Identification and Correction of Errors in Various Components of Dynamics and Physics of the Global Forecast System (GFS) Model

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This study is a close collaborative work with the project entitled ***"Sensitivity Studies of Indian Summer Monsoon Forecast Modeling" by Prof T N Krishnamurti, Florida State University.***

Objectives

- The primary objectives of this study are:
  1. To identify the sources of errors in the high-resolution GFS model that was identified as the primary model for studying summer monsoon over India under the National Monsoon Mission.
  2. Use the information learnt in point (1) above to statistically correct those components of the model and thus by improve its forecast skill.

Model Used

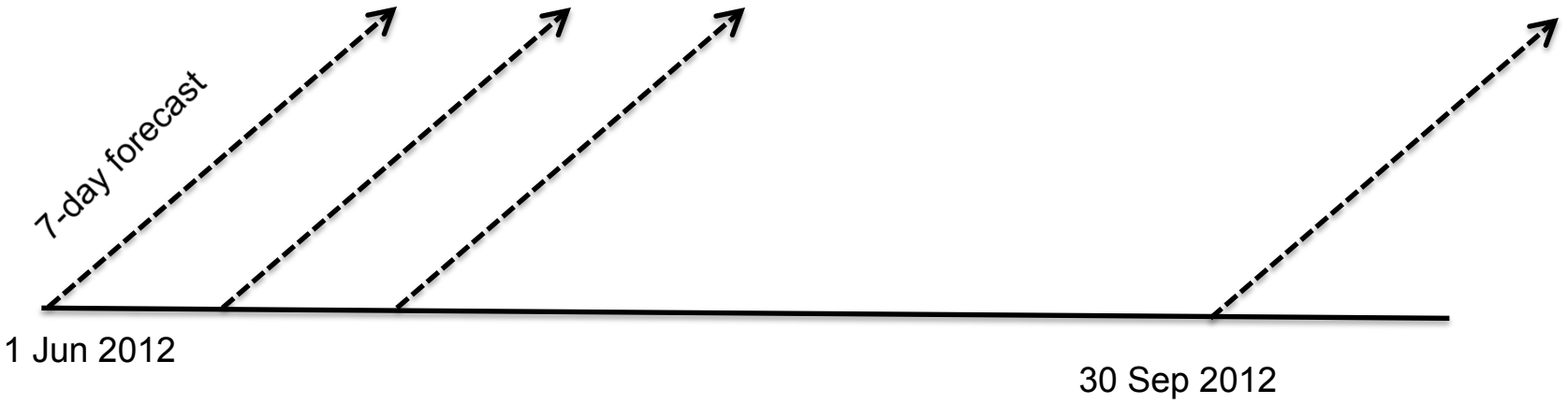
Global Forecast System

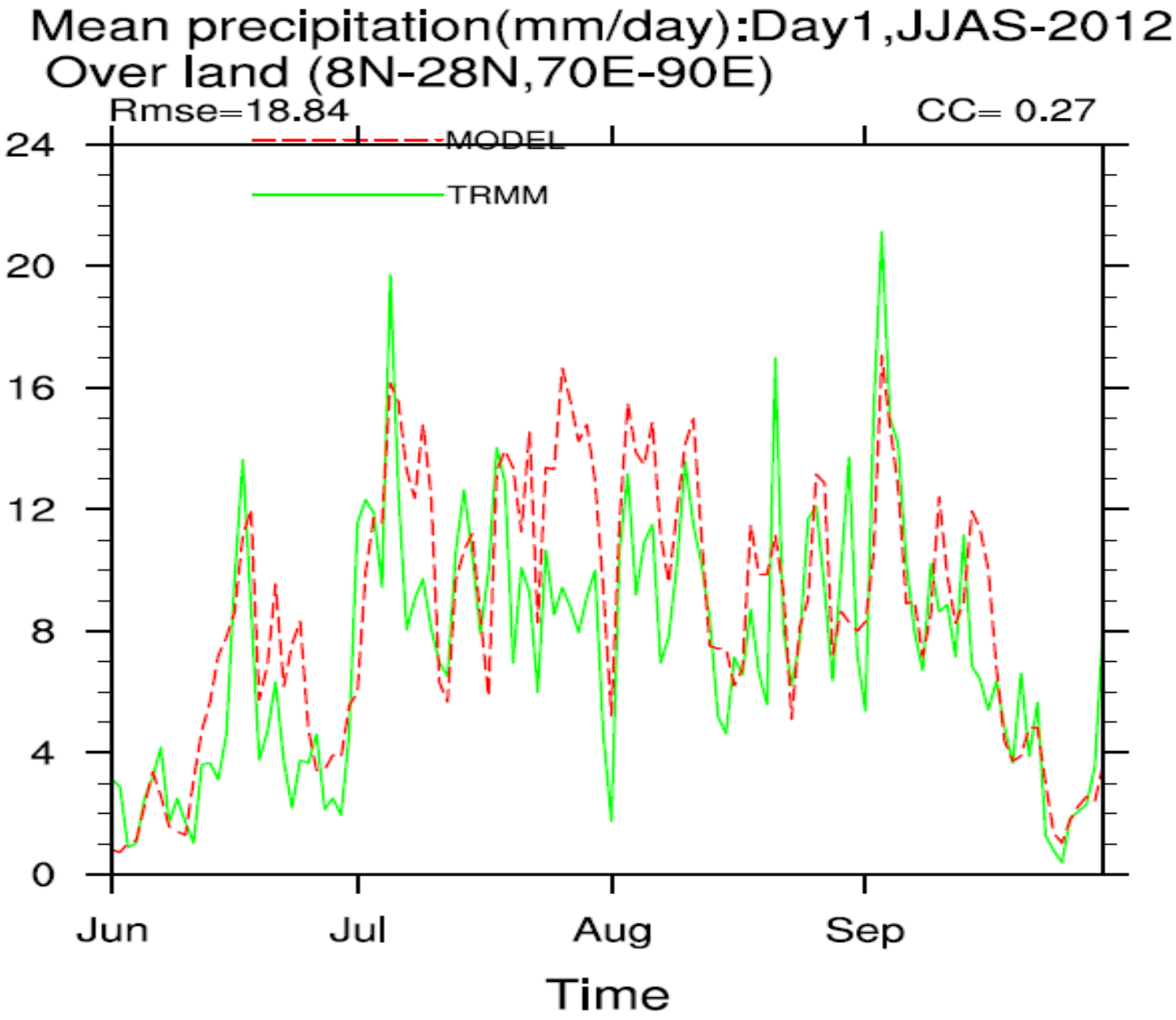
Model	Version	Resolution	Forecast Length (hrs)	Wall Clock Time (hrs)
GFS T574L64	GFS version 9.0.1	~22 km/ 64 levels	168	5

