

The Warm-Season Diurnal Rainfall Propagation in East Asia: An Update and Application in the Taiwan Mei-yu Season

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Presentation outline

1. Introduction
 2. An update using TRMM 3-hourly rain-rates
 3. Signals in an operational model
 4. Application in the Taiwan Mei-yu season
 5. Summary and conclusion
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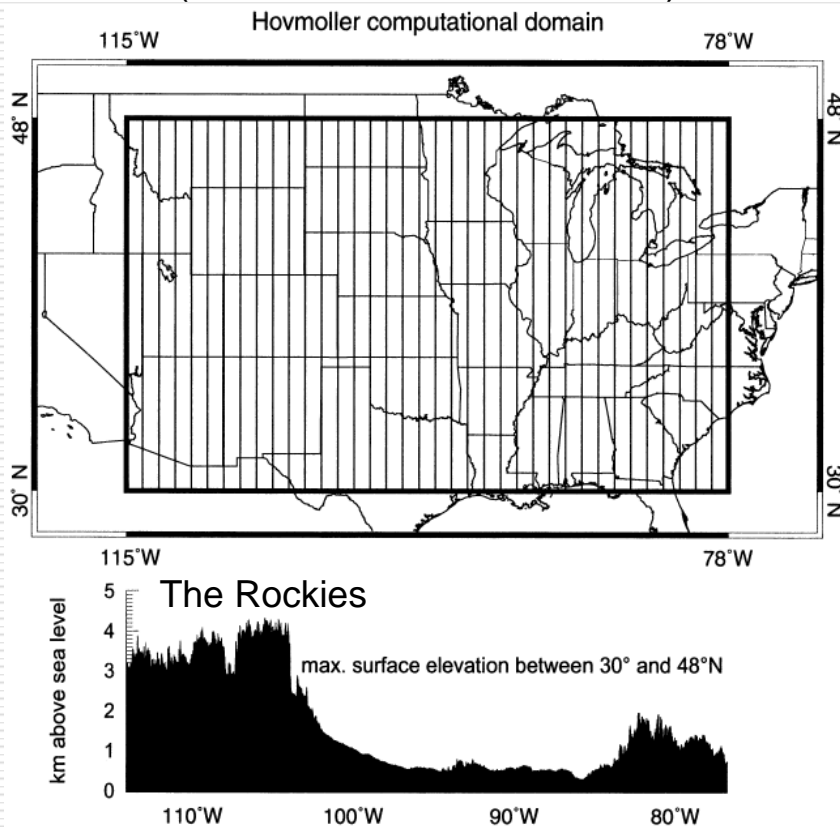
1. Introduction

- Present skills for warm-season quantitative precipitation forecasts (QPFs) are low all over the world
 - One area where improvements can be made is to the lee of major mountains, such as the Rockies in the North America and the Tibetan Plateau (TP) in the East Asia
 - In longitude-time (Hovmöller) space, precipitation/cloud episodes exhibit coherent behavior of downstream propagation
 - Zonal speed at 10-25 m s⁻¹ with westerly steering flow aloft
 - Often consist of multiple organized MCSs
 - Some with long zonal span (>1000 km) and duration (>24 h), suggesting intrinsic predictability
 - Episodes closely tied to elevated terrain (phase-locked):
 - Develop over the eastern slope in afternoon, then propagate eastward (downstream) overnight, sometime into the next day
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- Examples of episodes in the US and East Asia:
 - Calculation domain of Hovmöller plots and terrain elevation

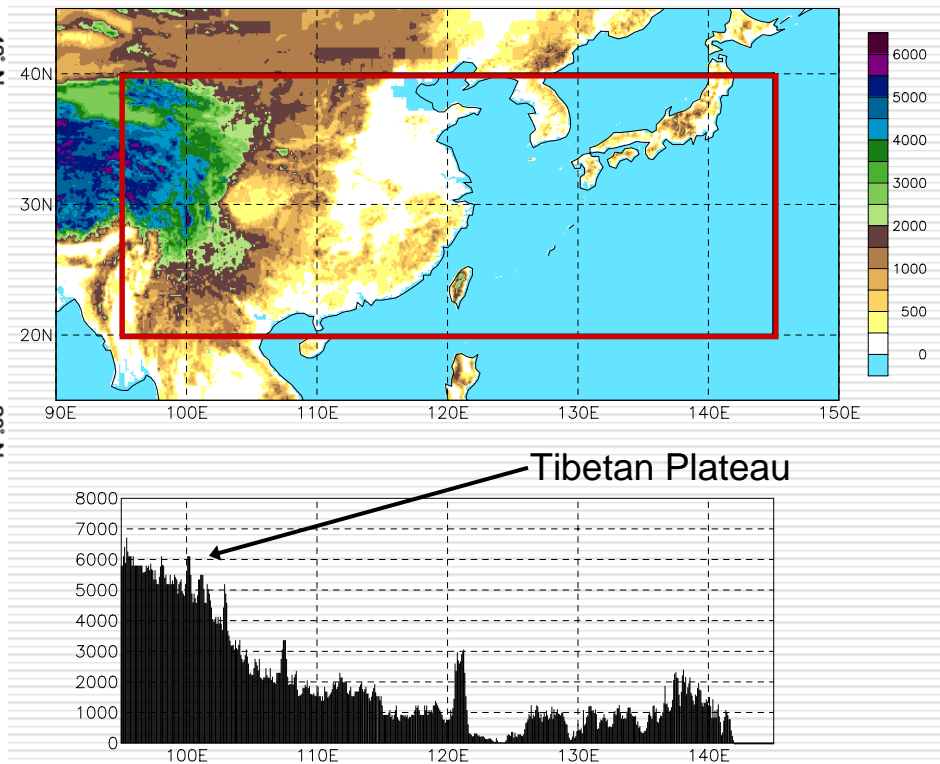
Continental US

(Carbone et al. 2002, JAS)



East Asia

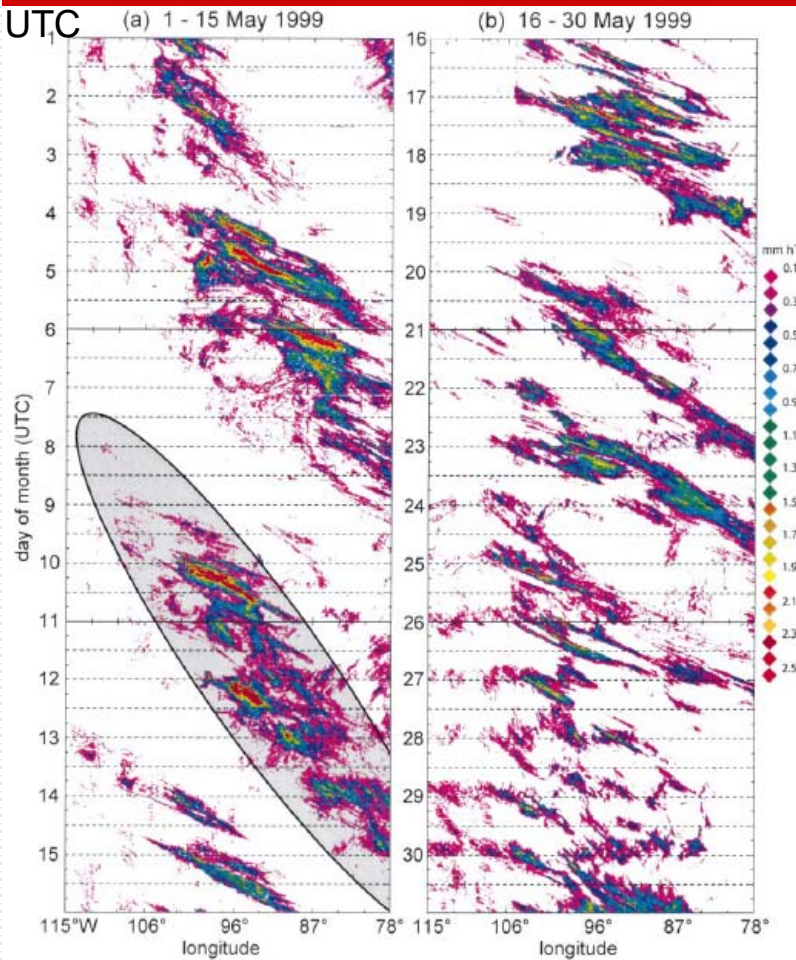
(Wang et al. 2004, MWR)



■ Example in Hovmöller plots for selected month:

Continental US

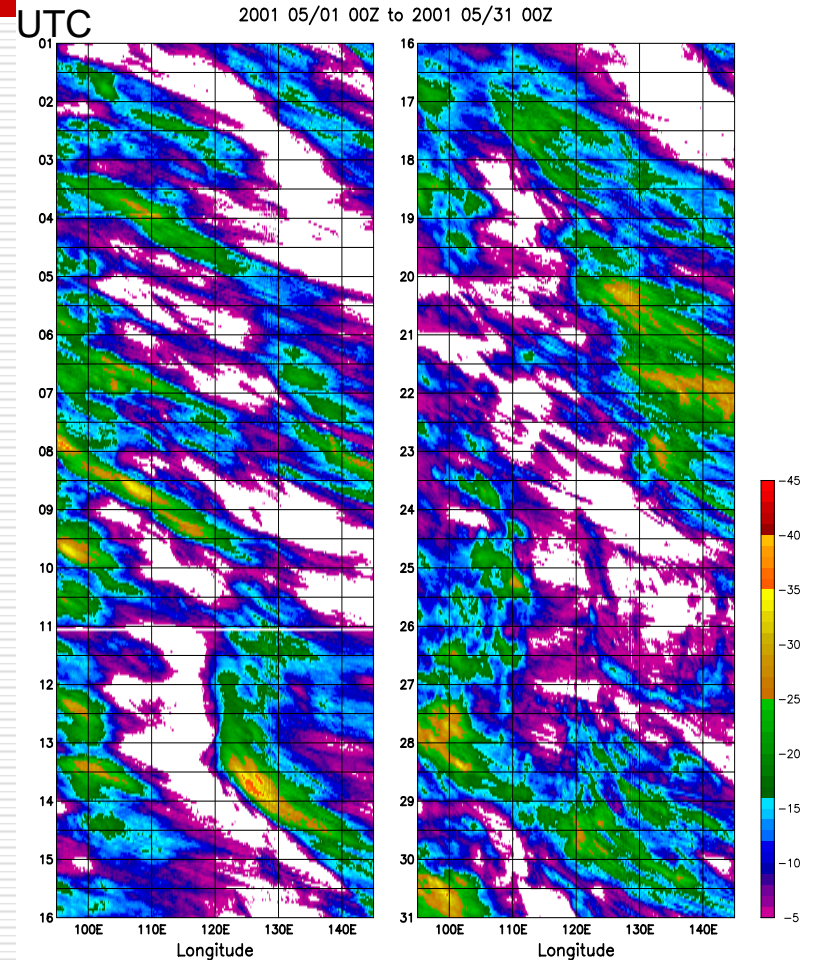
NEXRAD (4 km, 15 min), May 1999



Carbone et al. (2002, JAS)

East Asia

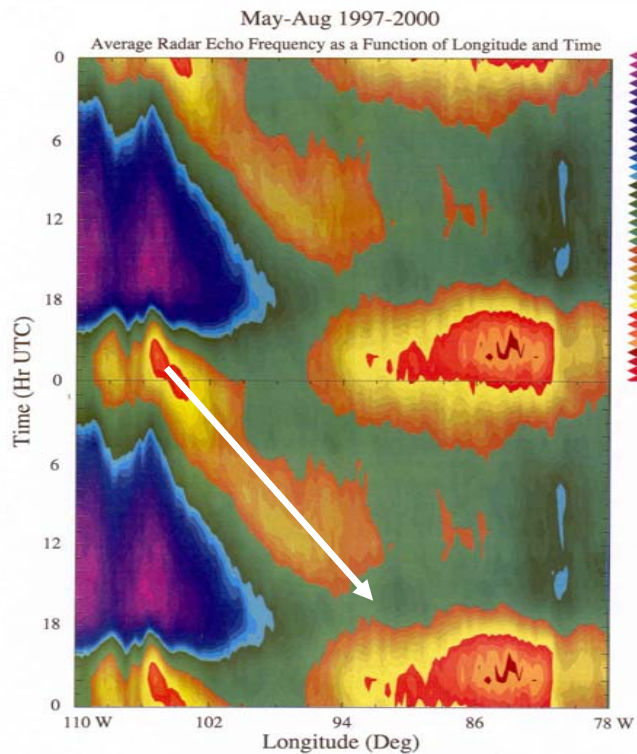
GMS T_B (5 km, 1 h), May 2001



Wang et al. (2004, MWR)

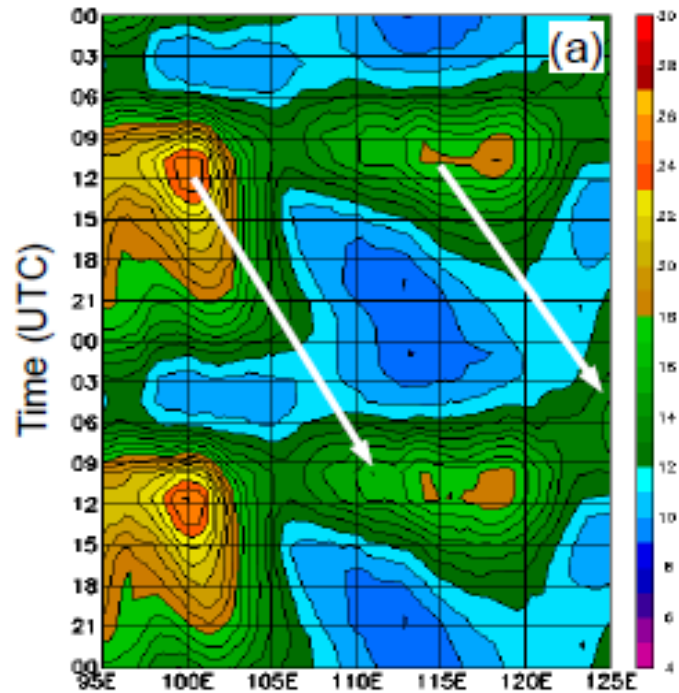
- Diurnal cycle tied to large-scale terrain of the region

Continental US
Radar echo frequency



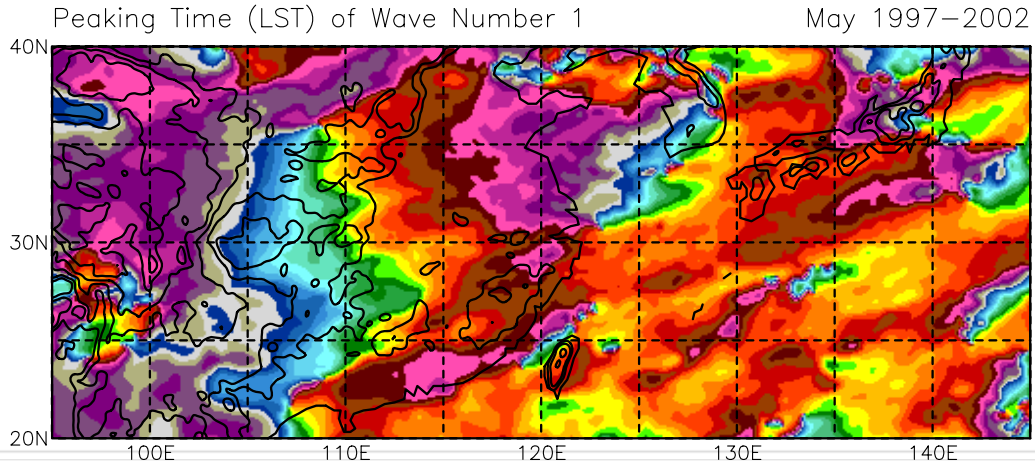
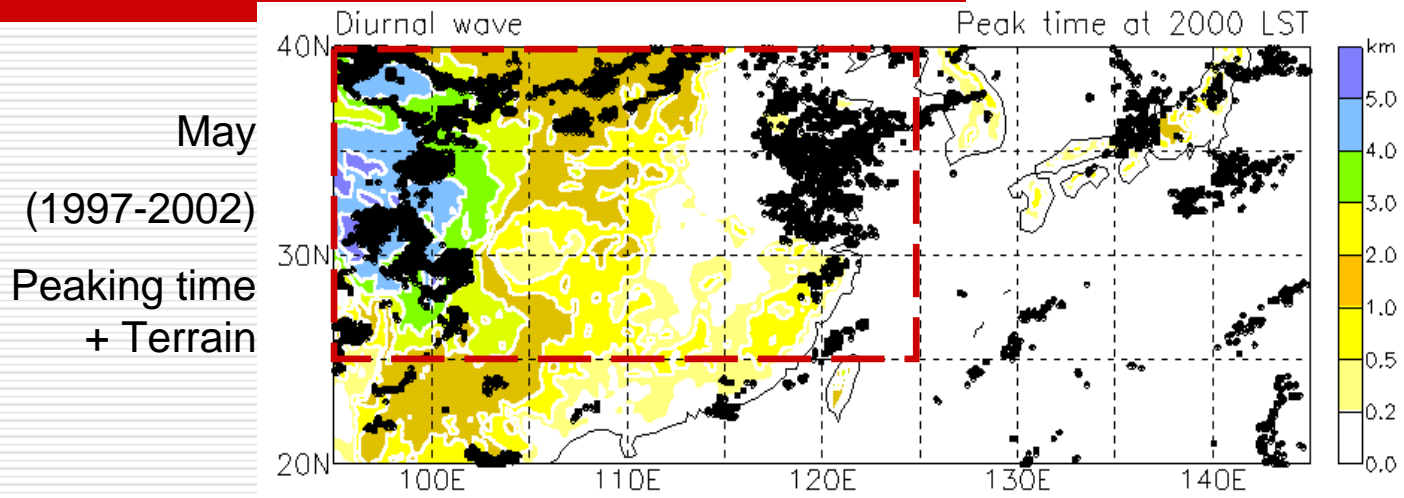
Carbone et al. (2002, JAS)

East Asia
Cold cloud ($< -32^{\circ}\text{C}$) frequency

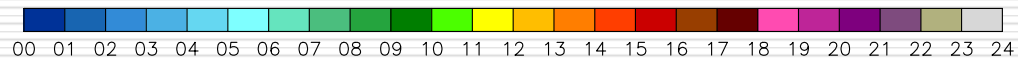


Wang (2007)

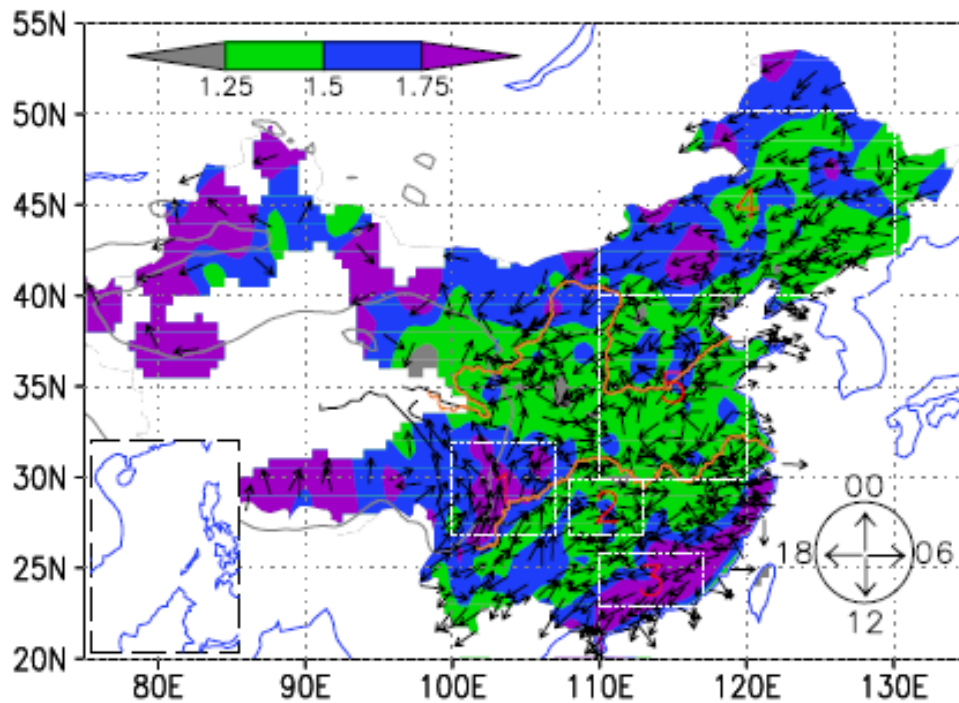
■ Peaking time (LST) of highest cold cloud frequency in a day



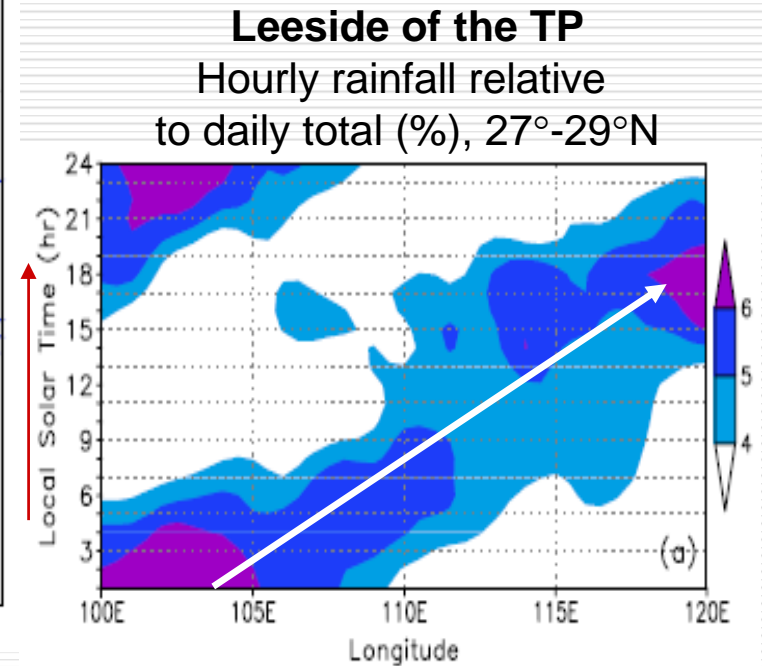
Wang et al.
(2005, MWR)



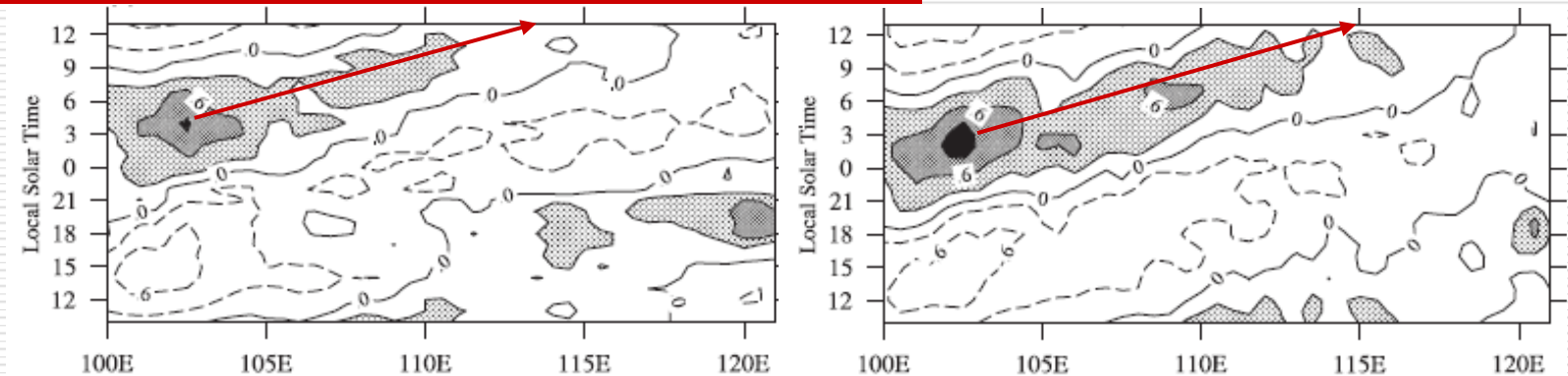
- Phenomenon confirmed by rainfall observations in East Asia
 - Yu et al. (2007): 588 rain gauges, Jun-Aug 1991-2004



Yu et al. (2007, GRL)



