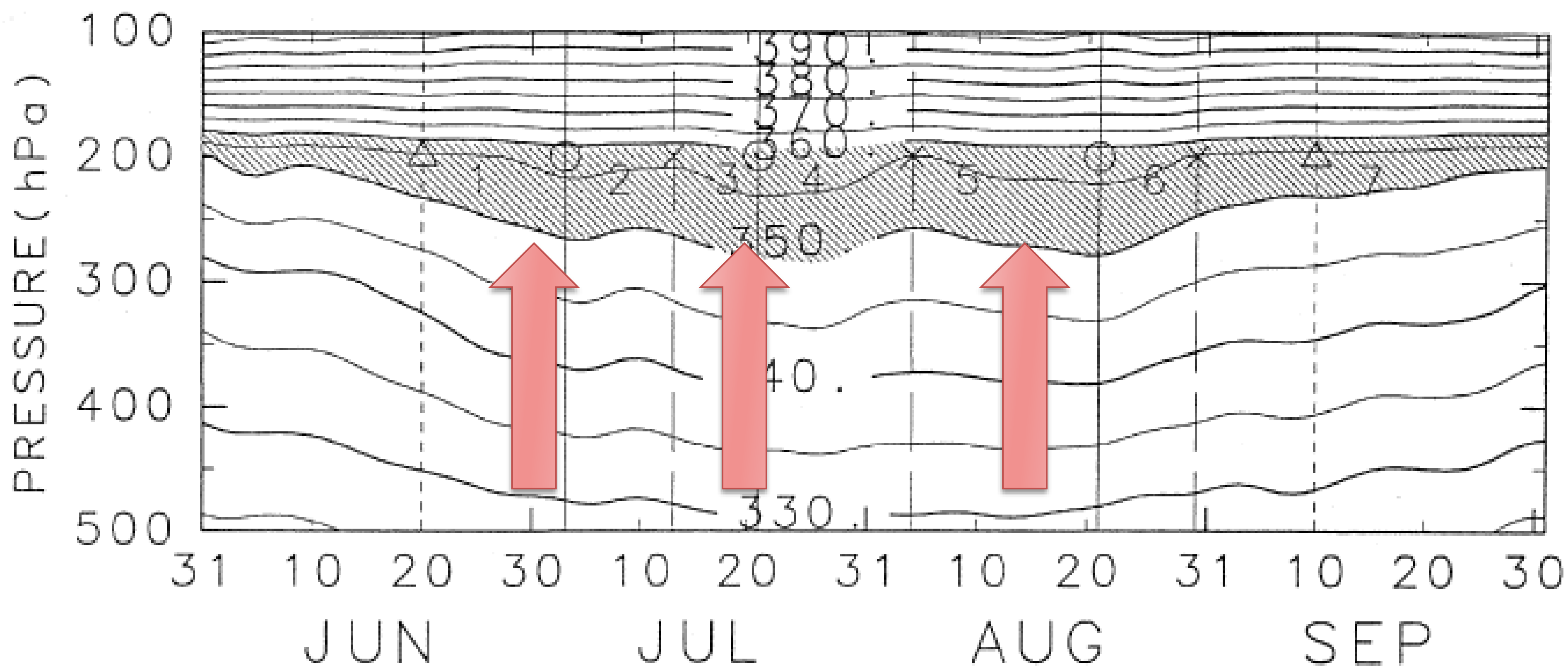
Tibetan High and Isentropic Circulation

- Seasonal March in σ_{355K} (Terao 1999)



Accumulation of High-θ airmass

- Airmass with θ=350-360K just below the tropopause was related with strength of the MTG and the Tibetan High.
- Source of the high θ airmass must come from high θ_e airmass in the lower troposphere.

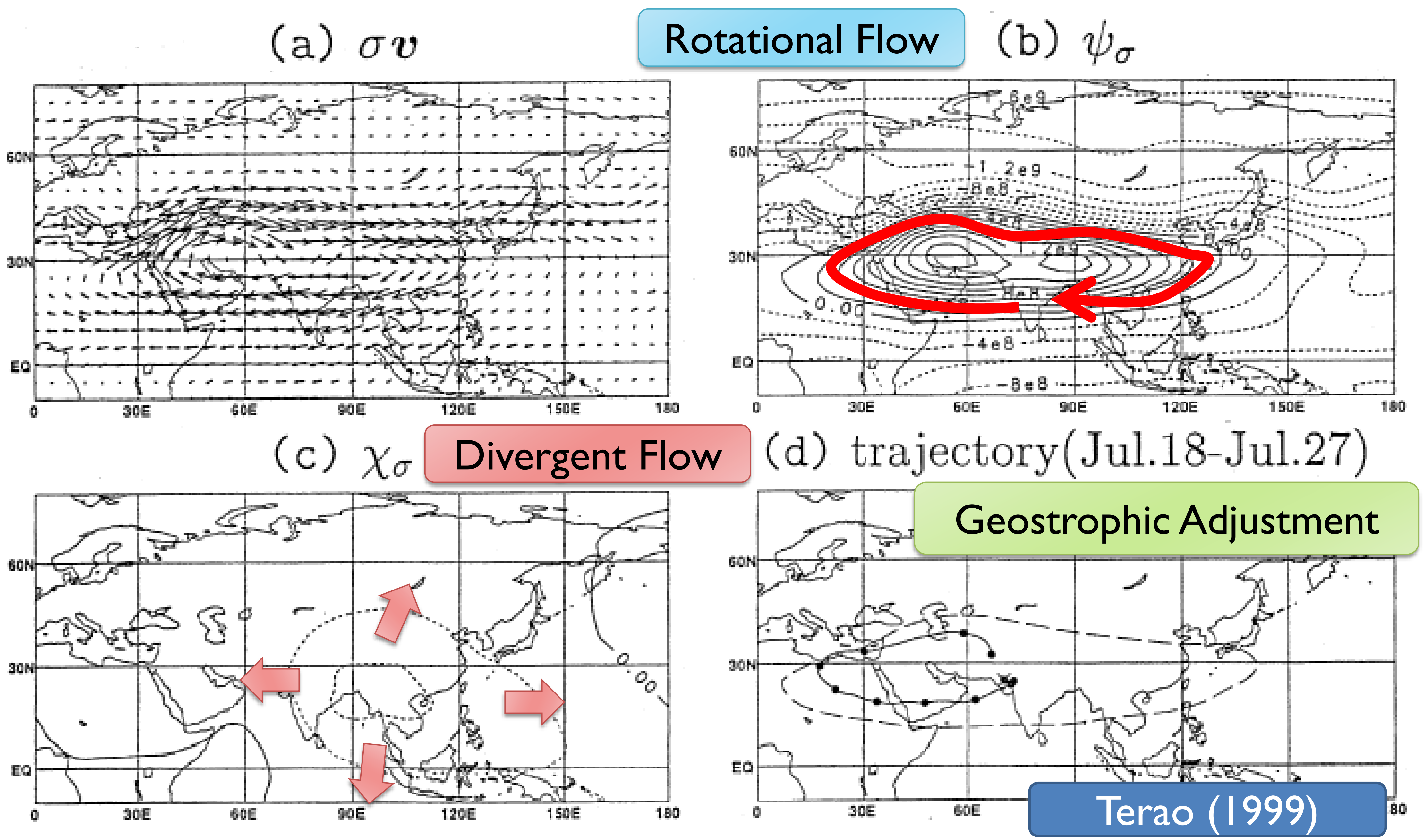


Terao (1999)

Fig. 5. Time-pressure cross section of potential temperature averaged over 30–120°E and 20–40°N. Contour interval is 5 K. The layer between 350 K and 360 K isentropic surfaces is hatched.

Accumulation of Heated Airmass

- Mass transport on 355K isentropic surface



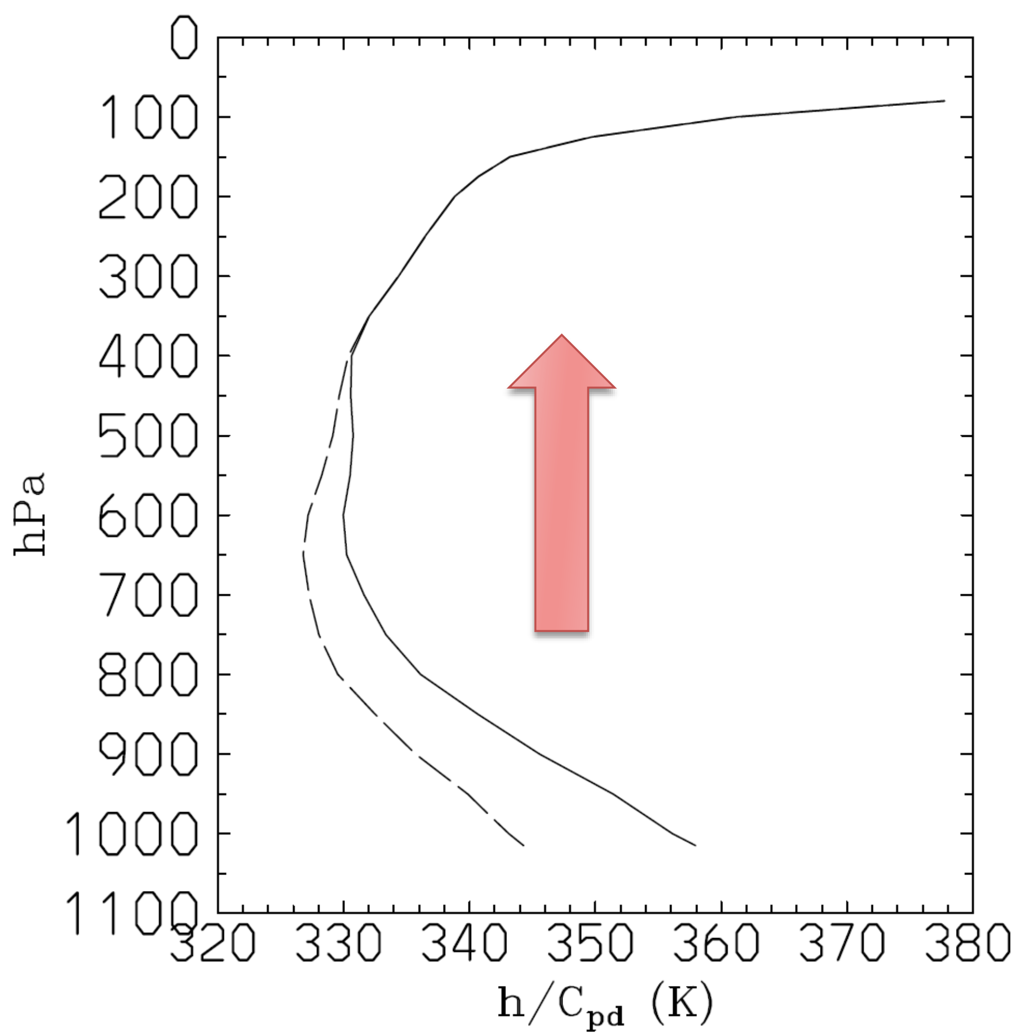
Enthalpy + Potential Energy + Latent heat of water vapor

Vertical profile of moist static energy

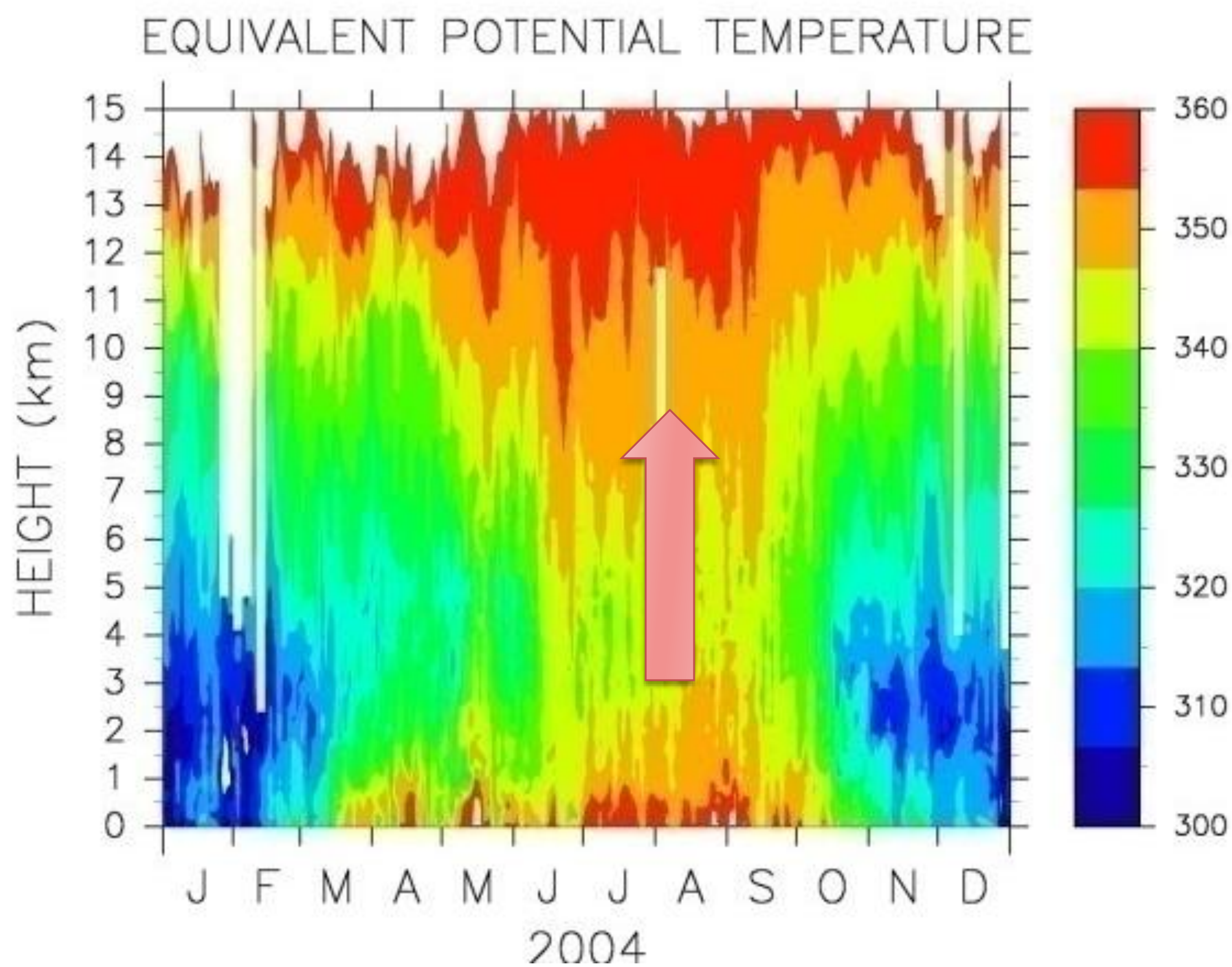
Conservative quantity for an airmass

- Atmospheric structure of troposphere

Dhaka Radiosonde

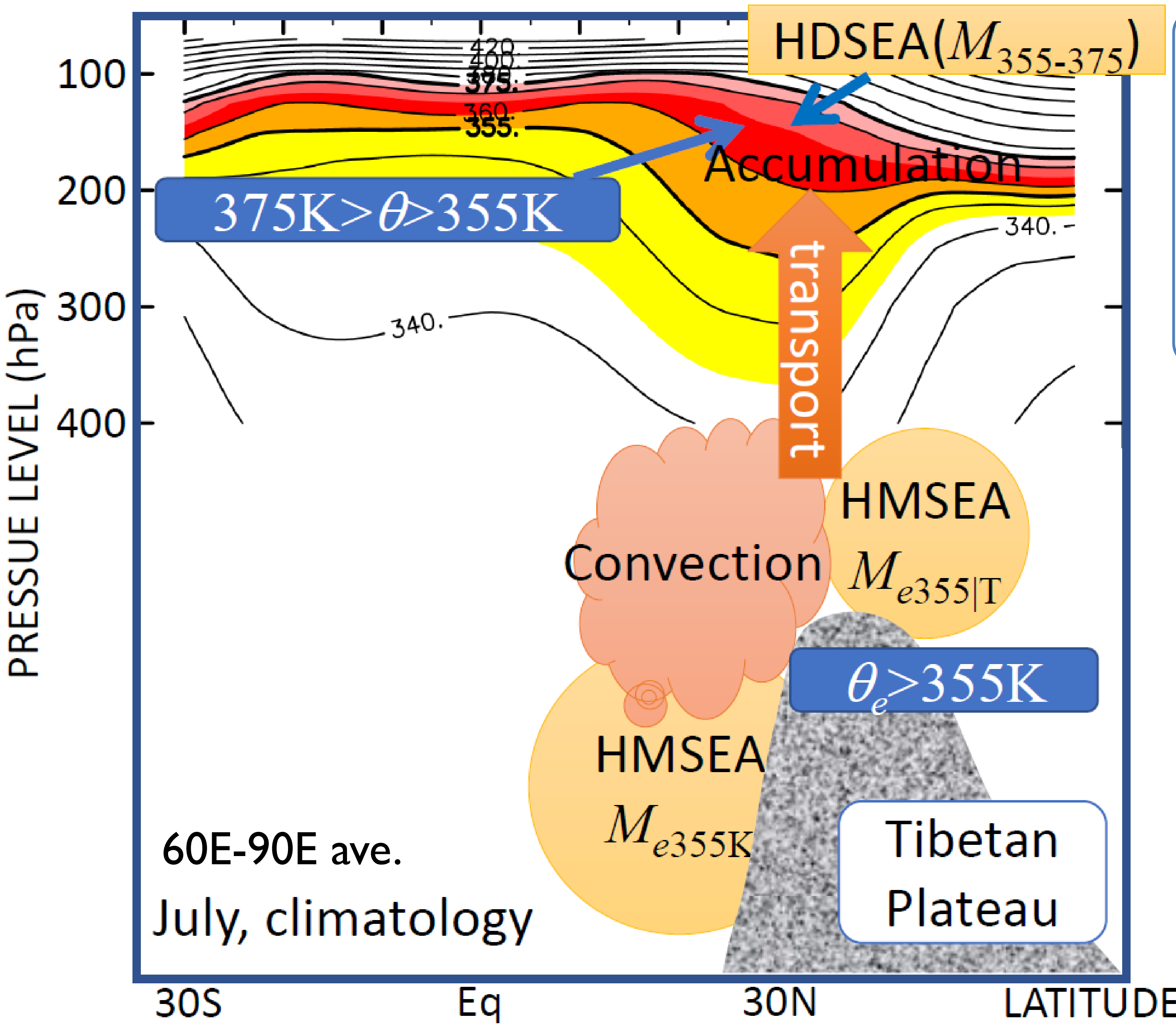


Yano and Ambaum (2017)



