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Comparison of the Seasonal Evolution of the Summer Monsoon over the Asian and Western North Pacific Sector in the WCRP CMIP3 Multi-model Experiments

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Tomoshige Inoue and Hiroaki Ueda

Life and Environmental Sciences, University of Tsukuba, Japan

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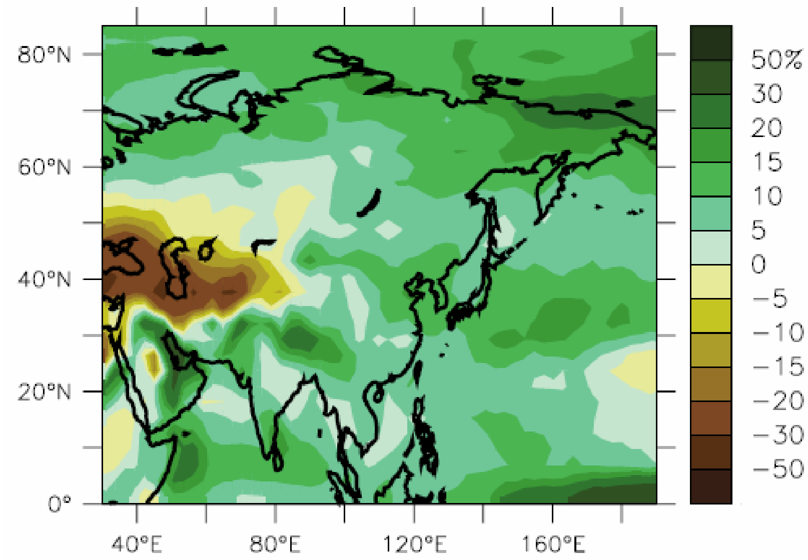
Introduction (1)

- IPCC-AR4 (2007) and other recent papers (e.g., Kimoto 2005, *GRL*; Ueda et al. 2006, *GRL*) described future projections of the Asian summer monsoon (ASM) based on the multi-model ensembles (MMEs) of CMIP3 CGCMs



JJA precipitation change (2080-99 relative to 1980-99) (IPCC 2007)

- On the other hand, recent studies (e.g., Lin et al. 2008, *J. Climate*) have pointed out that the there still remains large spread of reproducibility in various features of the ASM among these CGCMs.

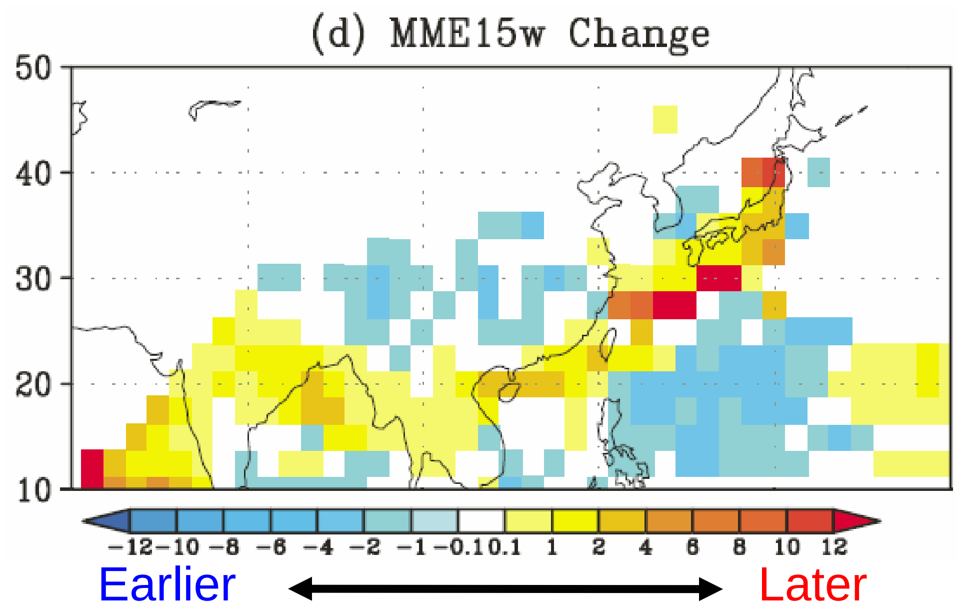
→ compare JJA-mean fields associated with the ASM circulation patterns in the CMIP3 CGCMs and observations

Introduction (2)

•ASM is characterized by abrupt monsoon onset

•Kitoh and Uchiyama (2006, *JMSJ*) showed future projection of the ASM seasonal changes based on the weighted MMEs

•Whereas, there are quite less papers that evaluate the seasonal marches themselves in the CMIP3 CGCMs



Future projection (2080-99 relative to 1980-99) of the ASM withdrawal (Kitoh and Uchiyama 2006)

→Compare the seasonal evolutions of the summer monsoon over the western north Pacific (WNP) and its vicinity in the CGCMs and observation