- Chen et al. (2010): 626 rain gauges, Jun-Aug 1991-2004

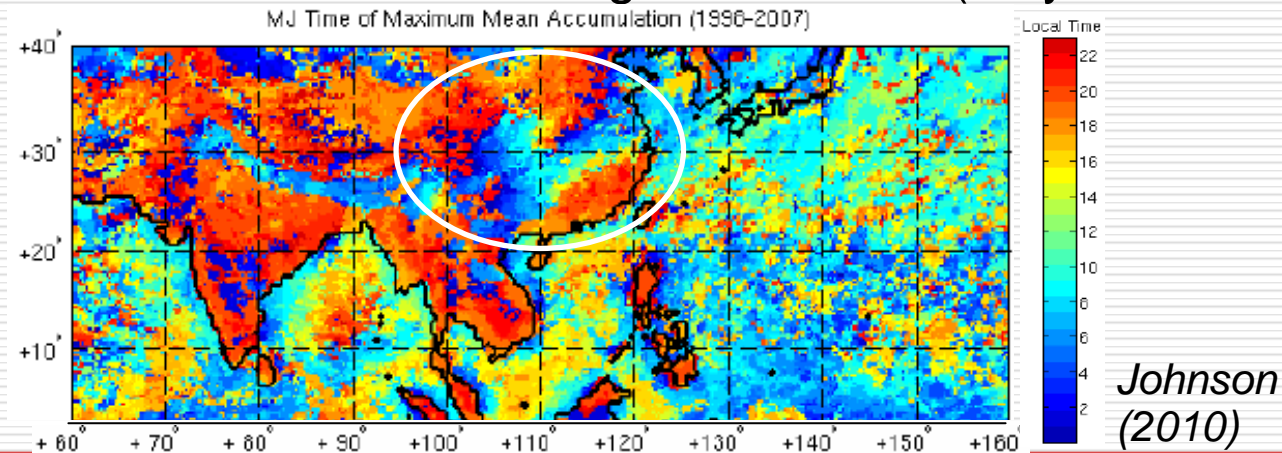


27°-33°N, all JJA rain

(Chen et al. 2010, JC)

27°-33°N, events ≥ 6 h

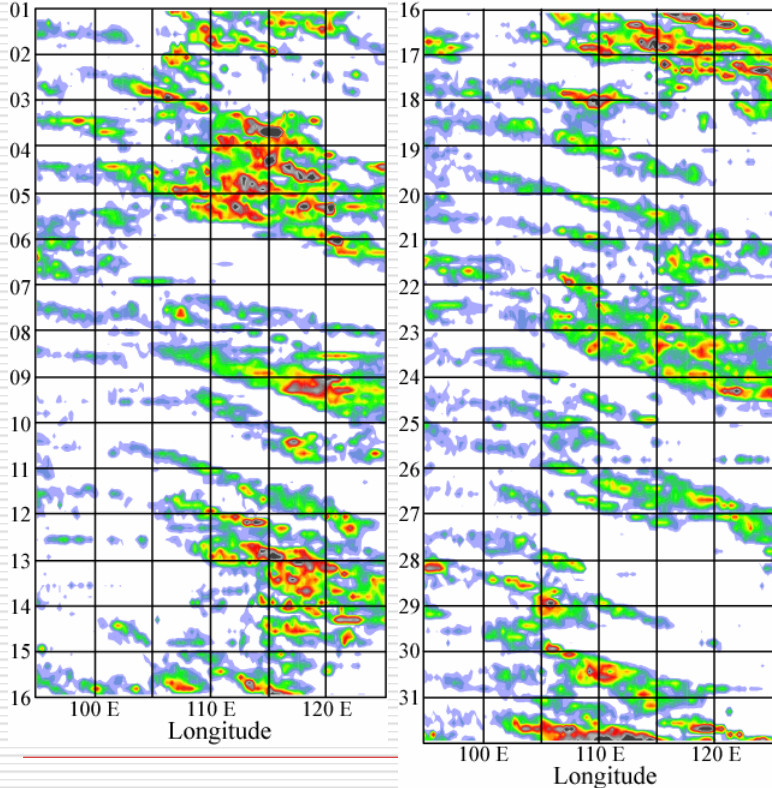
- TRMM 3B42 satellite merged rain-rates (May-Jun 1996-2007)



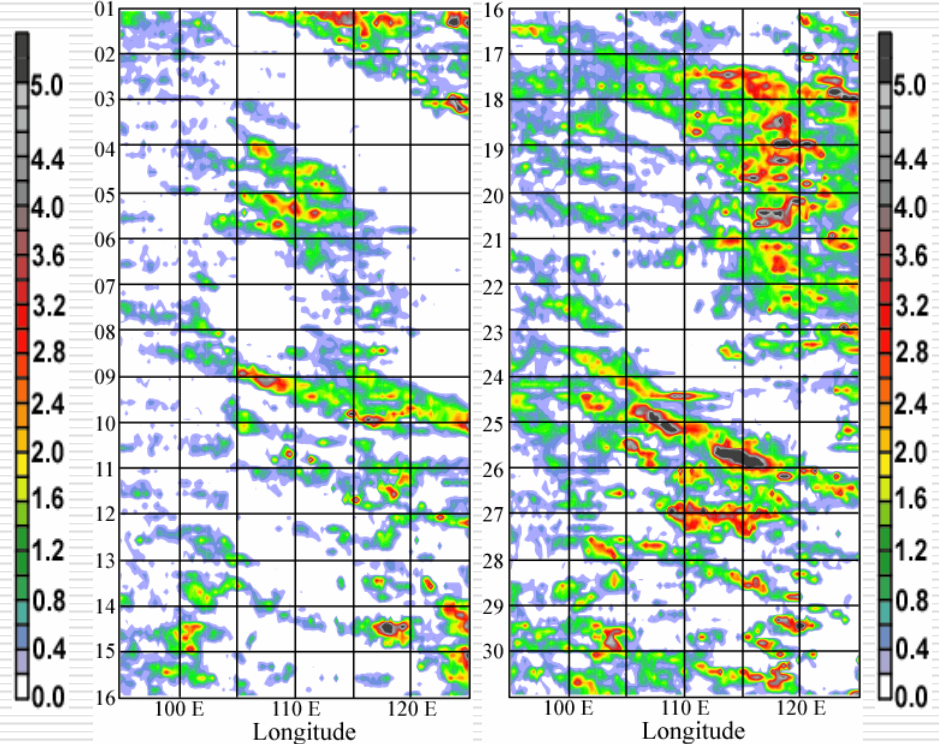
2. An update using TRMM rain-rates

- TRMM 3B42 rain-rates: 50°S - 50°N , $0.25^{\circ} \times 0.25^{\circ}$, every 3 h
- Hovmöller plots for May-Aug 2005 as examples (mm/3 h)

May 2005

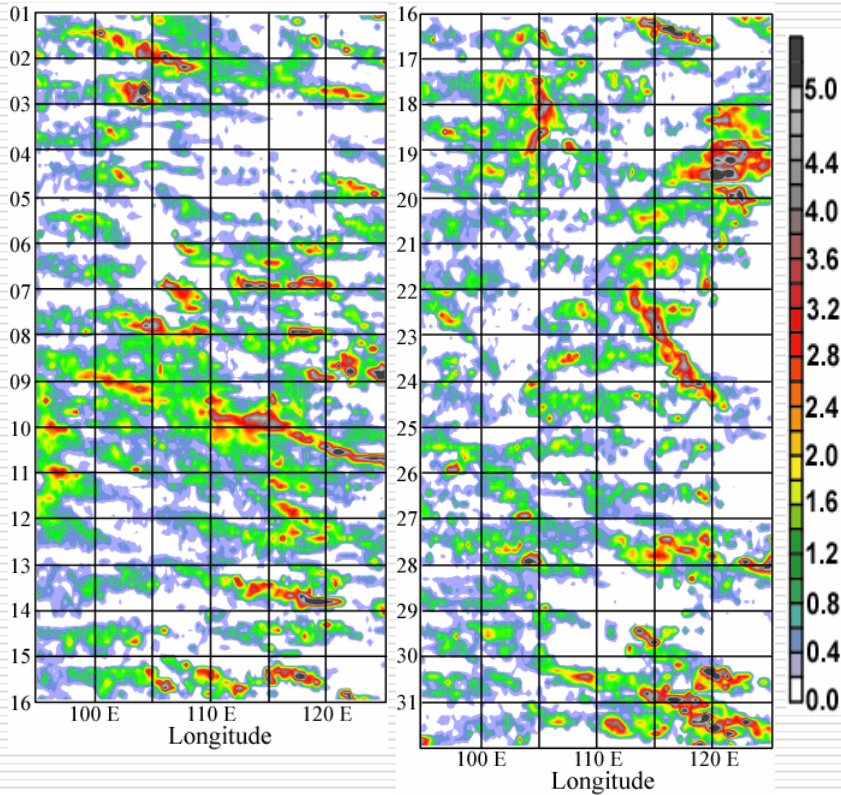


Jun 2005

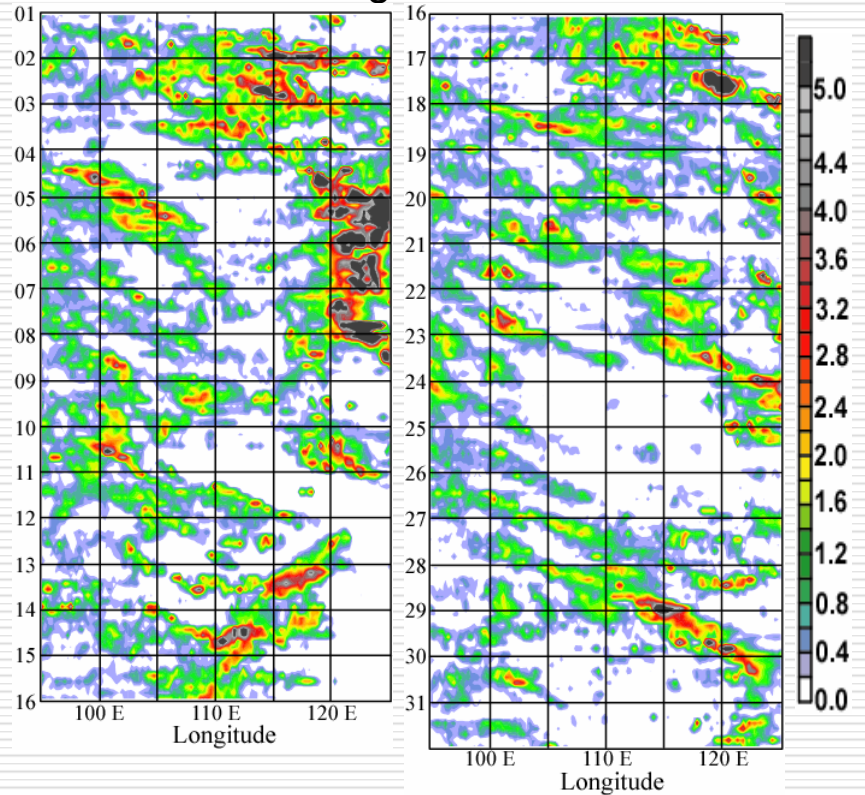


□ Calculation domain: 25°-40°N, 95°-125°E

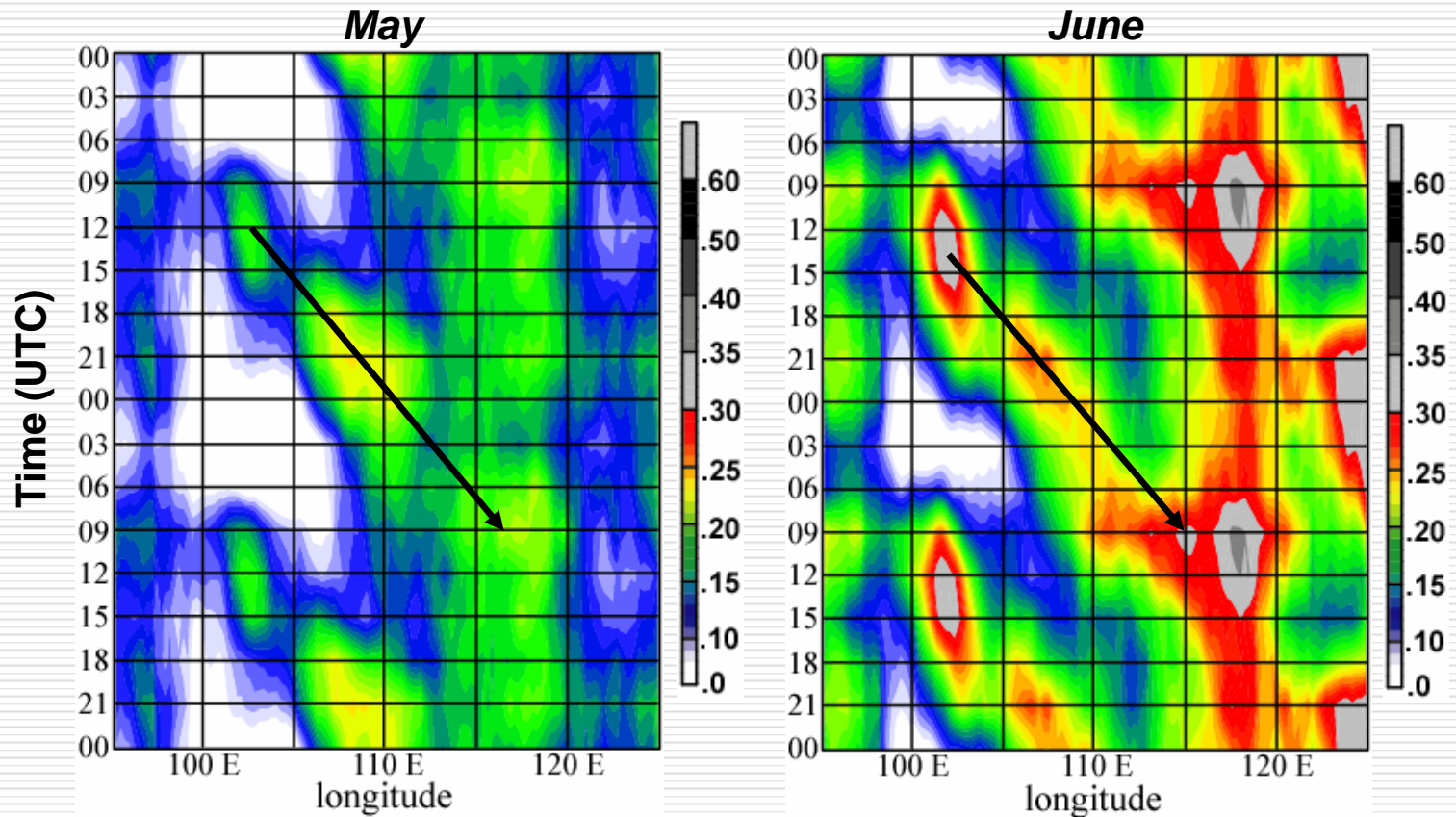
Jul 2005

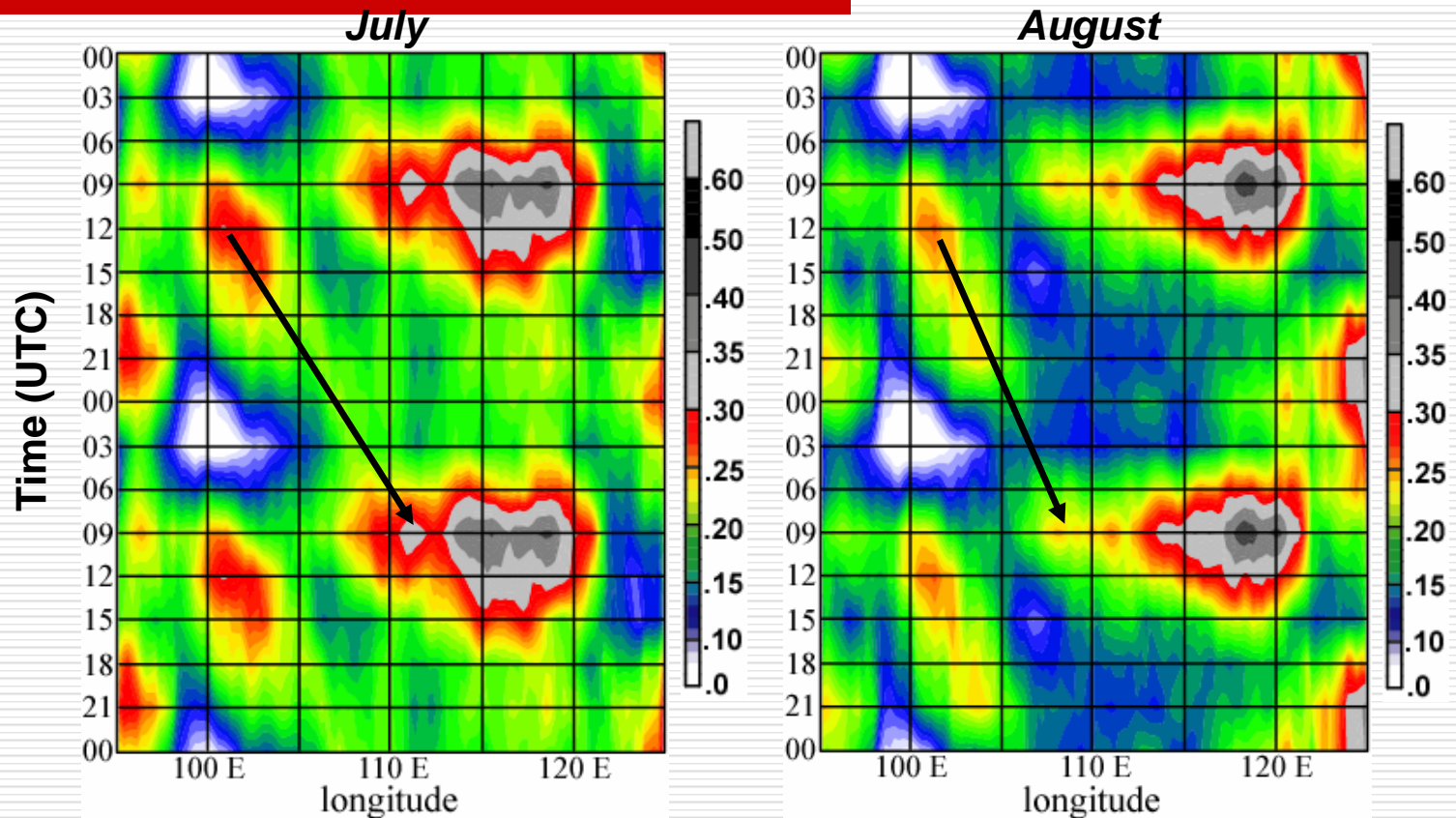


Aug 2005



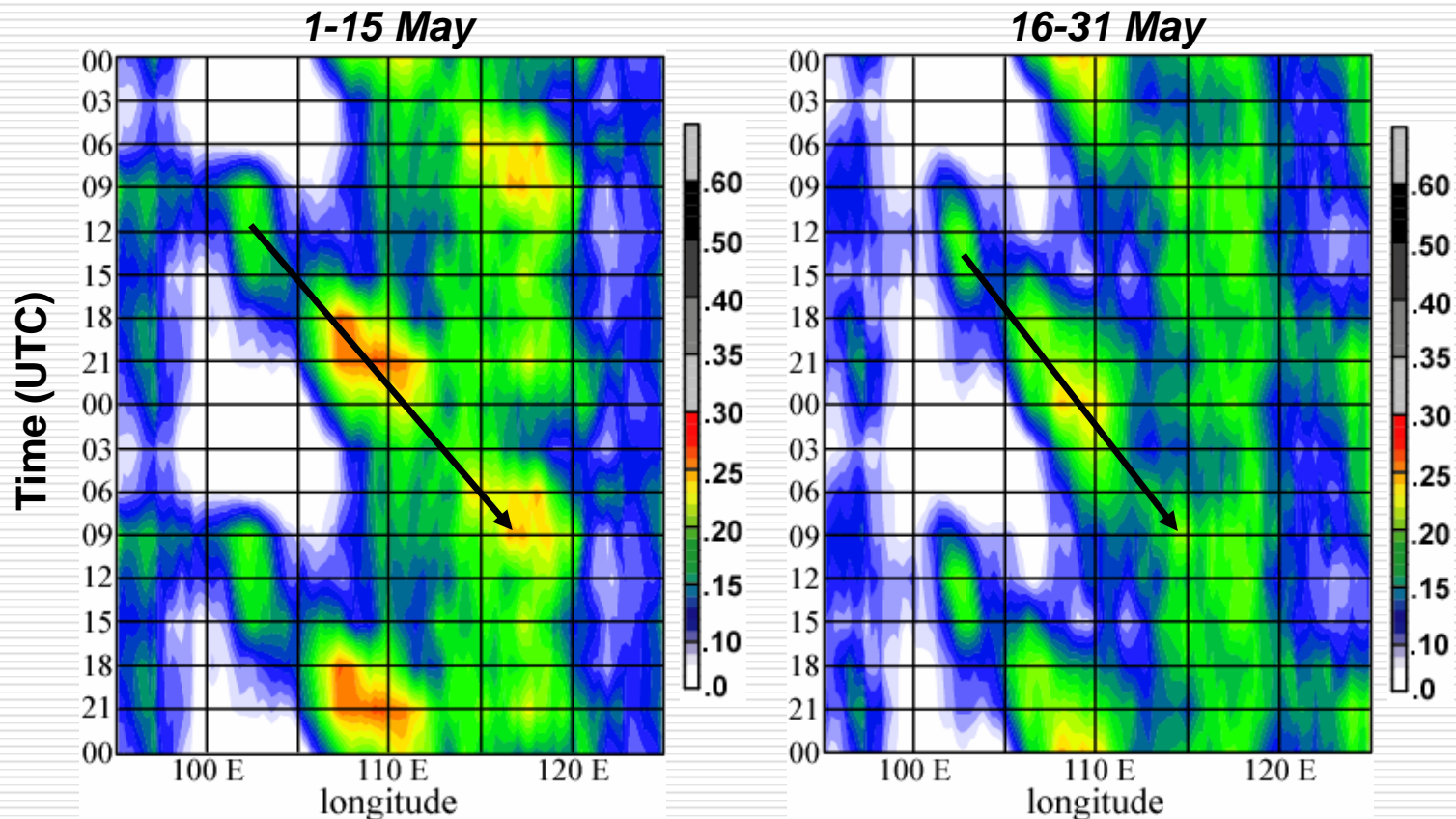
- Mean diurnal cycle for each month (May 1998-Jul 2008): (mm/h)

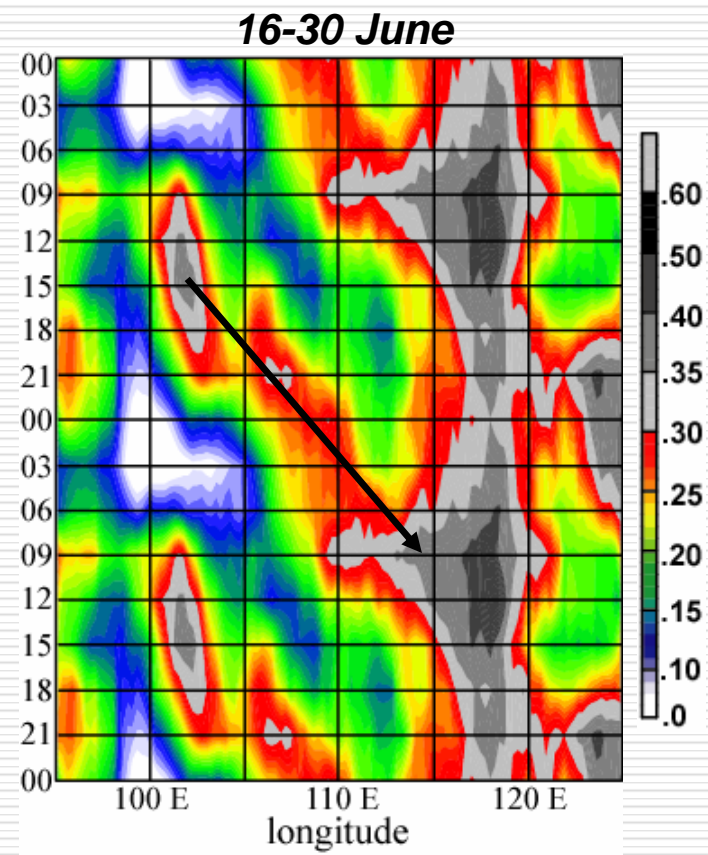
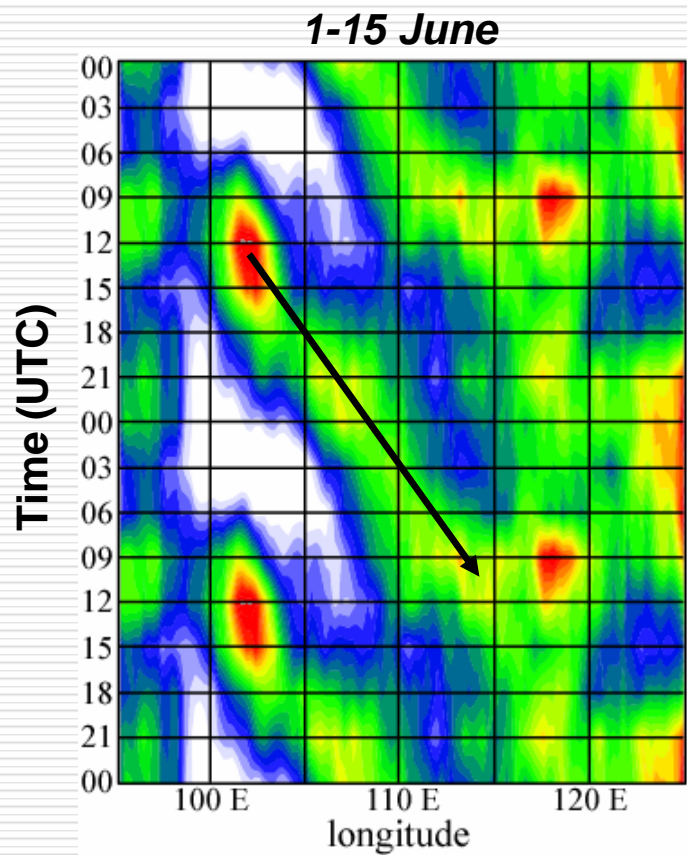