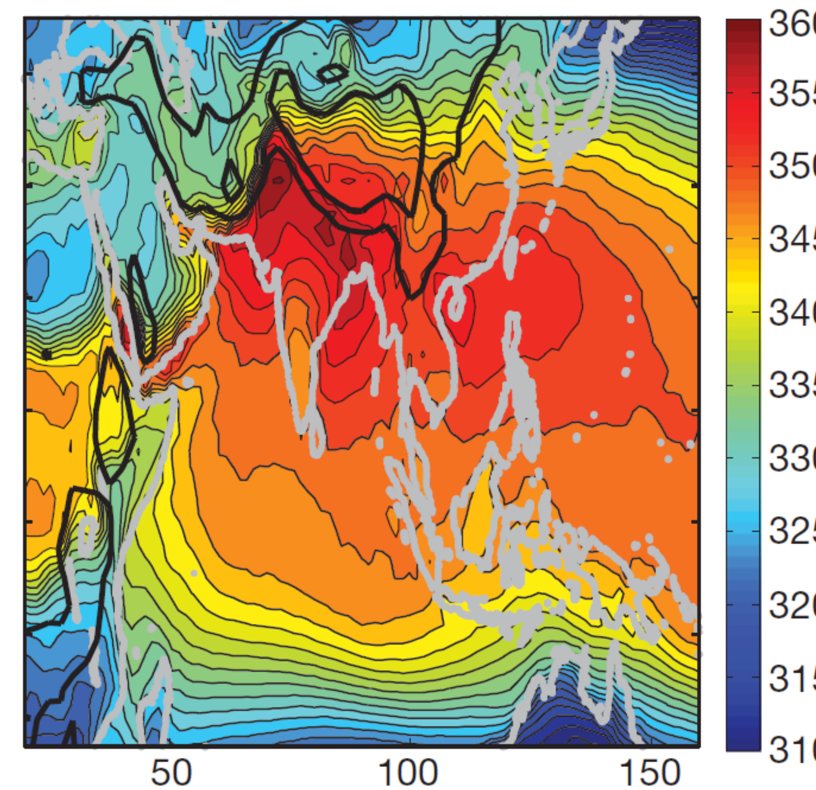
Terao et al. (in prep.)

LT-HMSEA/UT-HDSEA view



Terao et al. (in prep.)

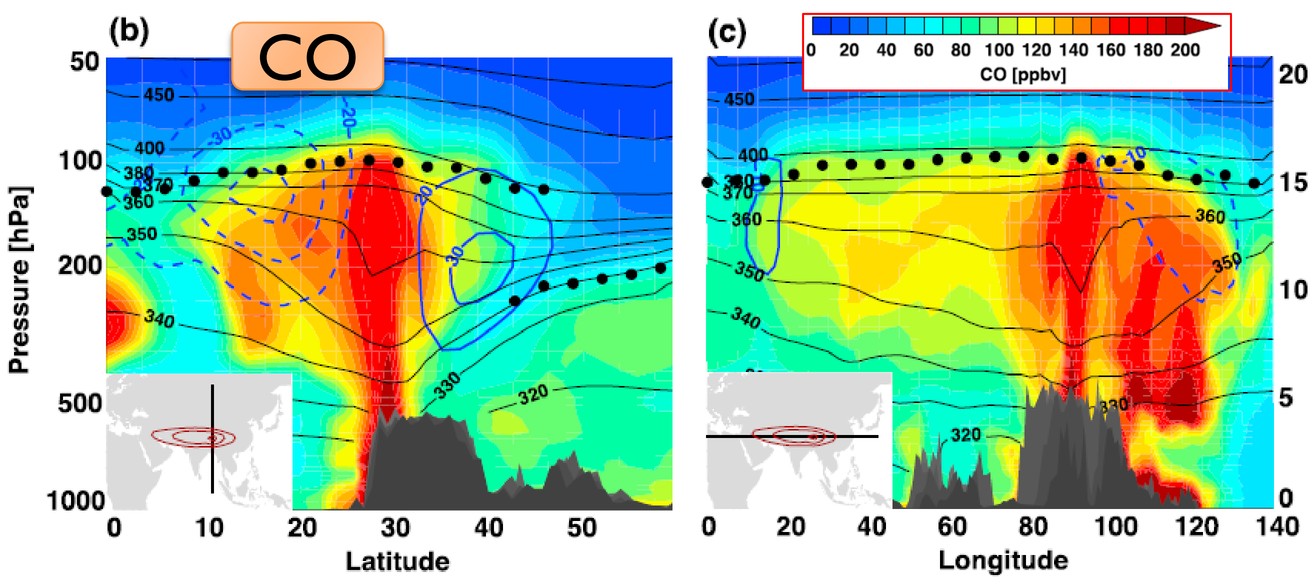
UT-HDSEA:
High Dry Static Energy Airmass (upper trop.)
LT-HMSEA:
High Moist Static Energy Airmass (lower trop.)



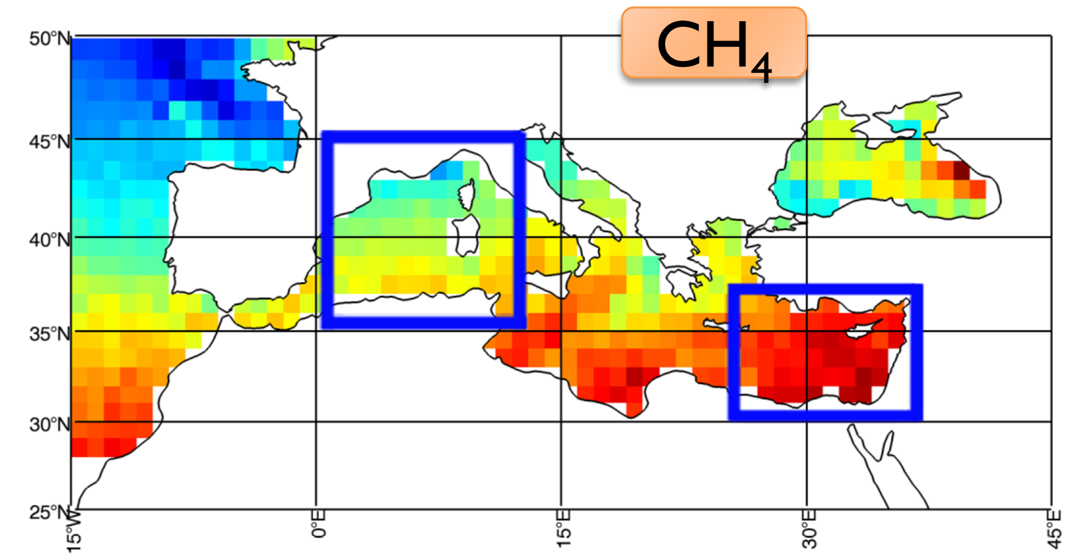
Boos and Kuang (2010)

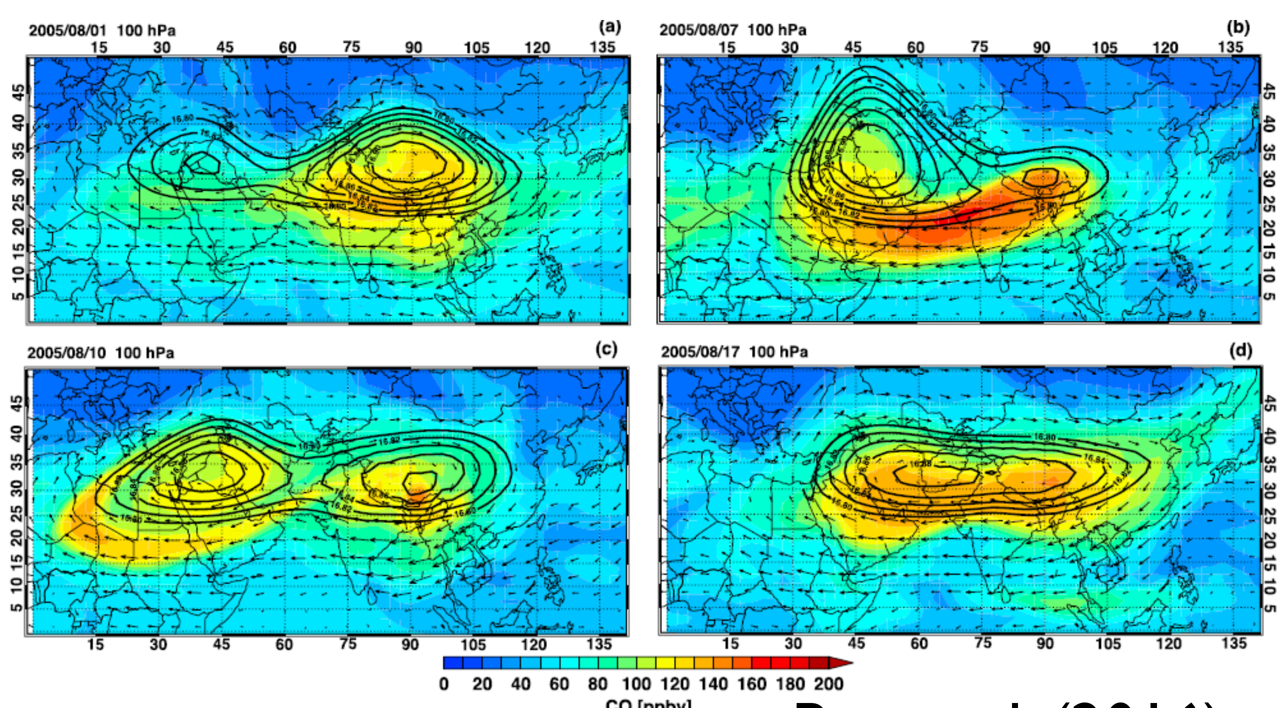
Boundary Layer -> Tropopause

- Investigated using tracer gas

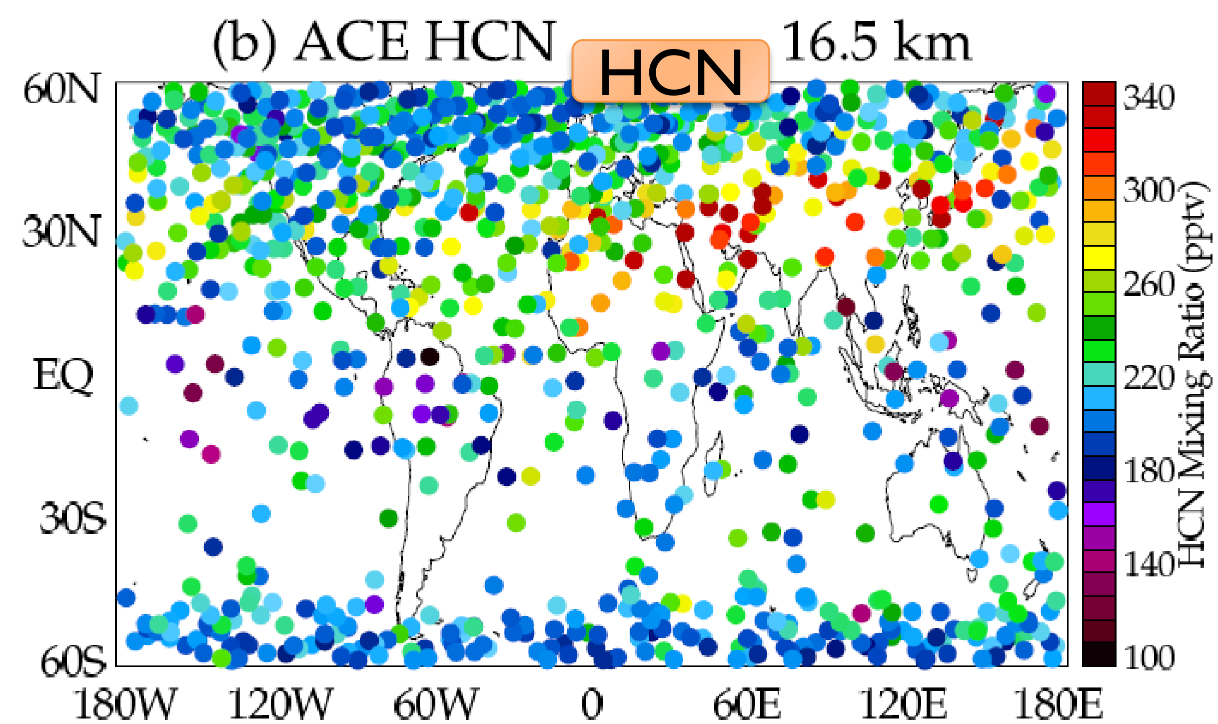


Ricaud et al. (2014)



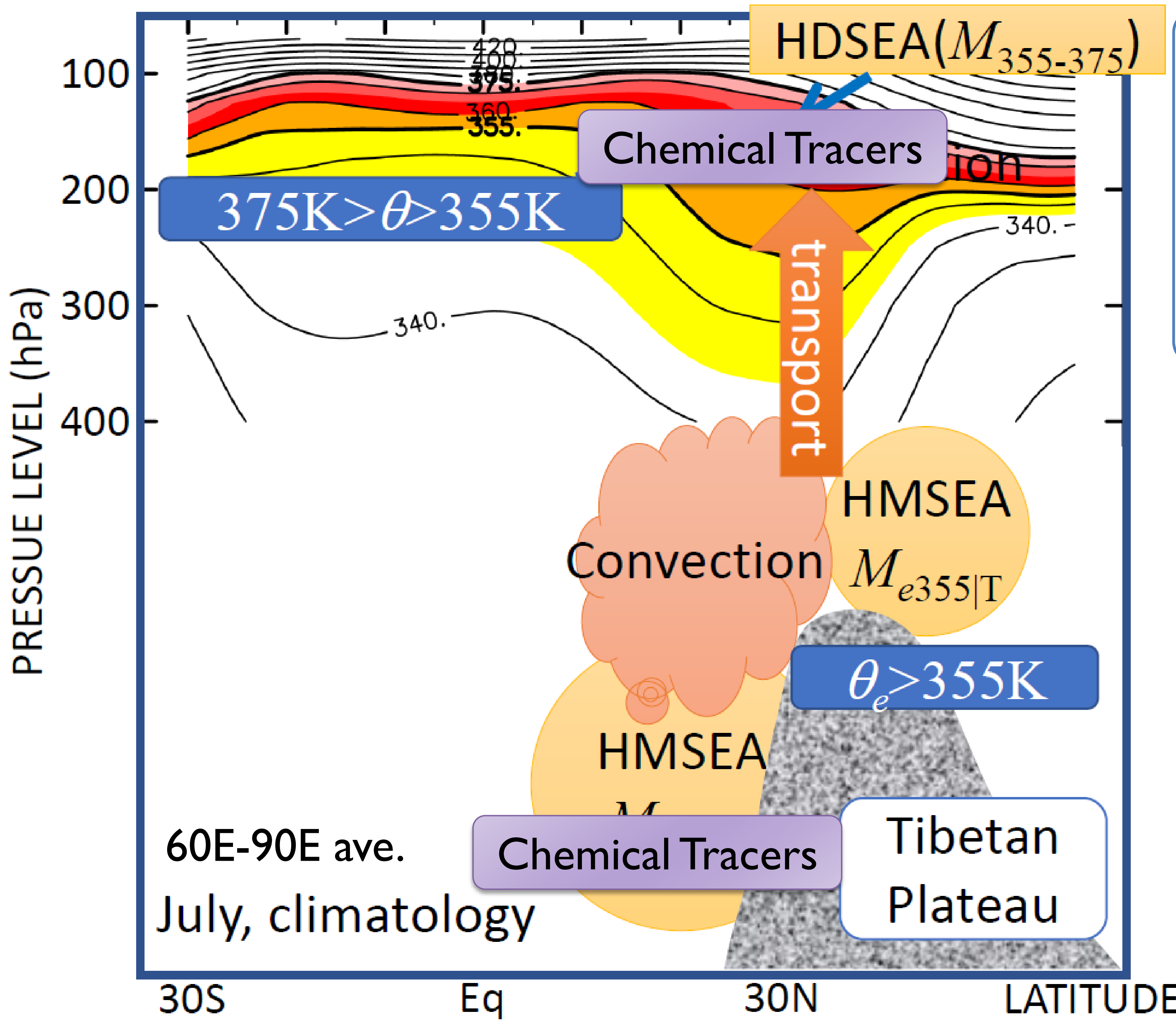


Pan et al. (2016)