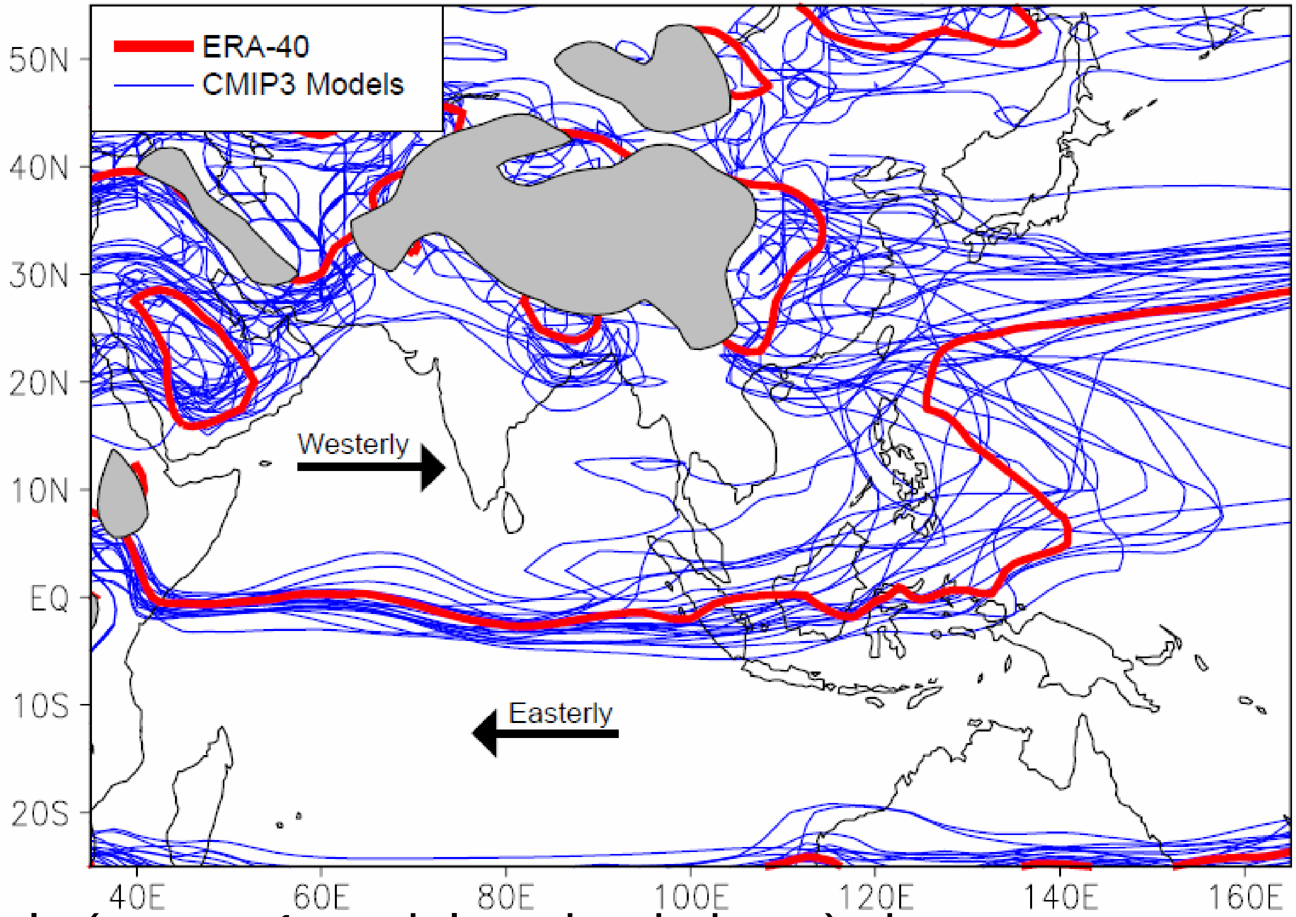
Data

- 20C3M of CMIP3 datasets
- 20 year climatology: 1980-99
- JJA-mean fields: 24 models
- Seasonal evolution: 18 models (daily data of precipitation and wind are available)

ID	Model	Country	Monthly	Daily
A	BCC-CM1	China	x	
B	BCCR-BCM2.0	Norway	x	x
C	CGCM3.1(T47)	Canada	x	x
D	CGCM3.1(T63)	Canada	x	x
E	CNRM-CM3	France	x	x
F	CSIRO-MK3.0	Australia	x	x
G	CSIRO-MK3.5	Australia	x	x
H	GFDL-CM2.0	USA	x	x
I	GFDL-CM2.1	USA	x	x
J	GISS-AOM	USA	x	x
K	GISS-EH	USA	x	
L	GISS-ER	USA	x	
M	FGOALS-g1.0	China	x	x
N	INGV-ECHAM4	Italy	x	x
O	INM-CM3.0	Russia	x	x
P	IPSL-CM4	France	x	x
Q	MIROC3.2(hires)	Japan	x	x
R	MIROC3.2(medres)	Japan	x	x
S	ECHO-G	Germany, Korea		x
T	ECHAM5/MPI-OM	Germany	x	x
U	MRI-CGCM2.3.2	Japan	x	x
V	CCSM3	USA	x	
W	PCM	USA	x	
X	UKMO-HadCM3	UK	x	
Y	UKMO-HadGEM1	UK	x	

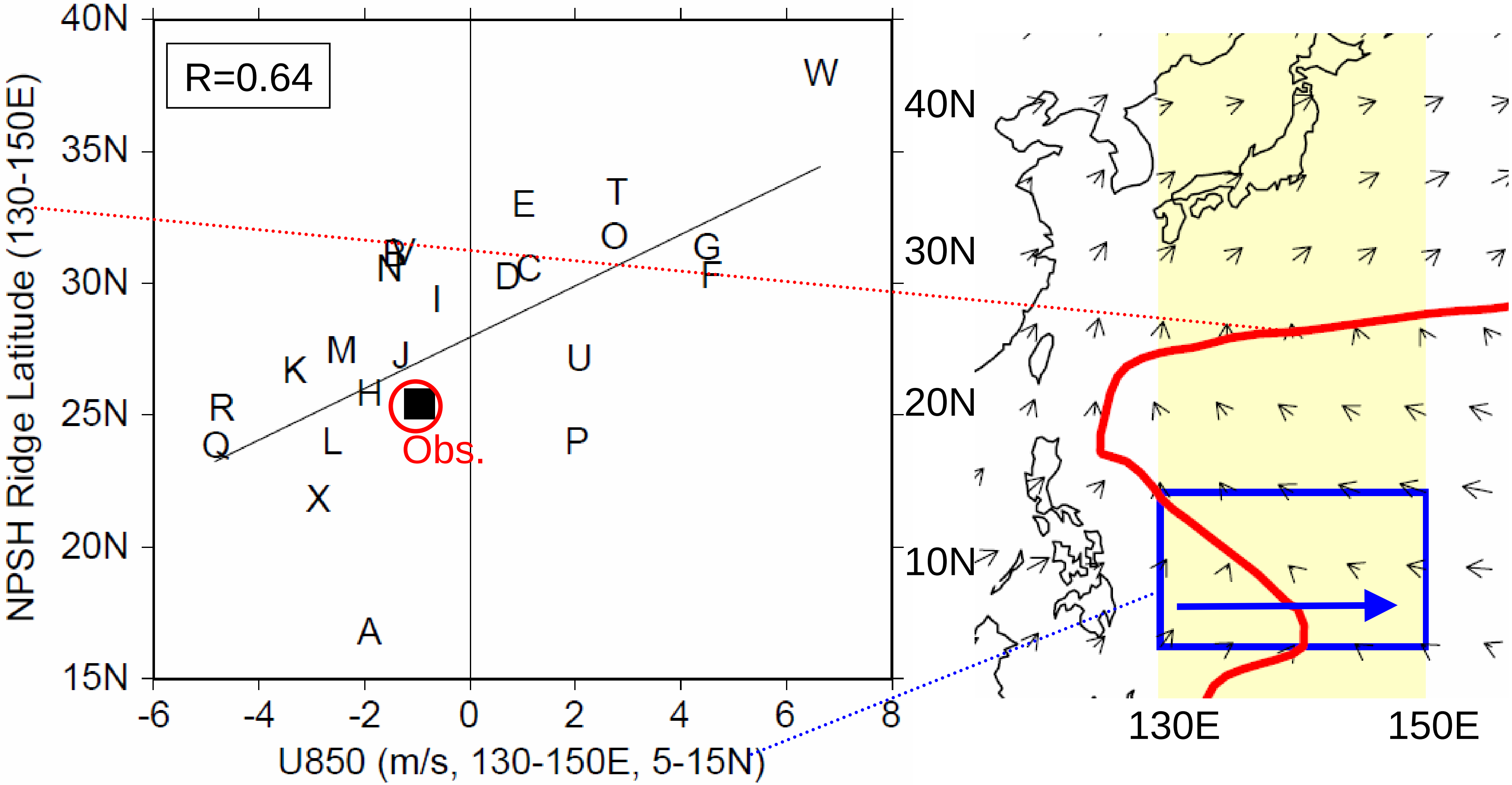
- Observational data for references
  - -Precipitation: CMAP precipitation (monthly and pentad)
  - -Atmospheric fields: ERA-40 (daily)