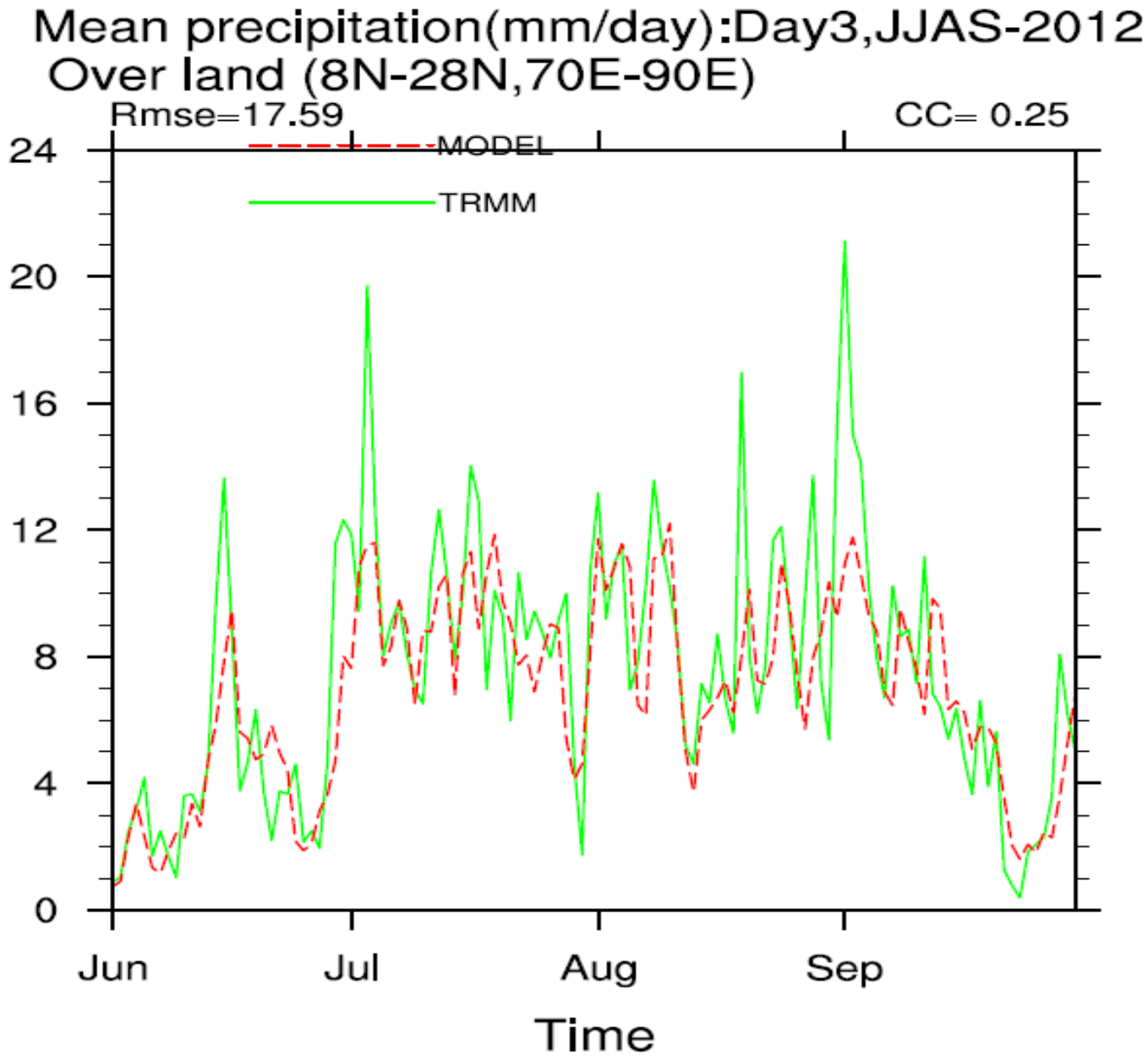
Physics		Scheme
Surface Fluxes		Monin-Obukhov similarity
Turbulent Diffusion		Non-local Closure scheme (Lock et al., 2000)
SW Radiation		Rapid Radiative Transfer Model (RRTM2) (Mlawer et al. 1997; Mlawer and Clough, 1998)- aerosols included– invoked hourly
LW Radiation		Rapid Radiative Transfer Model (RRTM1) (Mlawer and Clough 1997;1998). –aerosols included-invoked hourly
Deep Convection		SAS convection (Han and Pan, 2006)
Shallow Convection		Mass flux scheme (Han and Pan, 2010)
Large Scale Condensation		Large Scale Precipitation (Zhao and Carr ,1997; Sundqvist et al., 1989)
Cloud Generation		Based on Xu and Randall (1996)
Rainfall Evaporation		Kessler (1969)
Land Surface Processes		NOAH LSM with 4 soil levels for temperature & moisture (Ek et al., 2003)
Air-Sea Interaction		Roughness length by Charnock (1955), Observed SST, Thermal roughness over the ocean is based on Zeng et al., (1998). 3-layer Thermodynamic Sea-ice model (Winton, 2000)
Gravity Wave Drag & mountain blocking		Lott and Miller (1997), Kim and Arakawa (1995), Alpert et al., (1996)
Vertical Advection		Flux-Limited Positive-Definite Scheme (Yang et al., 2009)