Park et al. (2008)

LT-HMSEA/UT-HDSEA view



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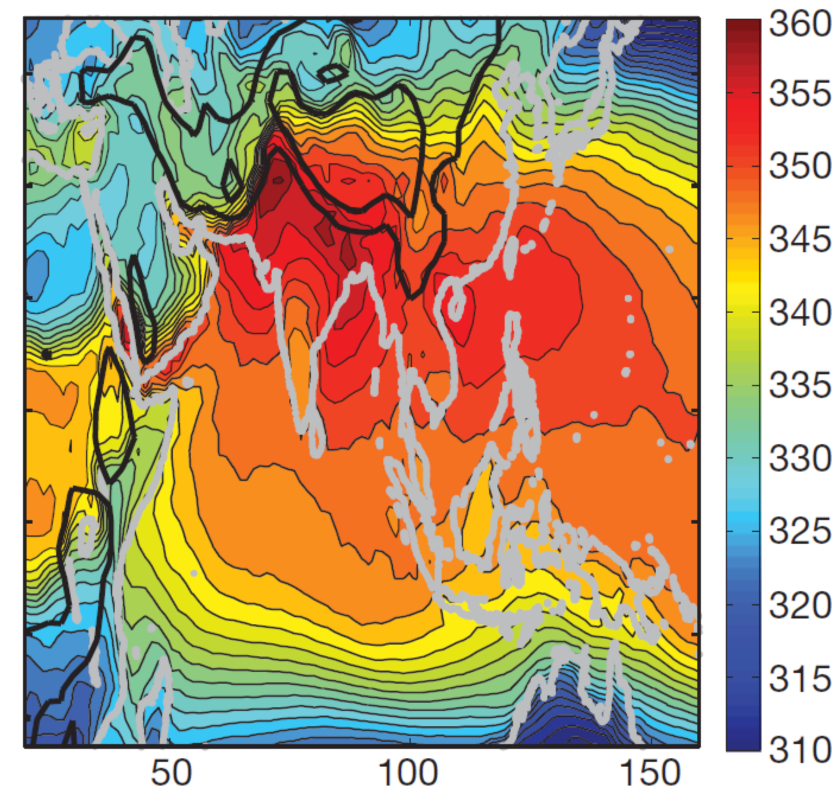


Boos and Kuang (2010)

Data

- ERA5 (2017 / Jan, Jul / Global, Apr-Sep / Asia)
  - Hourly 0.25 x 0.25 deg Lon-Lat Grid data at pressure levels from 1000 to 70 hPa and ground surface.
    - Temperature, specific humidity, zonal and meridional wind speed, geopotential height, and surface pressure.
  - Airmass for 5K isentropic layers and their horizontal flux are calculated for each horizontal grid and hour.
- ERA5 (1979-2019 / Apr-Sep / Asia)

  Hershbach et al. (2020)
  - Hourly 2.5 x 2.5 deg grid data (truncated).
- GSMaP
  - GSMaP standard product Version 6.
  - 2000-2019, Hourly, 0.1 x 0.1 deg.

  Kubota et al. (2007)

Apparent UT-HDSEA Source

- Conservation for UT-HDSEA ($355\mathrm{K} < \theta < 375\mathrm{K}$) mass, μ

$$\frac{\partial \mu}{\partial t} = -\nabla \cdot (\mu \boldsymbol{v}) + R$$

- R: the apparent mass source（radiation, conv., others）

$$R = R_r + R_c + R_o$$

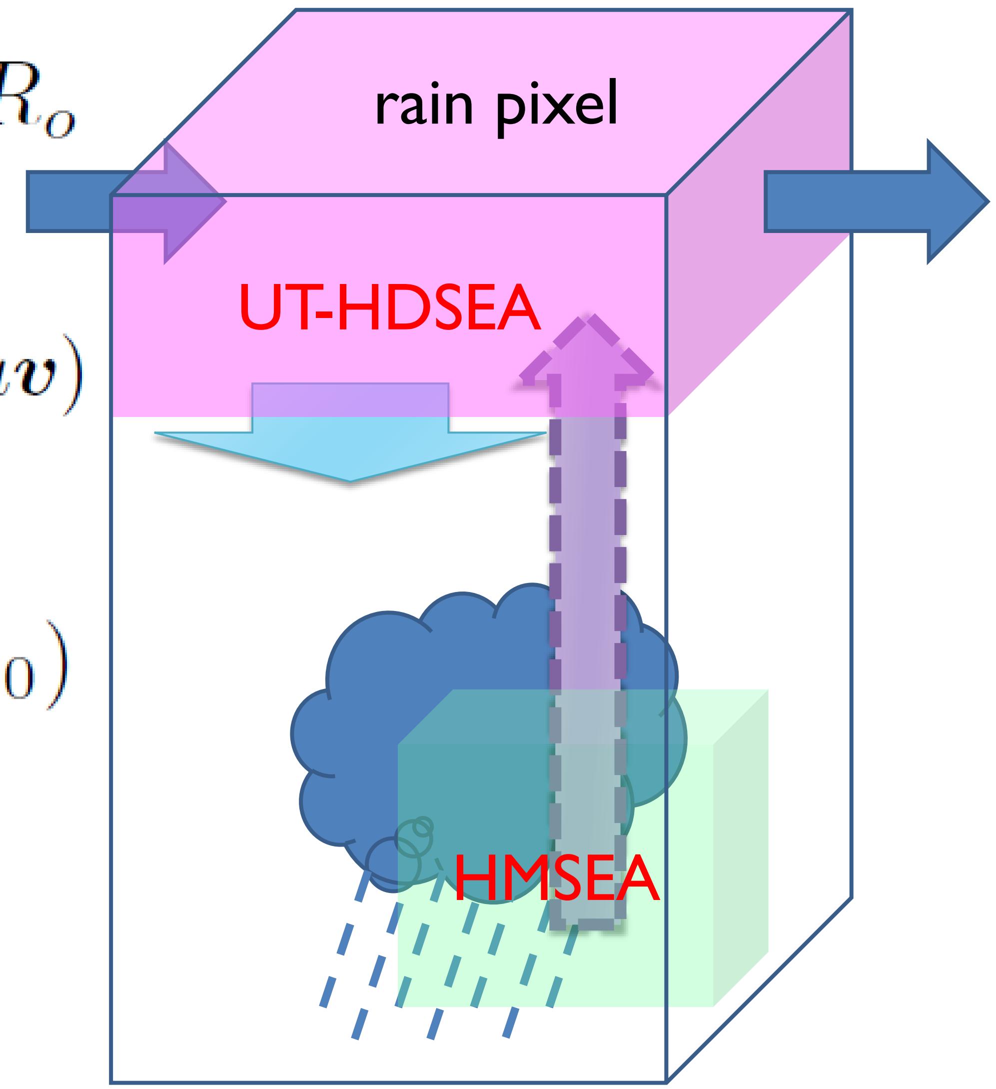
- If no rain ($R_c \approx 0$),

$$R_r \simeq \frac{\partial \mu}{\partial t} + \nabla \cdot (\mu \boldsymbol{v})$$

- Radiative equilibrium: μ_0

$$R_r \simeq -\nu(\mu - \mu_0)$$

- Newtonian cooling coefficient : ν
- e-folding time: $1/\nu$

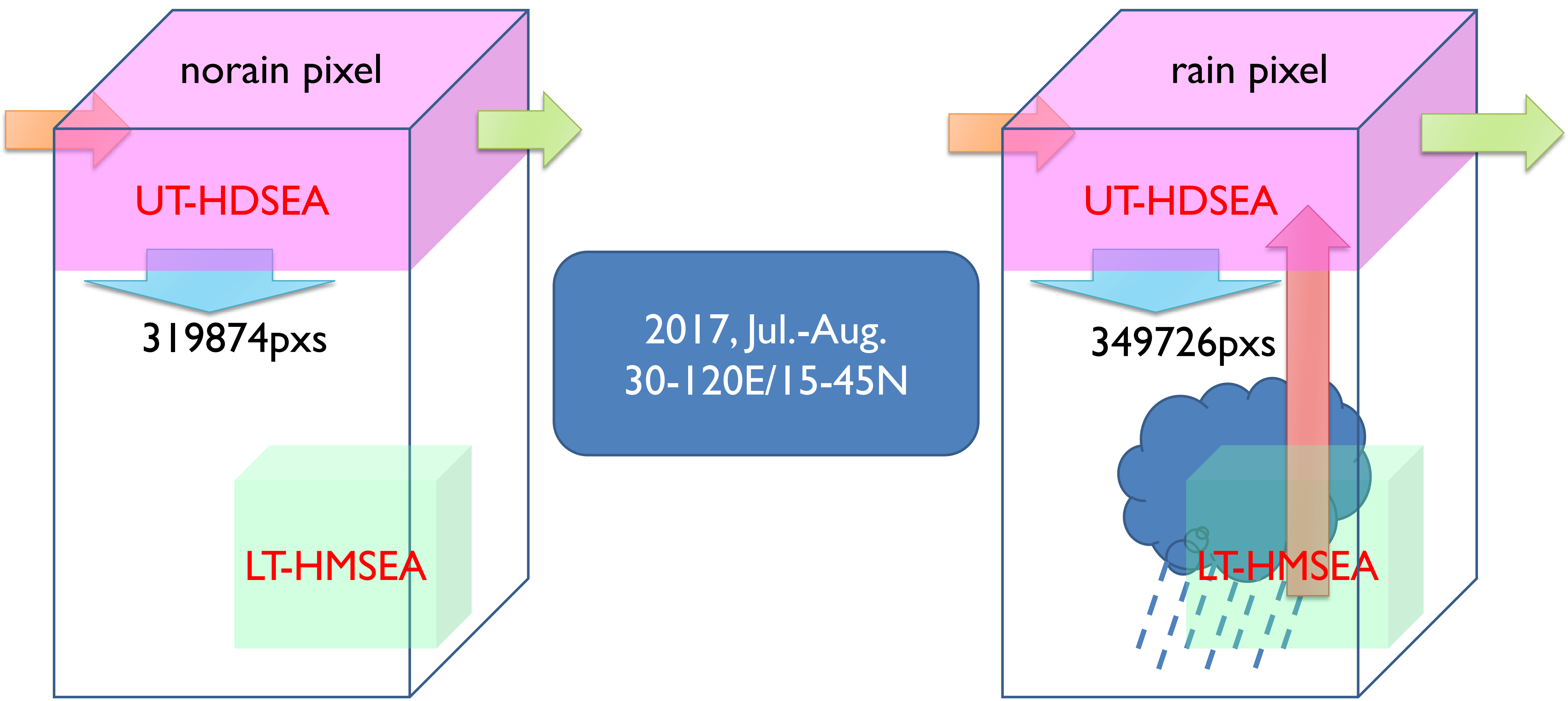


Terao et al. (in prep.)

Mass budget of UT-HDSEA (355K-375K)

- Apparent UT-HDSEA Source was evaluated
  - for rain pixel: Convection – Radiative cooling
  - for norain pixel: – Radiative cooling

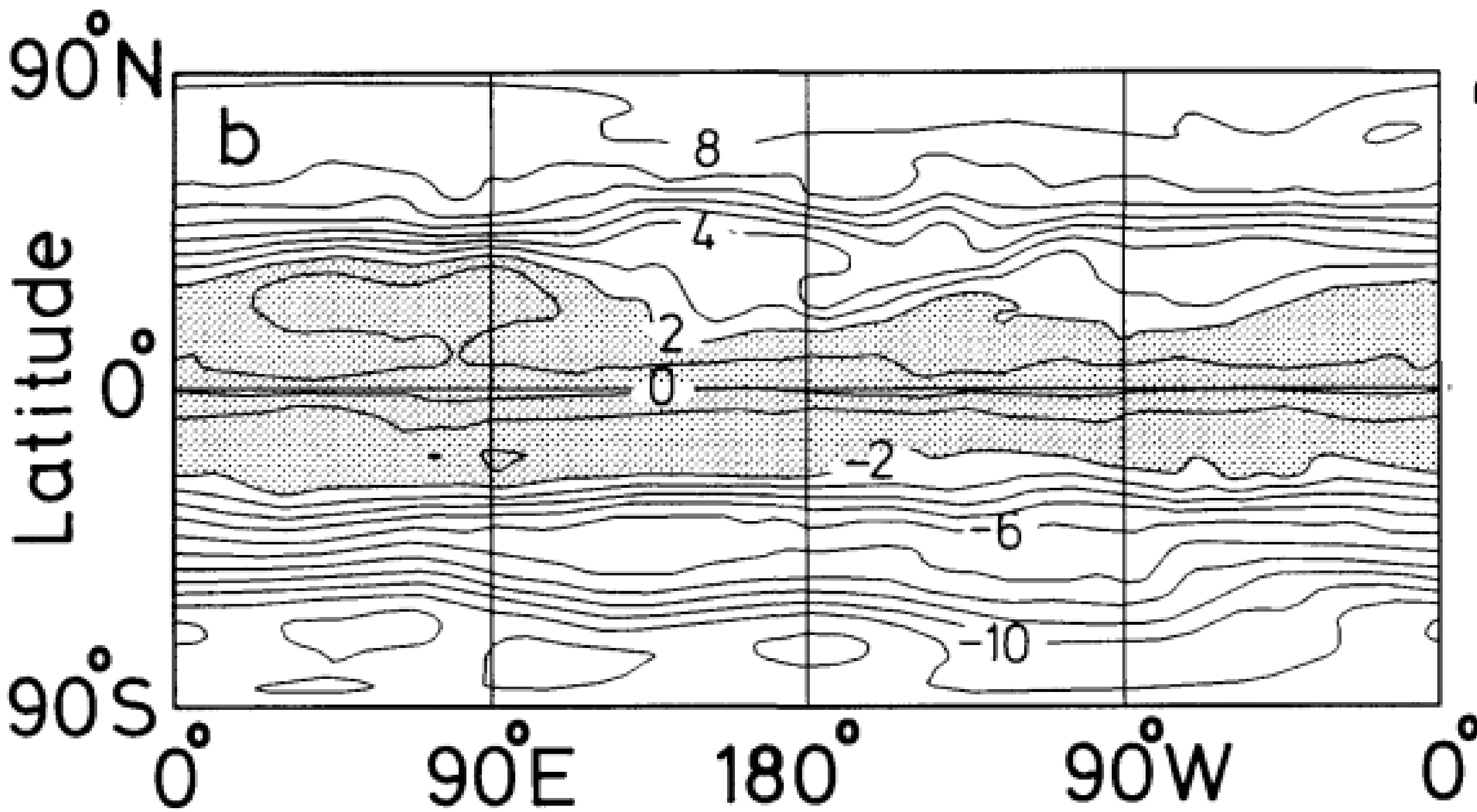
$$R = R_r + R_c + R_o$$

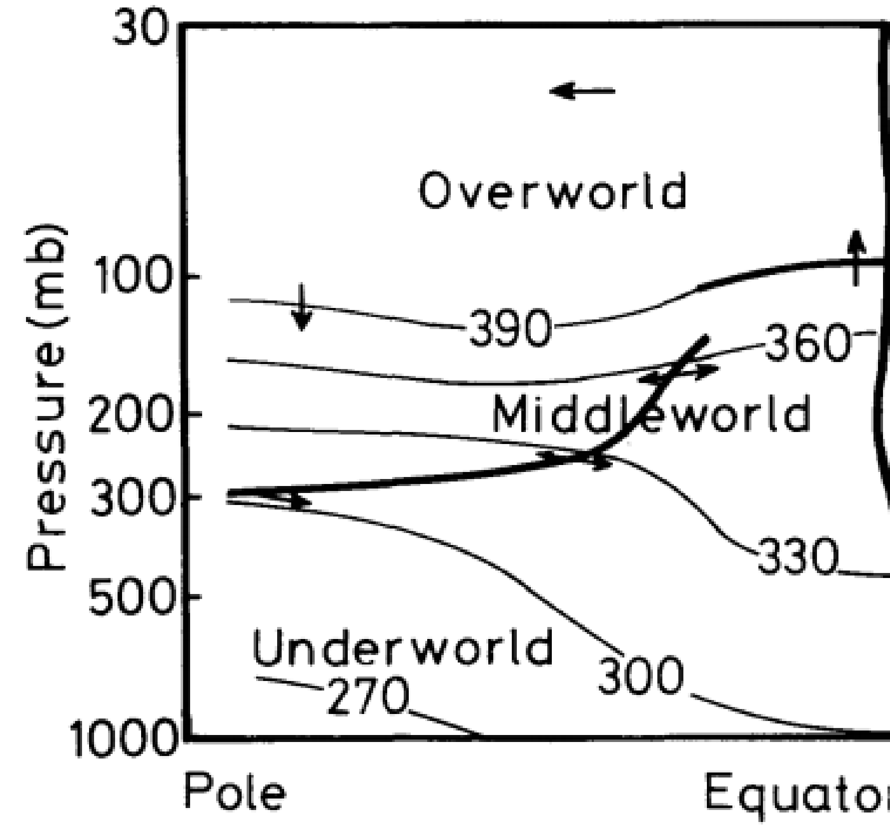


Terao et al. (in prep.)