JJA-mean 850 hPa zonal wind boundaries



- All models (except 1 model: omitted above) show monsoon westerlies over north Indian Ocean and its vicinity
- Eastern peripheries of the tropical westerlies vary greatly
- In many models, a subtropical ridge in WNP locates more northward than that in observation

Relationship between the strength of the WNP monsoon westerlies and the position of the subtropical ridge (JJA-mean)



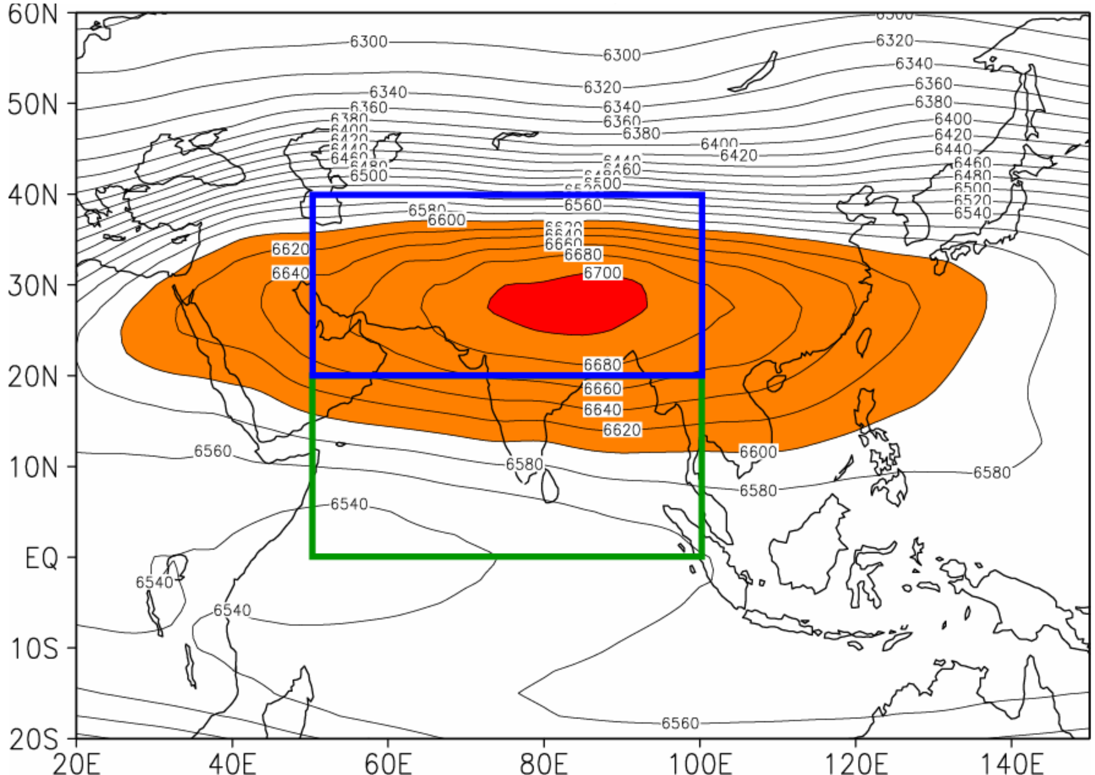
- enhanced monsoon westerlies over the WNP are concurrent with a northward position of the NPSH ridge

→climatological circulation in the CGCMs over the WNP-EA domain is at least partly influenced by the PJ teleconnection pattern (Nitta 1987)

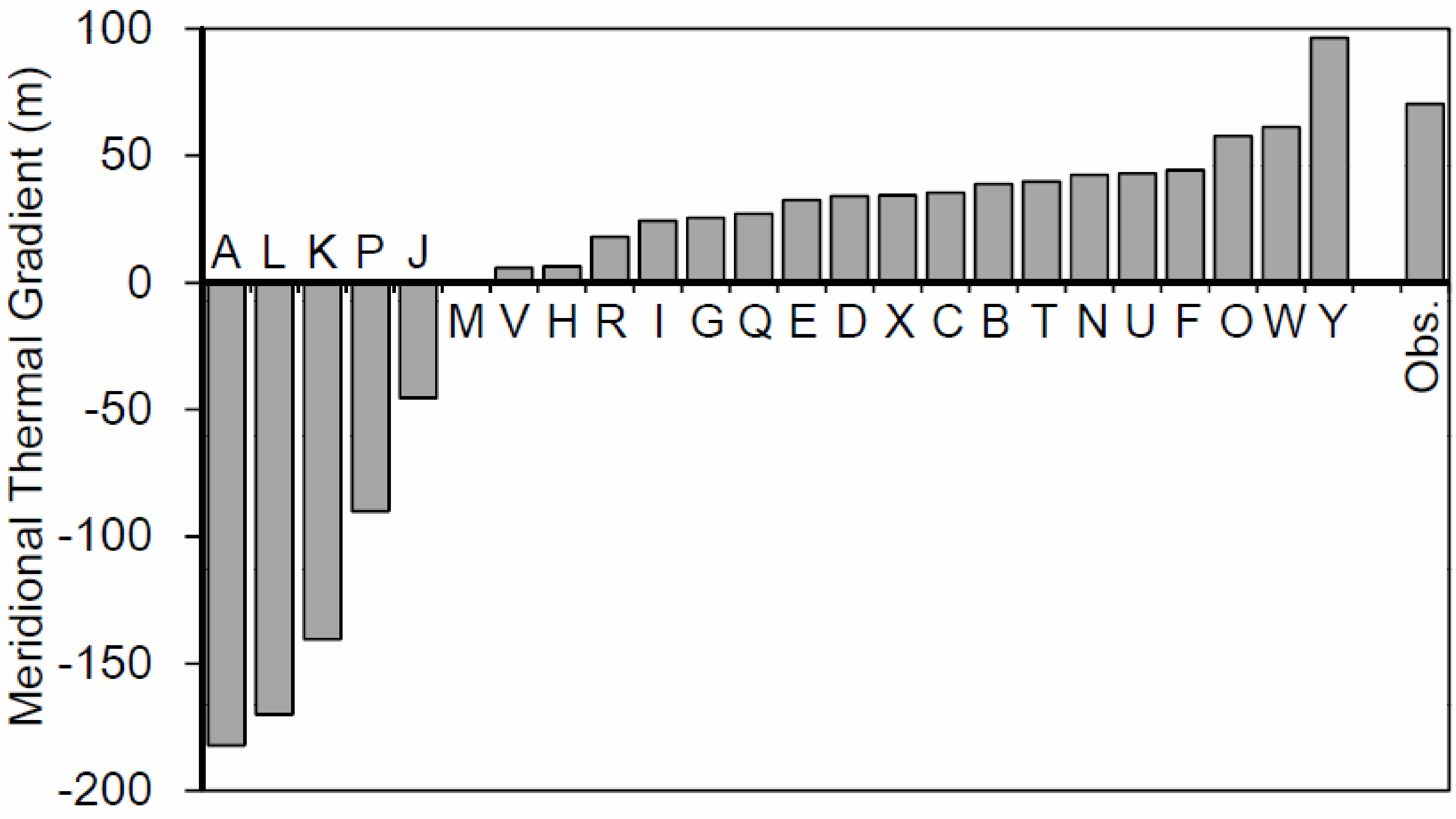
Meridional Thermal Gradient (MTG)