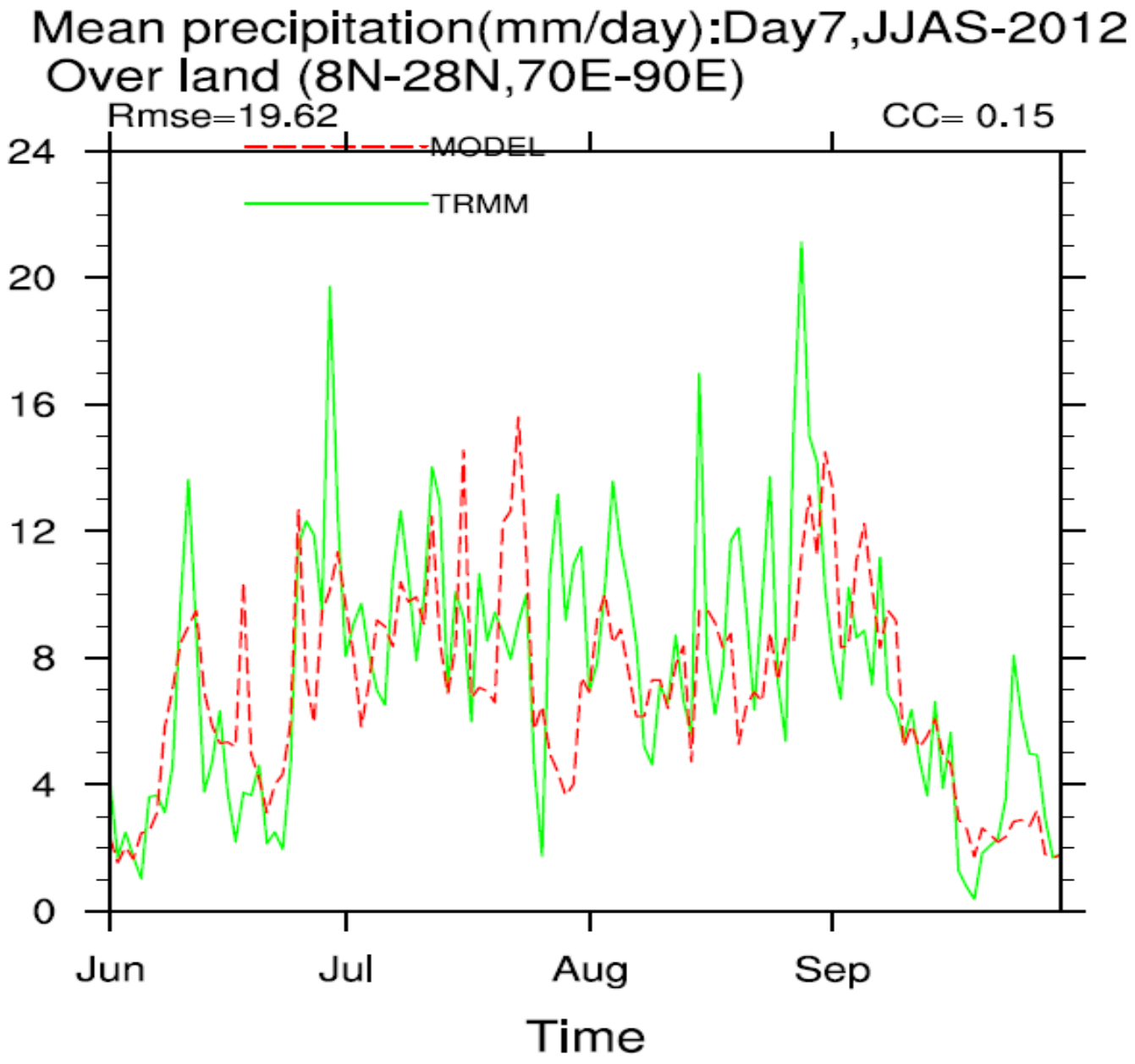
Experimental Details

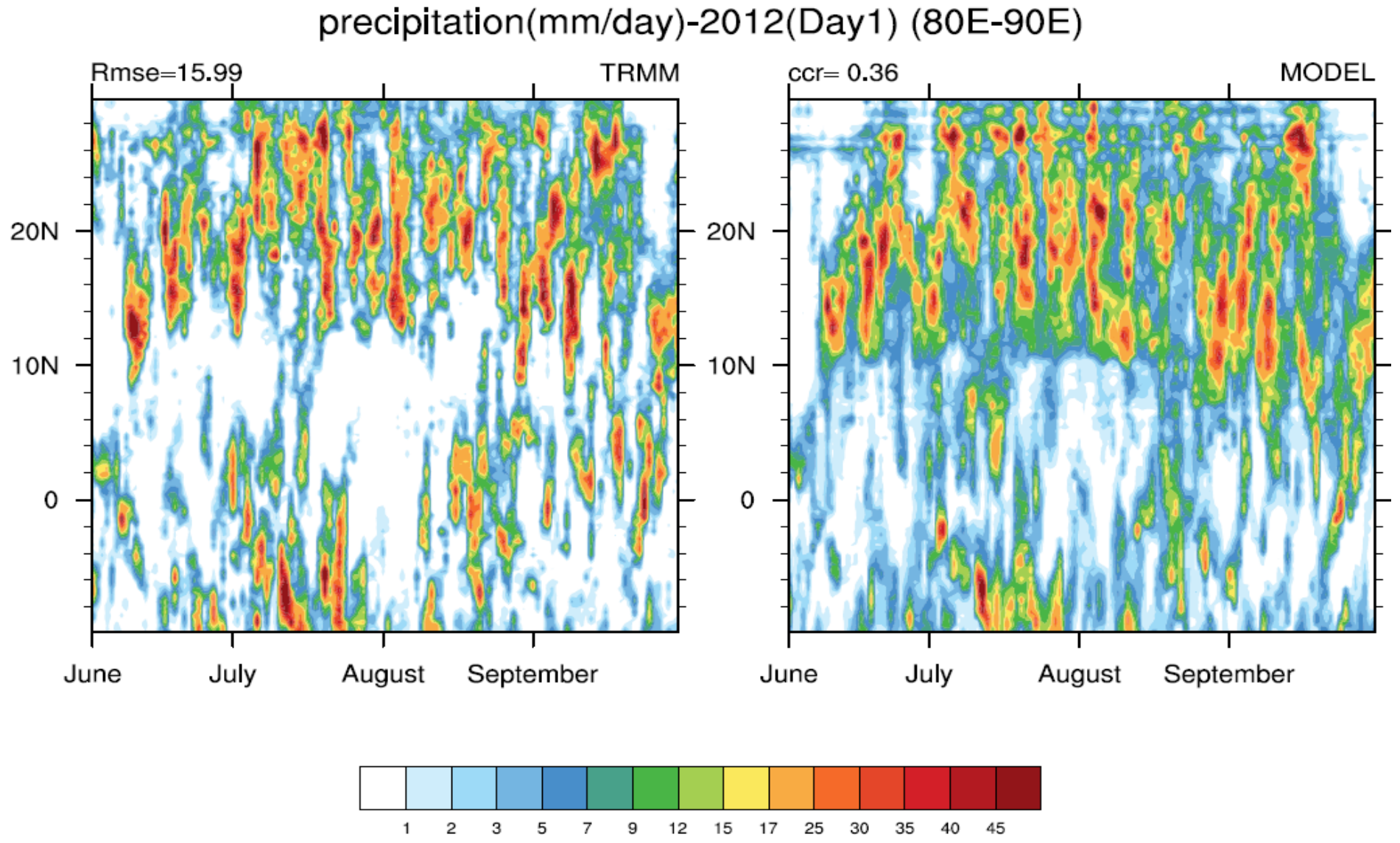
- Model was integrated for 7 days starting every 00 GMT of 1 June through 30 September 2012.
- Output was stored at 6-hour interval.
- In addition to storing regular parameters like precipitation, temperature and winds, tendencies of temperature and moisture from various components of model physics and dynamics were also stored. *This includes the convection scheme, the boundary layer scheme, and the radiation scheme, among others.*




Mean precipitation(mm/day):Day1,JJAS-2012
Over land (8N-28N,70E-90E)
Rmse=18.84
CC= 0.27
MODEL
TRMM
24
20
16
12
8
4
0
Jun
Jul
Aug
Sep
Time