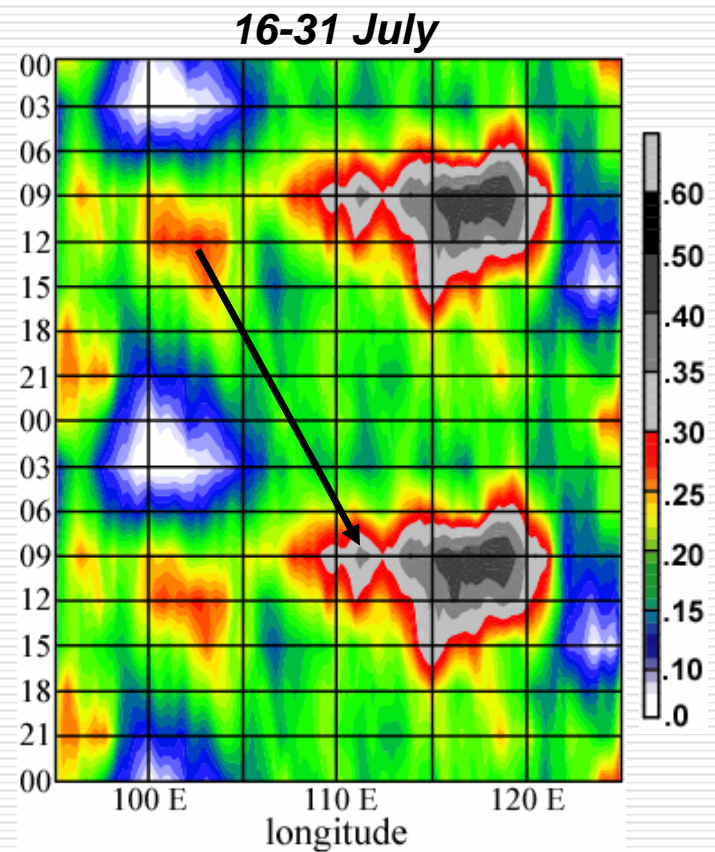
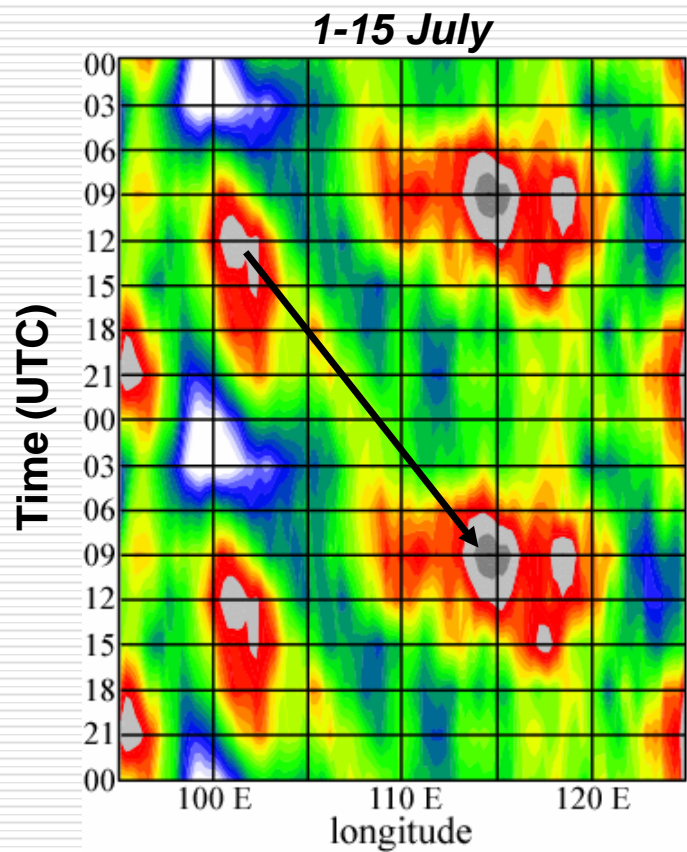


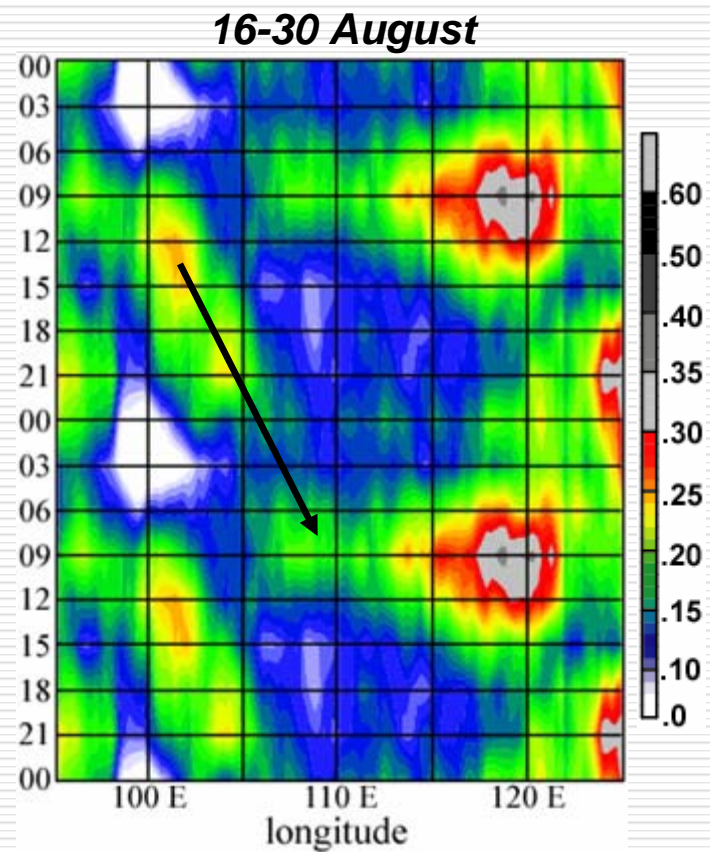
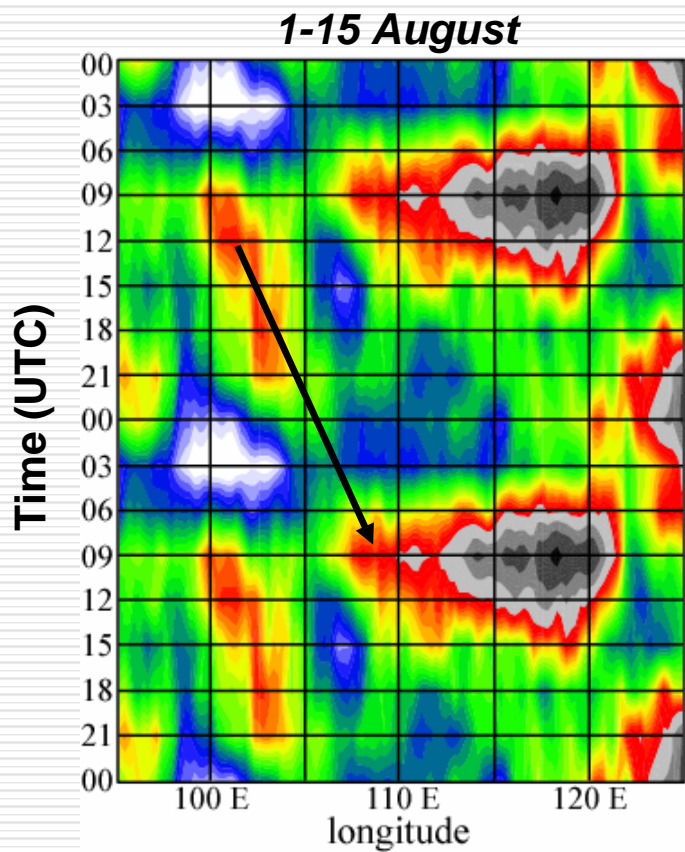
- Convection caused by daytime heating over eastern TP and slopes, and propagates downstream in sheared environment

- Mean diurnal cycle for each half month (mm/h):





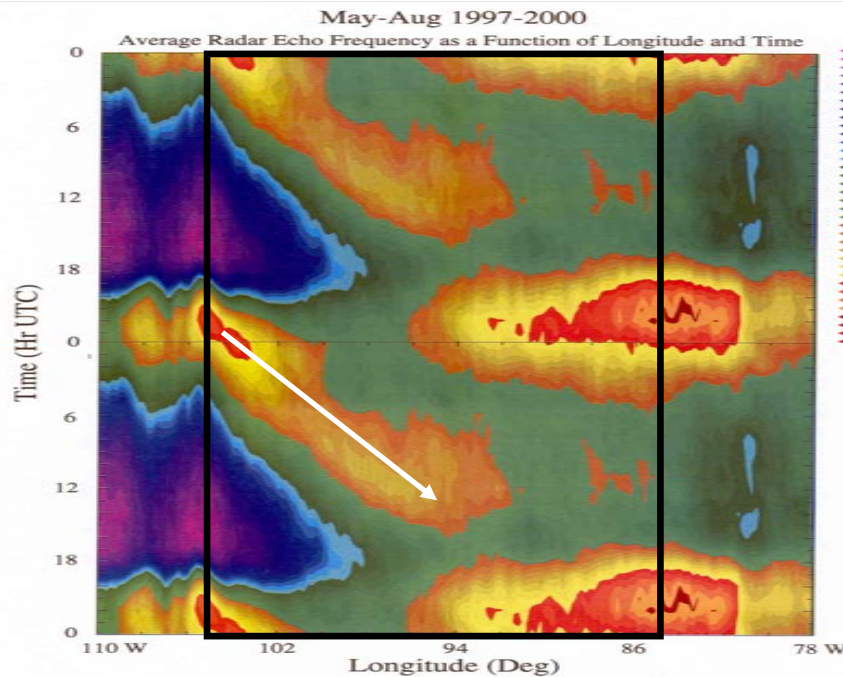




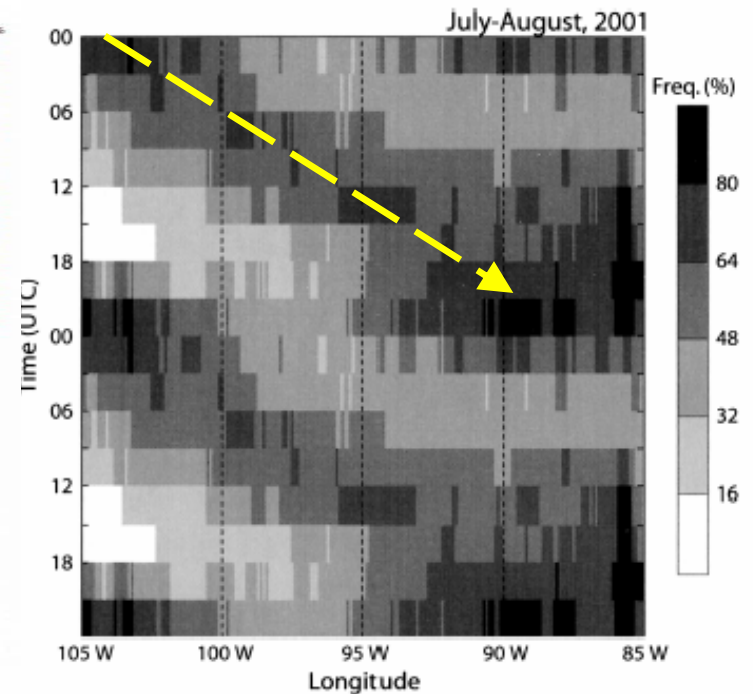
3. Signals in an operational model

- Propagating rainfall signals robust to the lee of TP and tied to the terrain within the diurnal cycle with high regularity
 - Possible to significantly improve warm-season QPFs if operational models can adequately capture the propagation
 - How are the propagation signals and other basic characteristics in East Asia captured in operational NWP models?
 - Evaluate the CWB non-hydrostatic forecast system (NFS)
 - Current regional operational model in Taiwan
 - Domain one (coarse domain) at grid spacing of 45 km
 - 0000 and 1200 UTC runs, 12-36 h QPFs, May-Aug, 2002-2005
 - Based on results of Davis et al. (2003) for the continental US, the answer is “not well captured”
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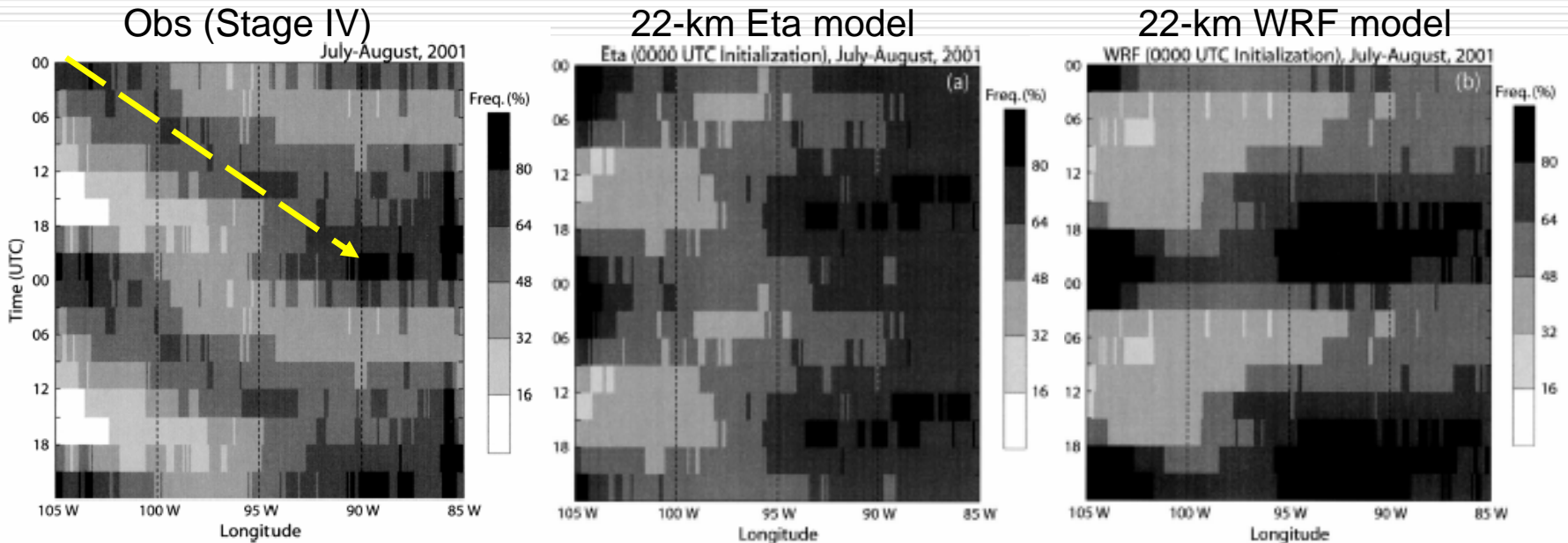
- In the US, eastward propagation overnight captured in radar-derived NCEP Stage-IV 3-h rainfall in Jul-Aug 2001 (domain: 85° - 105° W, 30° - 48° N)



(Carbone et al. 2002, JAS)

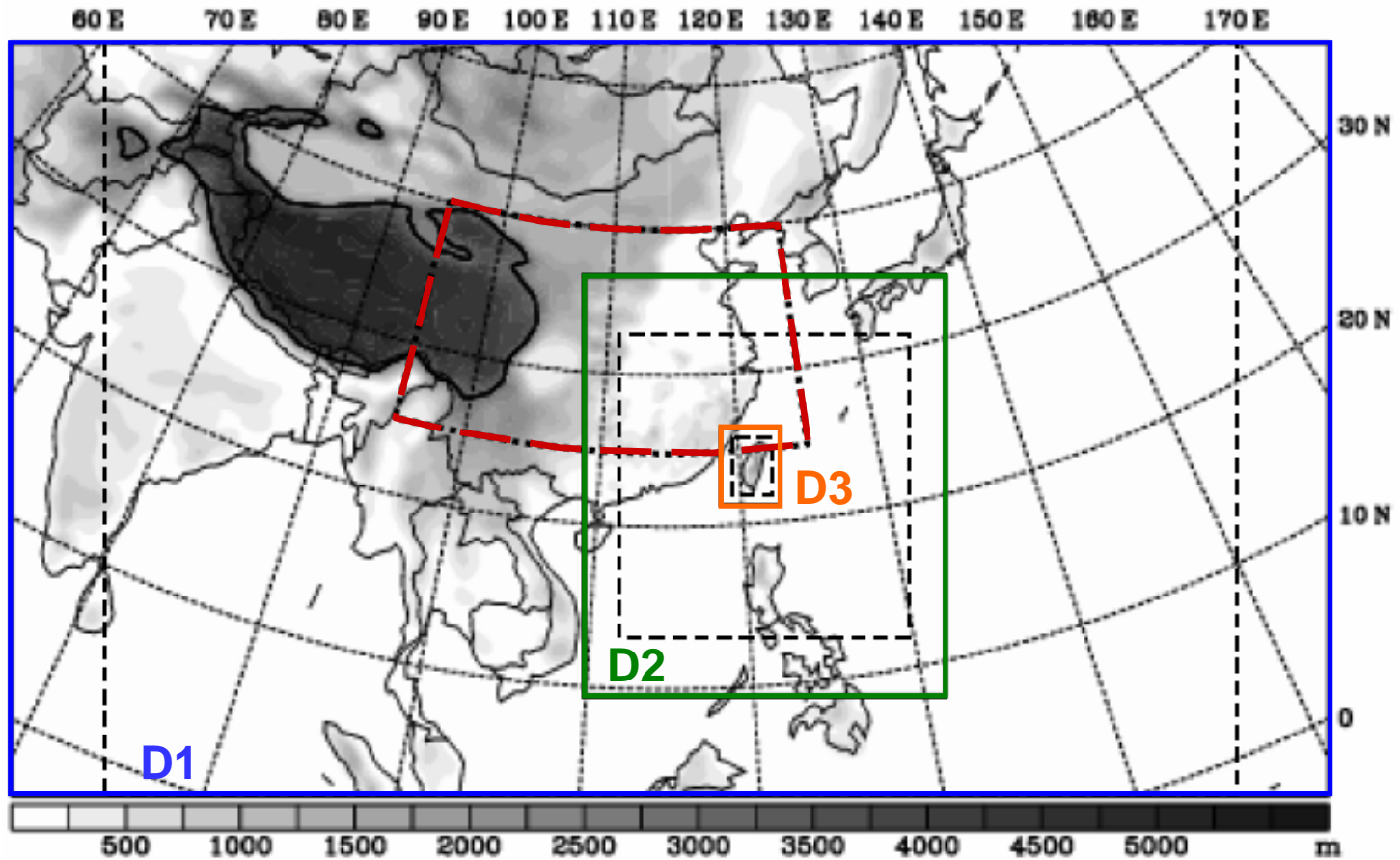


(Davis et al. 2003, MWR)



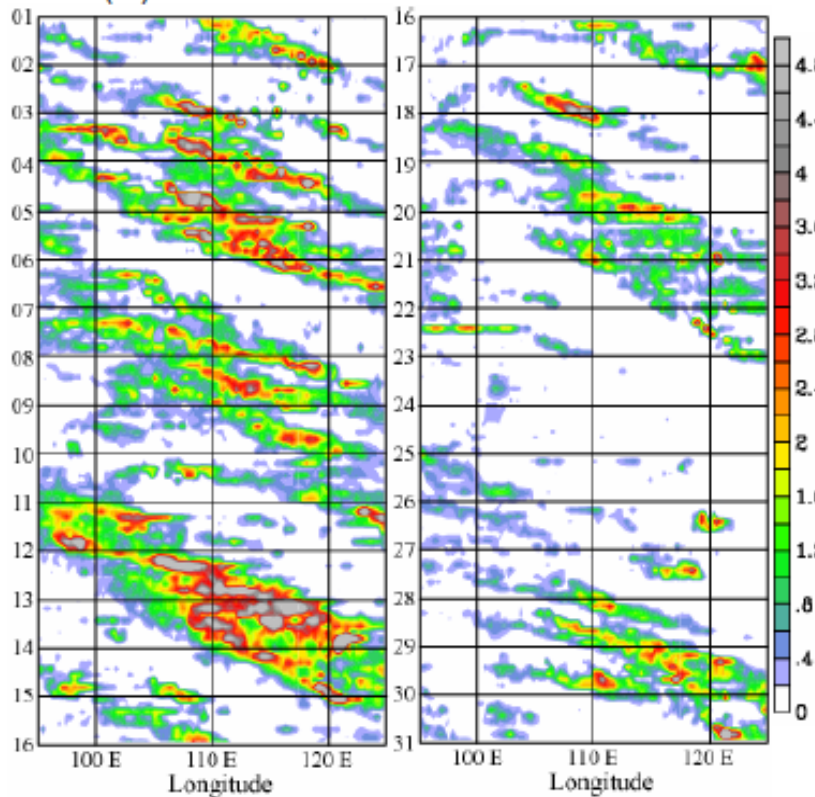
- Nocturnal propagation not well captured by both 22-km Eta, and 22-km and 10-km WRF models
- Reason: Inadequate model resolution and the use of cumulus parameterization scheme (not explicitly simulated), leading to internal structures of MCSs not resolved (cold pool in specific)

- CWB NFS domains: D1 (45 km) QPFs examined

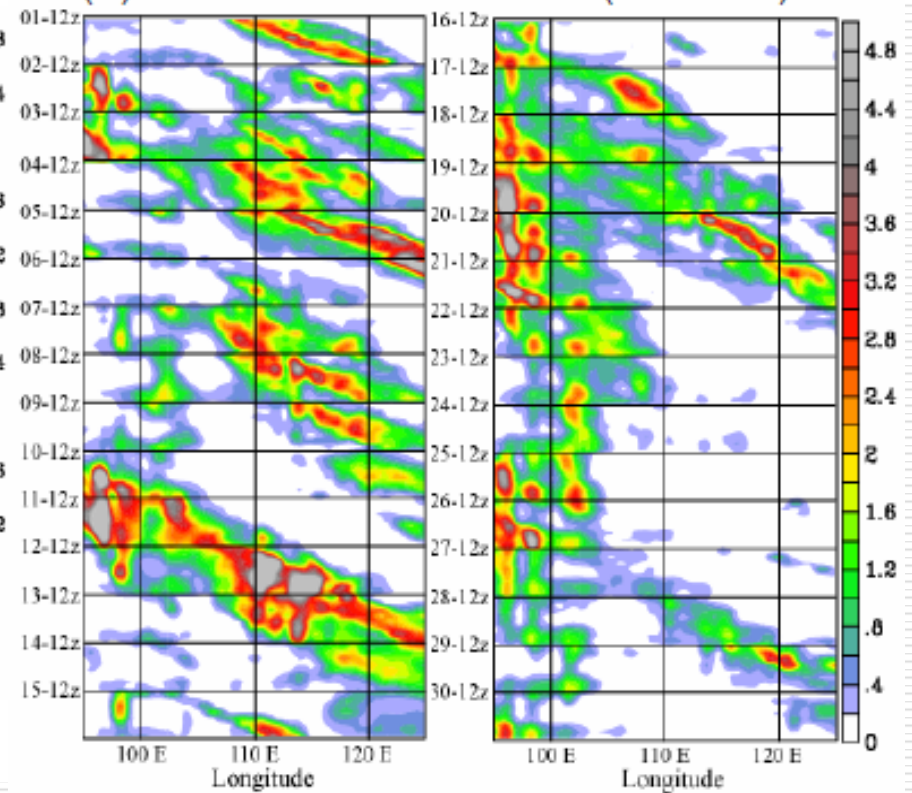


■ Direct comparison of Hovmöller plots for selected months:

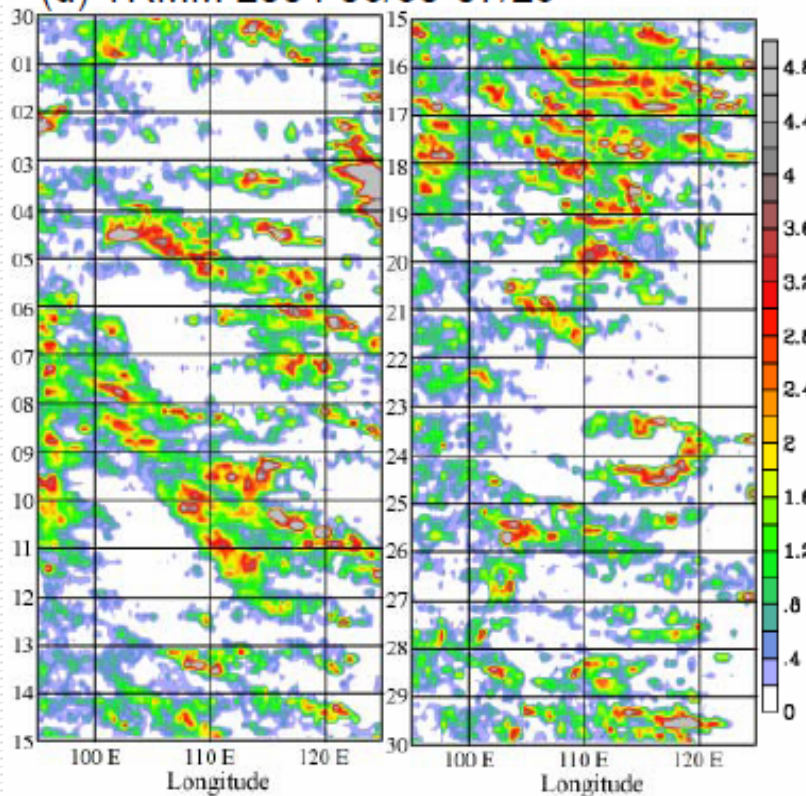
(a) TRMM 2002 05/01-05/30



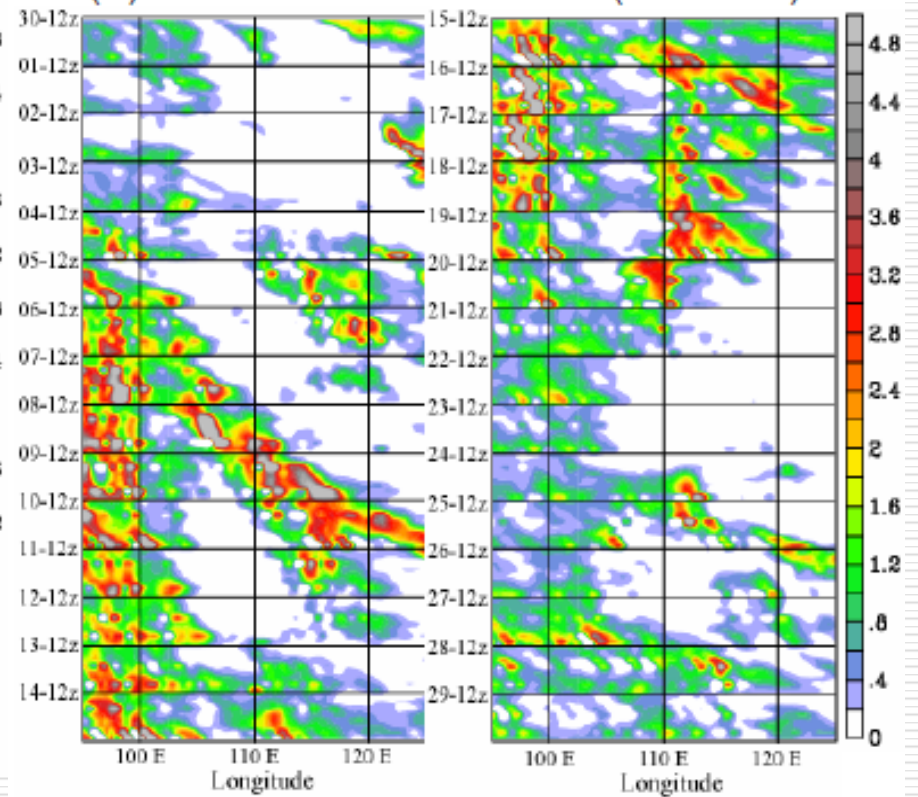
(a) NFS 2002 05/01-05/31 (00 Z run)



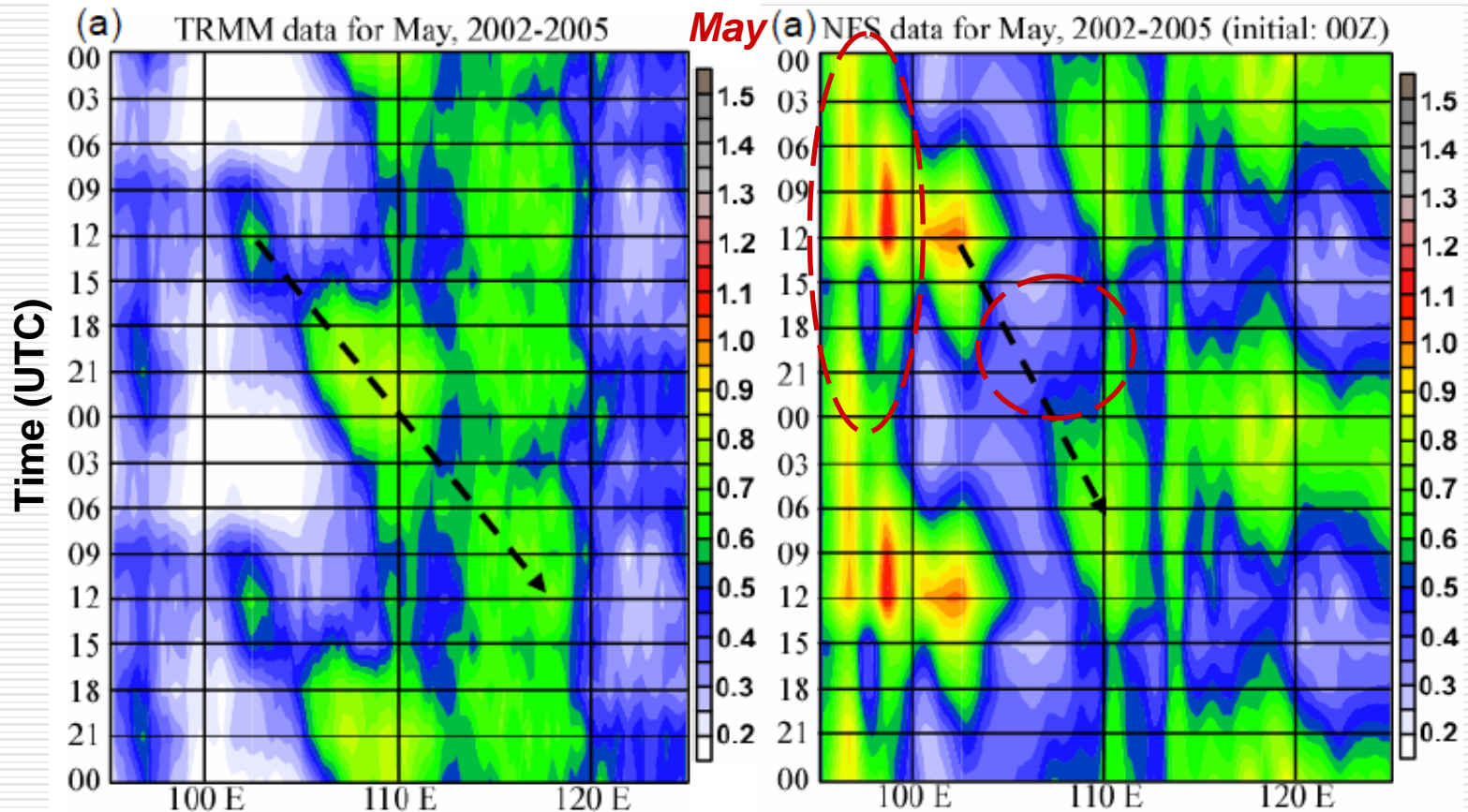
(d) TRMM 2004 06/30-07/29

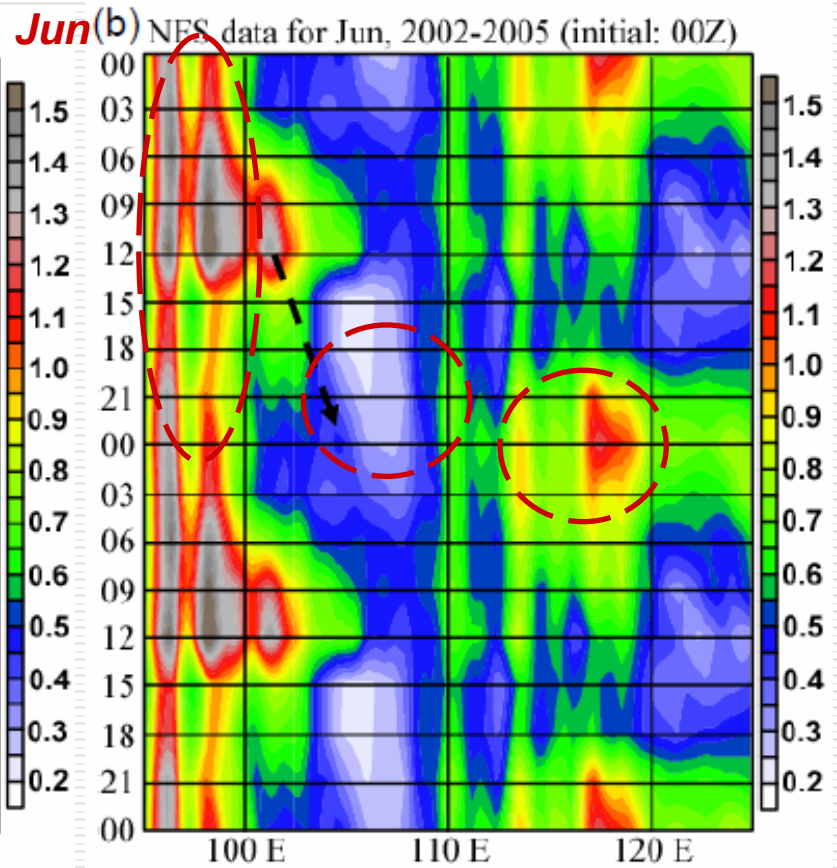
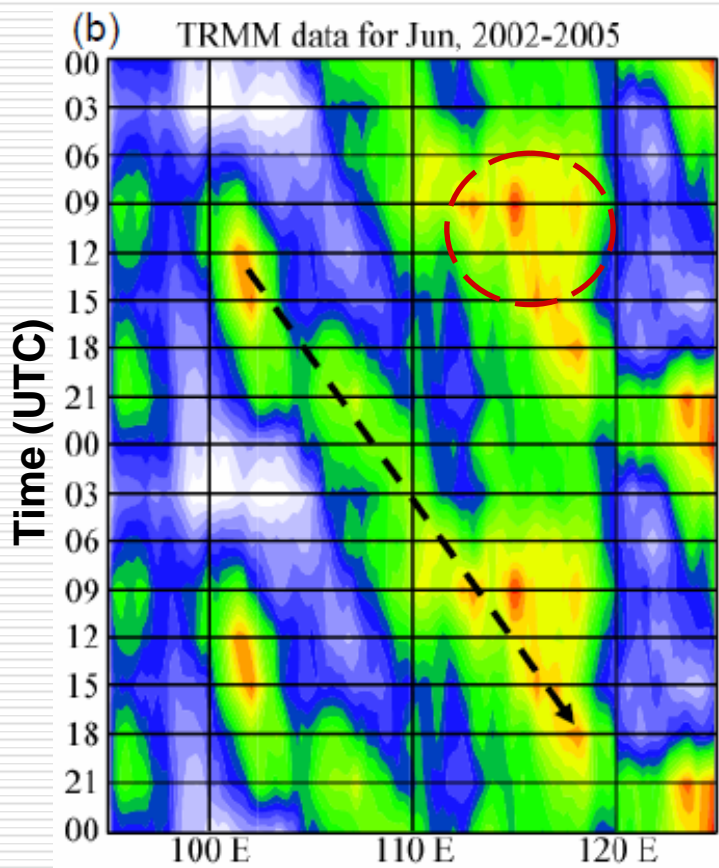


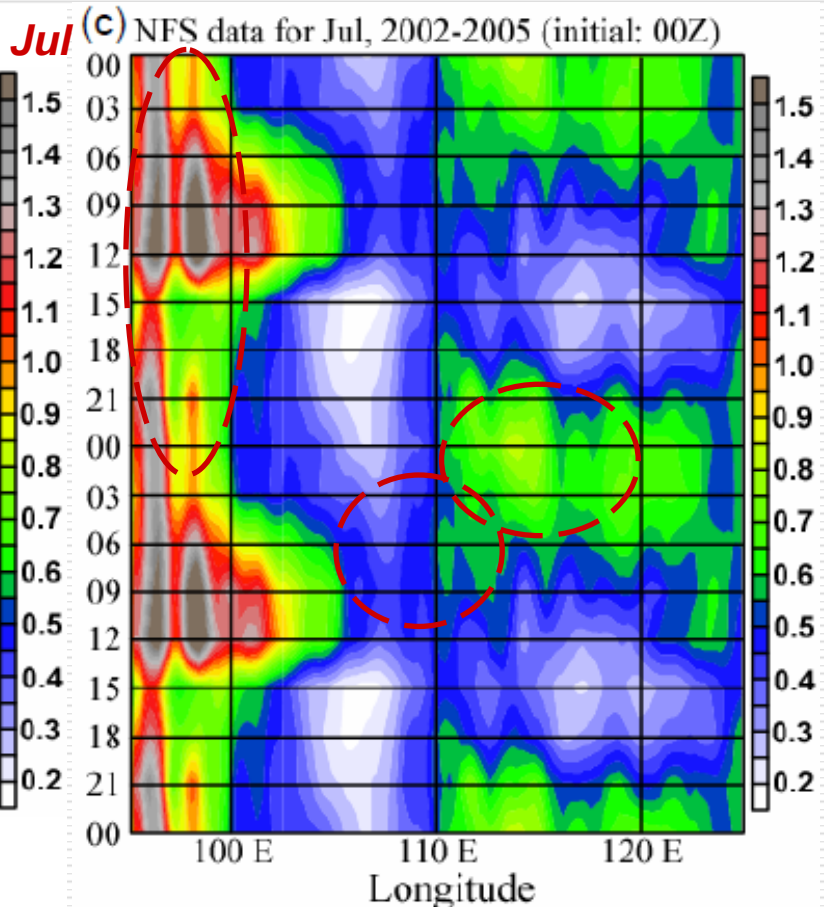
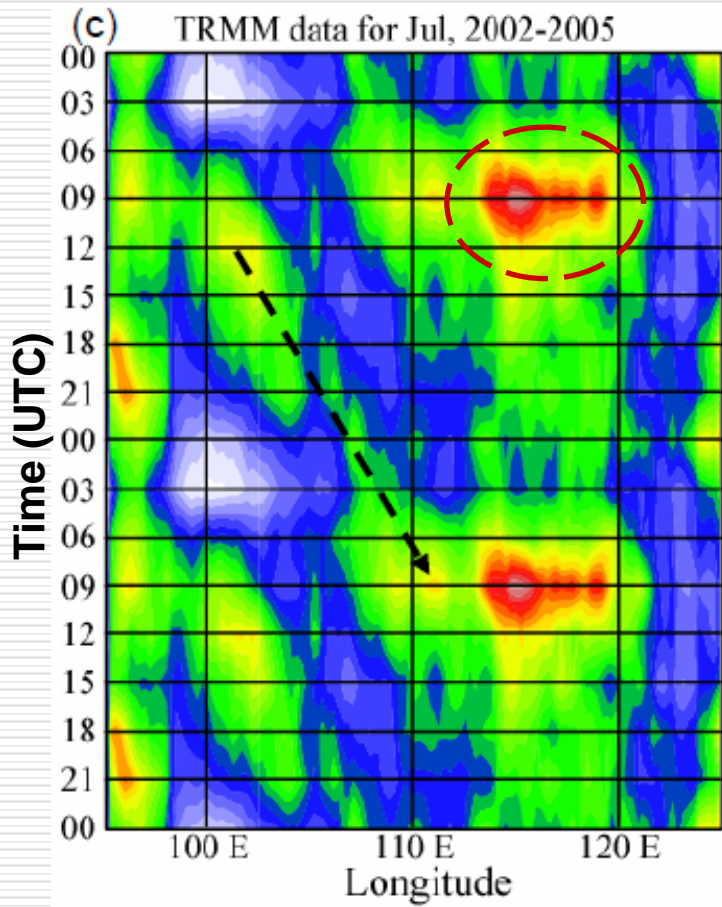
(d) NFS 2004 06/30-07/30 (00 Z run)

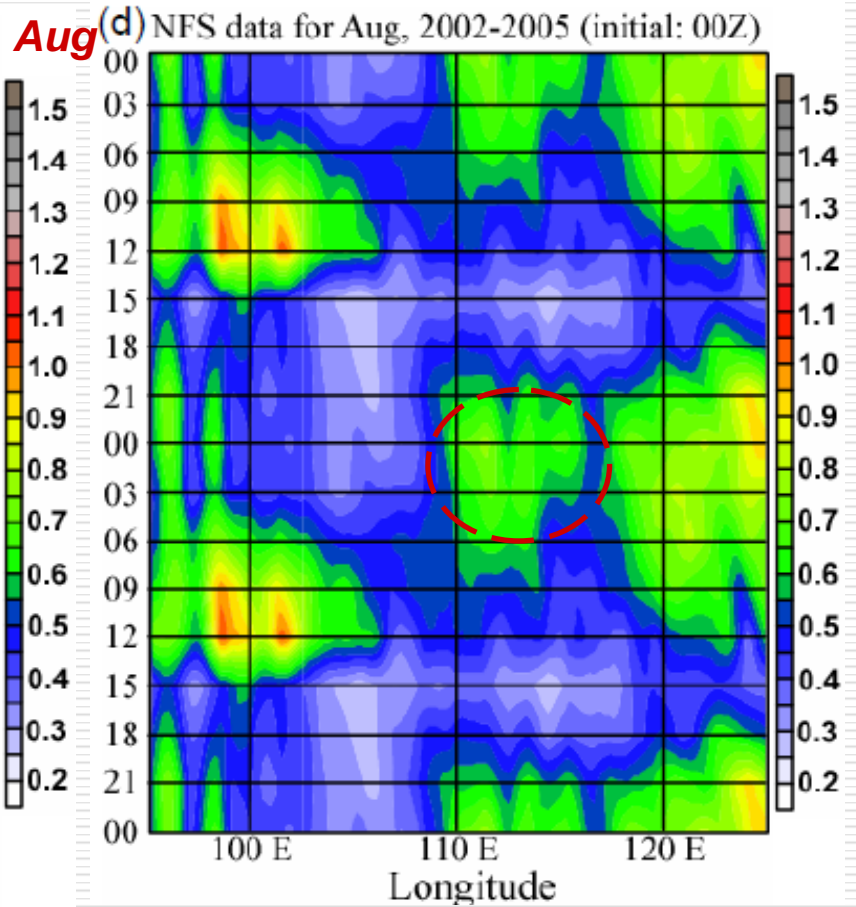
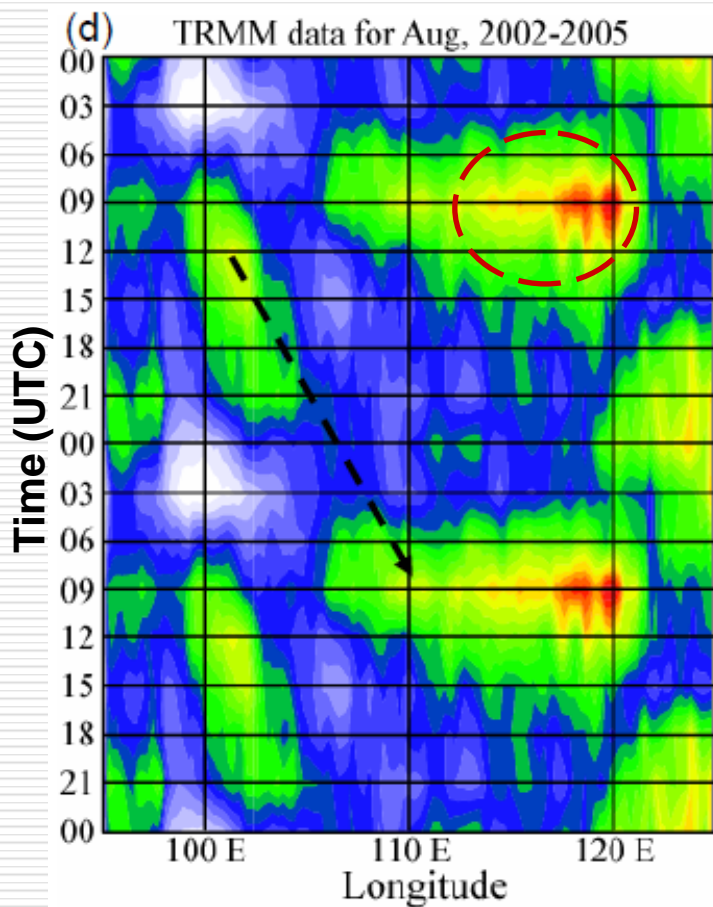


■ Comparison of mean diurnal cycle in Hovmöller space: (mm/3 h)



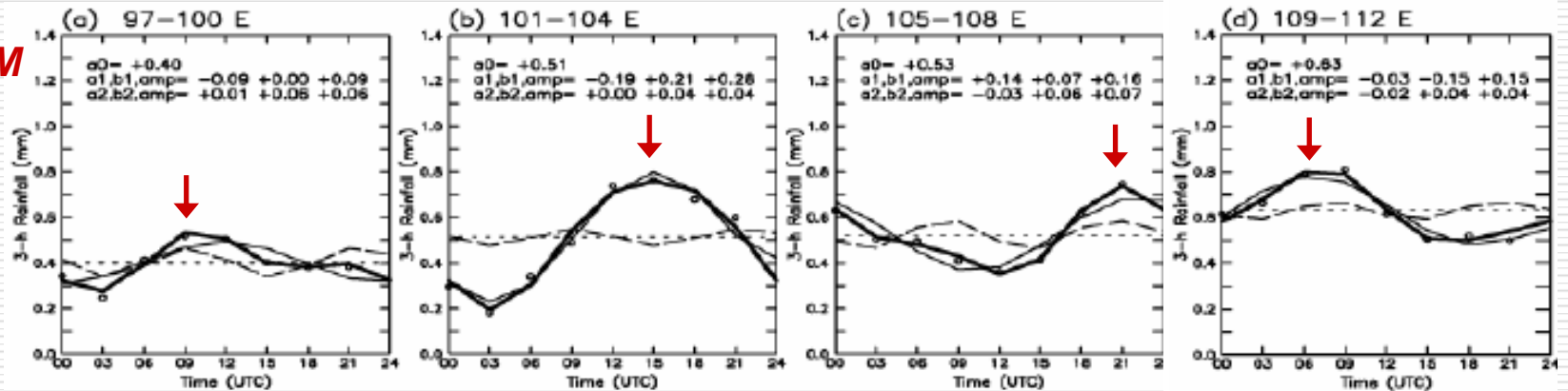




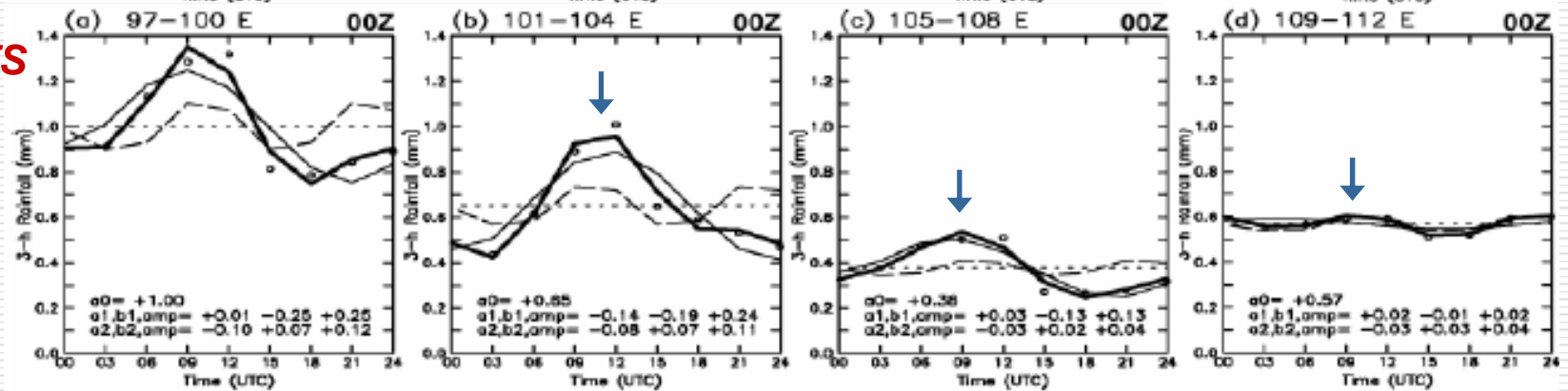


■ Fourier decomposition for June: (mm/3 h)