- MTG (Kawamura 1998, *JMSJ*): North-south difference of 200-500 hPa thickness (□-□)
- Degree of upper-tropospheric differential heating over the Tibetan Plateau and the north Indian Ocean
- Broad-scale index of the ASM circulation

JJA-mean 200-500hPa thickness (observation: ERA-40)

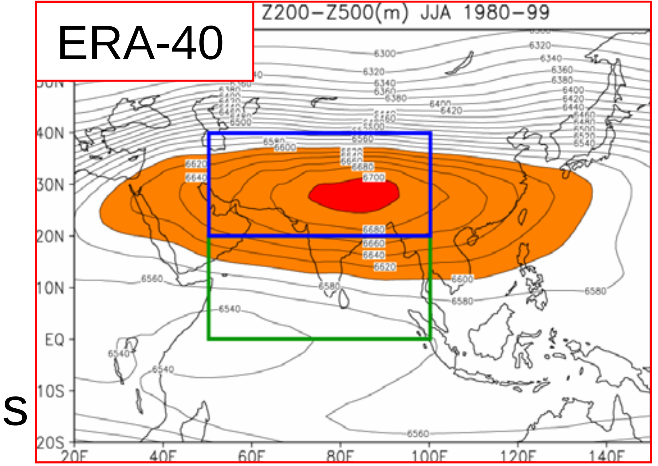


Meridional Thermal Gradient (MTG)



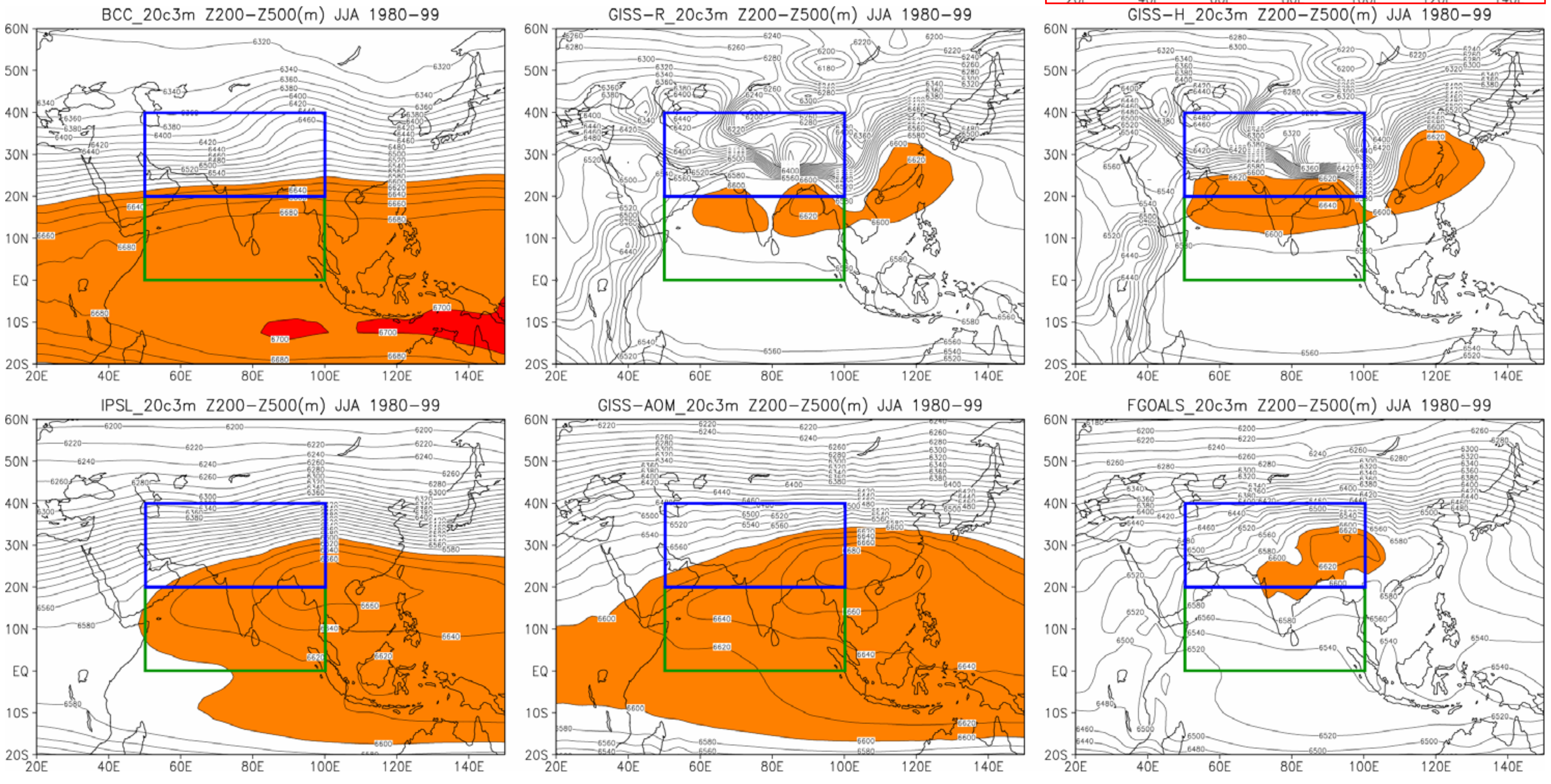
- Some models fail to reproduce the positive MTG over the South Asia and the North Indian Ocean sector

200-500 hPa thickness distribution (negative MTG models)