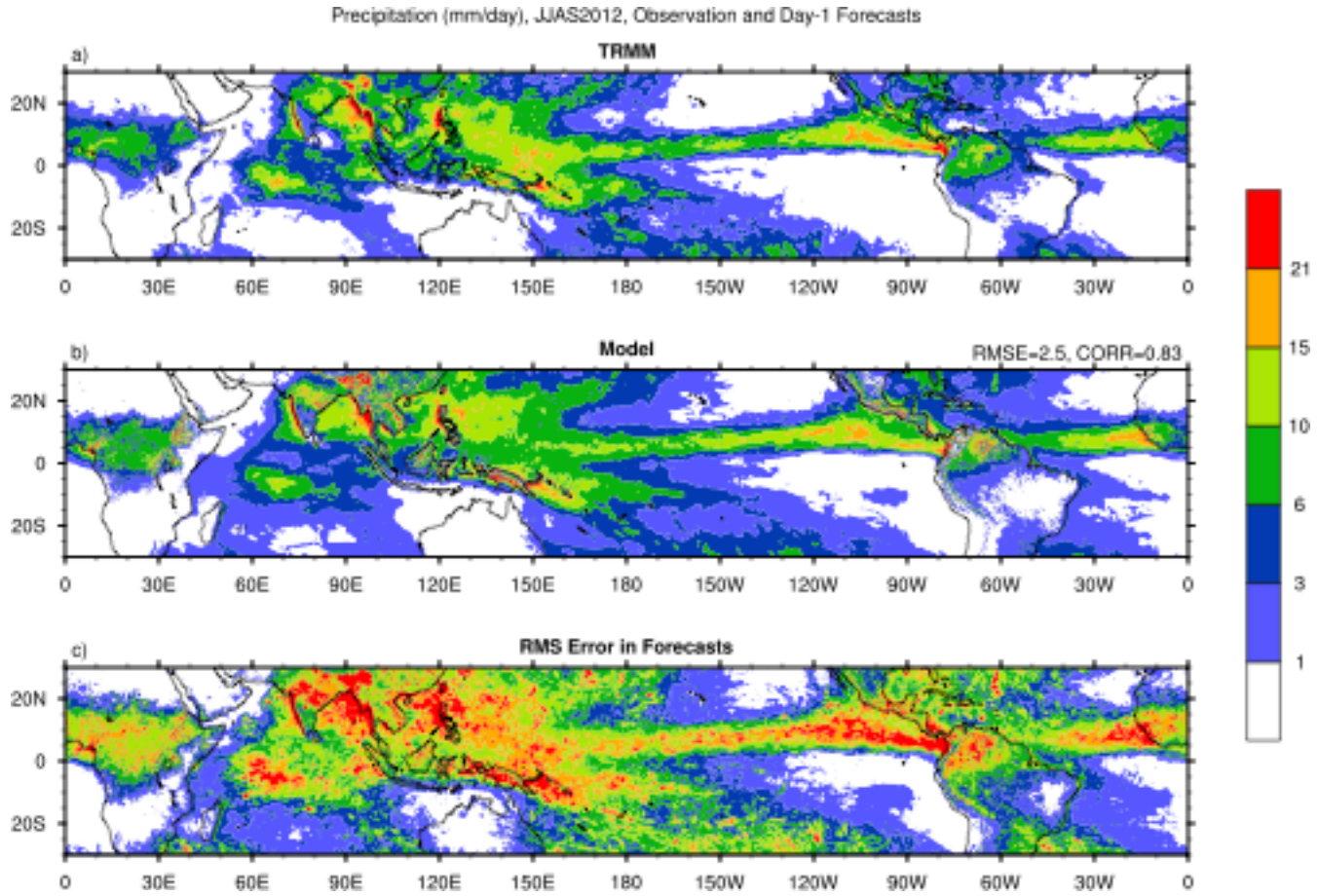

Mean precipitation(mm/day):Day3,JJAS-2012
Over land (8N-28N,70E-90E)
Rmse=17.59
CC= 0.25
MODEL
TRMM
24
20
16
12
8
4
0
Jun
Jul
Aug
Sep
Time


Mean precipitation(mm/day):Day7,JJAS-2012
Over land (8N-28N,70E-90E)
Rmse=19.62
CC= 0.15
MODEL
TRMM
24
20
16
12
8
4
0
Jun
Jul
Aug
Sep
Time



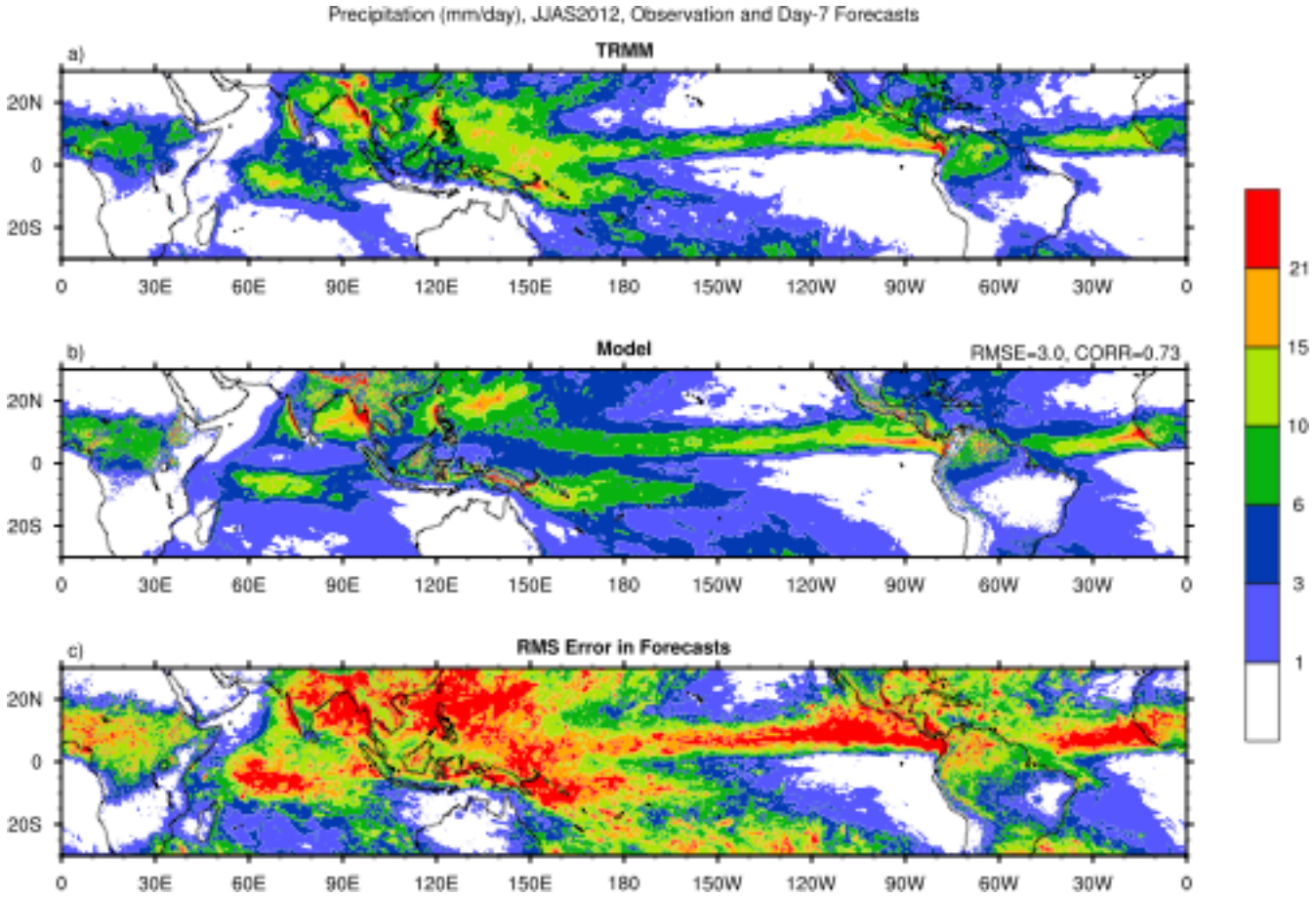
Too much drizzle.