AMA is in the Middle World

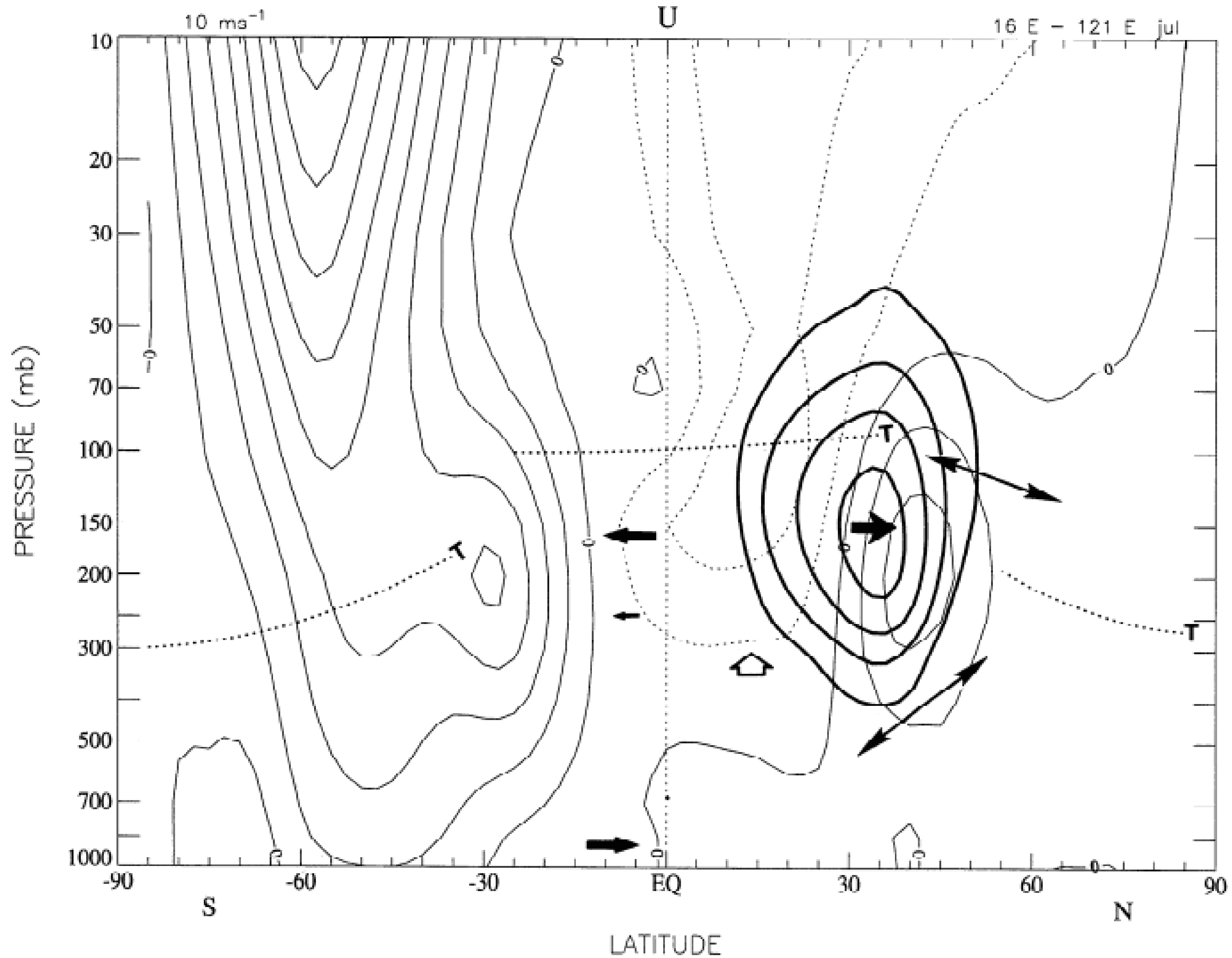
- Hoskins (1991)





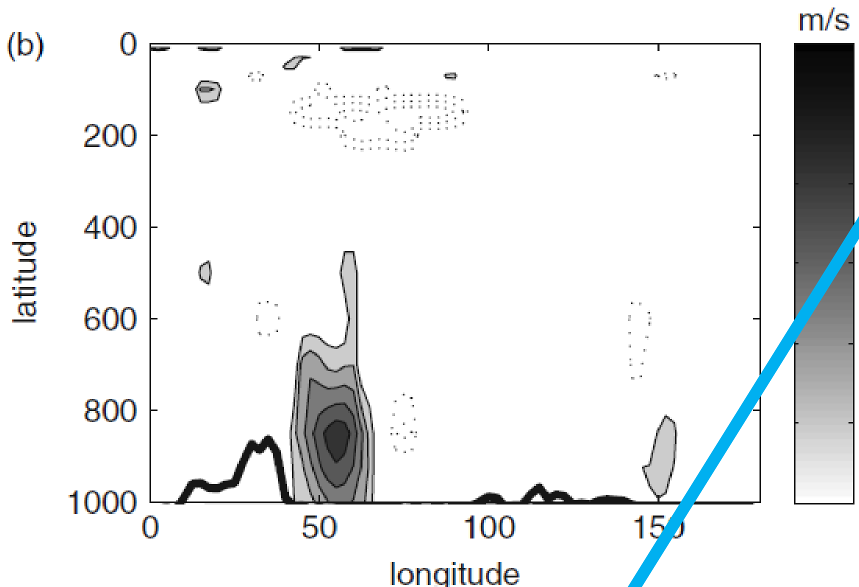
Asian Monsoon and TSE

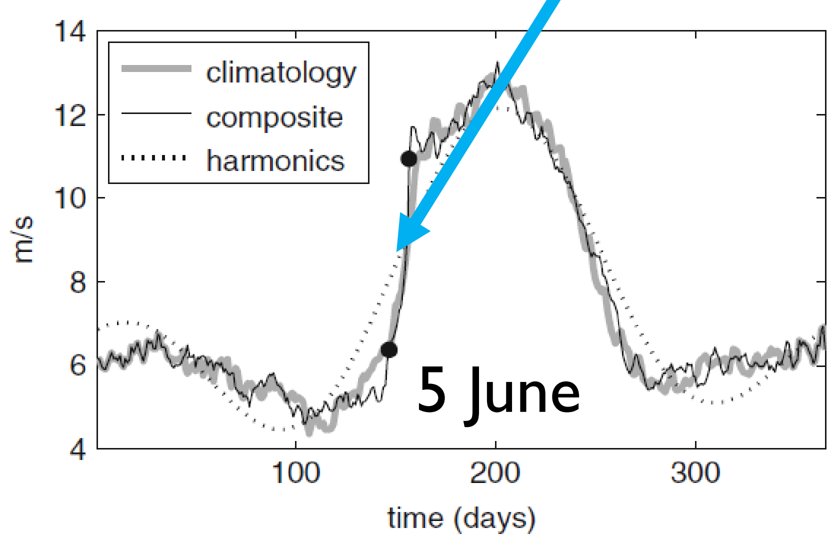
- Dunkerton (1995)

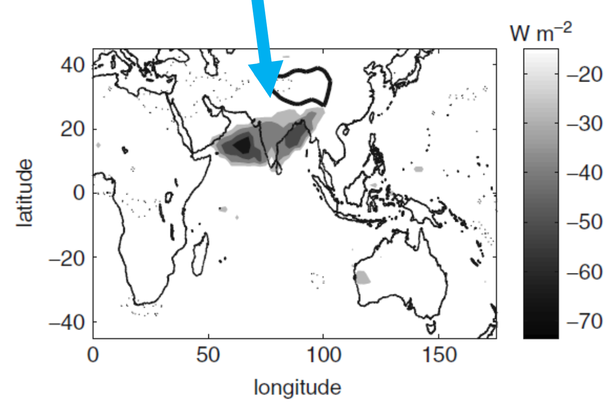


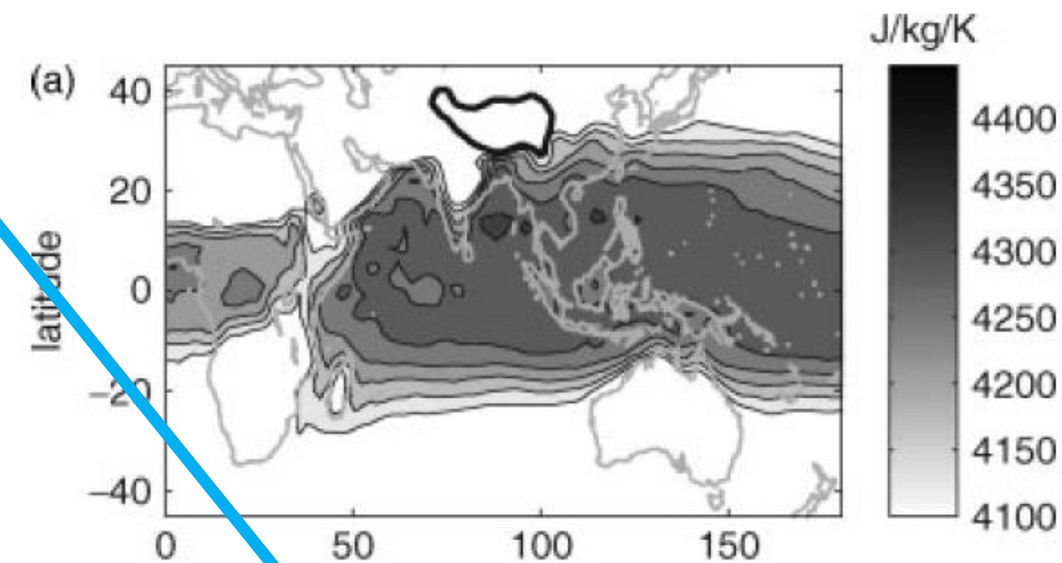
Asian monsoon-SA Moist Static Energy

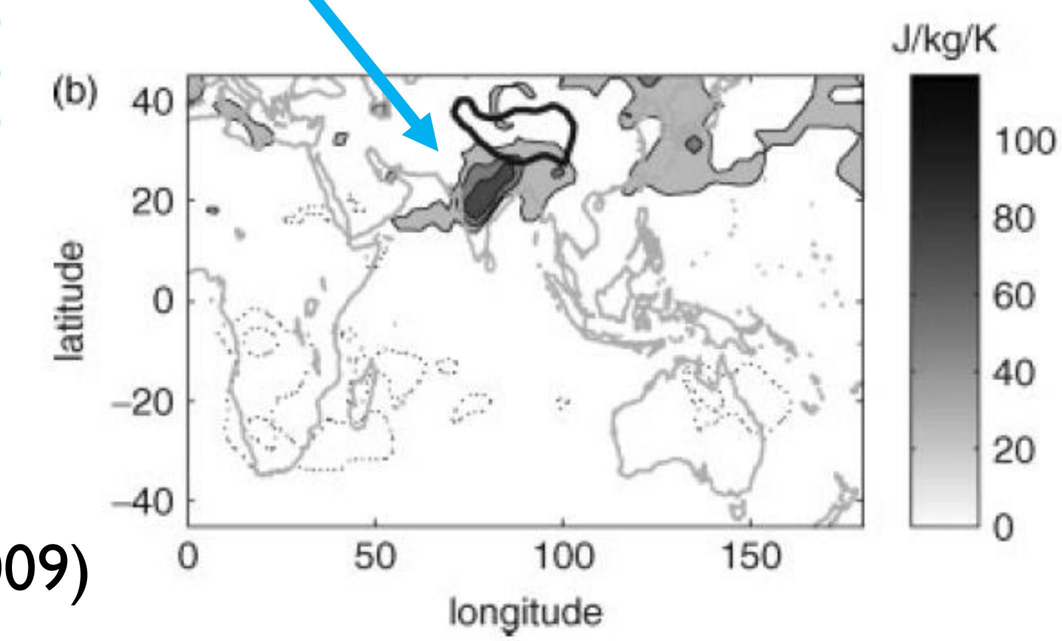
- Abrupt Monsoon SW jet onset is strongly correlated with increase in Moist Static Energy (MSE) over South Asia









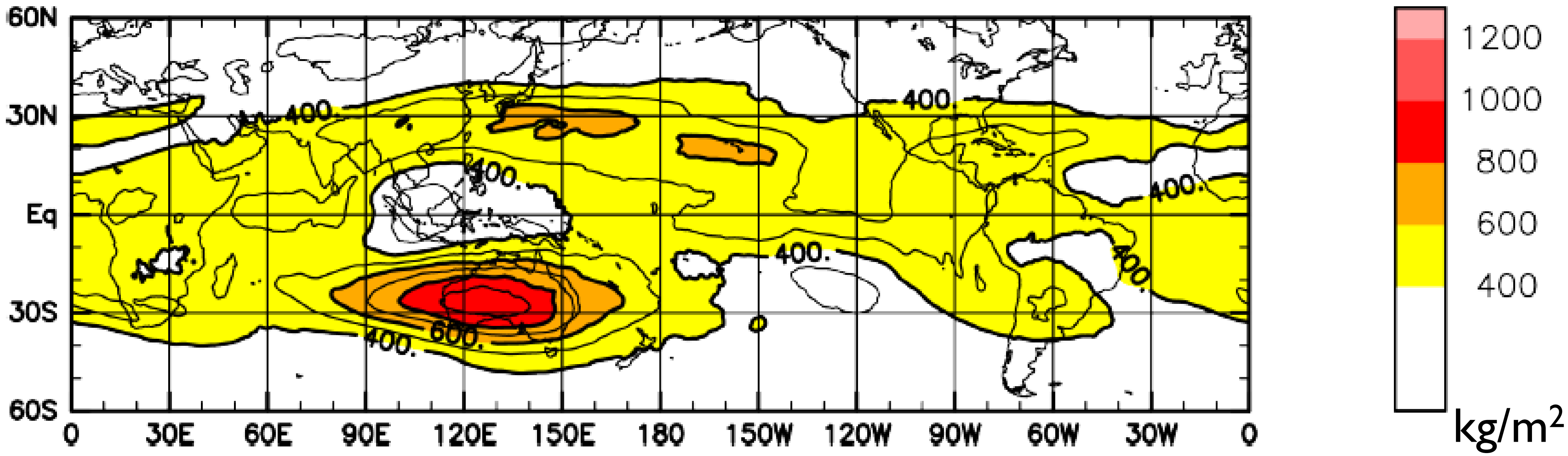


Boos and Emanuel (2009)