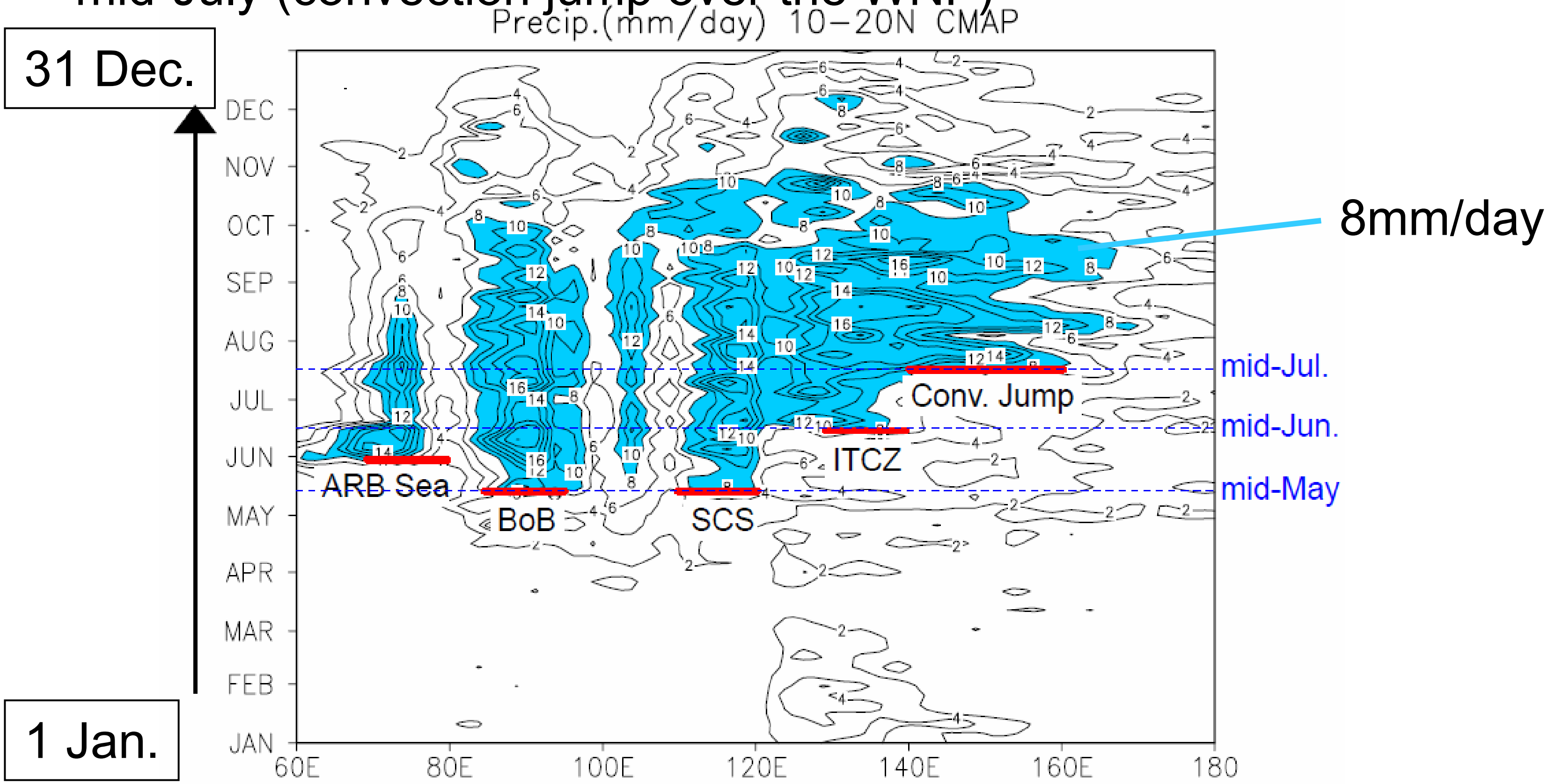
Orange: 6600-6700m   Red: 6700m-

- Heating center locates southeast of that in obs.
- Upper troposphere is disturbed too much in 2 models



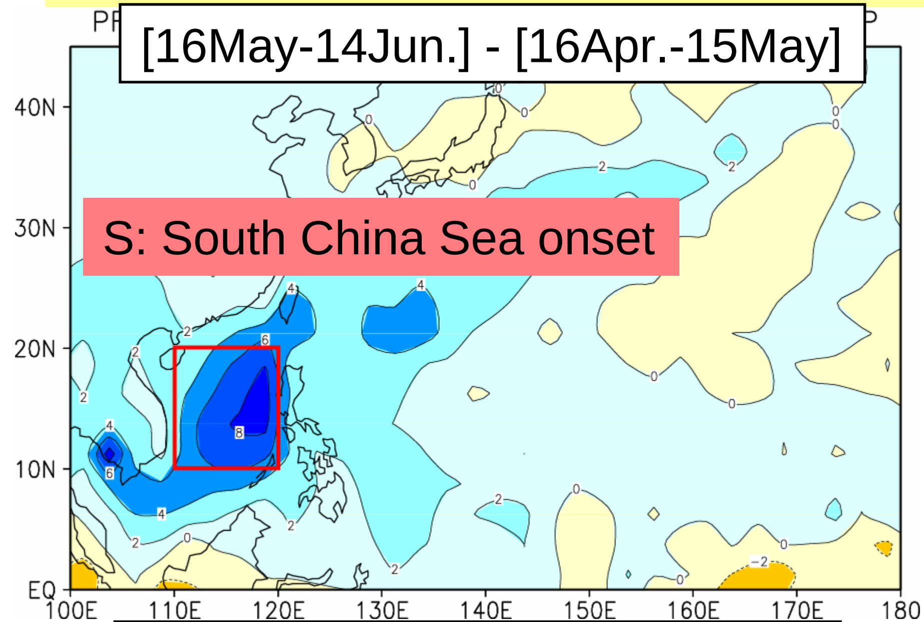
Stepwise seasonal evolution of the WNP summer monsoon (Observation)

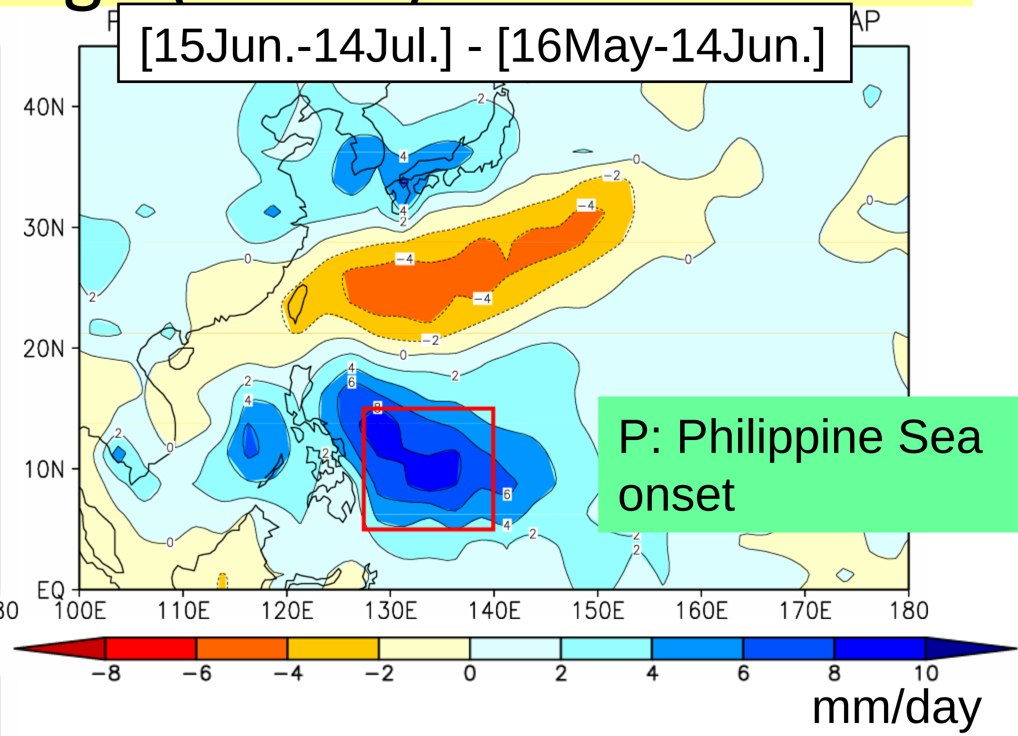
- Compare the stepwise seasonal evolution observed in the WNP summer monsoon
  - -mid-May (First Transition of the ASM, SCS onset)
  - -mid-June (mature phase of ITCZ over the Philippines Sea)
  - -mid-July (convection jump over the WNP)