Mean JJAS Precipitation, Day-1

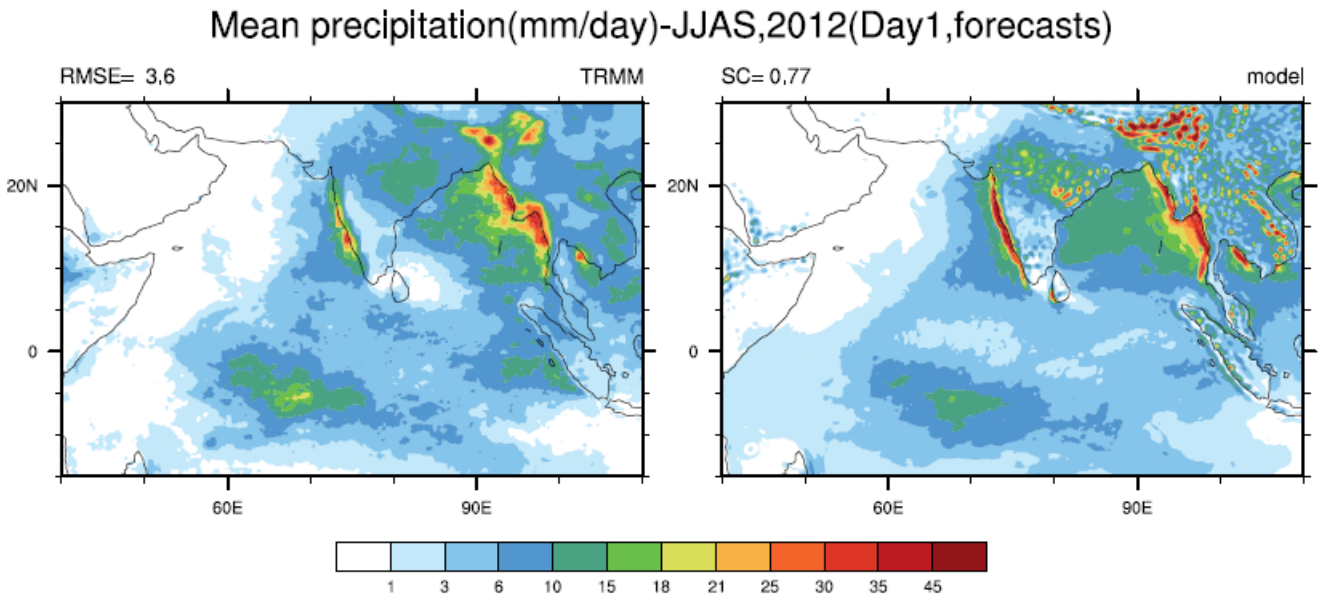


$$\mathrm{RMSE}_r = \sqrt{\frac{\sum_{i=1}^{N}(M_i - O_i)^2}{N}},$$

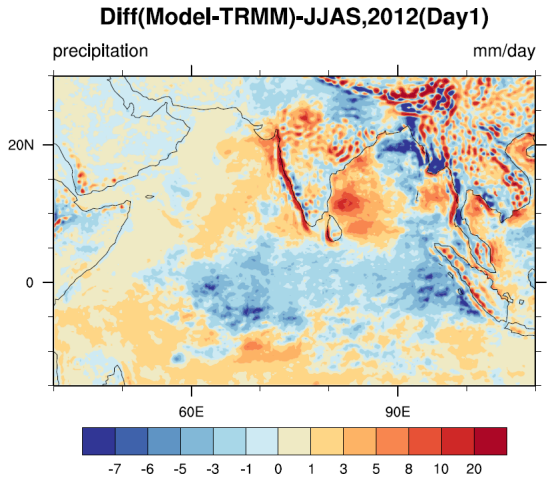
Mean JJAS Precipitation, Day-7

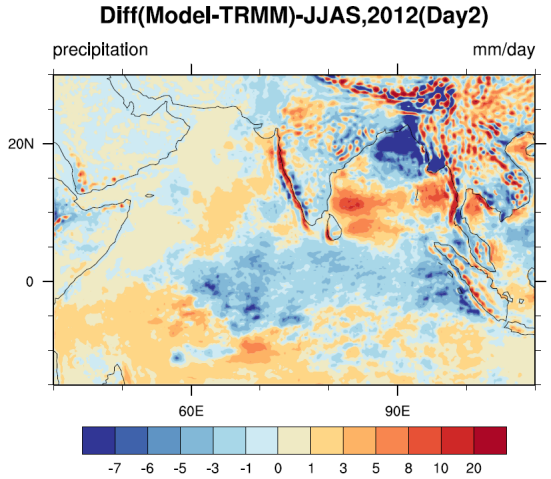


Day-1 Error

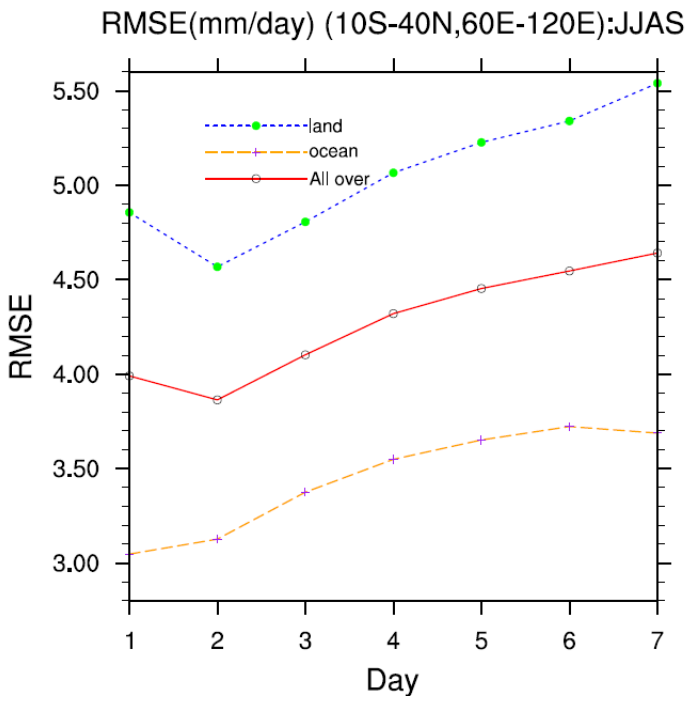


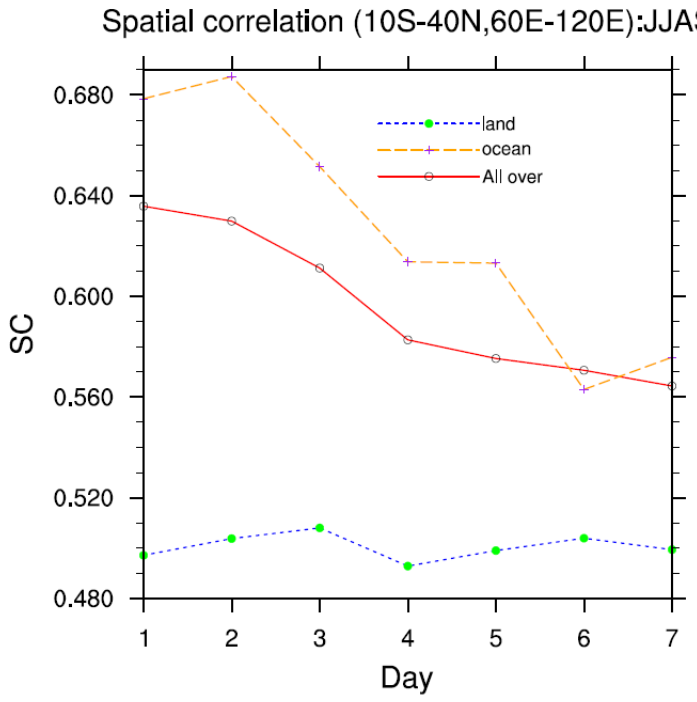
Need for physical initialization of precipitation?