TRMM

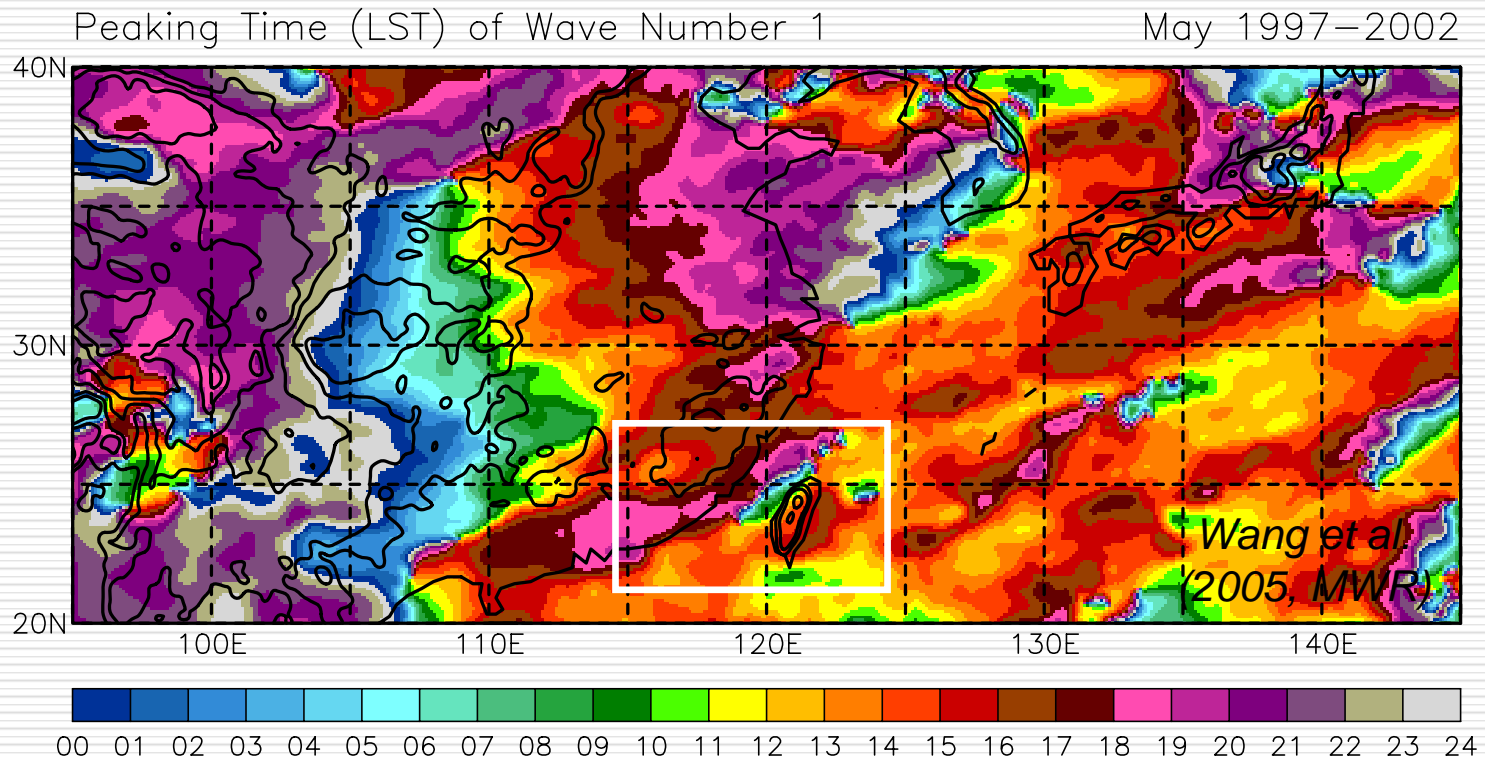


NFS

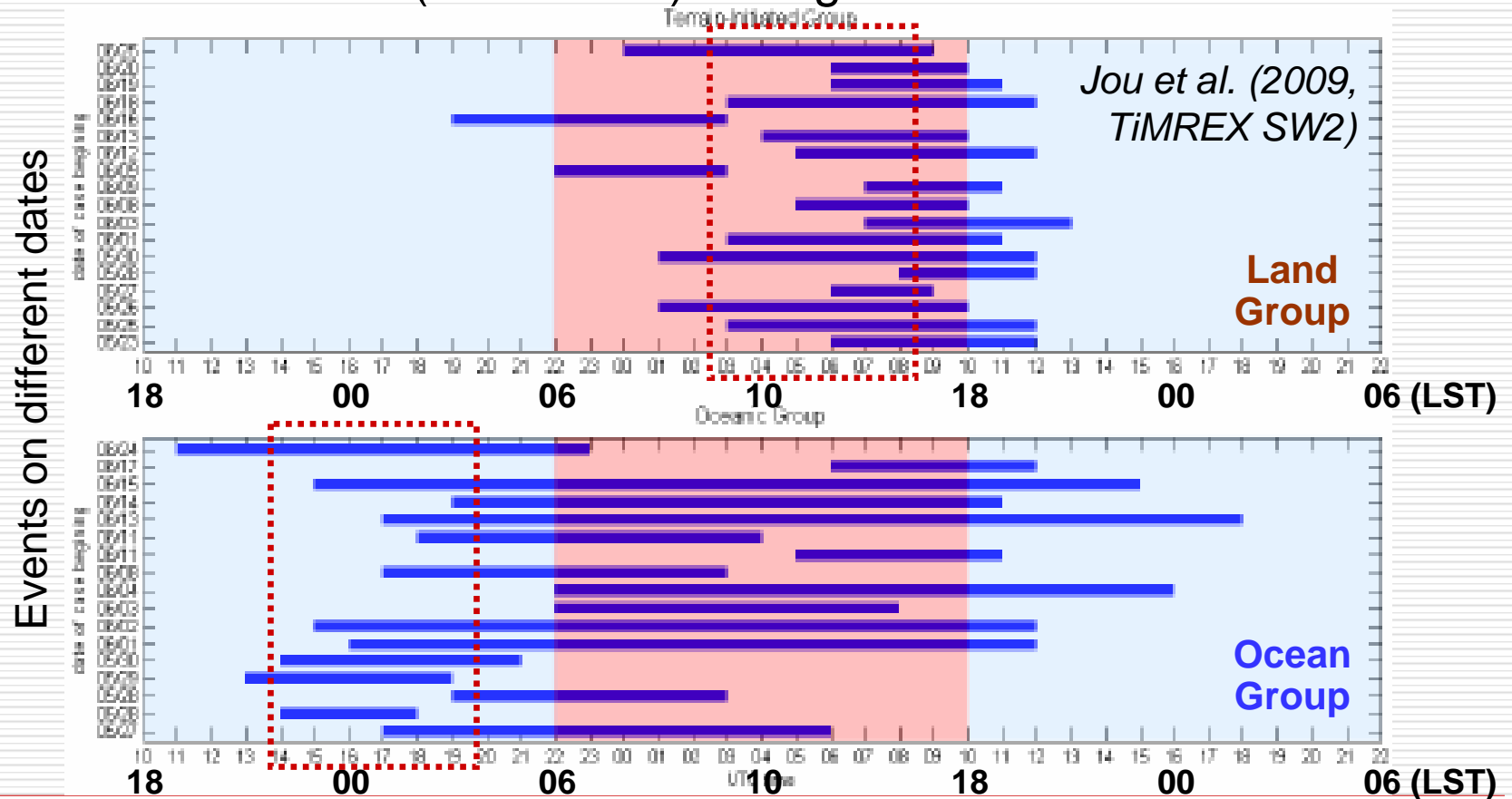


4. Application in the Taiwan Mei-yu season

- Peaking time (LST) of highest cold cloud frequency in a day
 - From GMS T_B in May 1997-2002, with terrain (*Wang et al. 2005*)

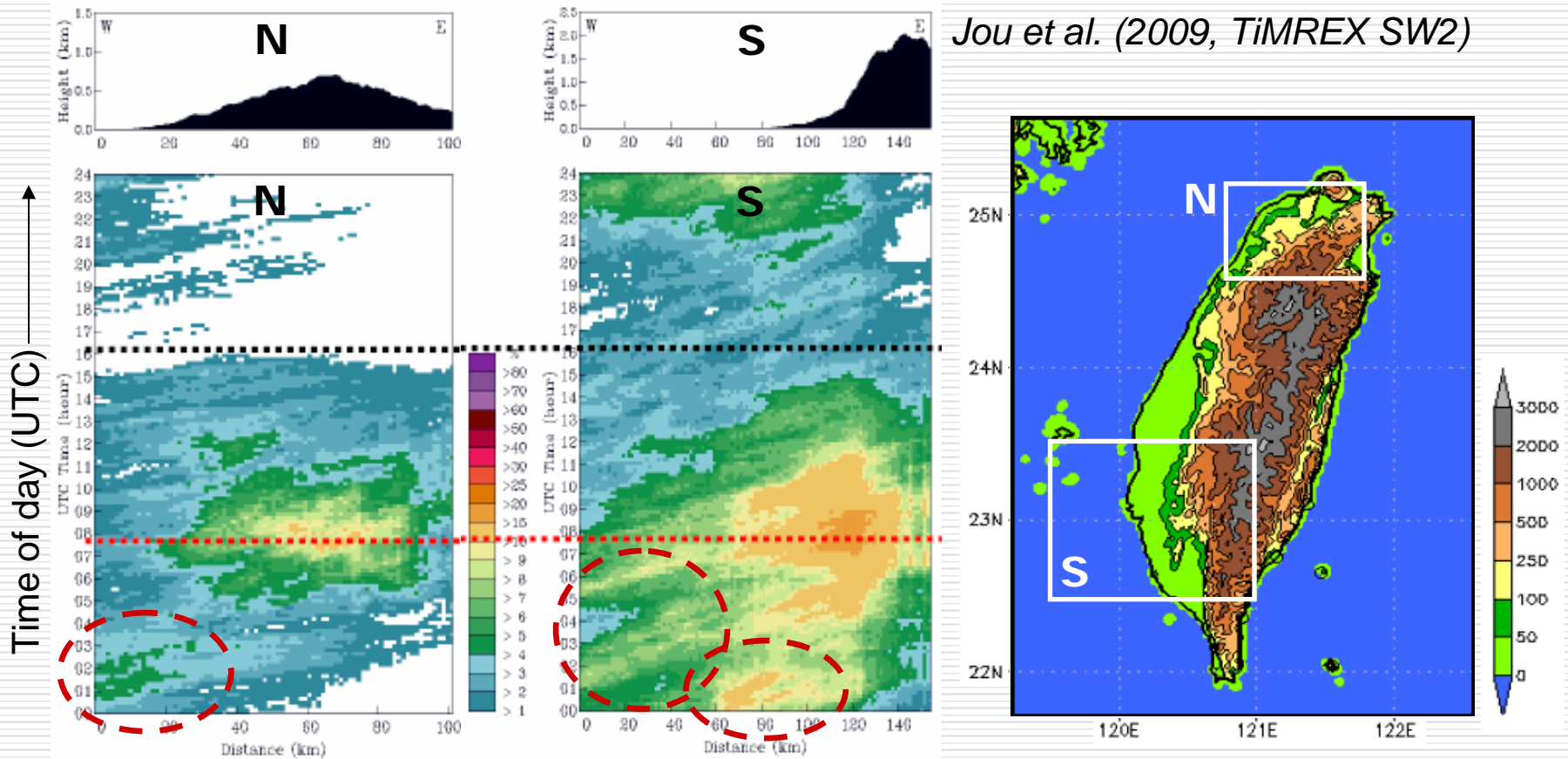


□ Rainfall events (>5.5 mm/h) during SoWMEX: Land vs. Ocean



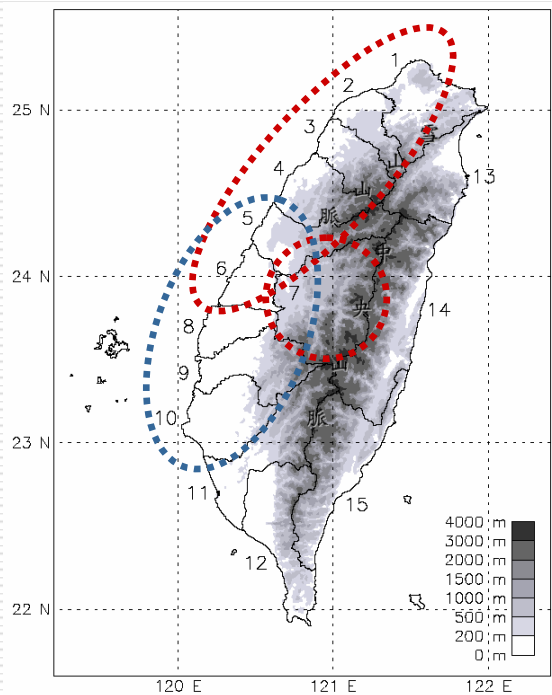
■ Diurnal variability of occurrence frequency: North vs. South

Jou et al. (2009, TiMREX SW2)

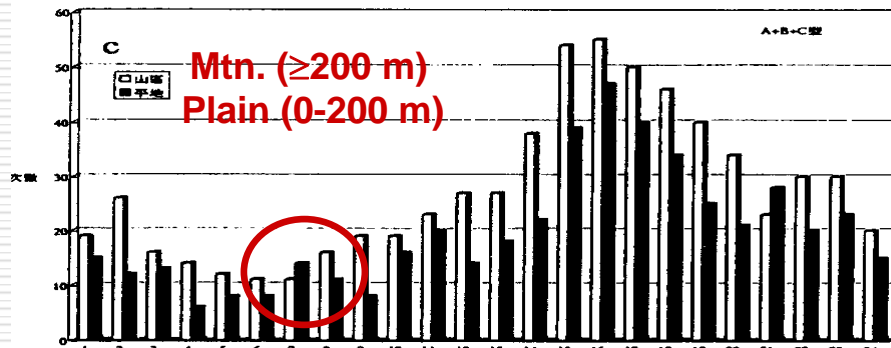
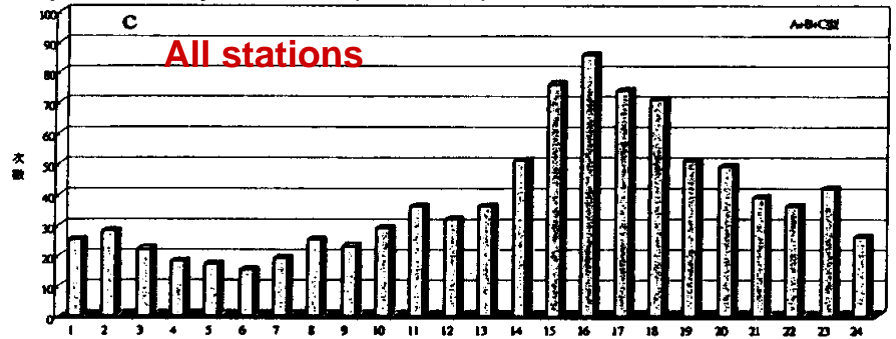


- Diurnal cycle of heavy rainfall occurrence in Mei-yu season
 - Northern to Central Taiwan (areas 1-7)

Post-TAMEX forecast areas



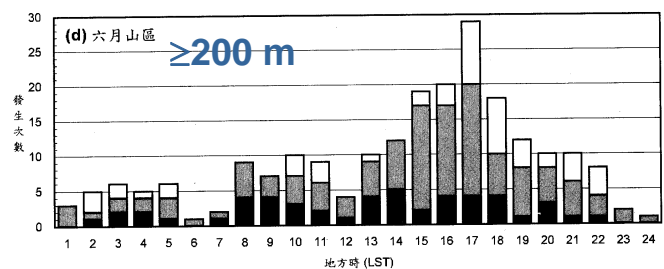
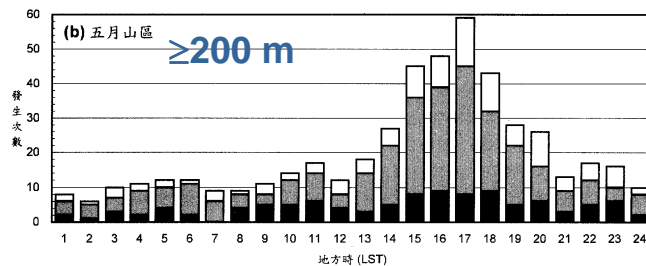
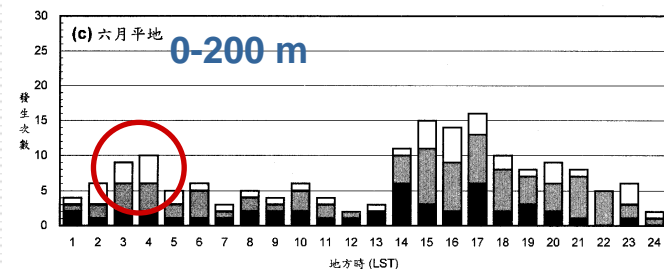
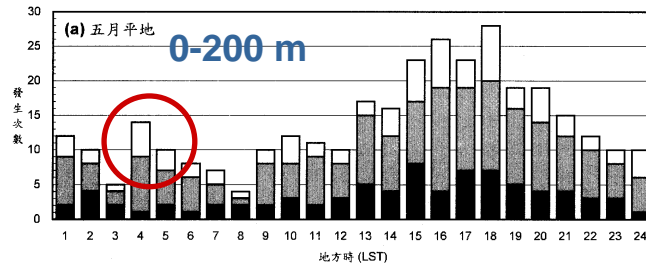
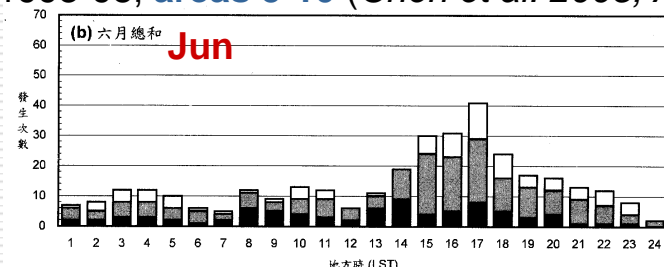
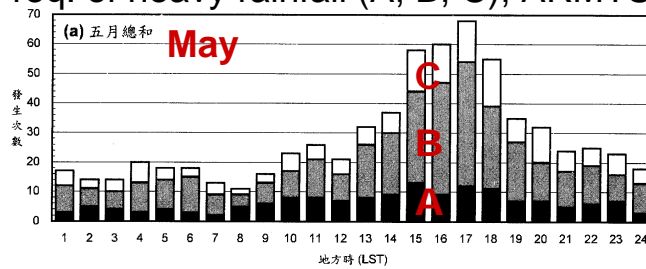
Freq. of heavy rainfall (A+B+C), ARMTS, 1991-96, **Area 1-7**



Chen and Chang (2002, AS)

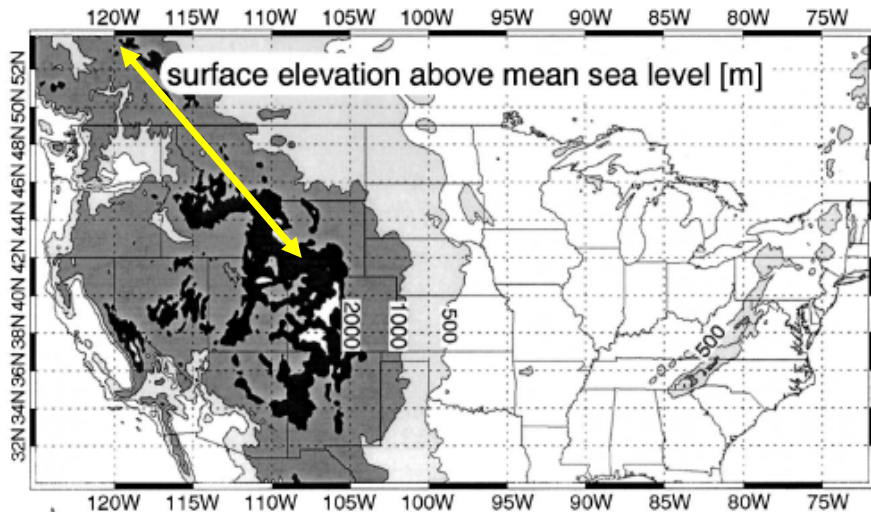
■ Central to Southern Taiwan (areas 5-10)

Freq. of heavy rainfall (A, B, C), ARMTS, 1993-98, **areas 5-10** (Chen et al. 2005, AS)

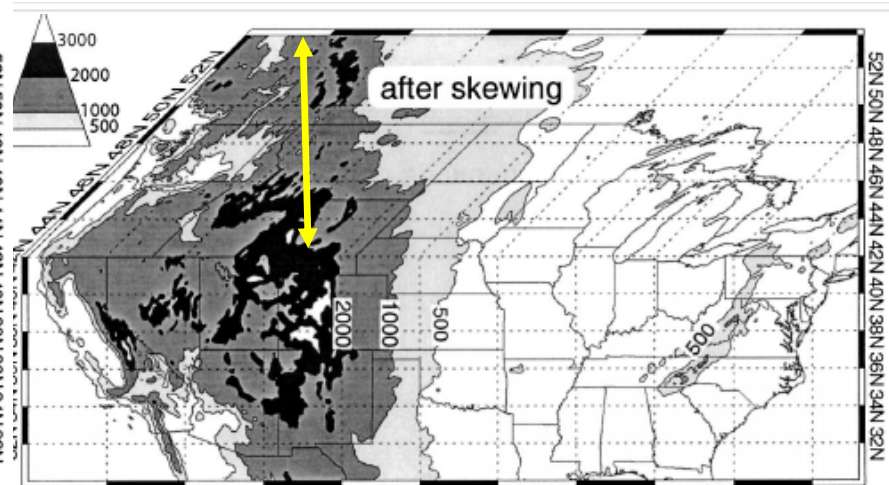


- Signals of coherent diurnal phase near Taiwan in TRMM data?
 - Have origin likely over the terrain in southeastern China
 - The orientation of Wu-yi mountain is NE-SW, not N-S
 - Similar problem has been handled for the Rockies in NW USA