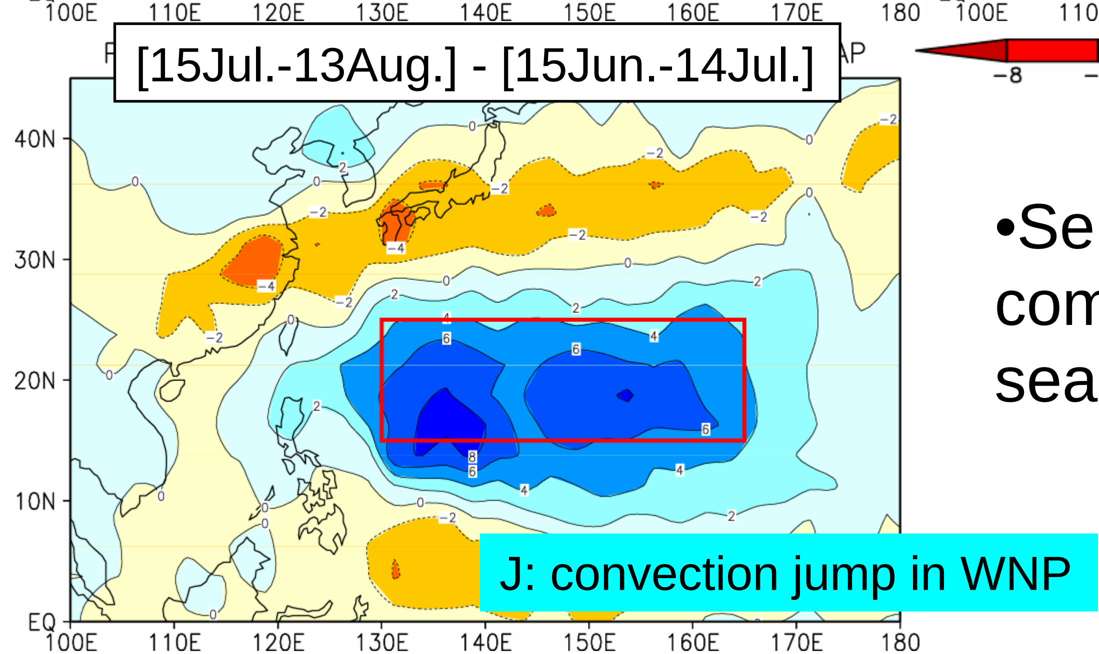


Ueda et al. (2009; J. Climate) modified

seasonal precipitation changes at each stage (CMAP)







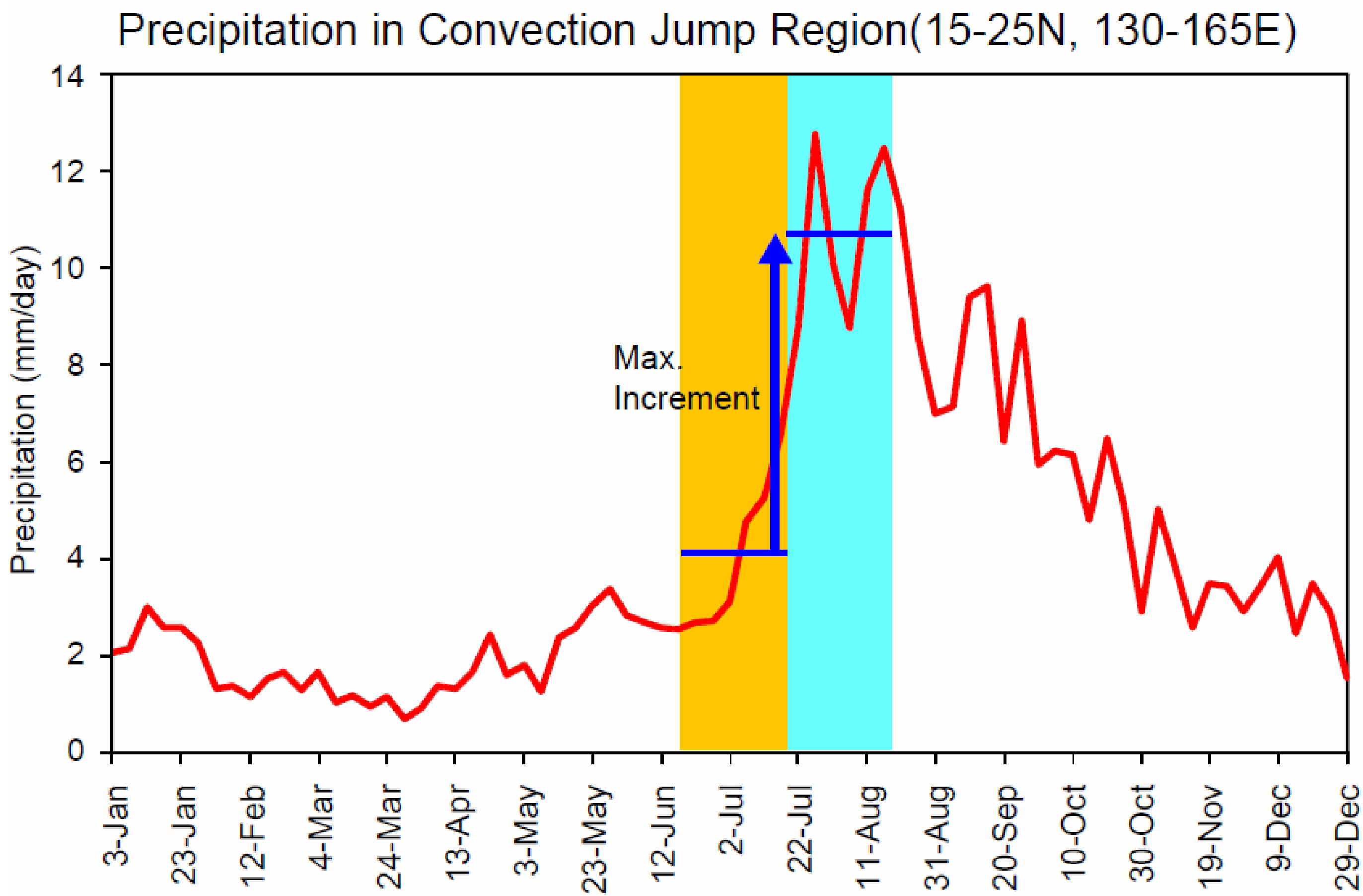
- Select three regions for comparison of the stepwise seasonal changes