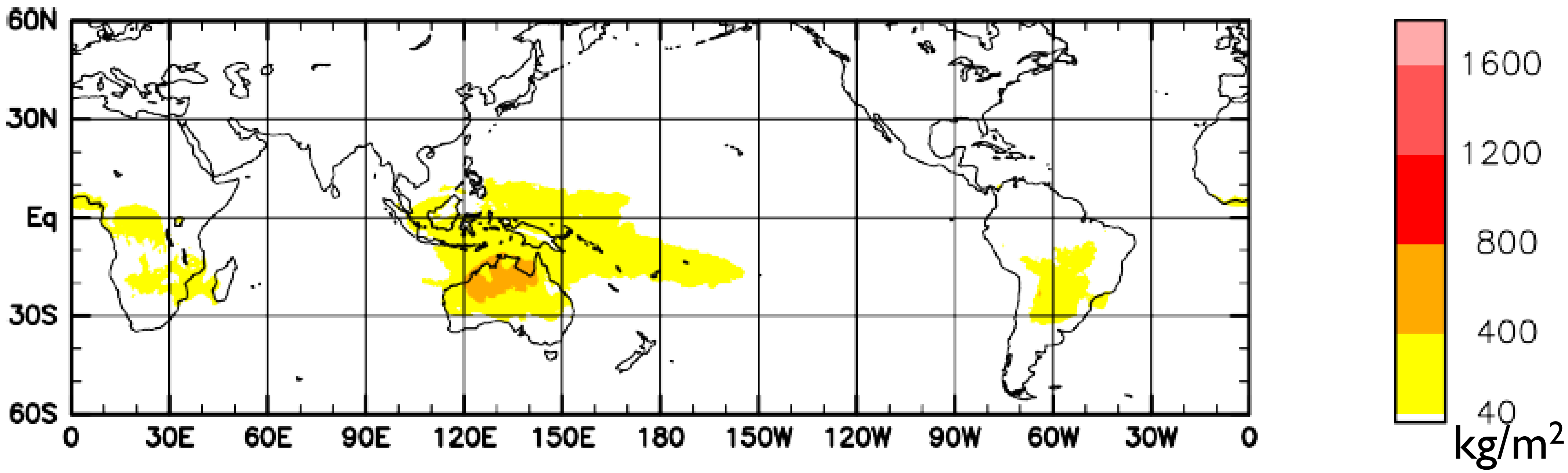
LT-HMSEA/UT-HDSEA View of Asian summer monsoon

LT-HMSEA/UT-HDSEA: Jan. 2017

(a) HDSEA / January 2017

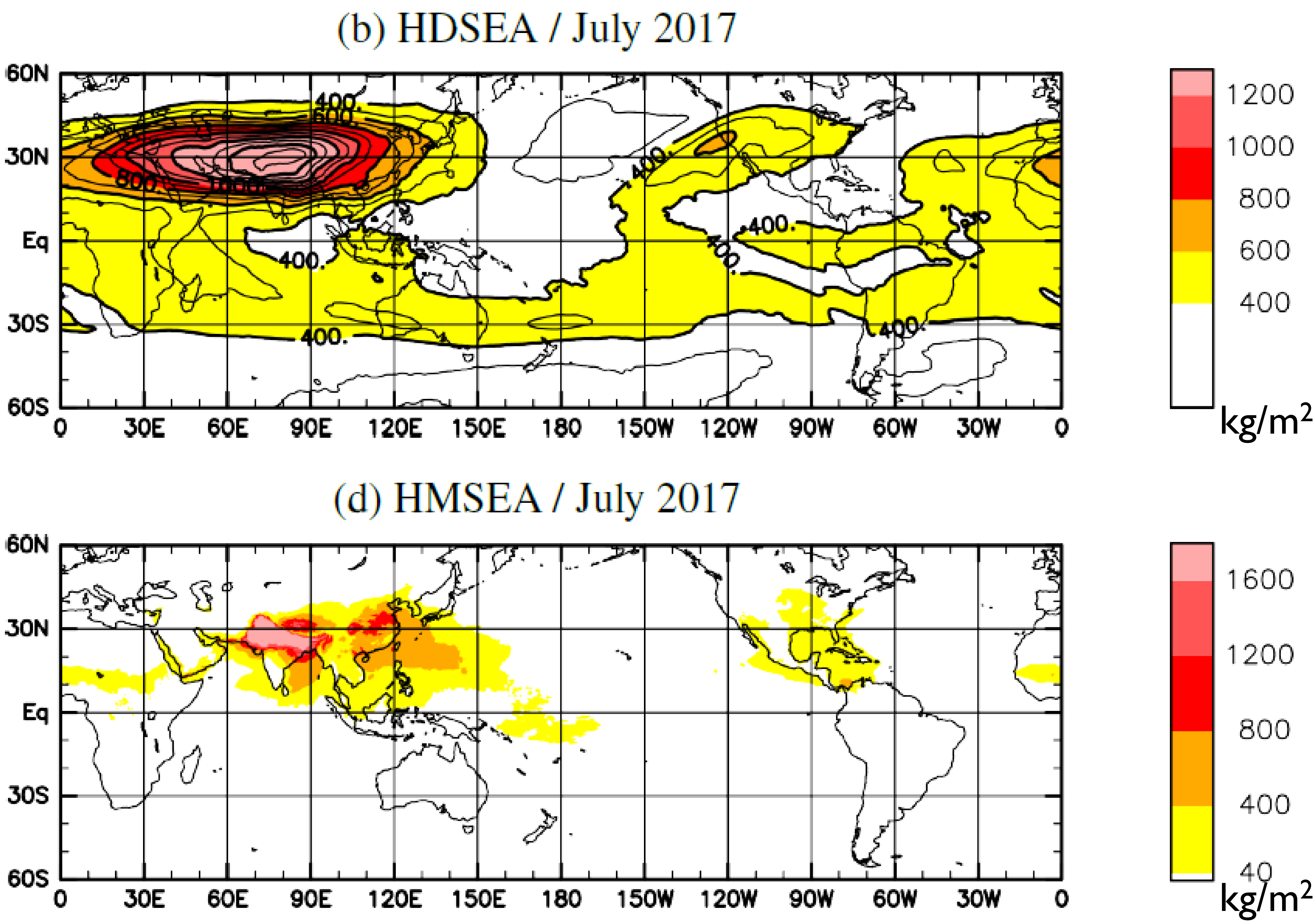


(c) HMSEA / January 2017



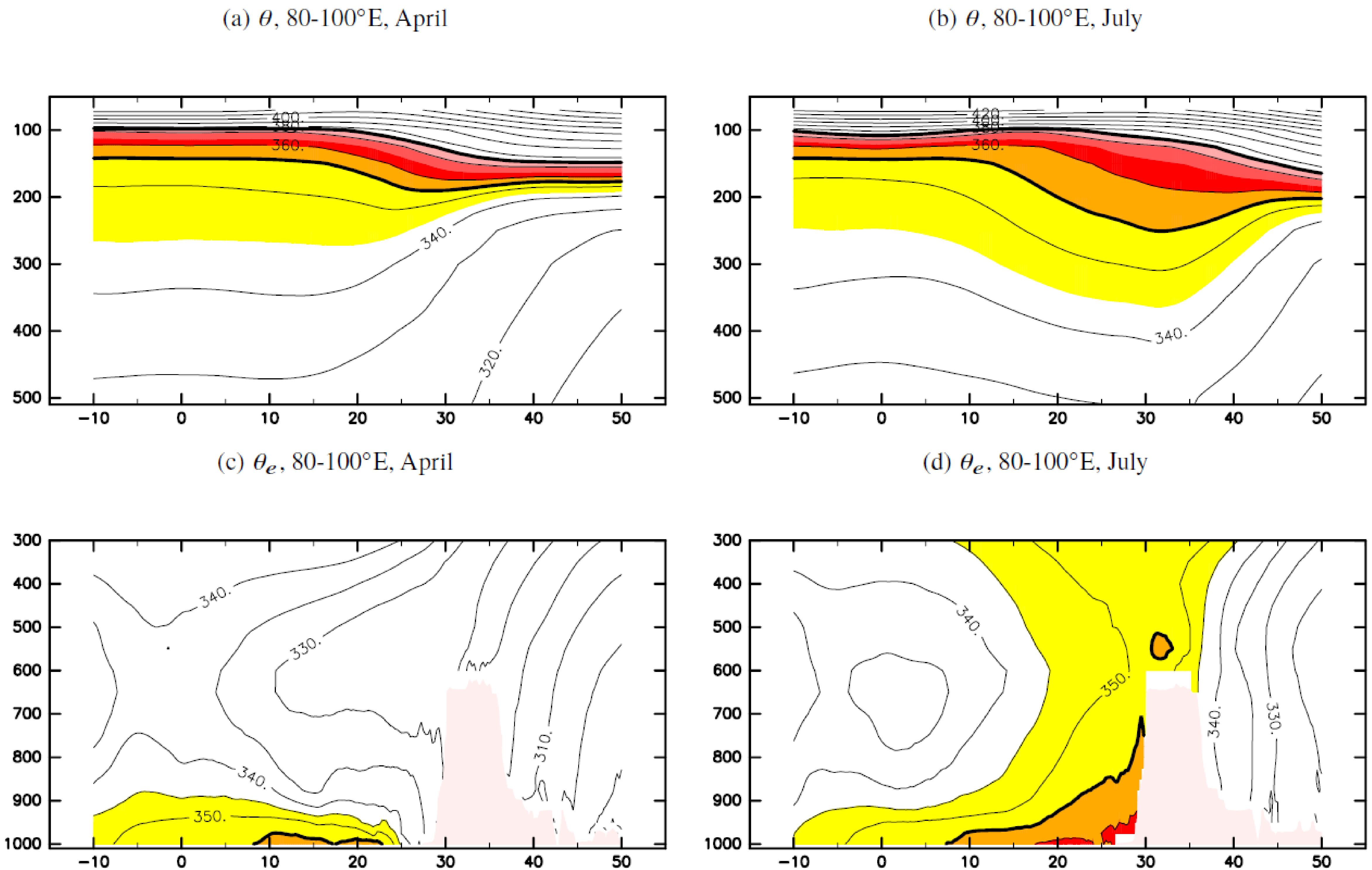
Terao et al. (in prep.)

LT-HMSEA/UT-HDSEA: Jul. 2017



Terao et al. (in prep.)

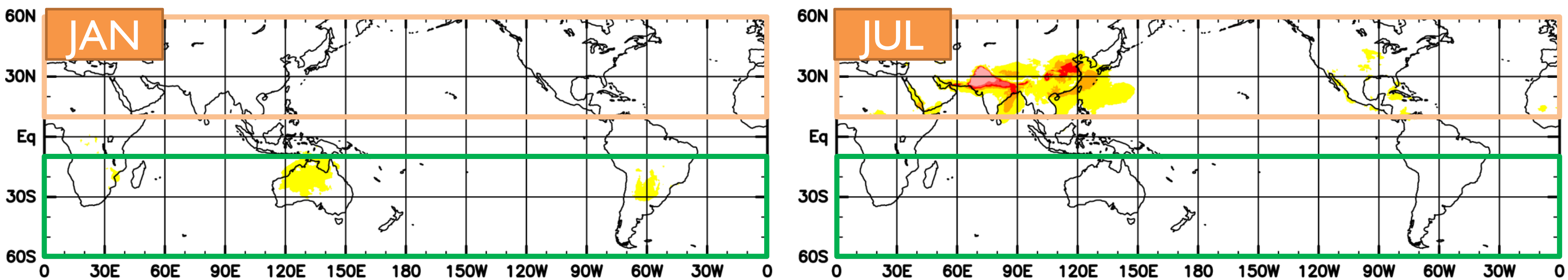
Meridional section of θ and θ_e.

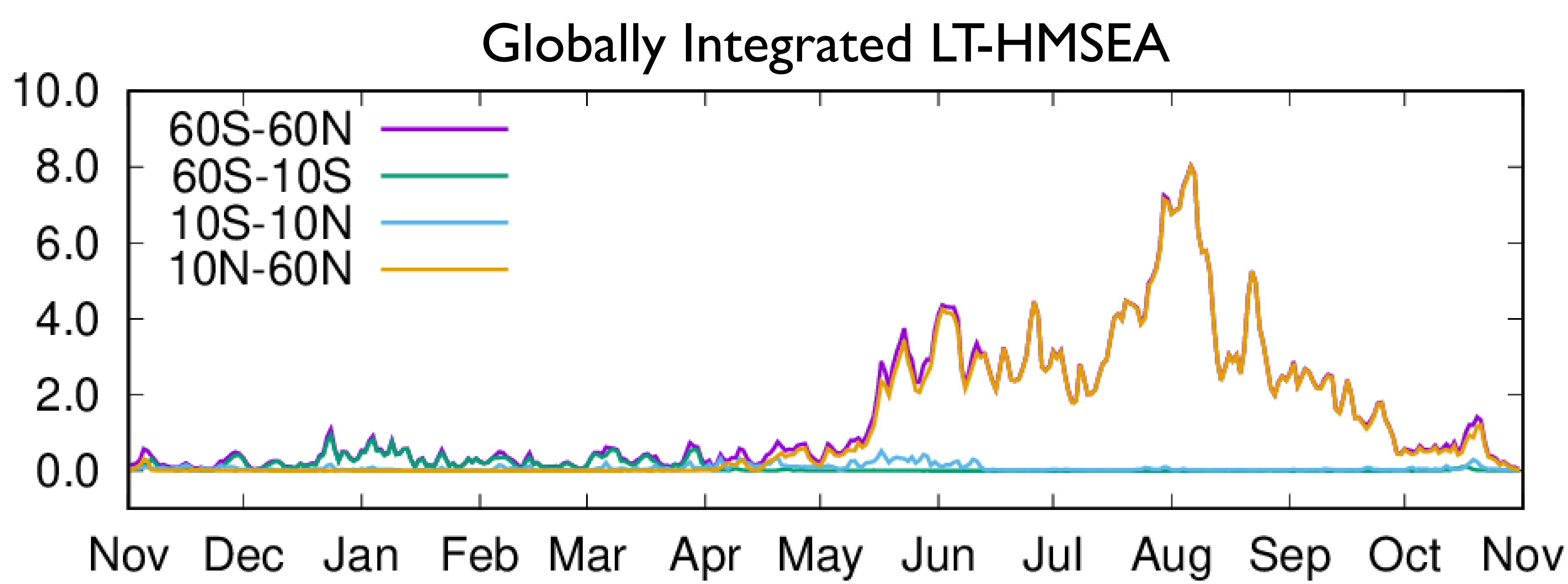


Terao et al. (in prep.)

LT-HMSEA(θ_e>360K, p>400hPa)

- LT-HMSEA strongly concentrates on Asian monsoon region especially in South Asia in boreal summer.