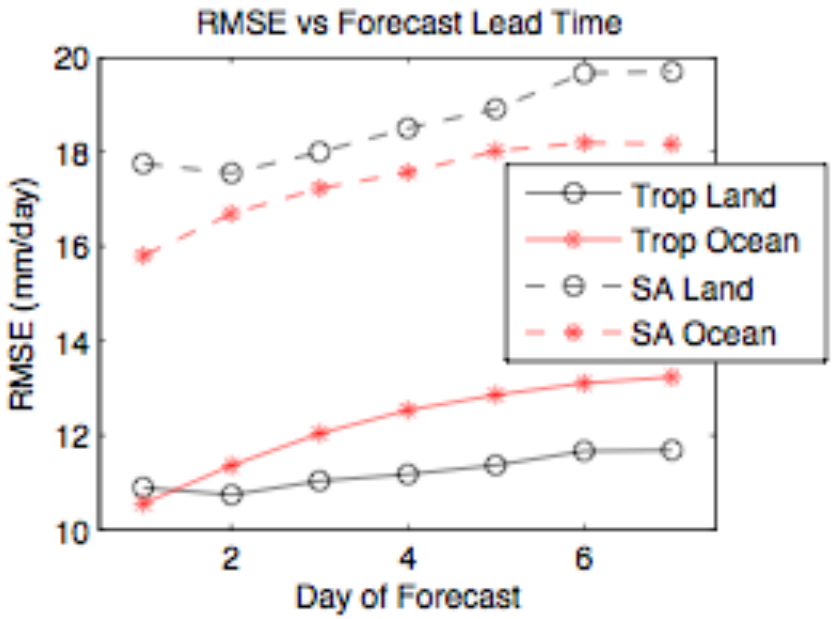
Error in Time-Mean





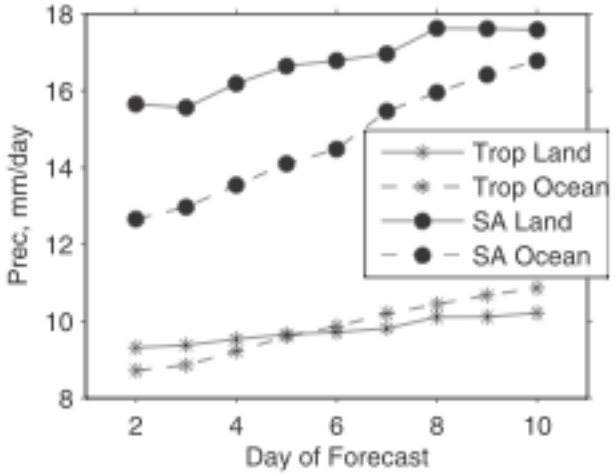
- Rate of growth of RMS error is similar over south Asian land and ocean.
- Error in spatial pattern of forecast decreases sharply over ocean than that over land.

GFS2 (2012)

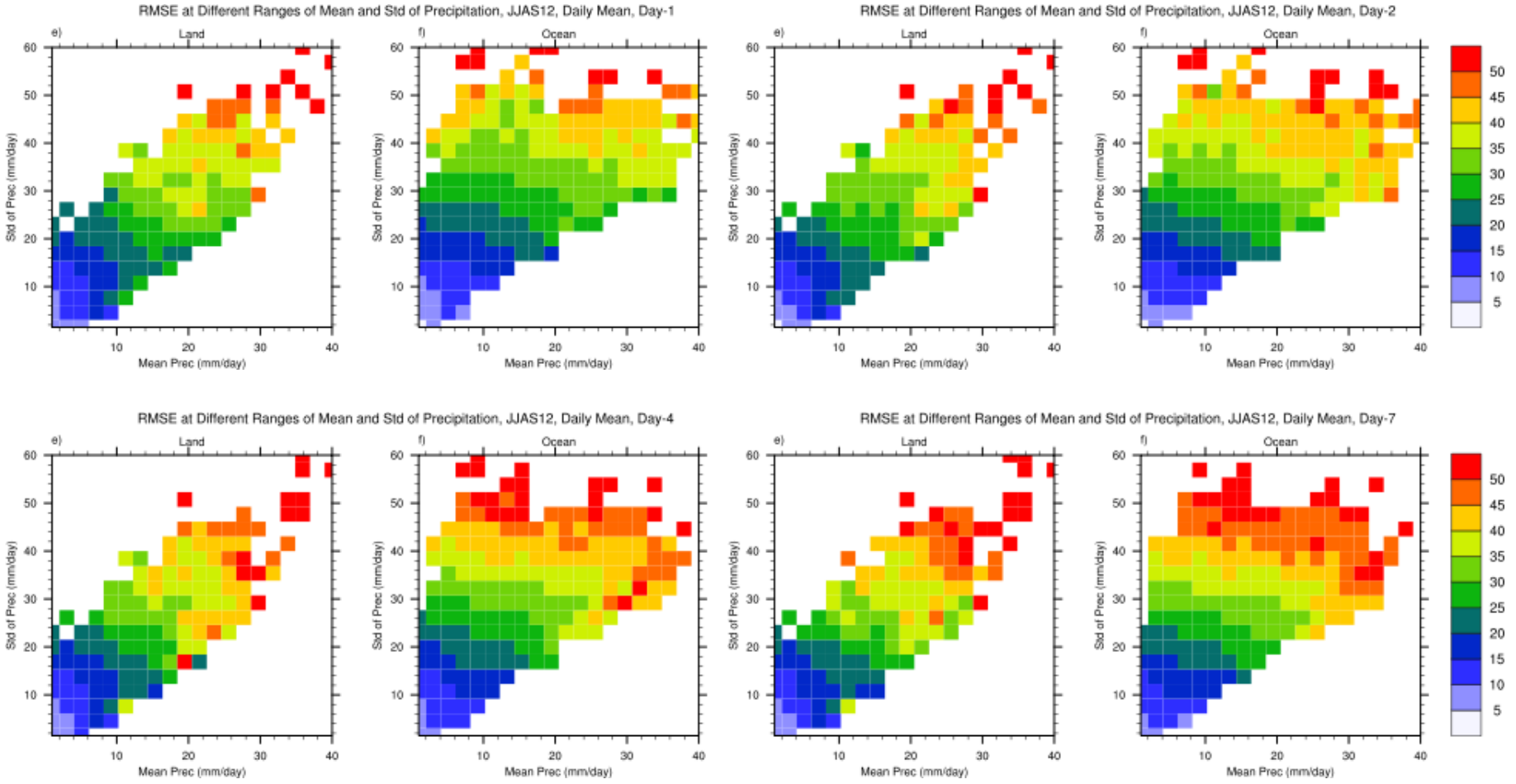


Faster growth of error over tropical ocean than over land. This is not so obvious over SA.