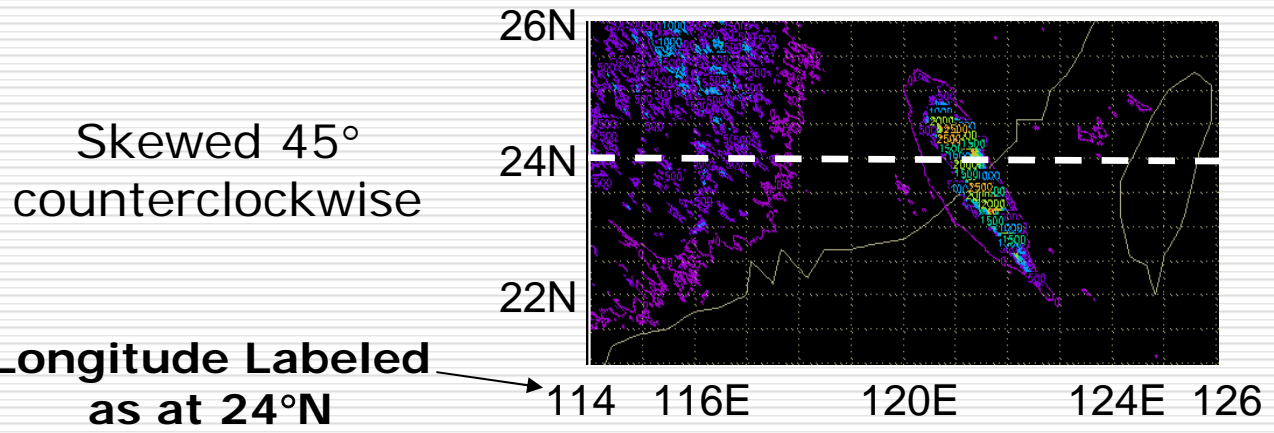
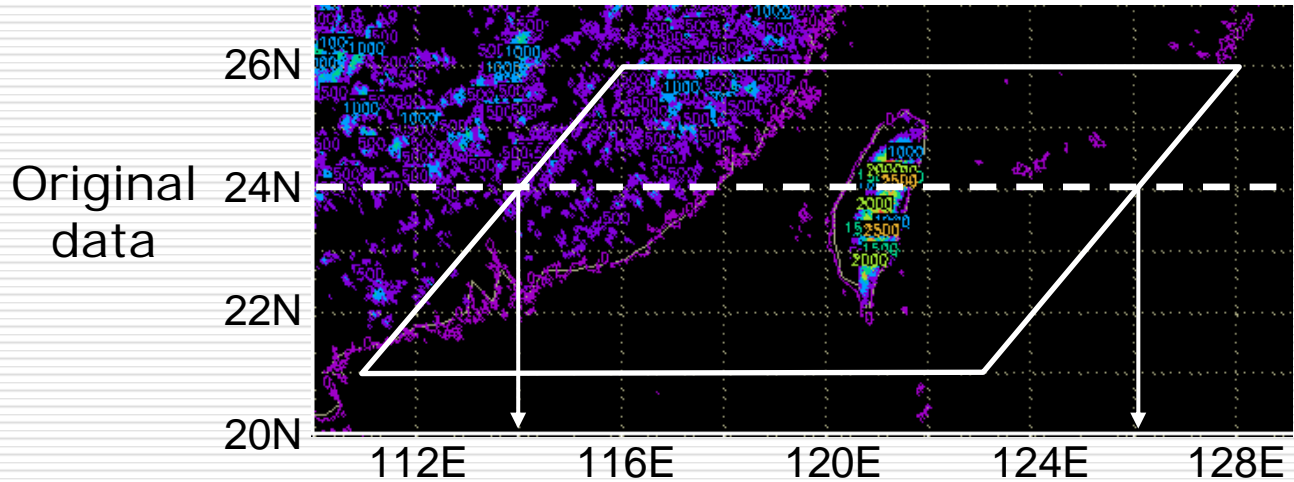
Original data before skewing



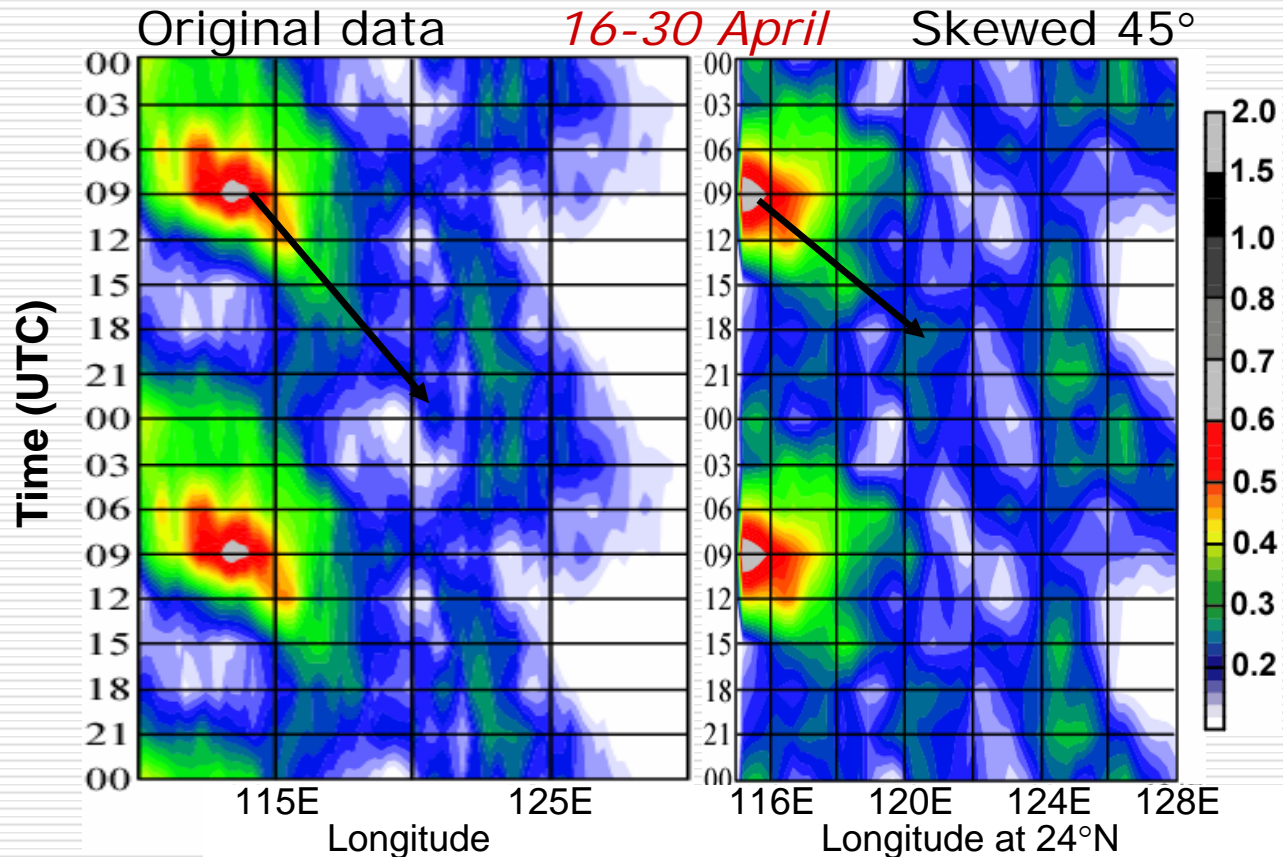
After skewing for 42°-54°N



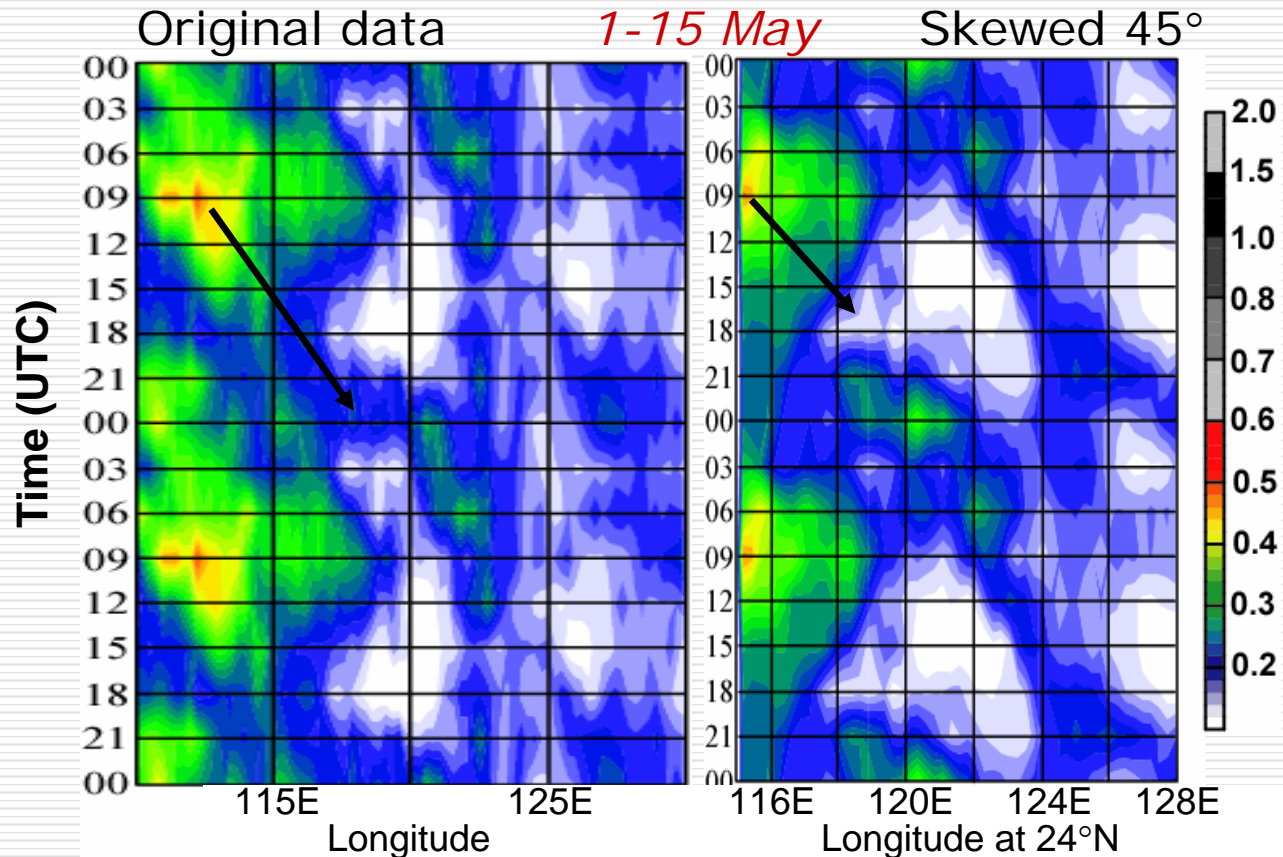
Ahijevych et al. (2004, JAS)



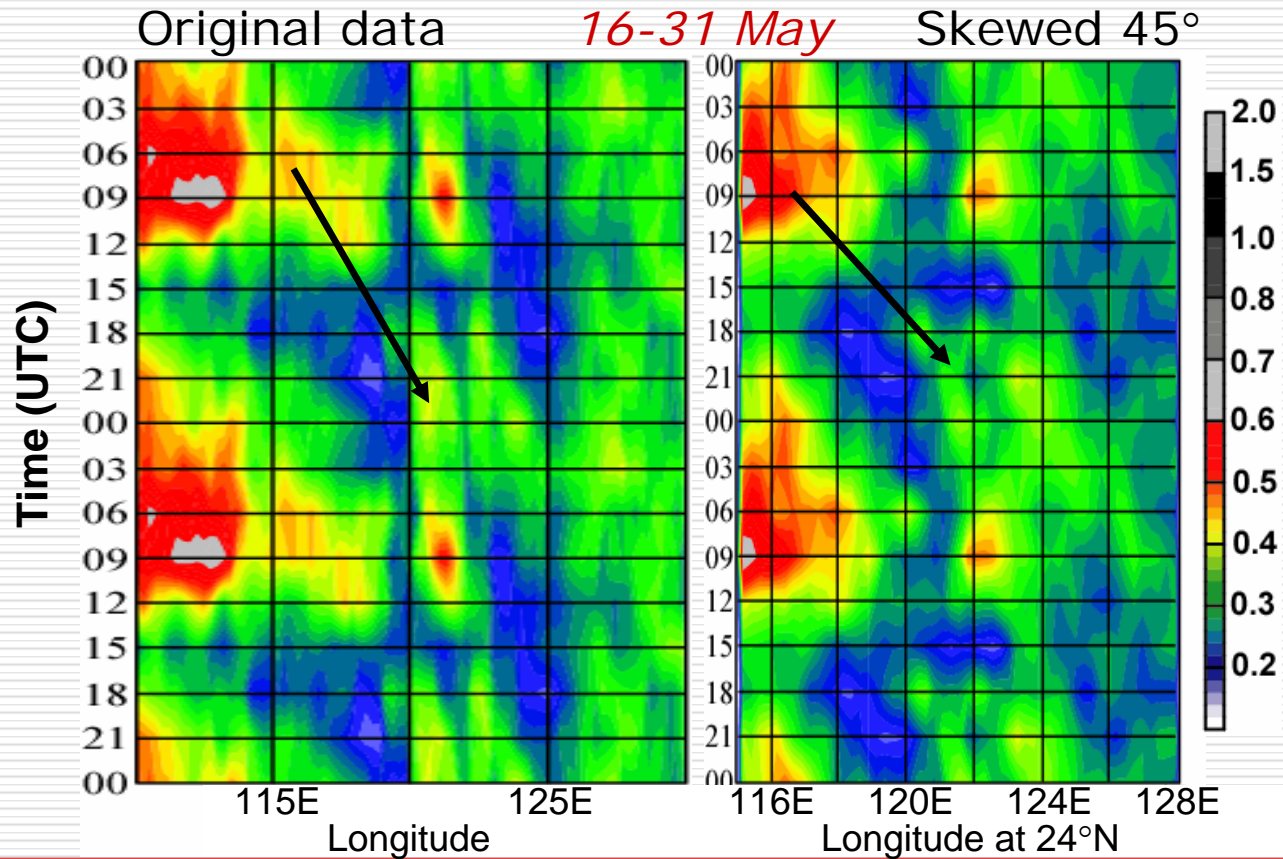
■ Long-term averaged diurnal cycle near Taiwan (1998-2008)



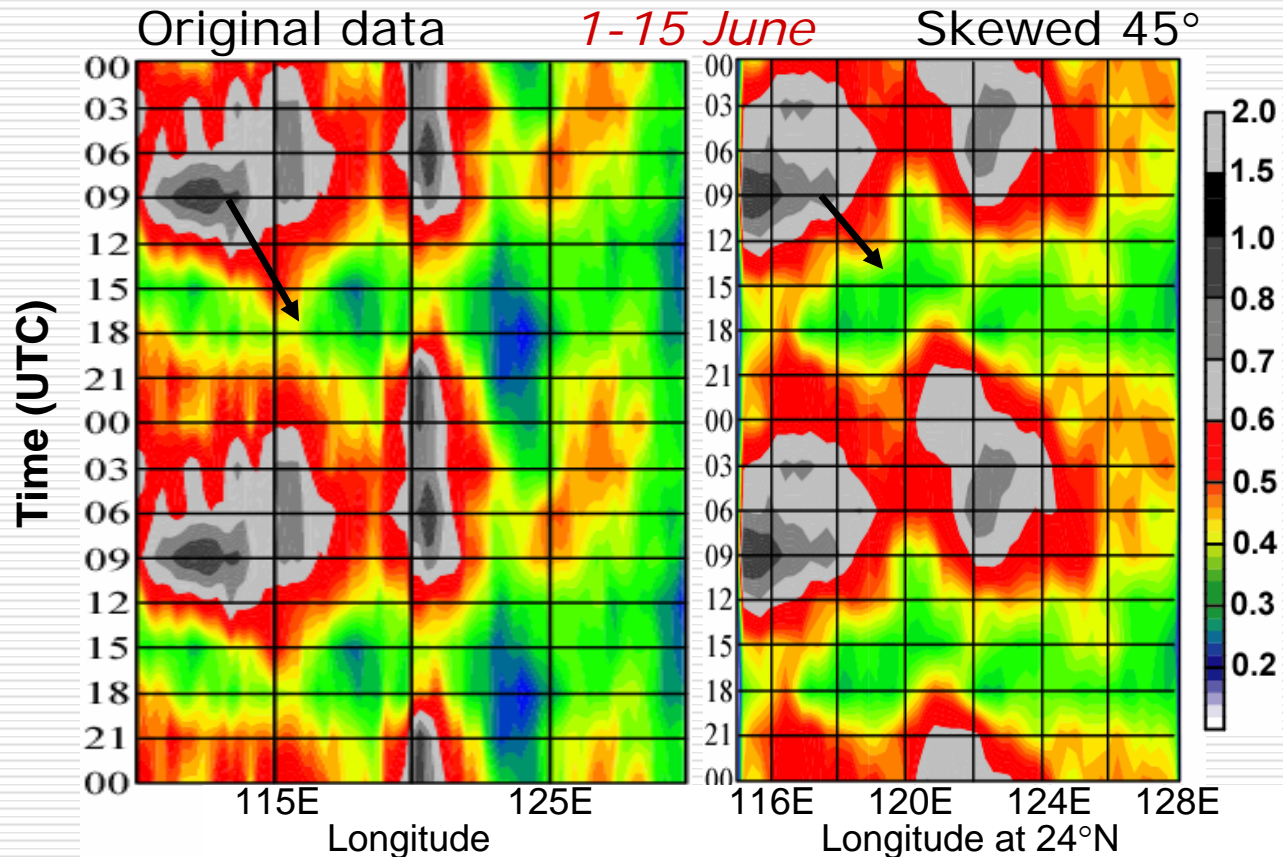
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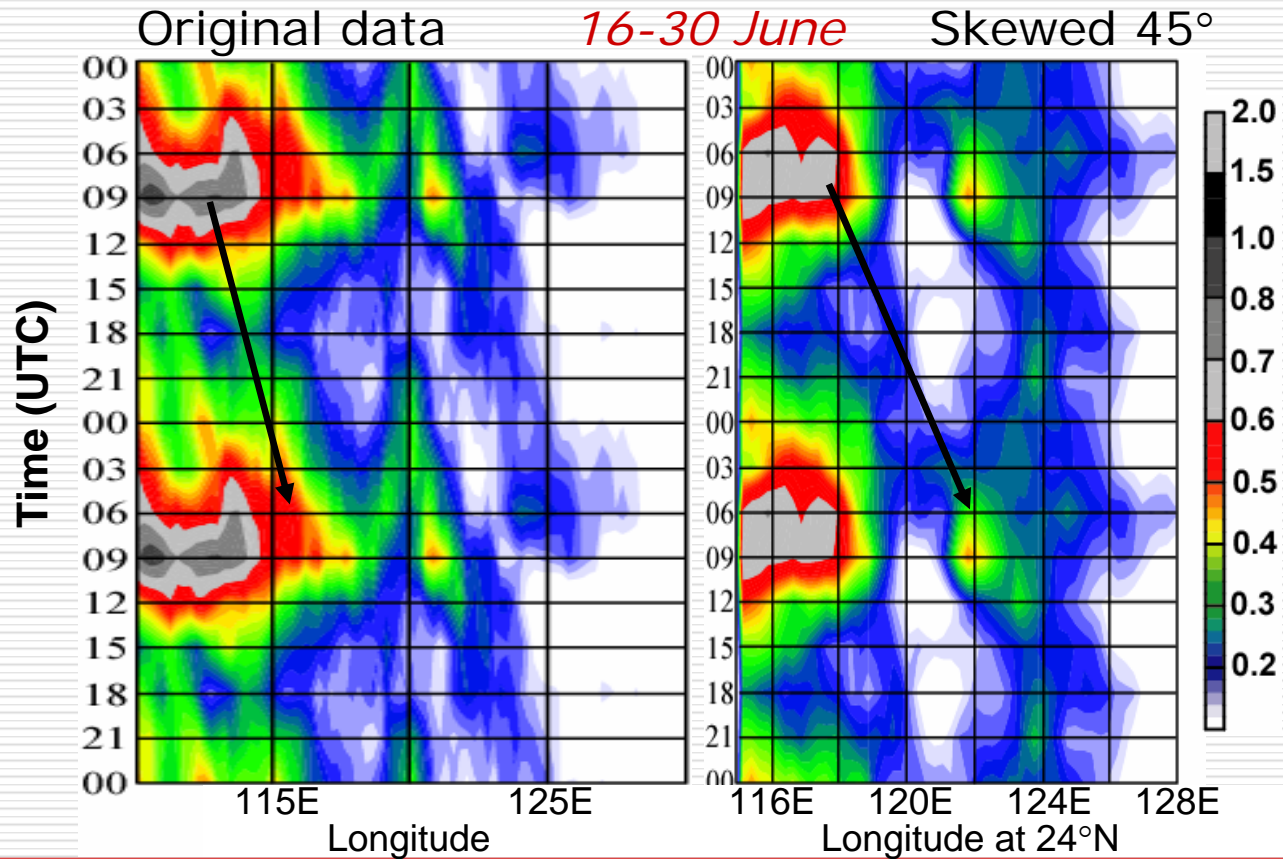
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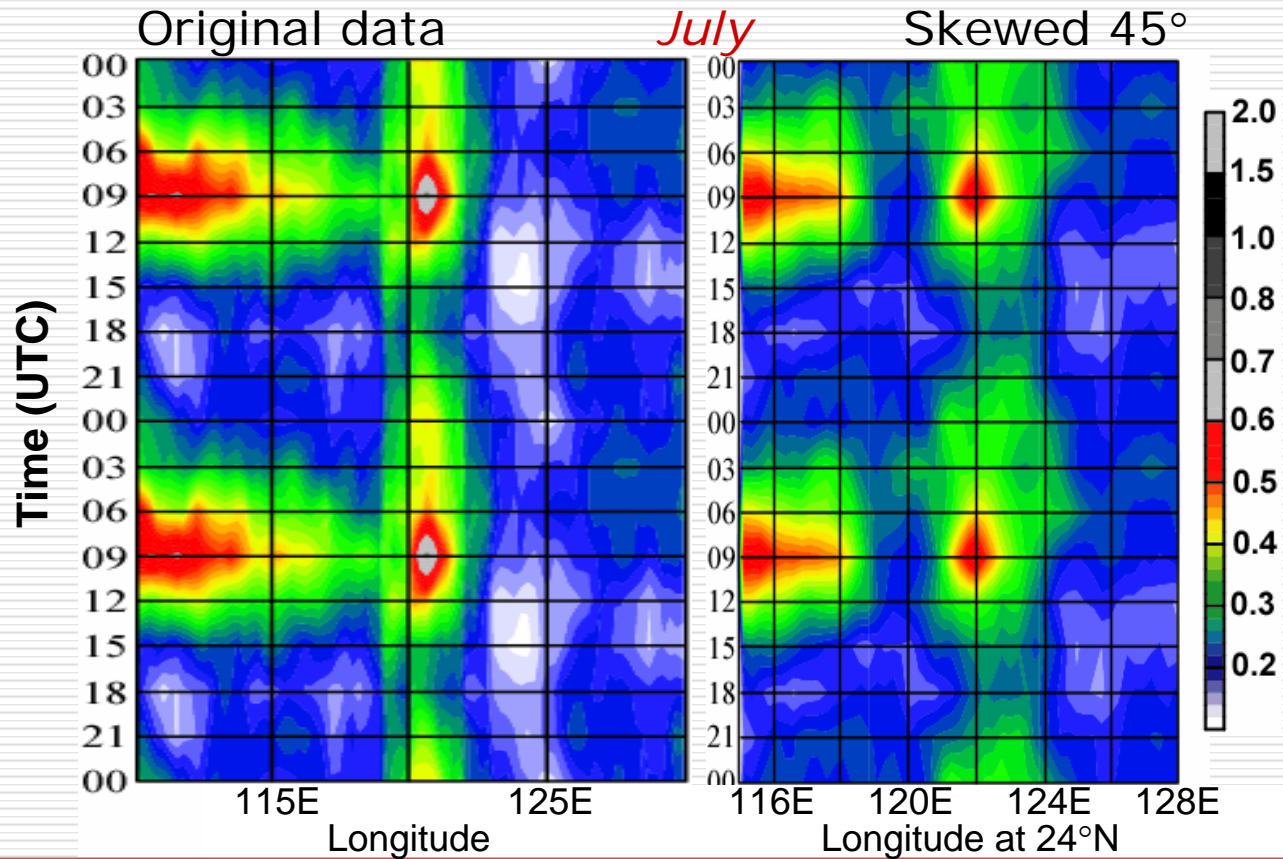
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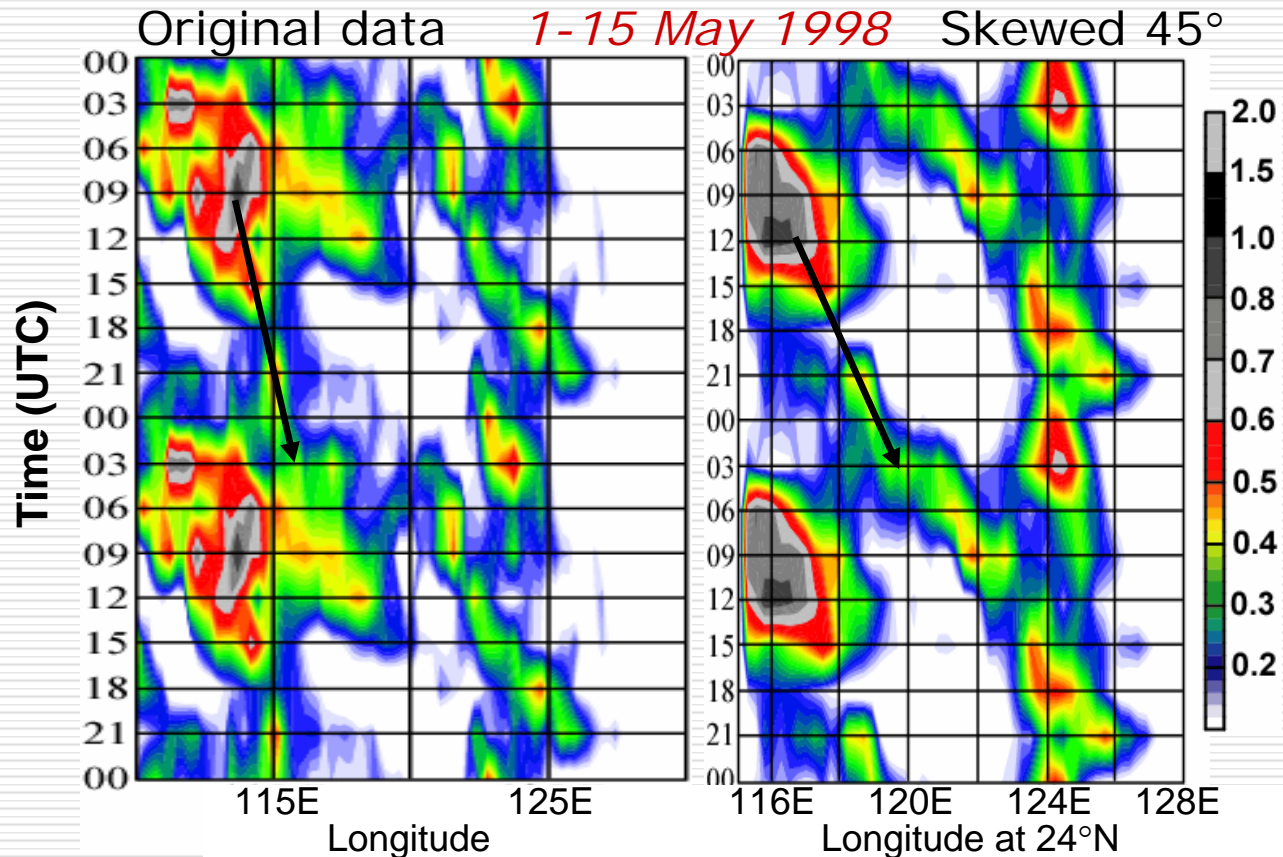
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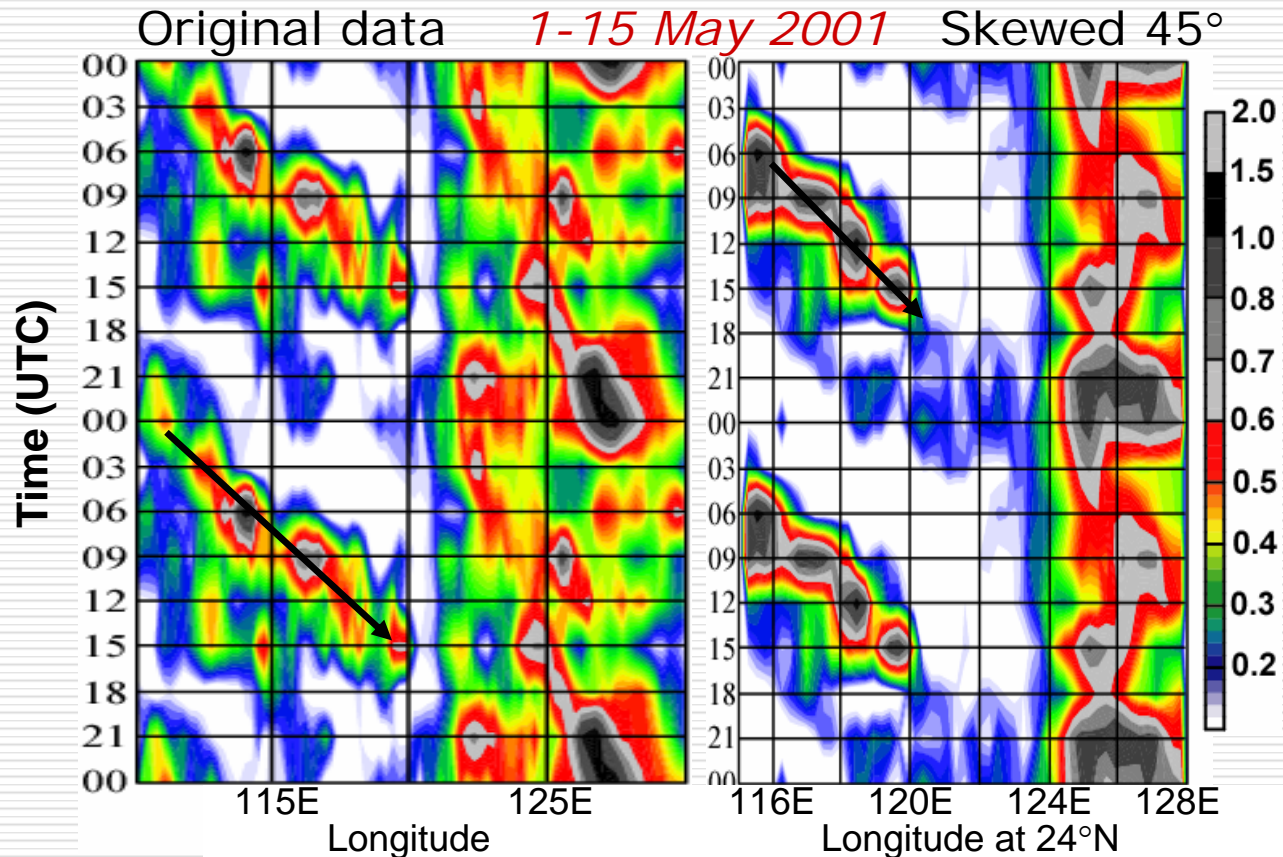
■ Long-term averaged diurnal cycle near Taiwan (1998-2008)