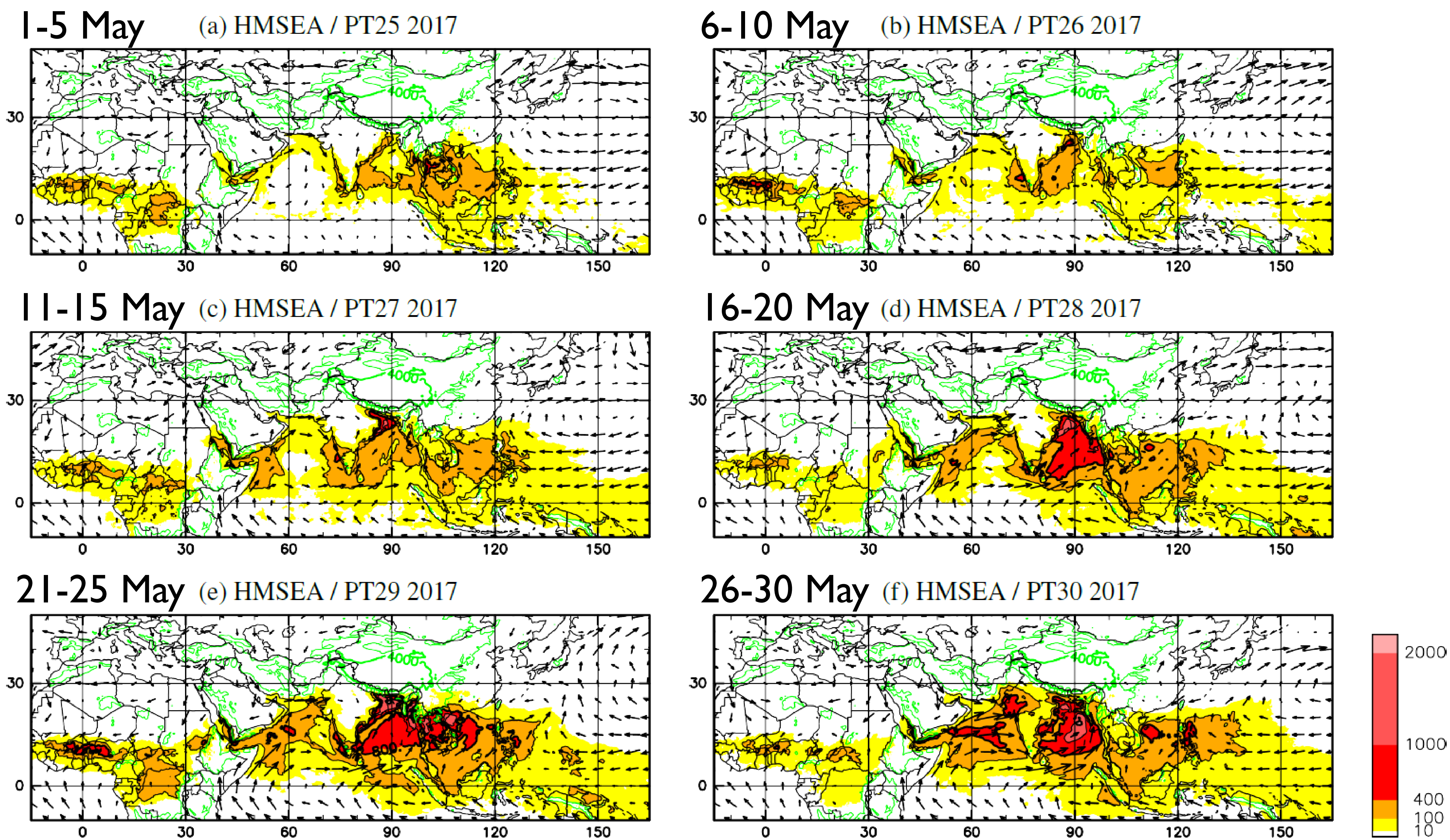




Terao et al. (in prep.)

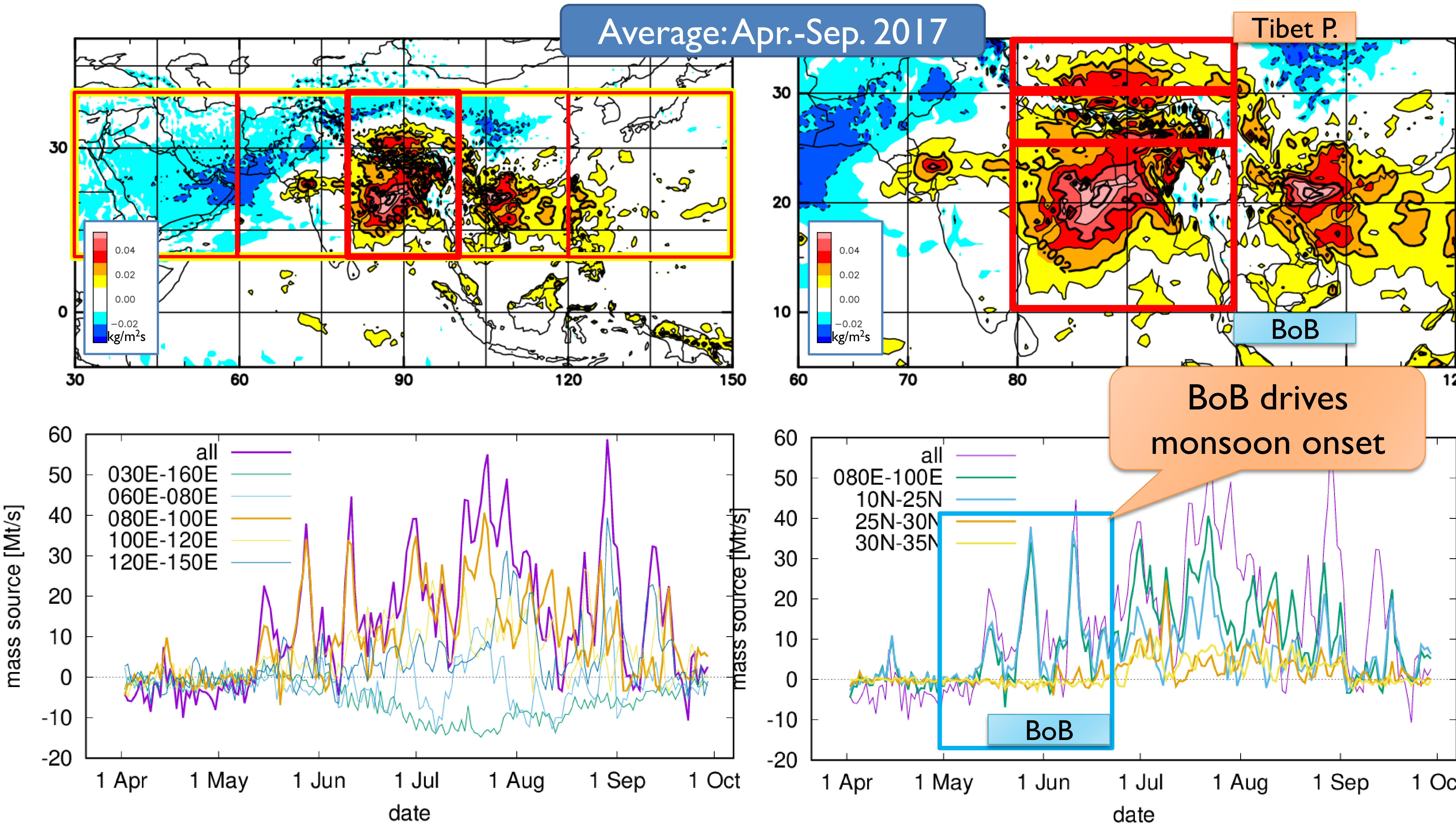
Initial LT-HMSEA increase around BoB

2017



Terao et al. (in prep.)

UT-HDSEA Source Term



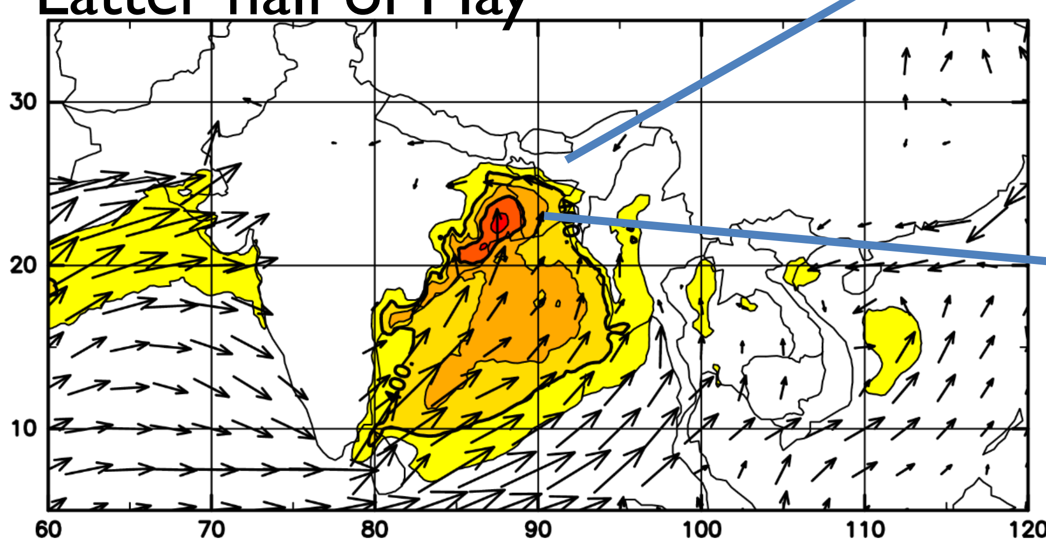
Terao et al. (in prep.)

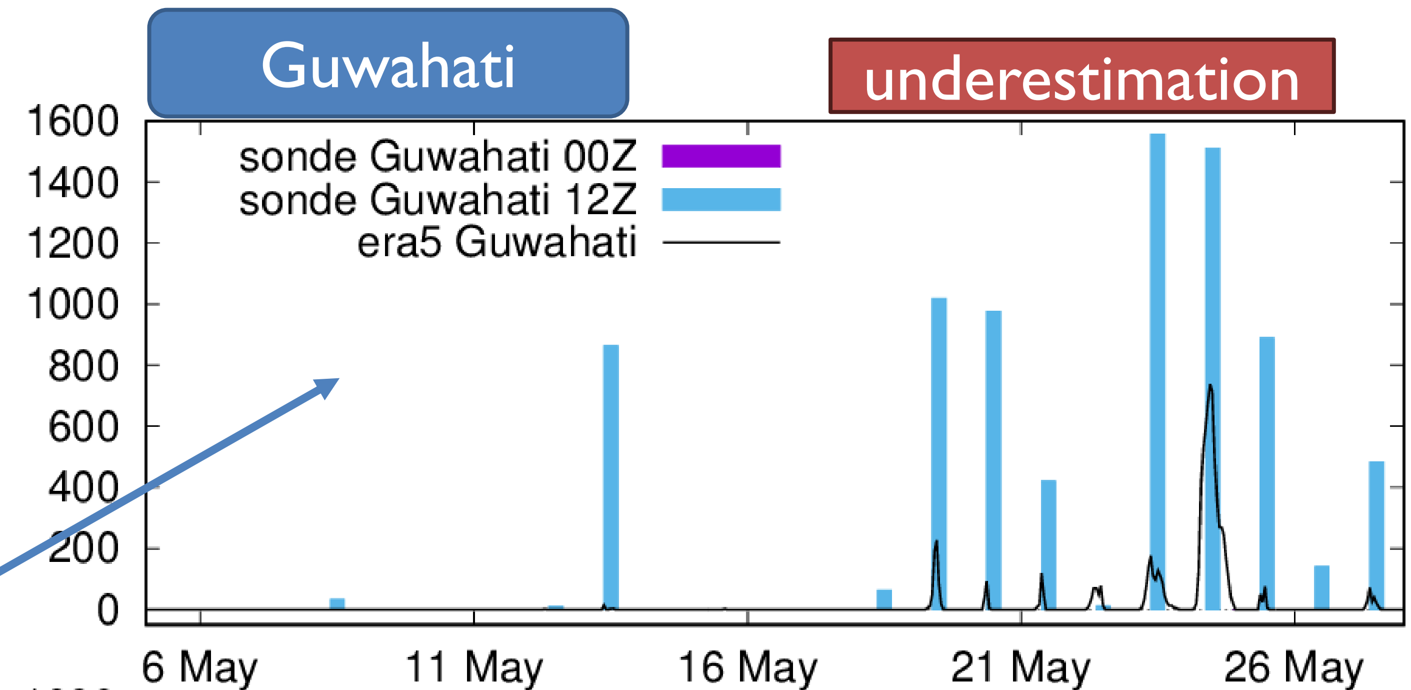
Comparison with Local Sonde Obs.

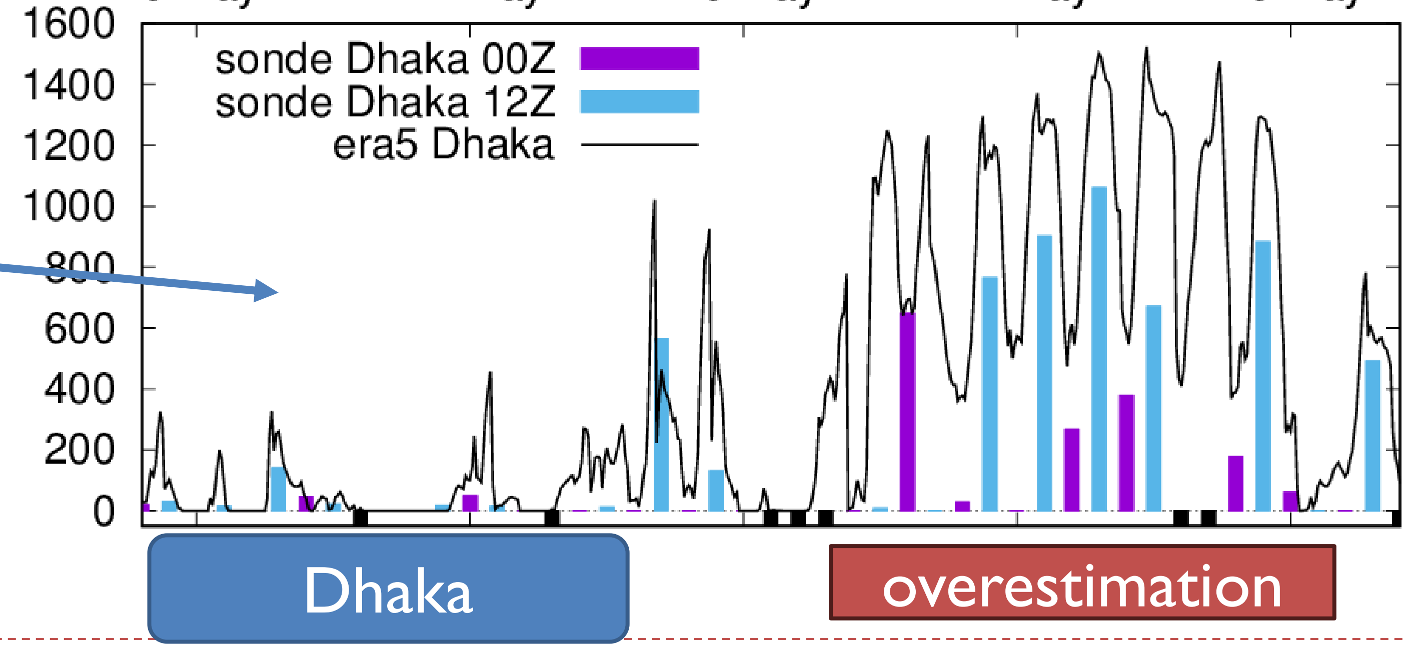
- Large diurnal variation / inconsistency