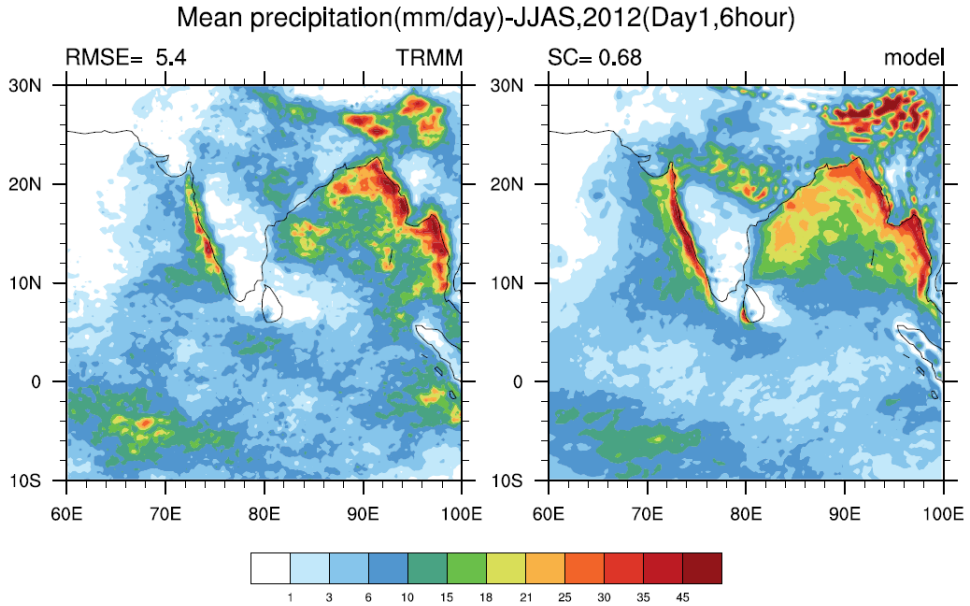
ECMWF (2008)