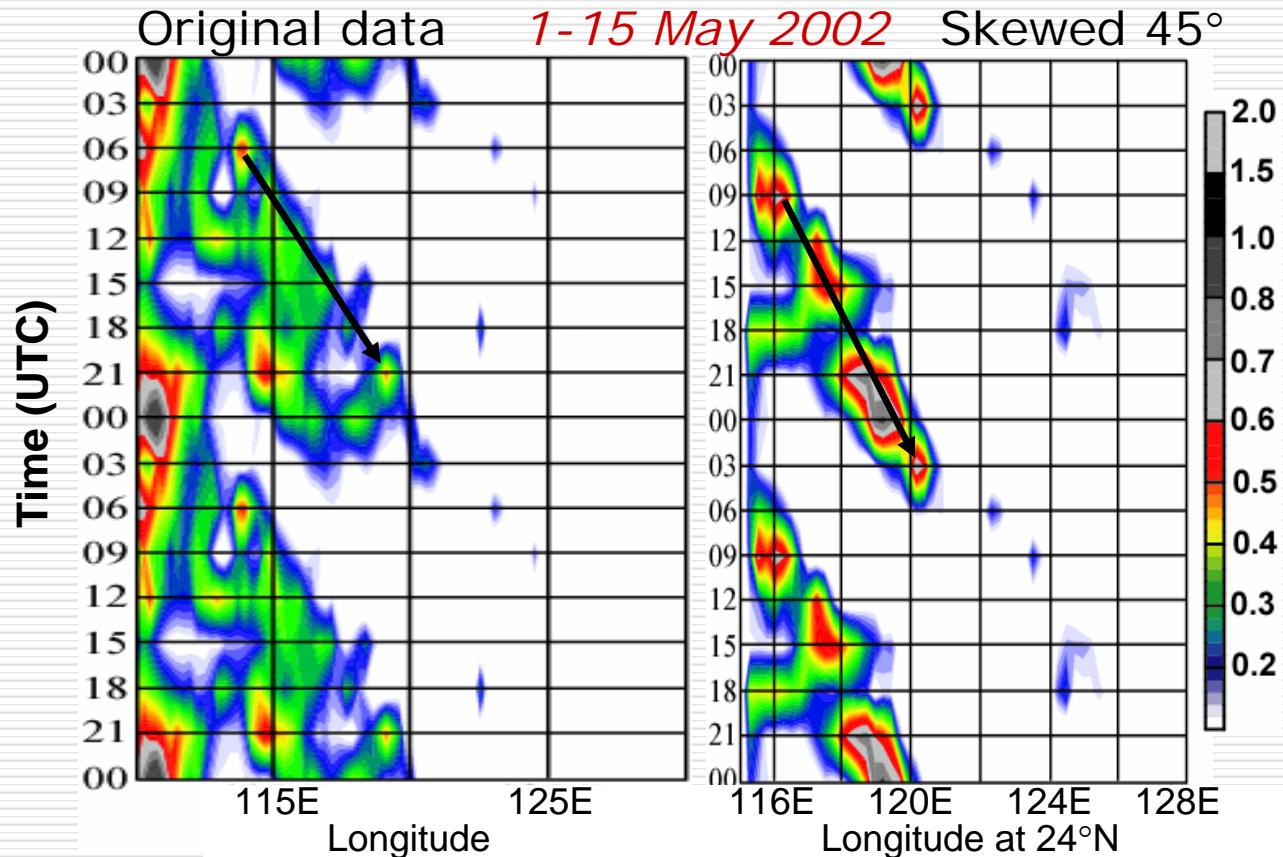
- Half-months of stronger signals at coherent phase in May-June



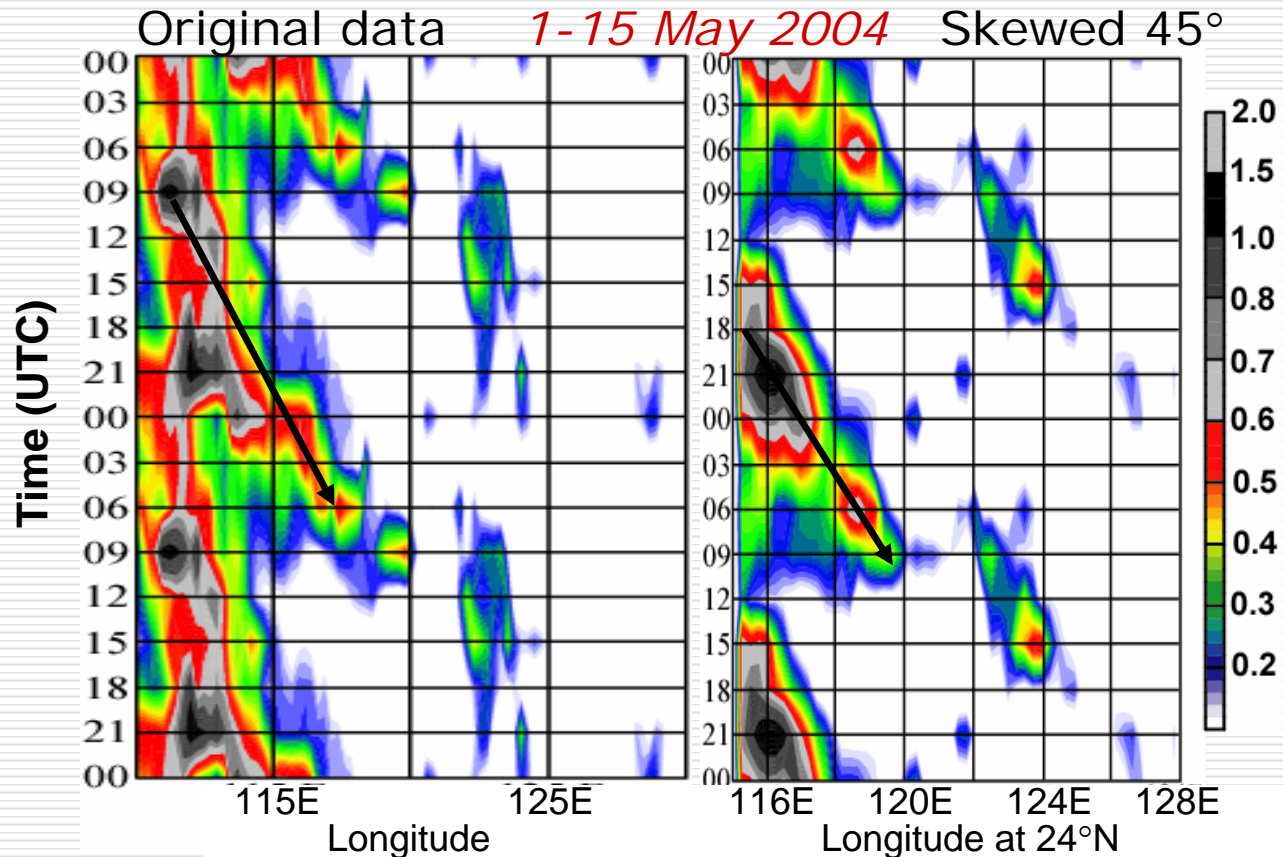
- Half-months of stronger signals at coherent phase in May-June



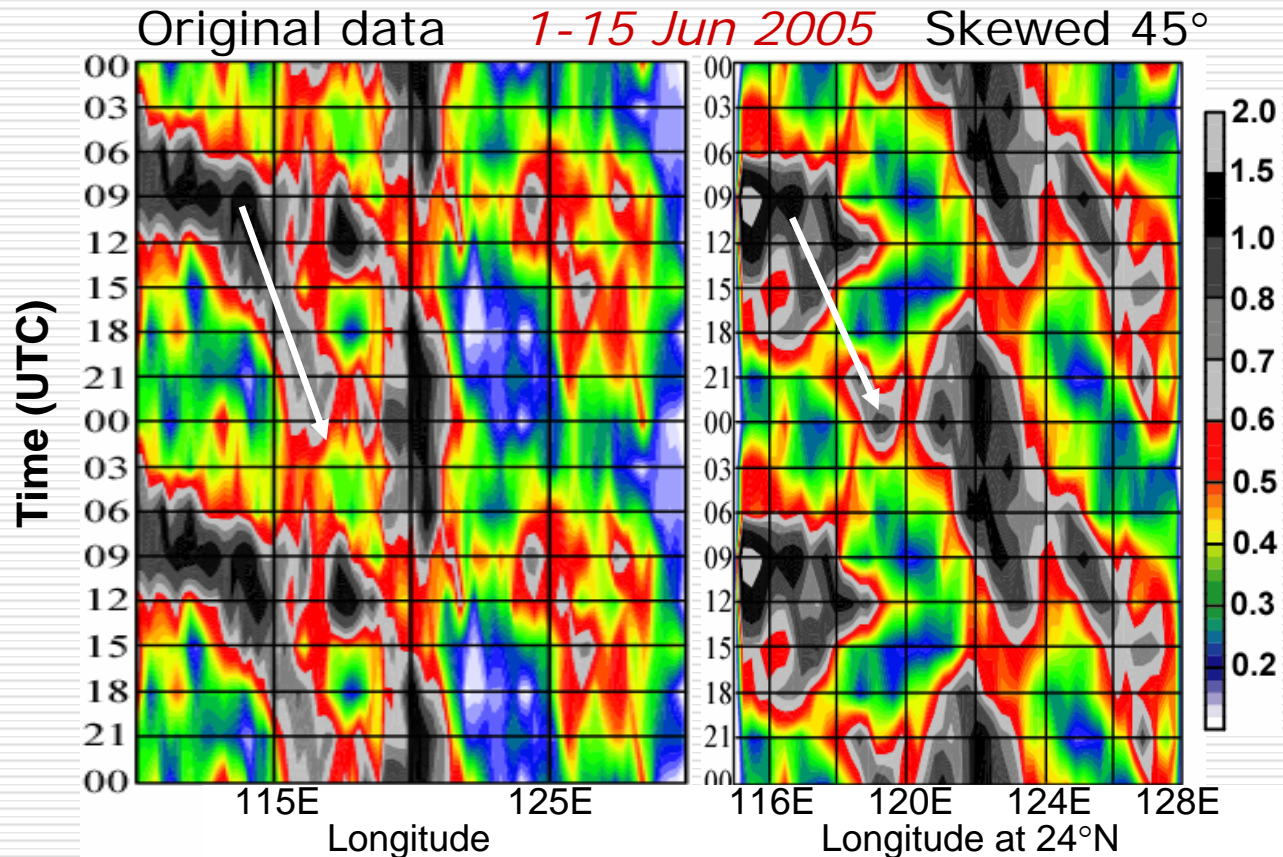
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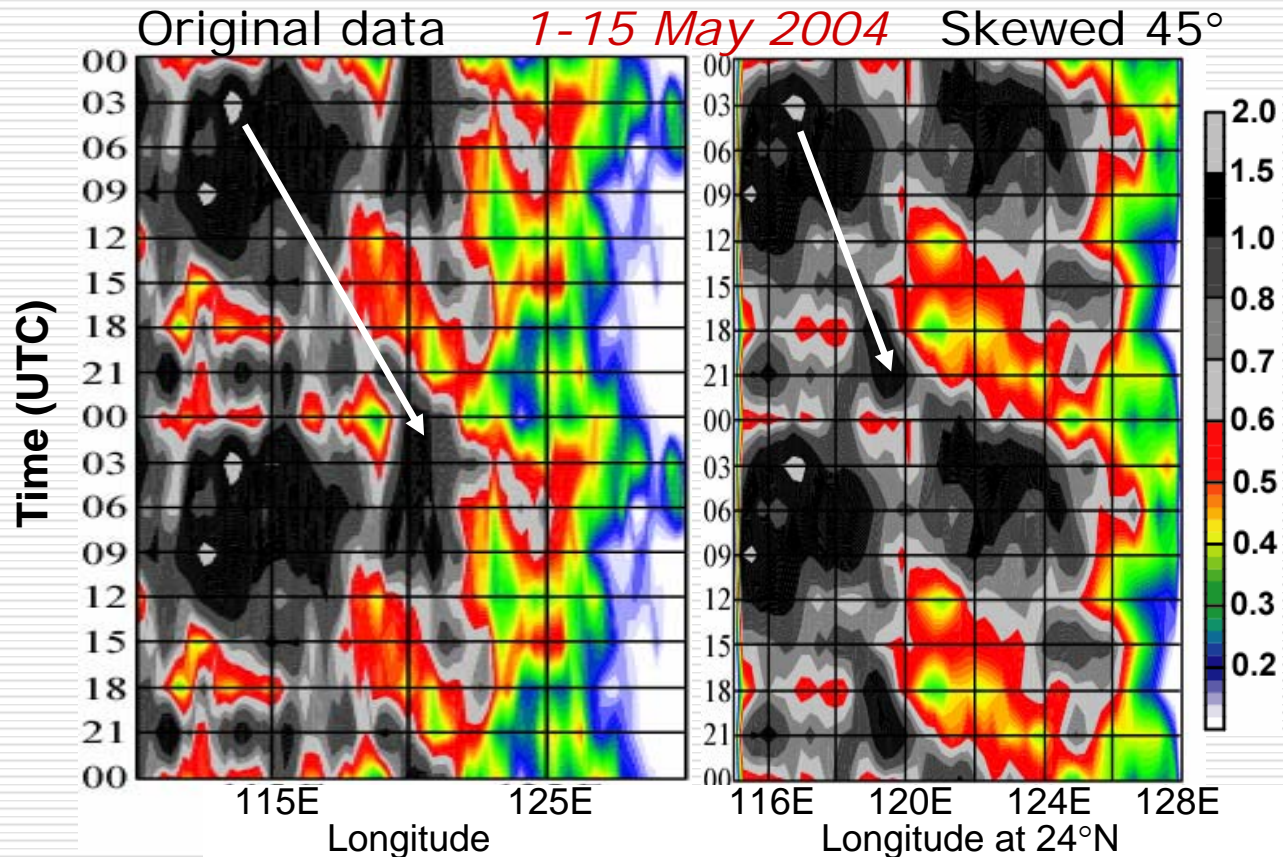
- Half-months of stronger signals at coherent phase in May-June



- Half-months of stronger signals at coherent phase in May-June

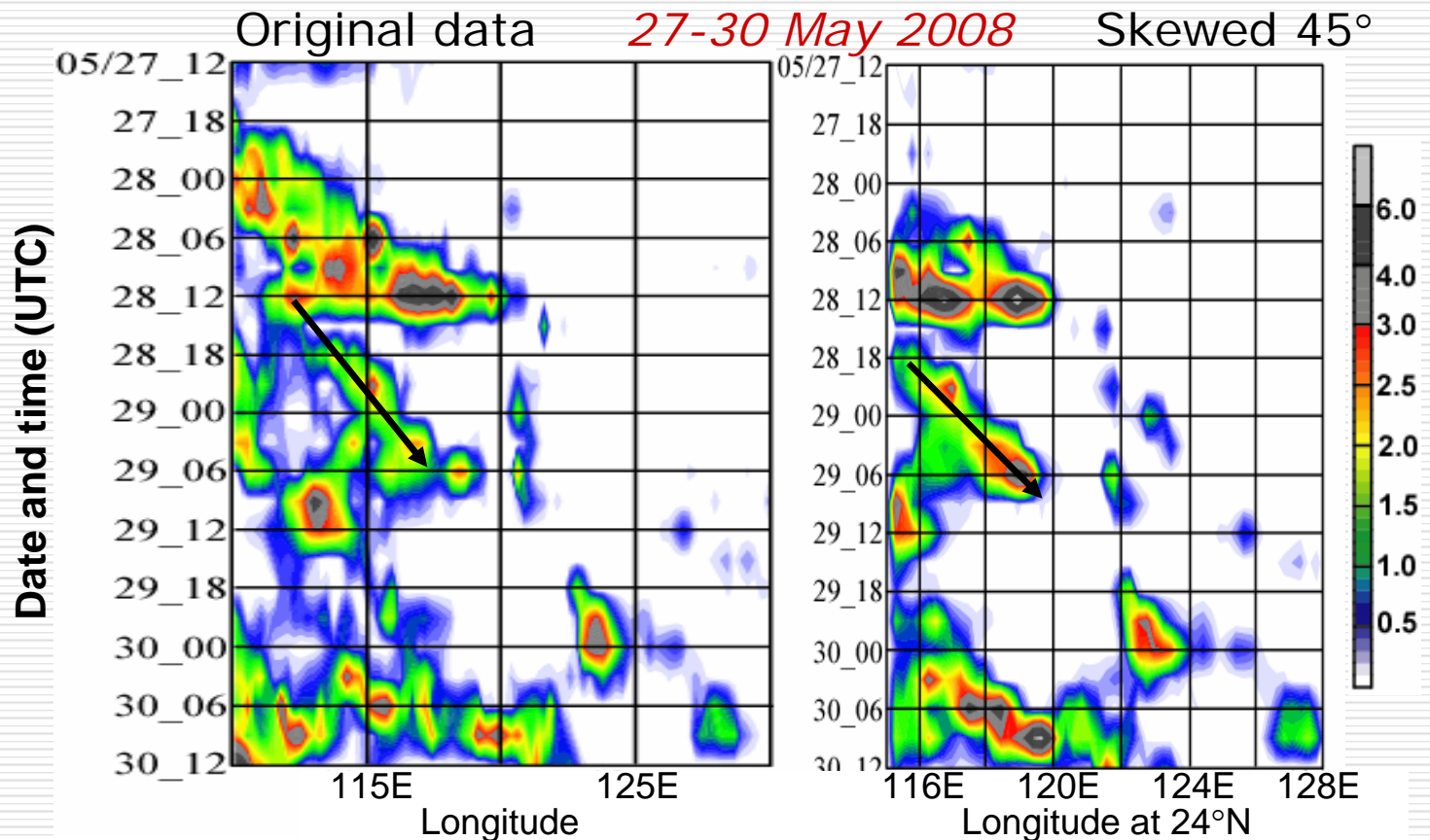


- Half-months of stronger signals at coherent phase in May-June

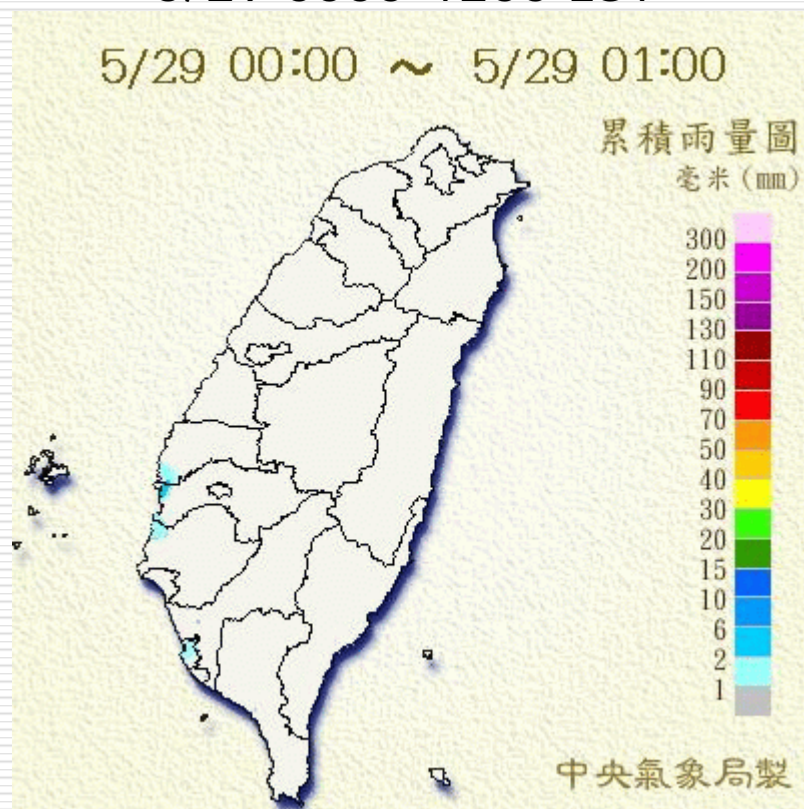


□ Examples during IOPs of SoWMEX/TiMREX:

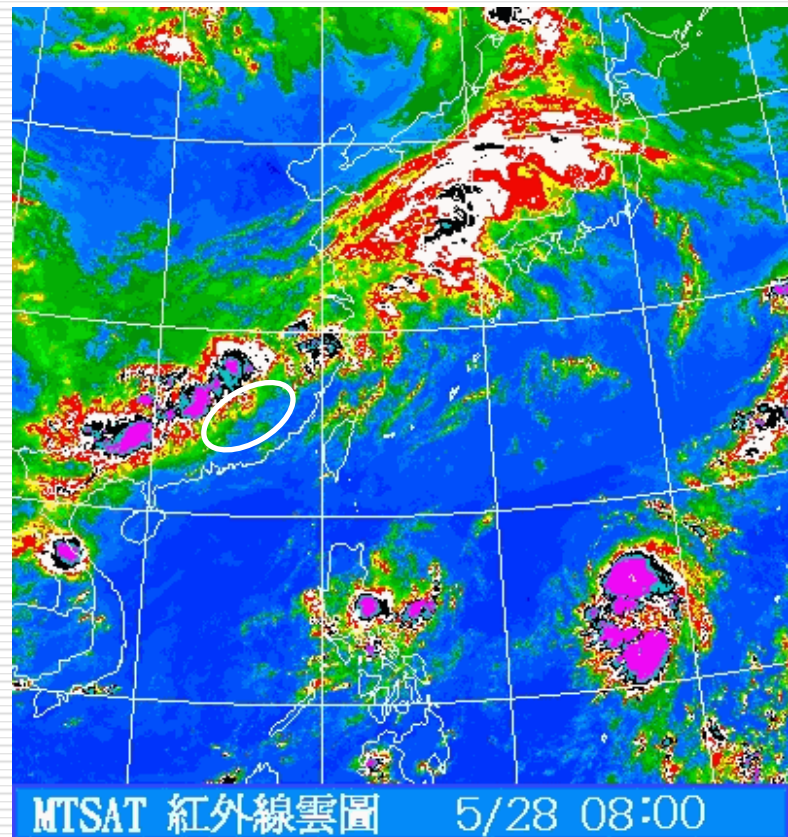
■ IOP-2: 28-29 May 2008



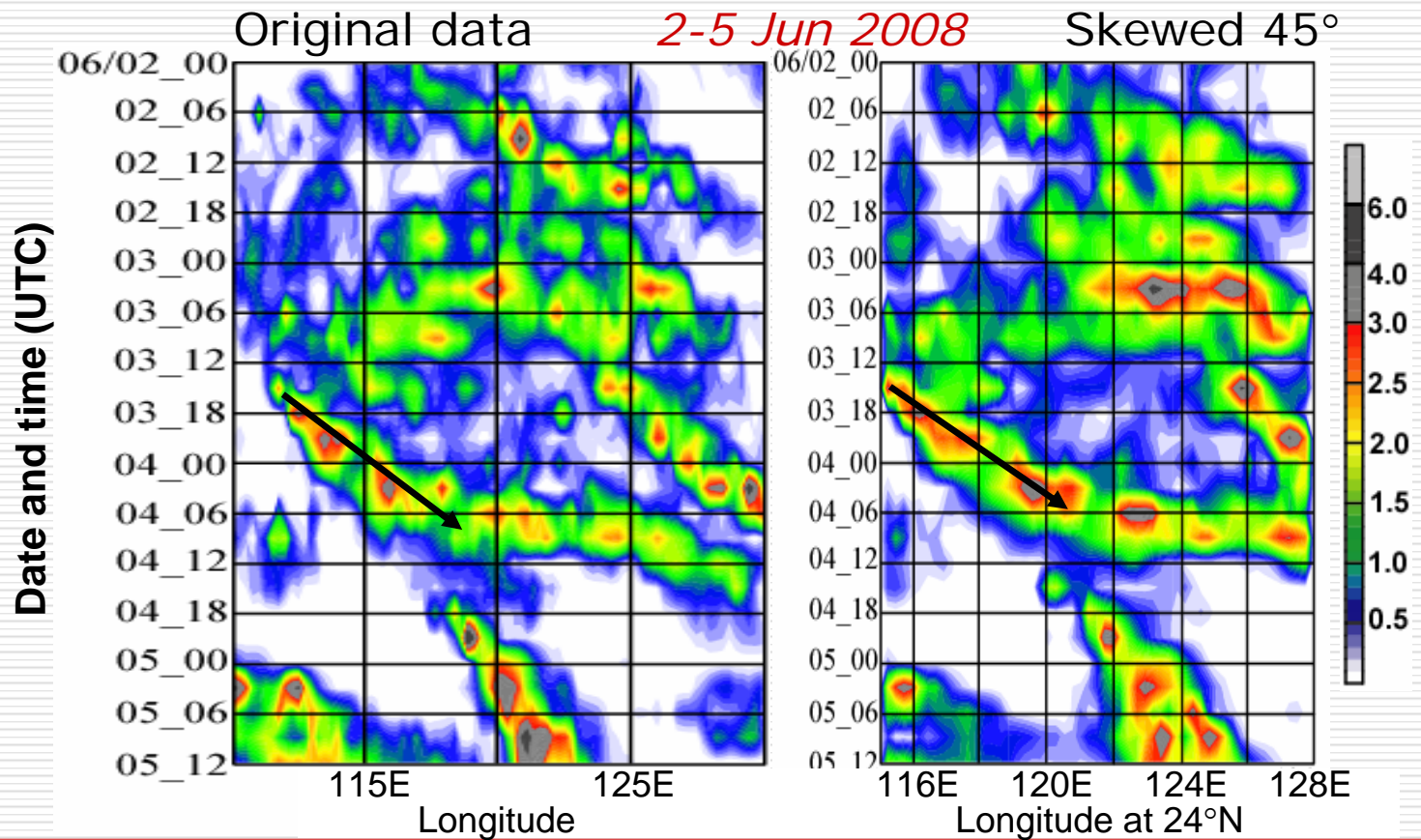
Hourly rainfall
5/29 0000-1200 LST



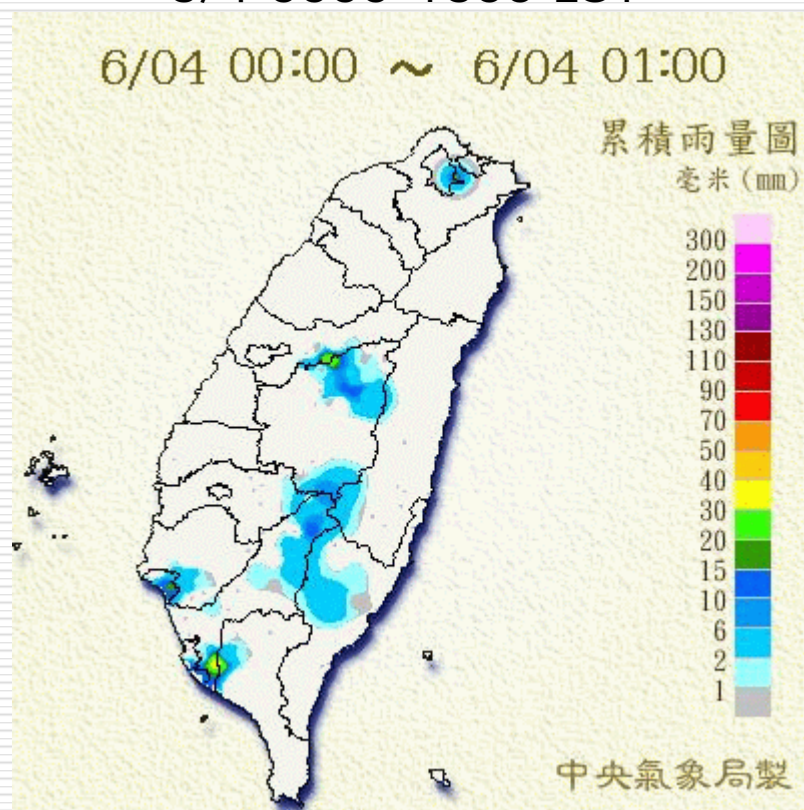
MTSAT IR enhanced
5/28 0800-5/29 2000 LST



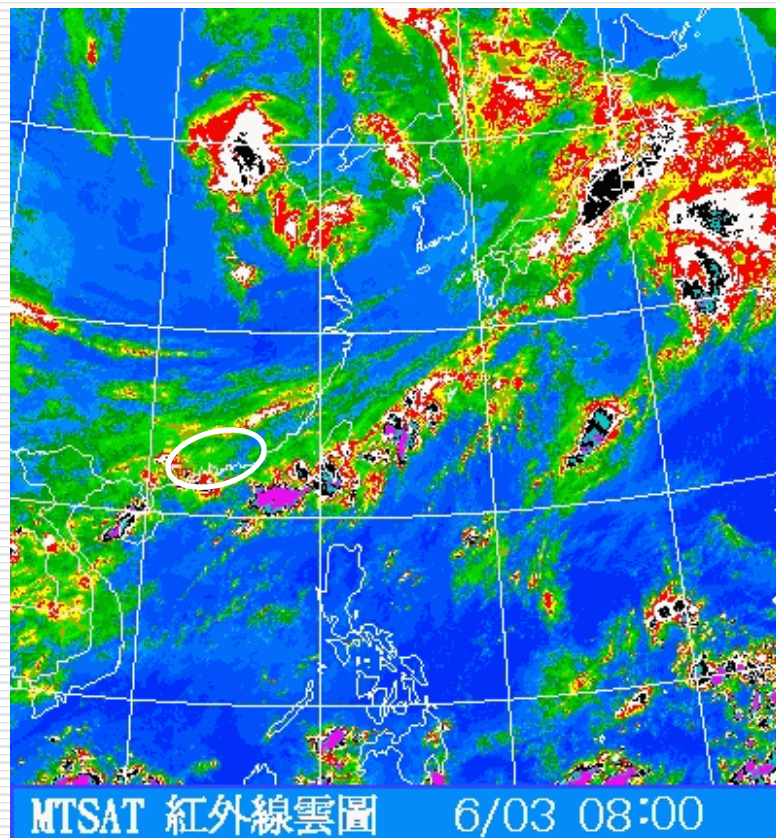
■ IOP-5: 3-4 June 2008



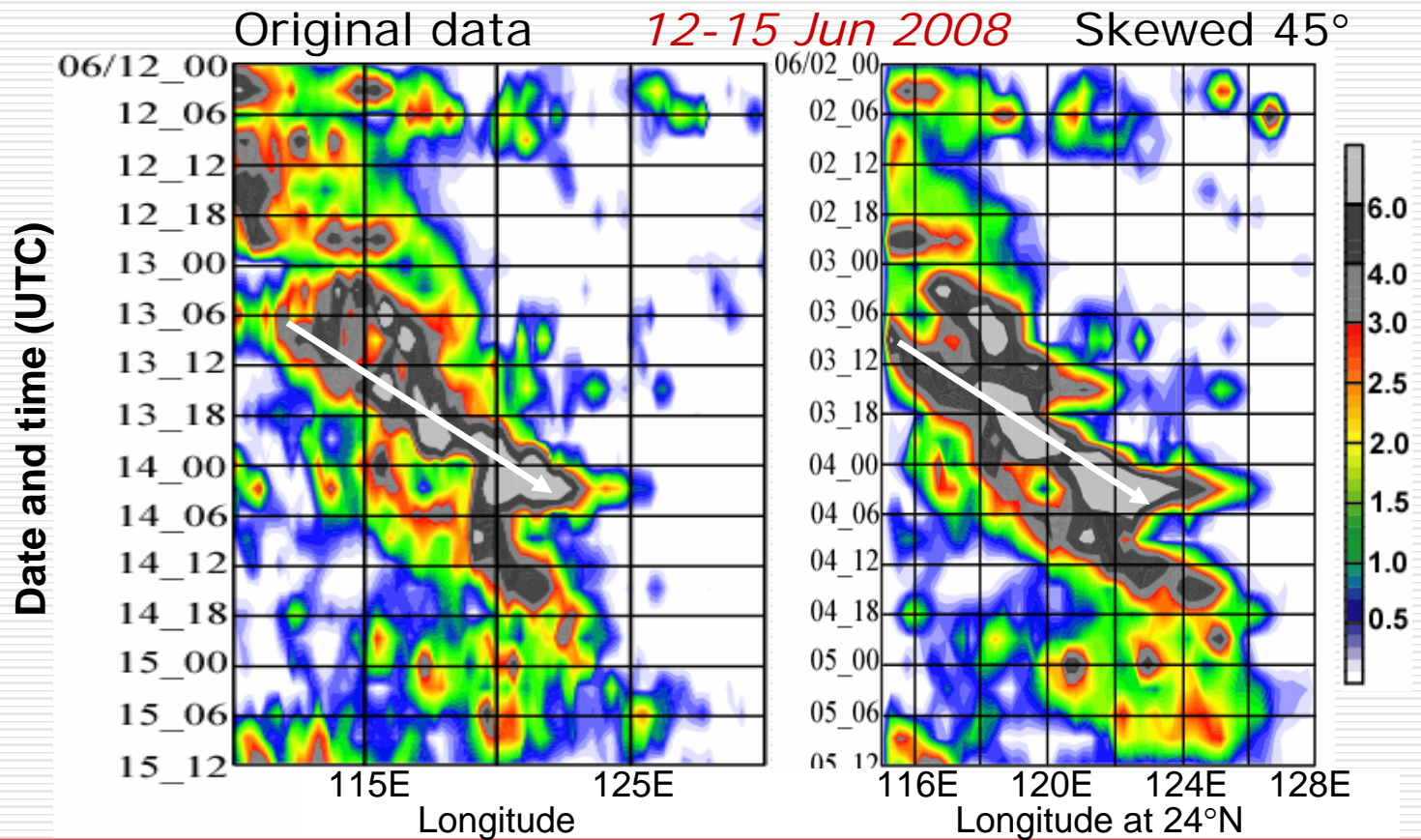
Hourly rainfall
6/4 0000-1600 LST



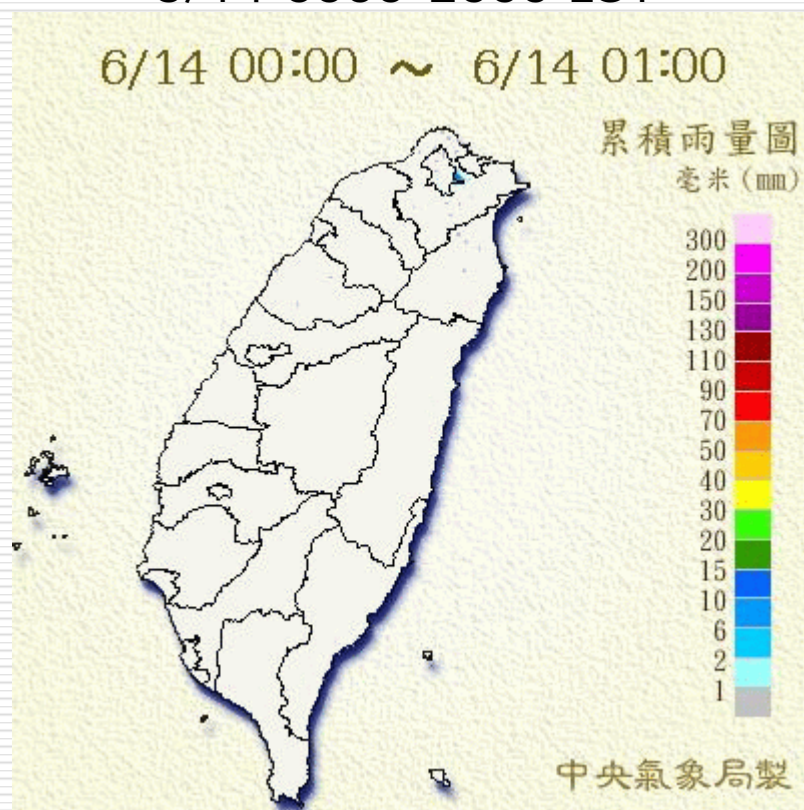
MTSAT IR enhanced
6/3 0800-6/4 2000 LST



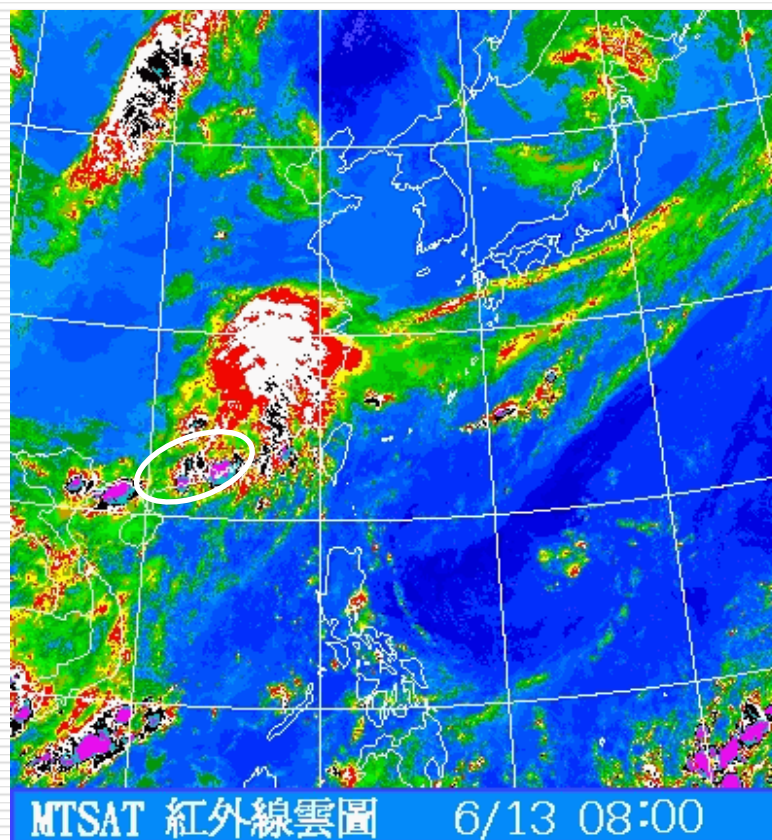
■ IOP-8: 13-14 June 2008



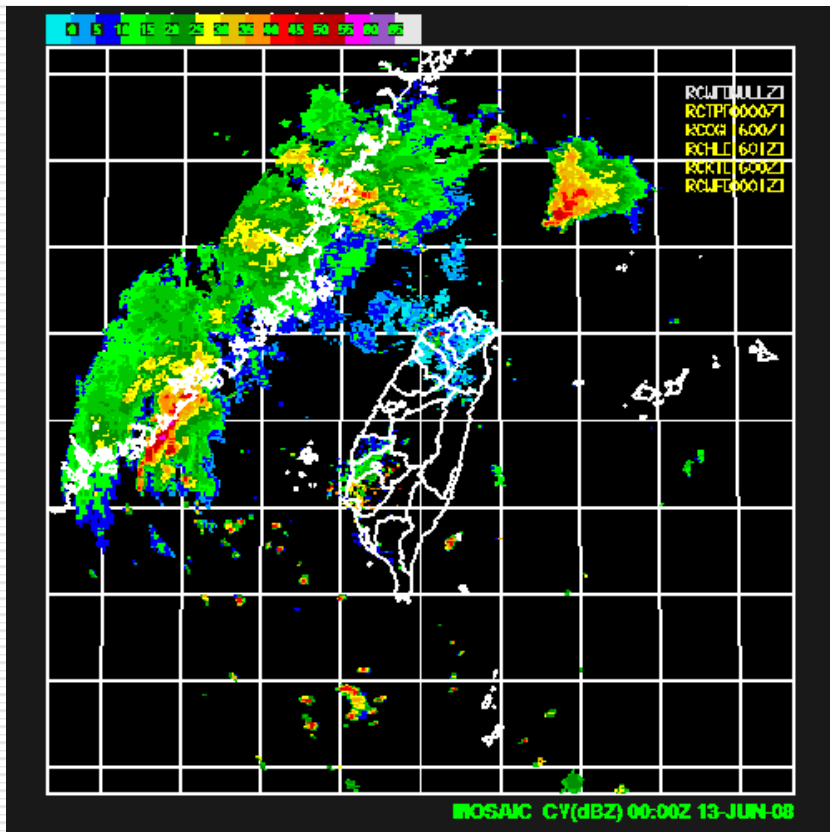
Hourly rainfall
6/14 0000-2000 LST



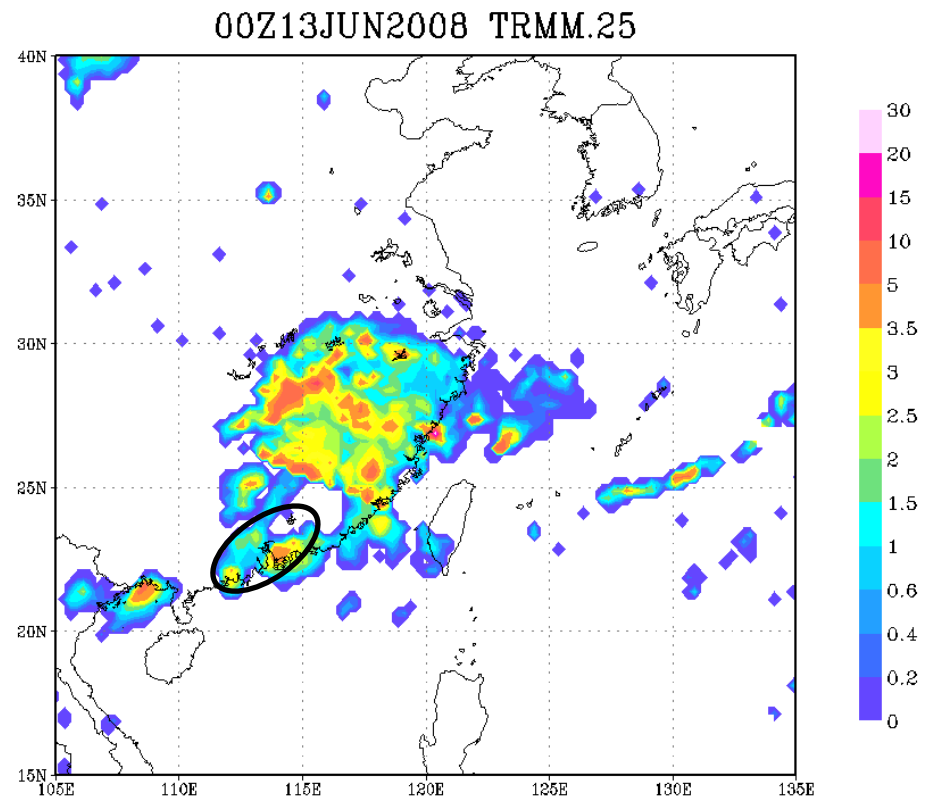
MTSAT IR enhanced
6/13 0800-6/14 2000 LST



Radar composite
6/13 0000-6/14 1200 UTC



TRMM 3-hr rain-rate (mm)
6/13 0000-6/14 1200 UTC



5. Summary and conclusion

- Propagating rainfall signals in sheared environment robust to the lee of TP and tied to the terrain within the diurnal cycle
 - Potential to improve warm-season QPFs due to the coherent behavior with high regularity (fixed location and time)
 - Evaluation of CWB NFS using TRMM data: (to appear in *TAO*)
 - Propagating signals not well captured in NFS D1 QPFs, similar to results in the US (Davis et al. 2003, MWR)
 - Largest disagreement in June, smallest in May (still inadequate)
 - The NFS produces too much rain over ETP and not enough to the lee, partially attributable to a lack of propagation
 - Phase error of rainfall peak time of at least 7 h near 110°-120°E
 - Application to rainfall forecasts in Taiwan during Mei-yu season:
 - Identify synoptic controlling factors for initiation and propagation
 - Inter-annual to intra-seasonal variability
-

--- The End ---

Thank you for your attention!