Sonde:
from Univ. of Wyoming
For 2017

Latter half of May







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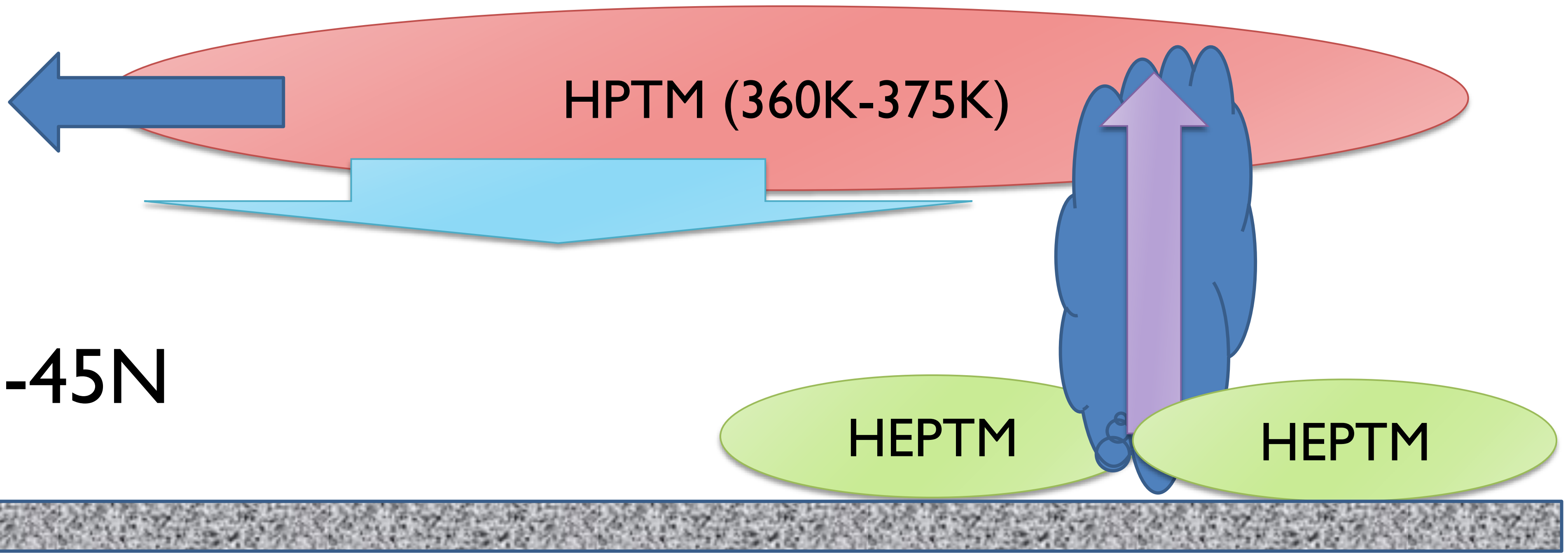
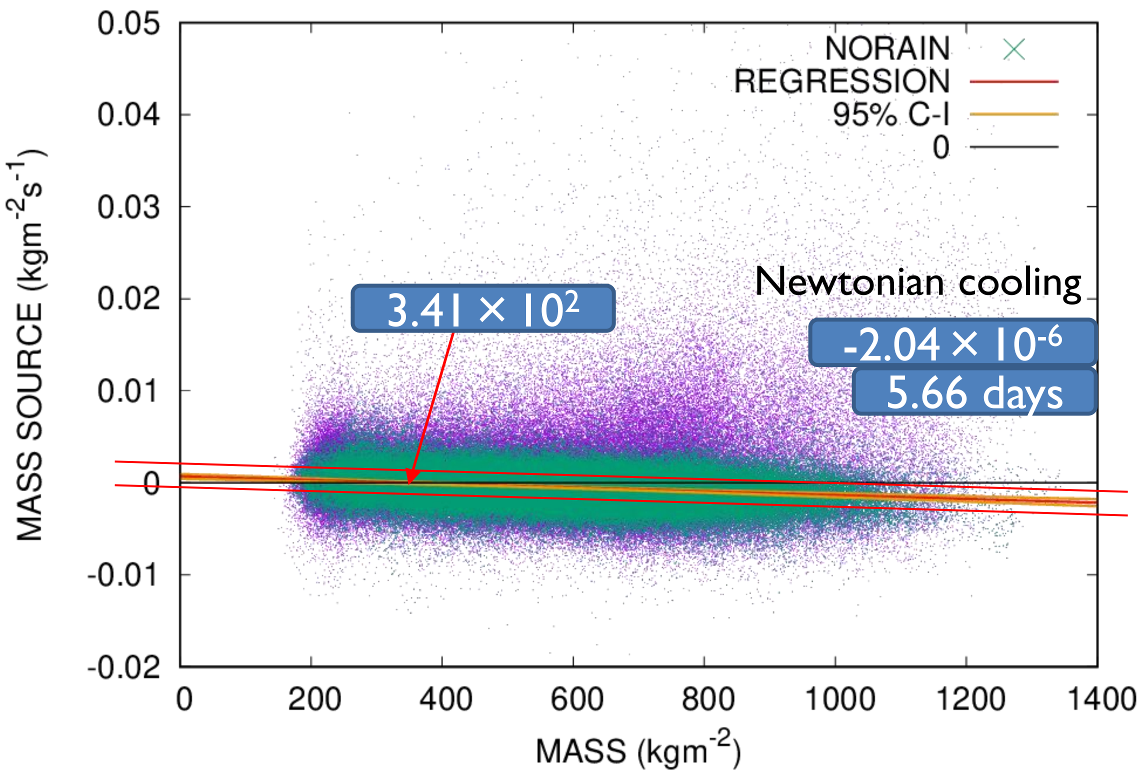
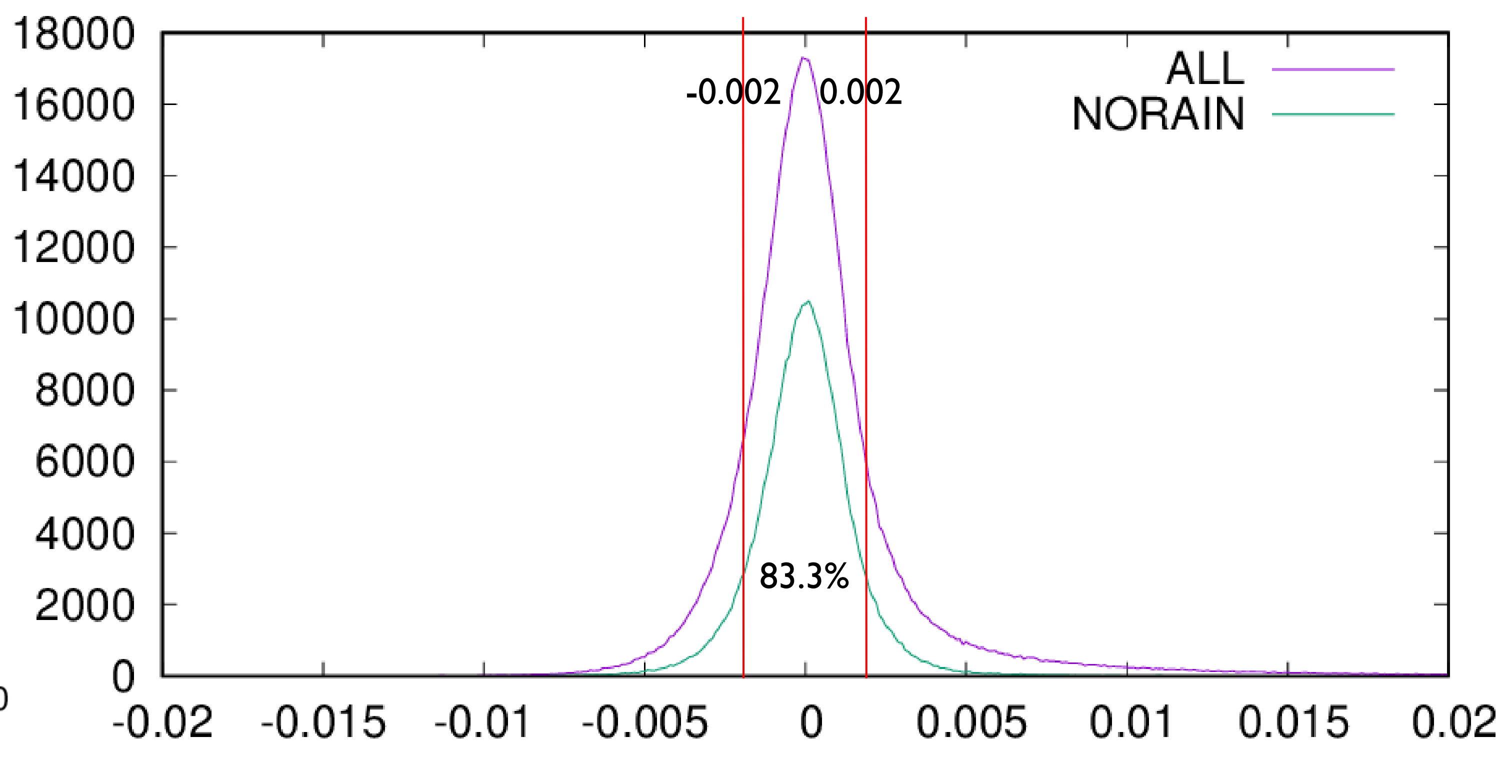
Mass vs. Mass source/Regression



- Jul.-Aug.
- 30-120E / 15-45N





Terao et al. (in prep.)

AsiaPEX and Field Campaign

AsiaPEX Kick-off Conference

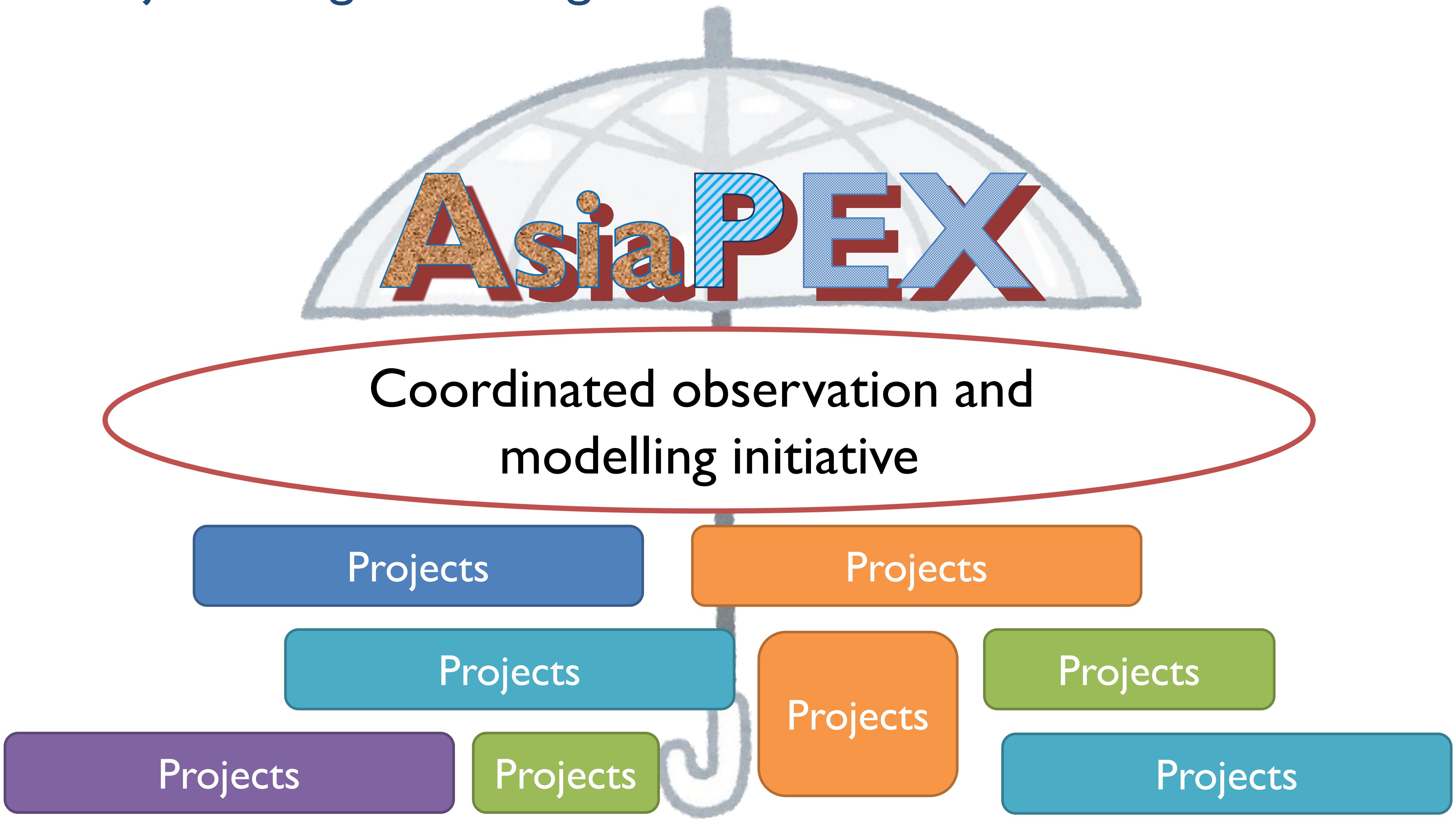
- Date: 28-30 August 2019
- Venue: Hokkaido University, Sapporo, Japan
- Participants: 72 from 10 countries
  - Philipping, Vietnam, Indonesia, Bangladesh, Mongolia, Nepal, USA, India, China, Japan
- 7 Sessions, 61 Presentations including 16 posters

Objectives of the AsiaPEX

- General Objective
  - Understanding of Asian Land Precipitation over Diverse Hydroclimatological Conditions: For Better Prediction, Disaster Reduction and Sustainable Development

AsiaPEX as an umbrella

- Coordination of individual research activities
  - Project design / funding source / interaction with GEWEX

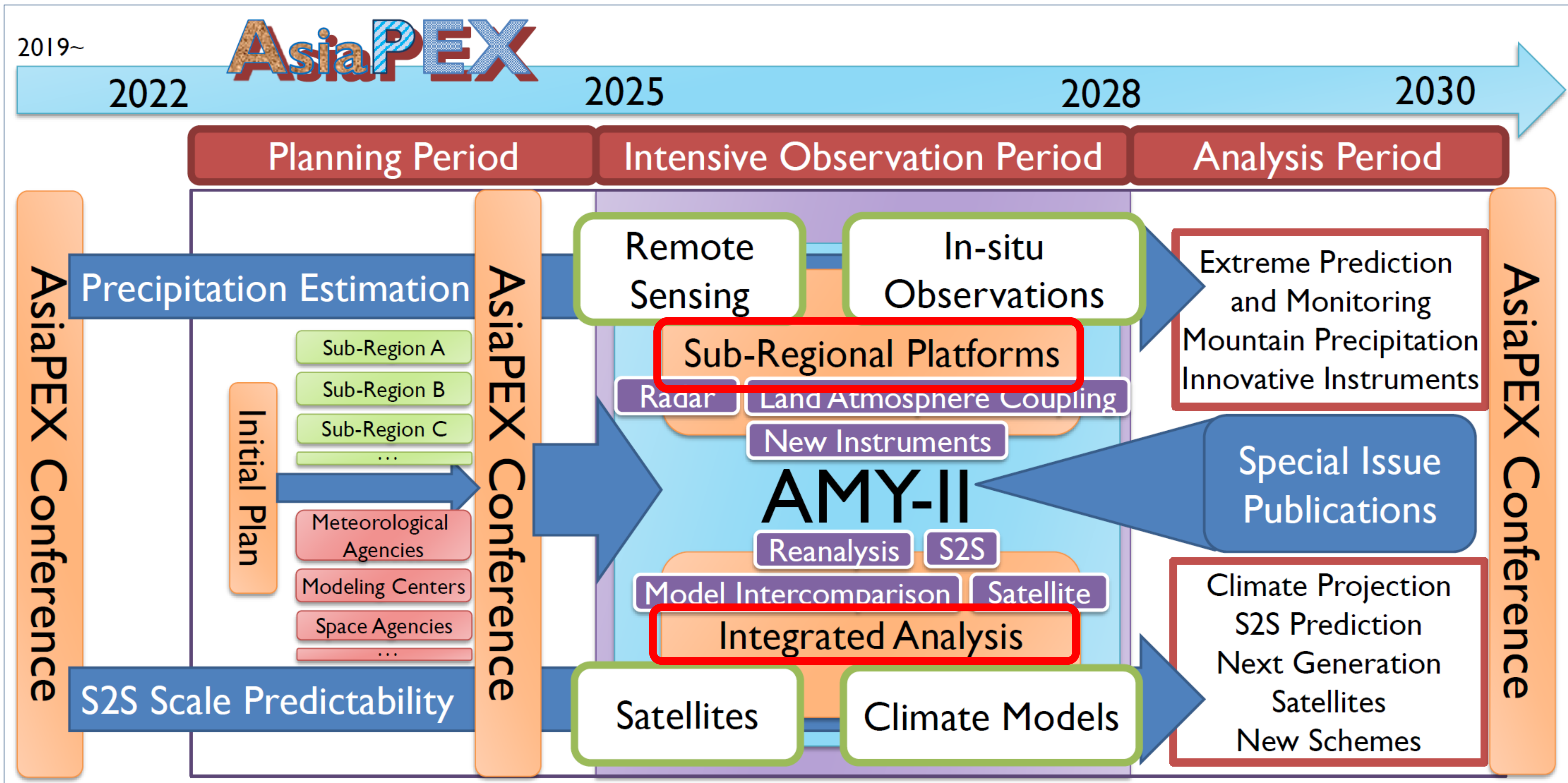


5 Observational and Modeling Initiatives

Field Campaign: Asian Monsoon Year-II

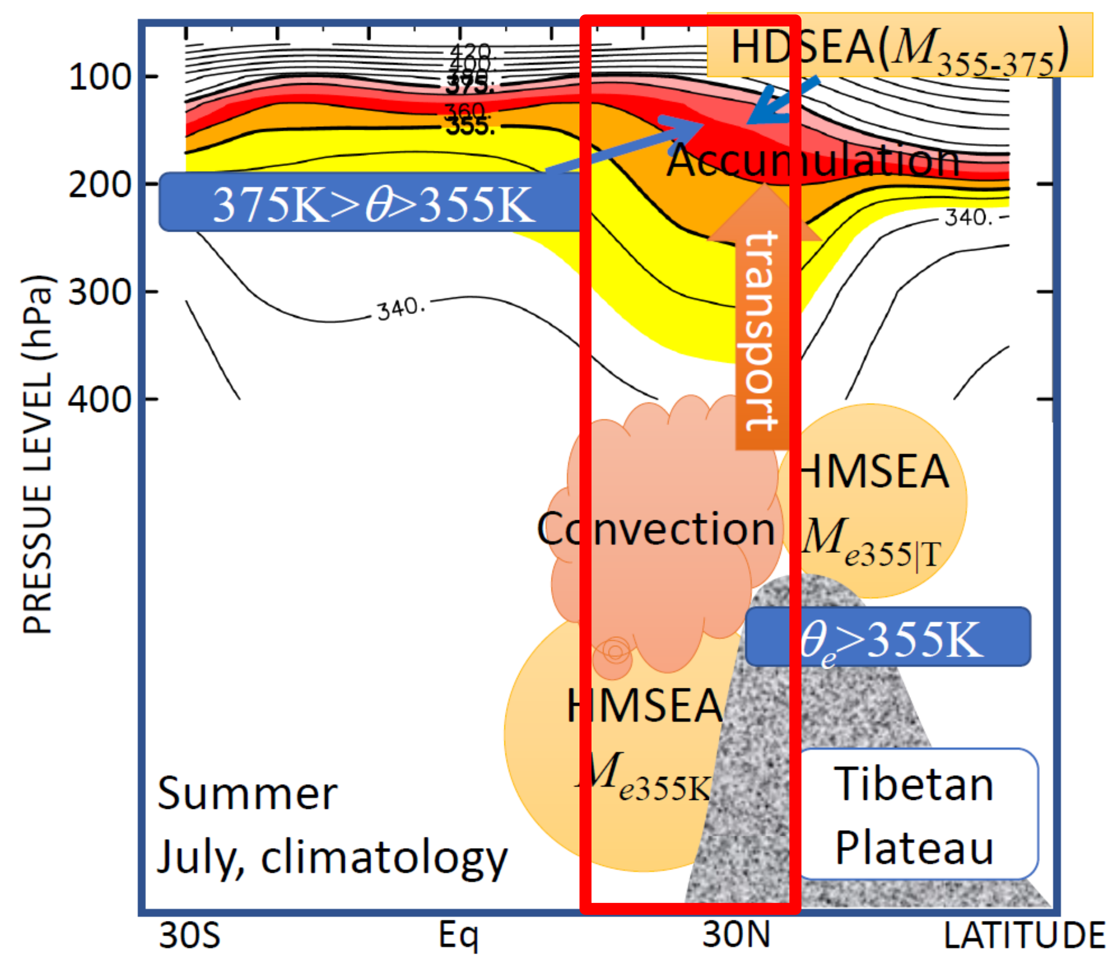
Two Strategic Approaches:

1) the subregional process-oriented coordinated observation platforms at scales of tens to hundreds of kilometers with collaborative observations and
2) integrated analysis using global modeling, reanalysis, and remote sensing dataset that can be underpinned by subregional observation platforms.