Definition of monsoon onset pentad

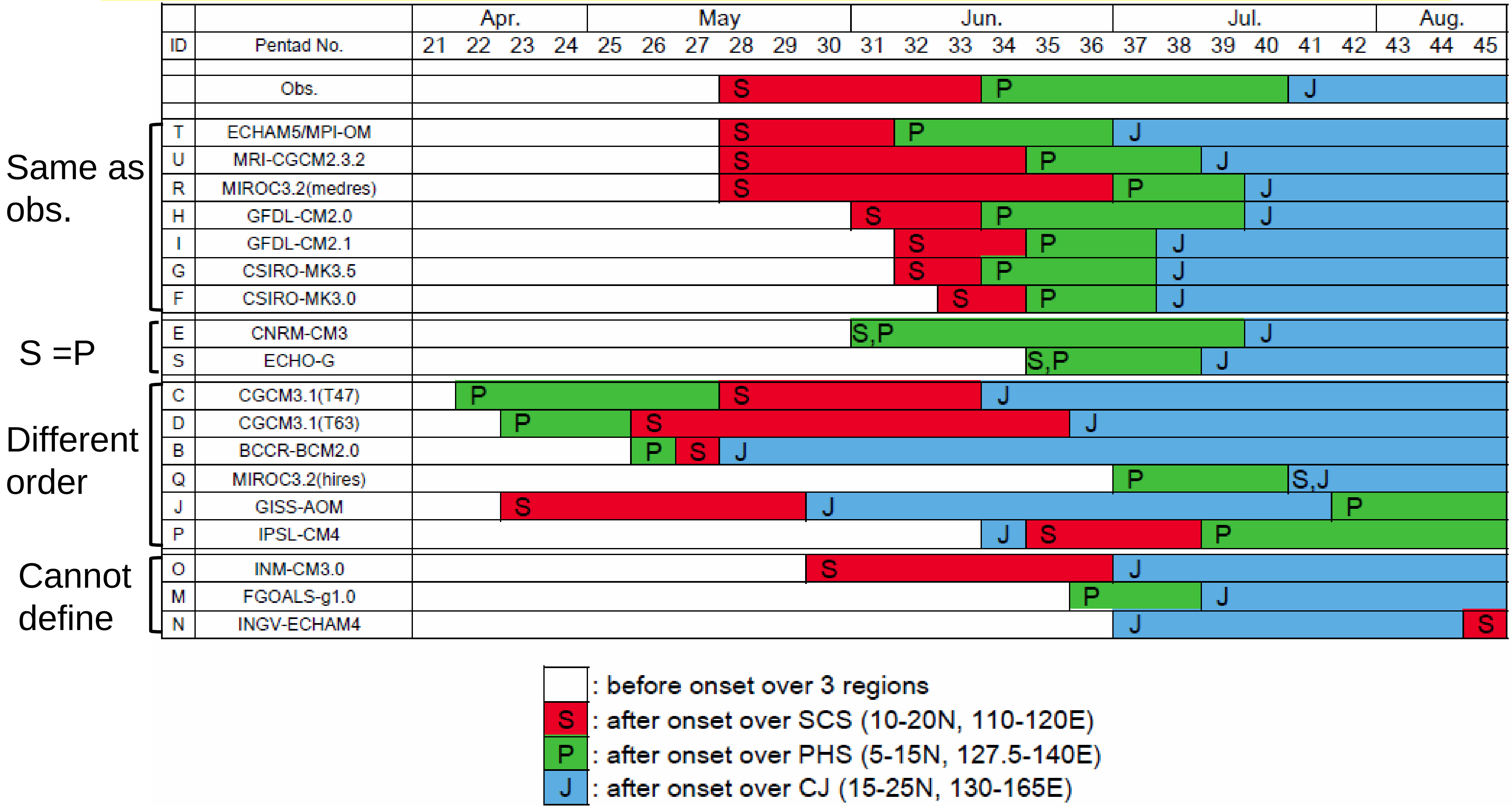
•Definition of onset pentad is based on abruptness of precipitation change

onset pentad (P): PR [P+0 to P+5 average] – PR [P-6 to P-1 average] shows a maximum increment

Ex. Observation(CMAP), convection jump region: 41st pentad (20-24 Jul.)



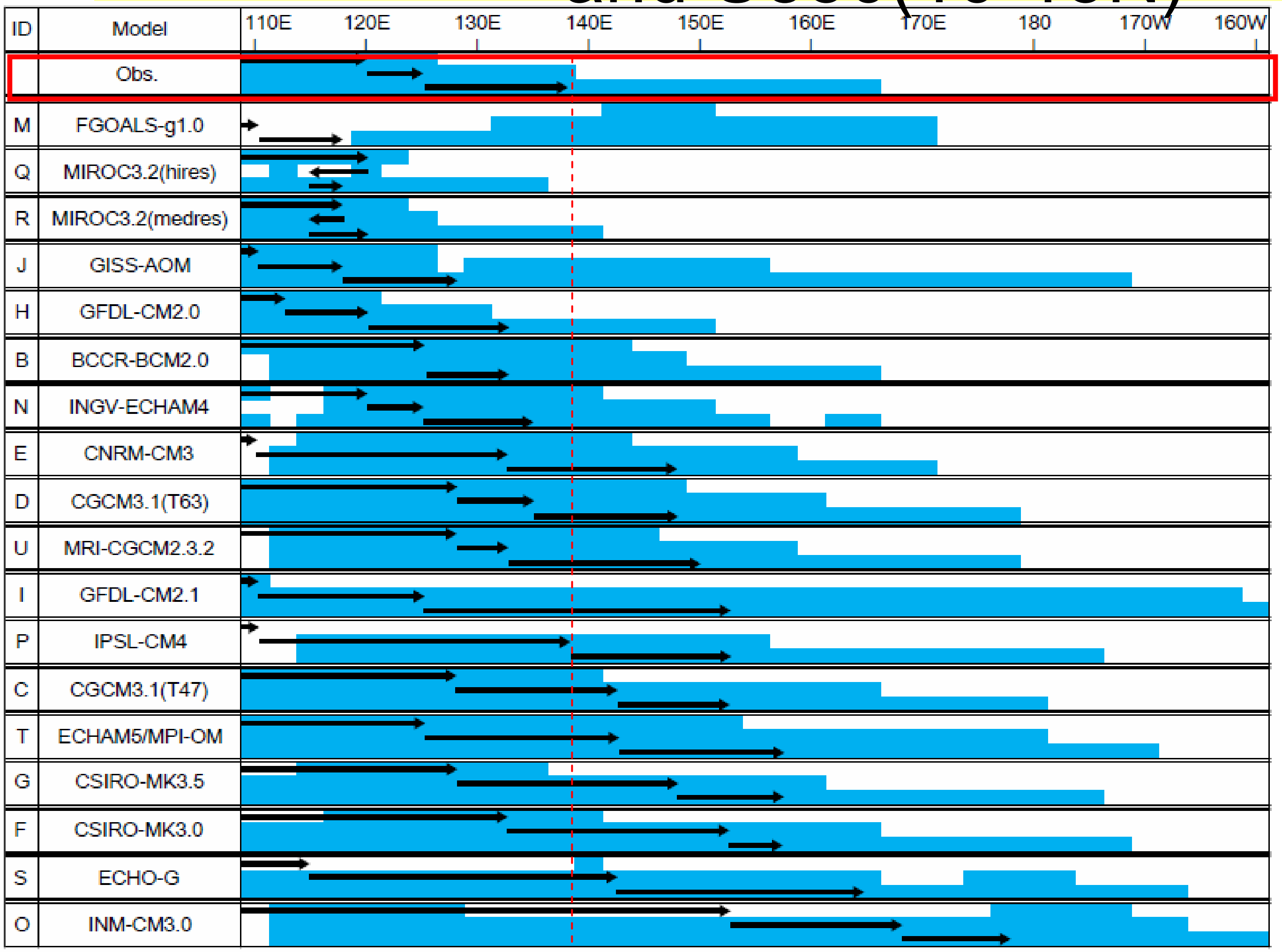
Result: onset pentads of the 3 areas



- South China Sea onset (mid-May): later than observation
- Philippine Sea onset (mid-June): most unstable (April to July)
- Convection jump (mid-July): earlier than observation

→In many models, the eastward stepwise shift is faster than that in observation

Seasonal marches of precipitation (15-20N) and U850(10-15N)



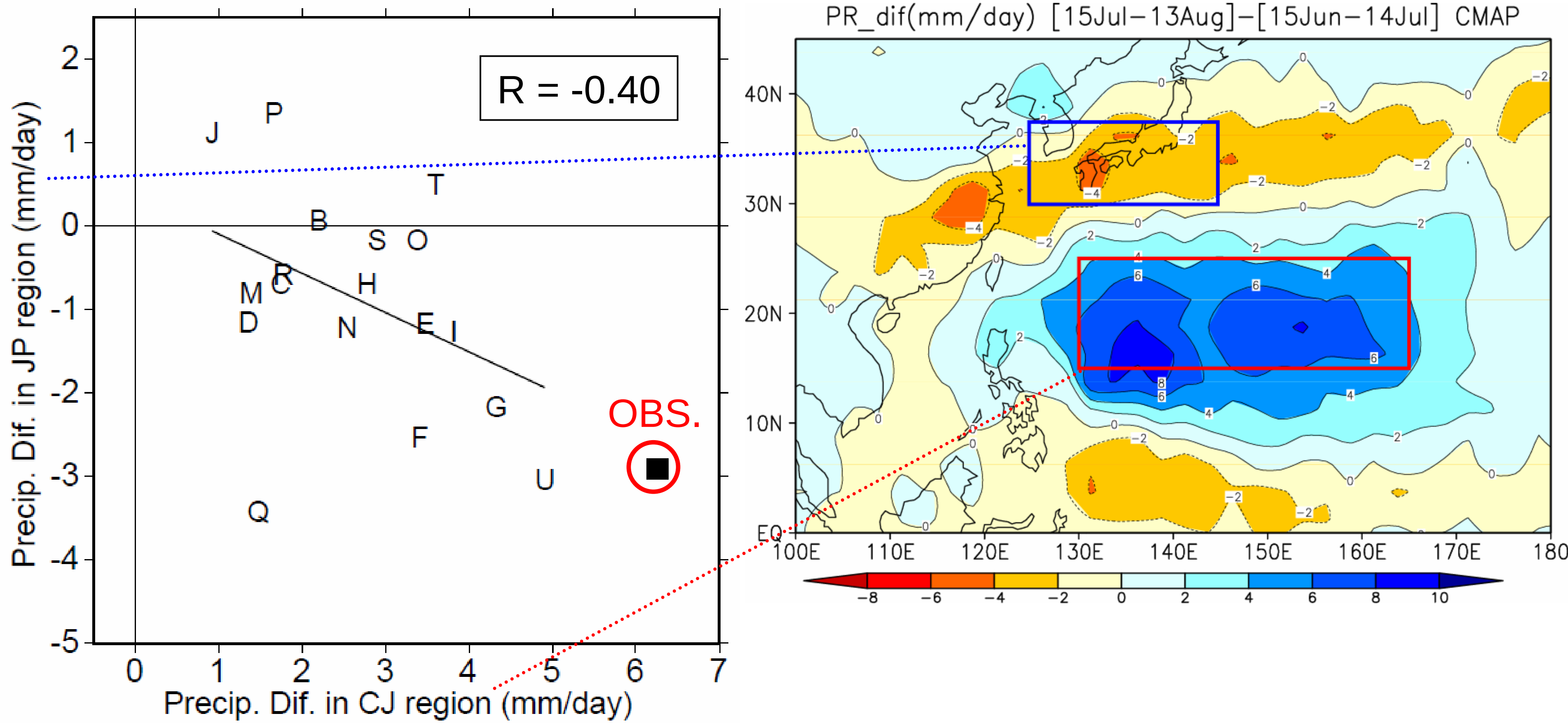
Shading : PR > 5mm/day (15-20N)

Vector: 850 hPa westerly(10-15N)

Upper : 15May-14Jun.
Middle : 15Jun.-14Jul.
Lower : 15Jul.-13Aug.

- As in observations, eastward expansion of the monsoon rain area and westerly area region are common, but their speed differs greatly from model to model
- In many models, the eastward expansion is more rapid than those in observations

Convection Jump and withdrawal of the Baiu rainy season over central Japan in mid-July
PR [(15Jul.-13Aug.) – (15Jun.-14Jul.)]



•Precipitation increment over the “convection jump” region in mid-July is negatively correlated with precipitation change around central Japan (associated with the end of the Baiu rainy season)

→the convection jump is one of the key phenomena to reproduce the disappearance of the Baiu rain band in mid-July

summary

•Comparison of ASM circulation patterns in JJA–mean fields

(1) lower-tropospheric circulation over the East Asia through the WNP, and the location and intensity of the North Pacific subtropical high exhibit large inter-model variability

(2) Some models fail to reproduce a reversal of the upper-tropospheric MTG over the South Asia and the North Indian Ocean sector

•Comparison of seasonal evolutions over the WNP and its vicinity

→In many models, the eastward stepwise shift of the WNP summer monsoon is faster than that in observation

Acknowledgment

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