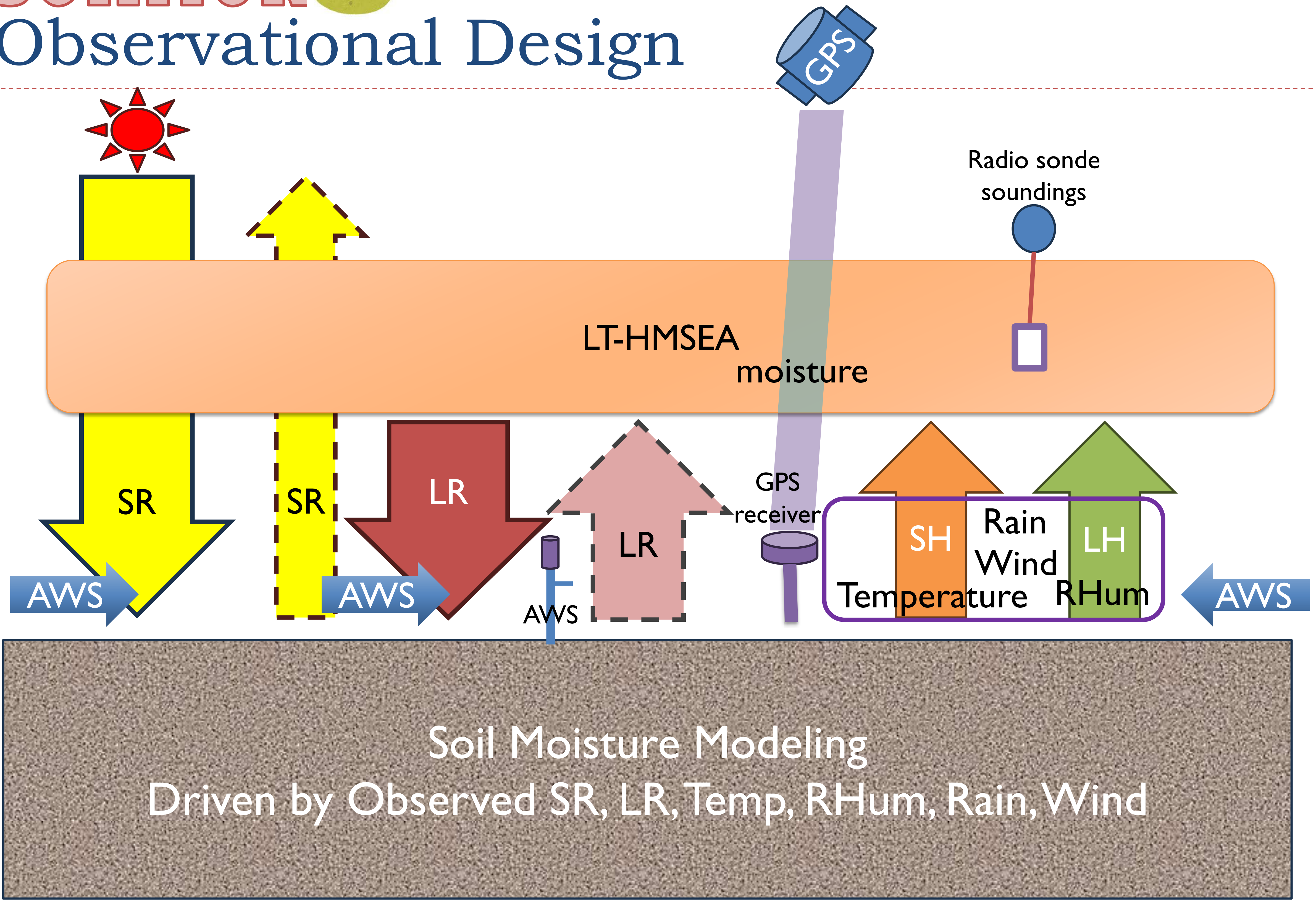


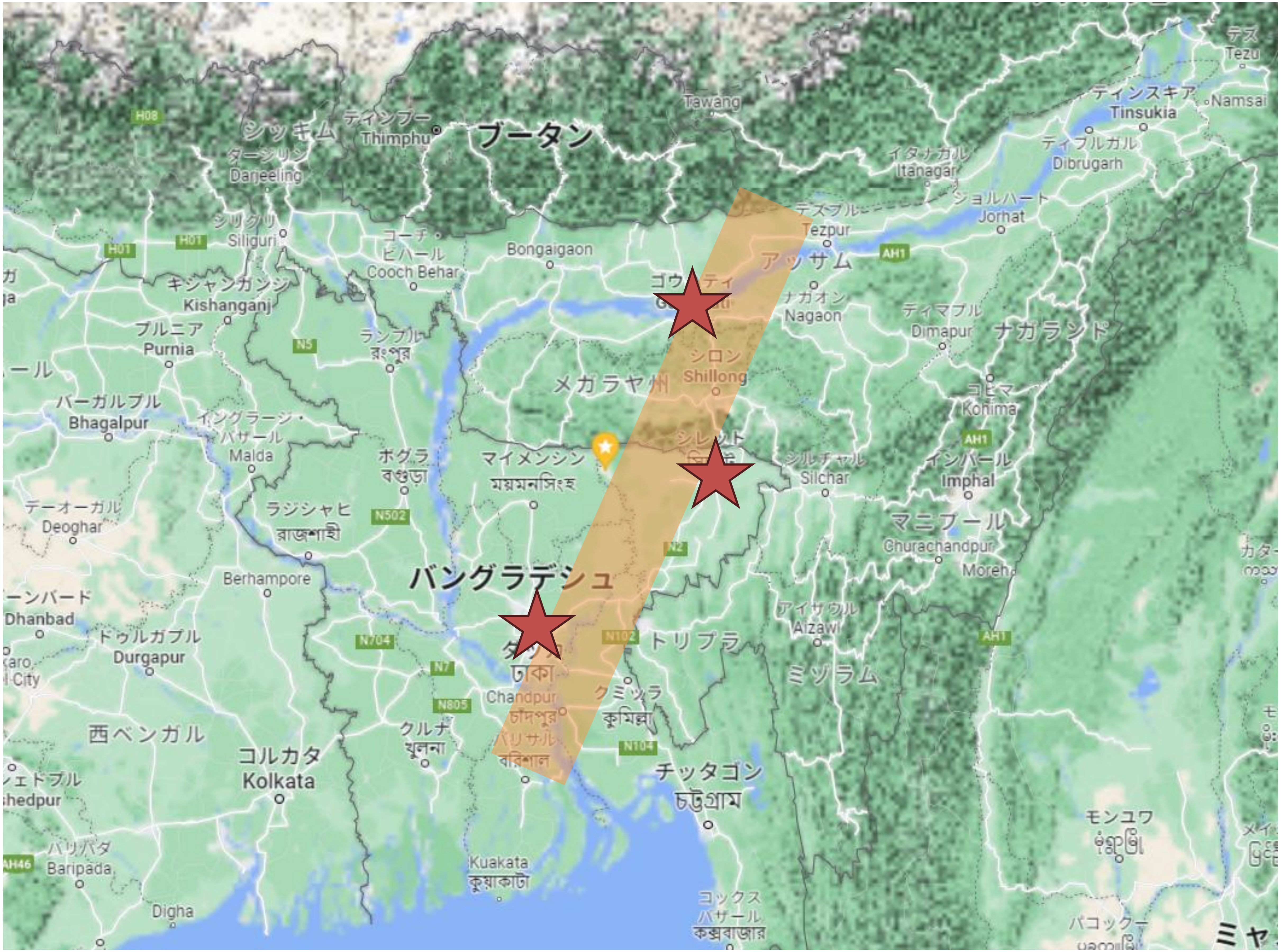
Intensive Obs. In 2024

- Acc. process of LT-HMSEA over NE-Indian subcontinent
  - Focus: May-Jun, monsoon onset process
- Observation plan in 2024 around monsoon onset season
  - Dhaka, Sylhet (with BMD), Guwahati (with IMD)
    - Rawin-sonde, 4-times daily, ~10days
    - Precipitable water by GPS receivers
    - Surface observation by AWSs
- Combined with
  - Land surface modeling
  - Hi-res. reanalysis dataset
- Other observational platforms?



SOHMON Observational Design





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Darjeeling
イタナガル
Itanagar
ディブルガル
Dibrugarh
テズプル
Tezpur
ジョルハート
Jorhat
シリグリ
Siliguri
コーチ・ビハール
Cooch Behar
Bongaigaon
アッサム
キシャンガンジ
Kishanganj
ゴウハティ
ナガオン
Nagaon
ディマプル
Dimapur
ナガランド
プルニア
Purnia
ランプル
シロン
Shillong
メガラヤ州
コヒマ
Kohima
バーガルプル
Bhagalpur
イングラージ・バザール
Malda
シレット
マイメンシン
ボグラ
シルチャル
Silchar
インパール
Imphal
デーオーガル
Deoghar
ラジシャヒ
マニプール
Churachandpur
Moreh
Berhampore
バングラデシュ
ダンバード
Dhanbad
ドゥルガプル
Durgapur
トリプラ
アイザウル
Aizawl
ダッカ
ミゾラム
Chandpur
クミッラ
西ベンガル
クルナ
バリサル
コルカタ
Kolkata
チッタゴン
ジャムシェドプル
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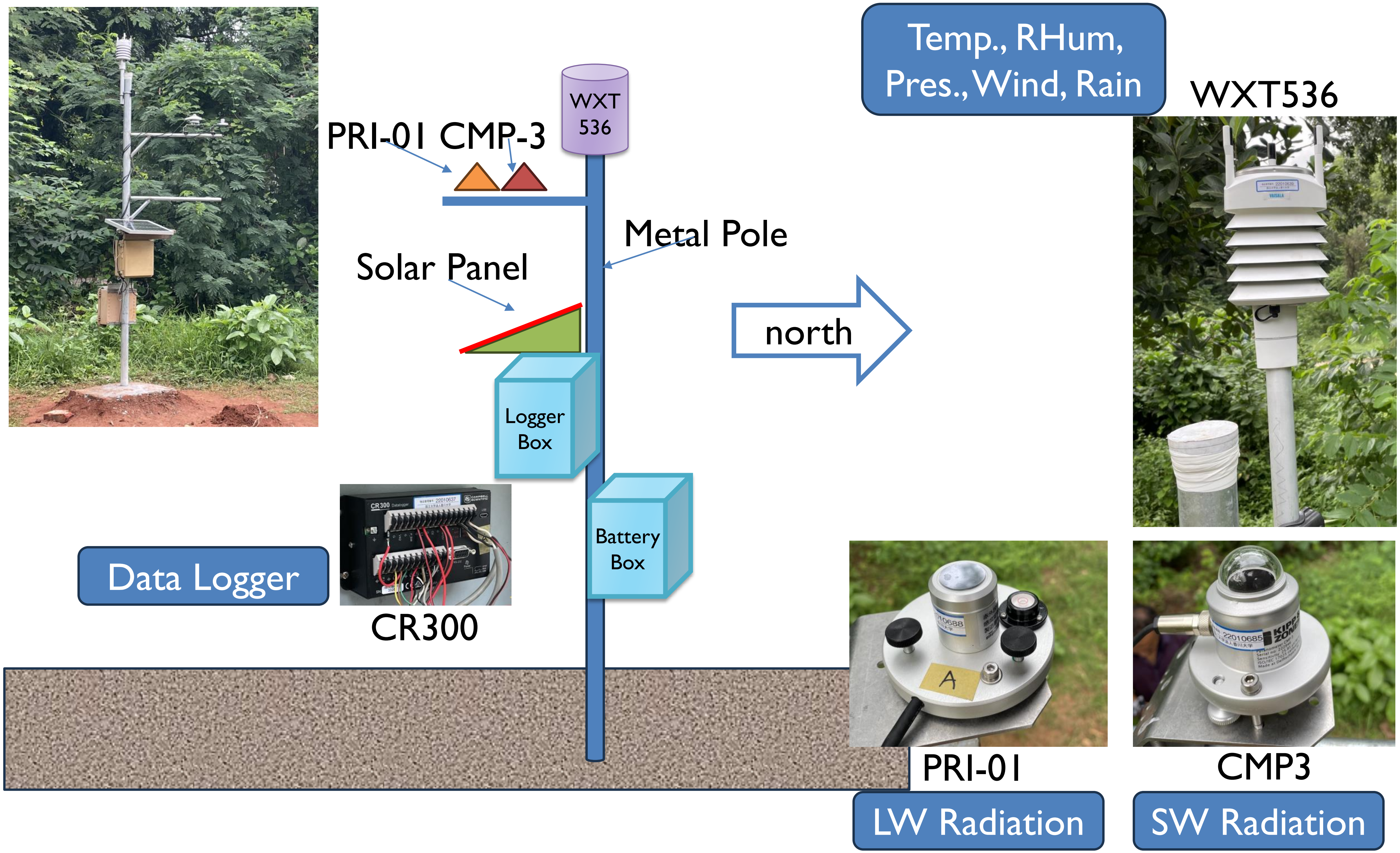
SOHMON Automatic Weather Station



Summary

- Asian summer monsoon atmospheric heating can be diagnosed by LT-HMSEA/UT-HDSEA view
  - LT-HMSEA is airmass $\theta_e > 355\mathrm{K}$ below 400 hPa
  - UT-HDSEA is airmass $375\mathrm{K} > \theta_e > 355\mathrm{K}$ between 500 hPa and 70 hPa
- Both LT-HMSEA and UT-HDSEA are large only over the Asian summer monsoon region.
- We performed case study for 2017 summer.
  - Diabatic source term of UT-HDSEA was large over the Bay of Bengal sector of Asian summer monsoon region.
  - Timing of increase of UT-HDSEA (middle of May) corresponds with appearance of high LT-HMSEA over the Bay of Bengal flowing toward Bengal Plain.
  - Diabatic source of UT-HDSEA was not large over the Tibetan Plateau before July.
- Diabatic source of UT-HDSEA over the pixels without precipitation was well modeled by a simple Newtonian cooling mechanism, indicating radiative cooling, i. e. subsidence in the troposphere.
- Under the AsiaPEX / SOHMON collaboration, we are now conducting a field campaign targeting on the accumulation and ascending process of LT-HMSEA over the Northeastern Indian subcontinent.

Thank you !