Tropical Land and Ocean

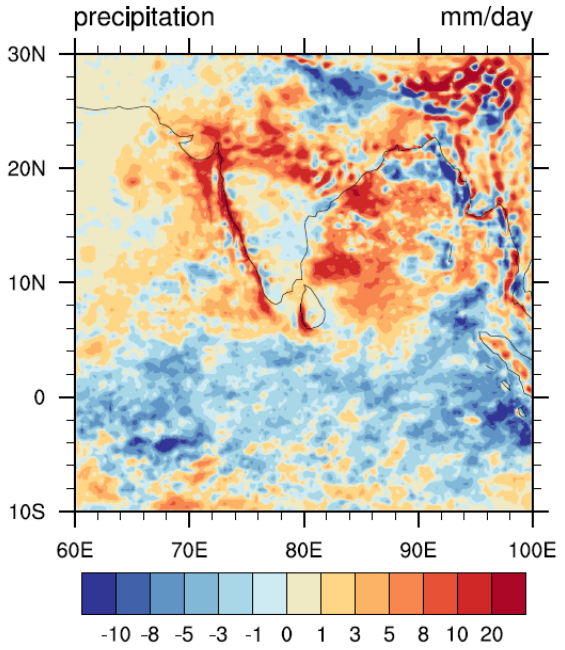


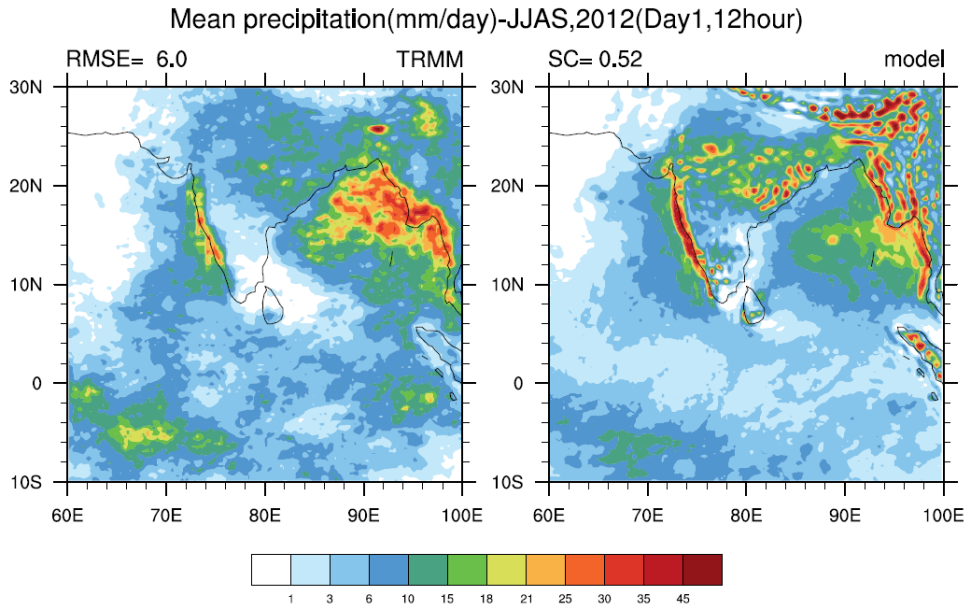
Diurnal Cycle of Precipitation



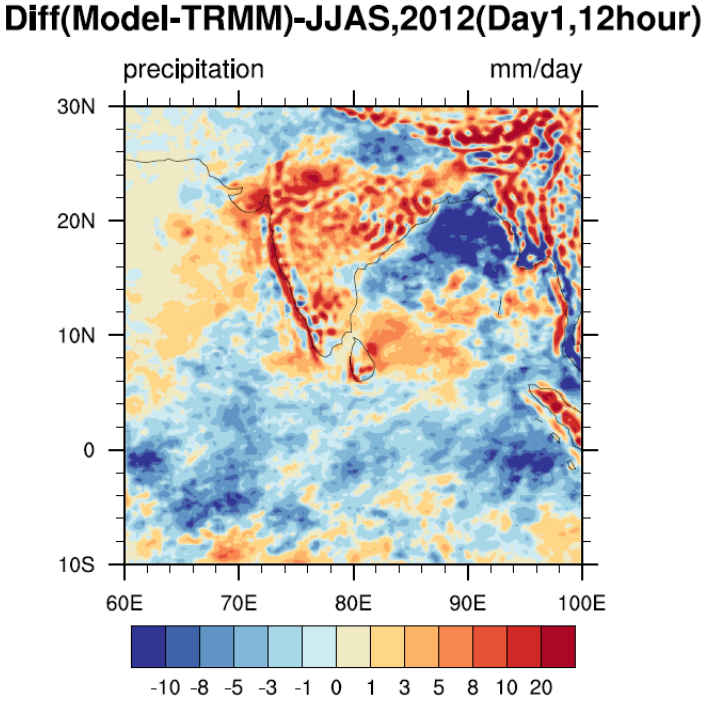
Day-1, 0-6 GMT

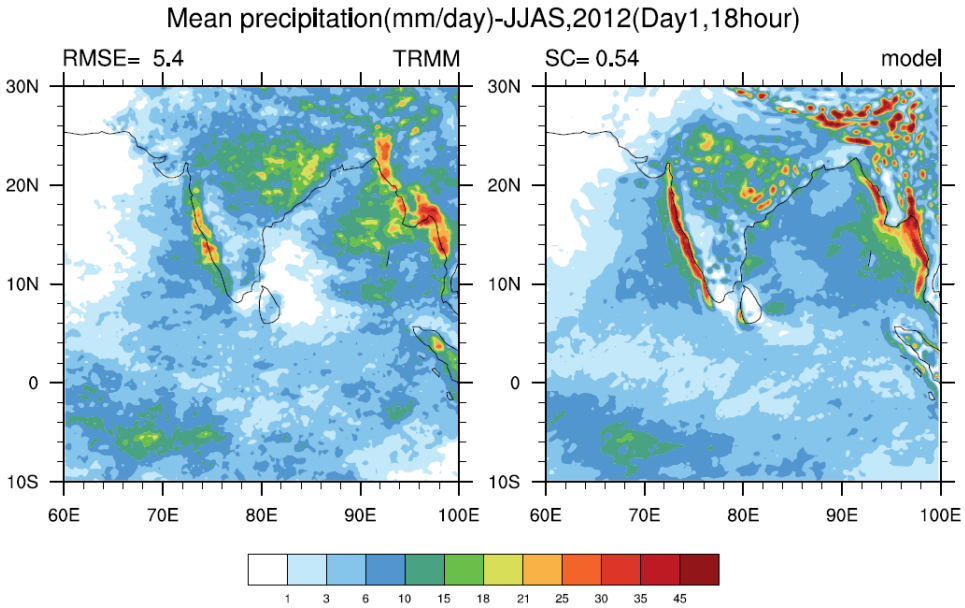
Diff(Model-TRMM)-JJAS,2012(Day1,6hour)



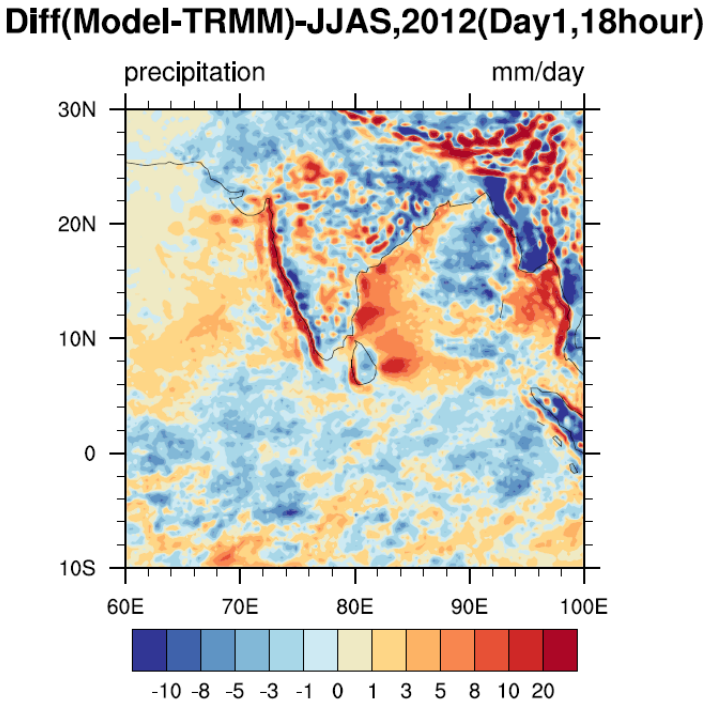

Mean precipitation(mm/day)-JJAS,2012(Day1,12hour)
RMSE= 6.0
TRMM
SC= 0.52
model
30N
20N
10N
0
10S
60E
70E
80E
90E
100E
1
3
6
10
15
18
21
25
30
35
45

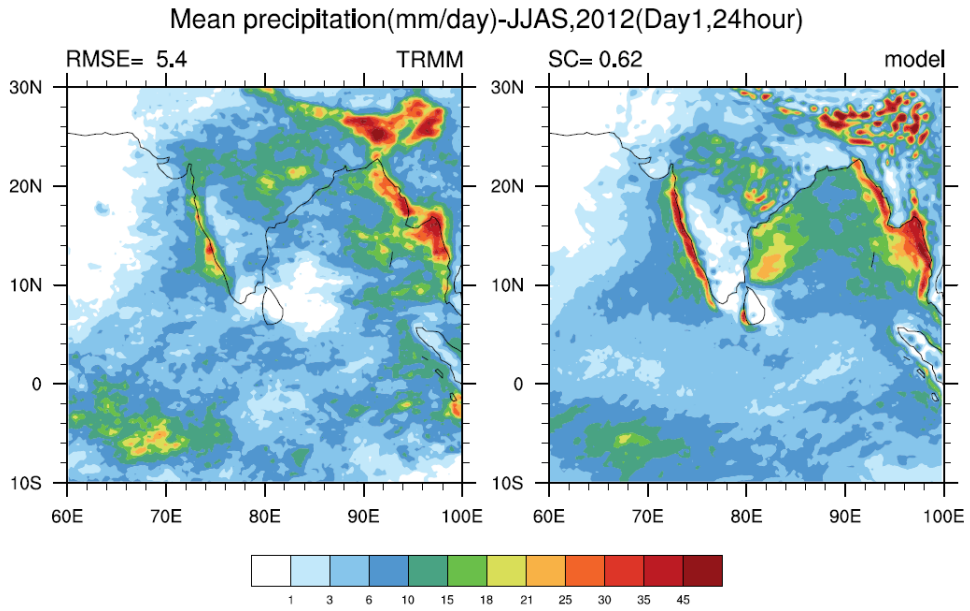
Day-1, 6-12 GMT


Diff(Model-TRMM)-JJAS,2012(Day1,12hour)
precipitation
mm/day
30N
20N
10N
0
10S
60E
70E
80E
90E
100E
-10 -8 -5 -3 -1 0 1 3 5 8 10 20

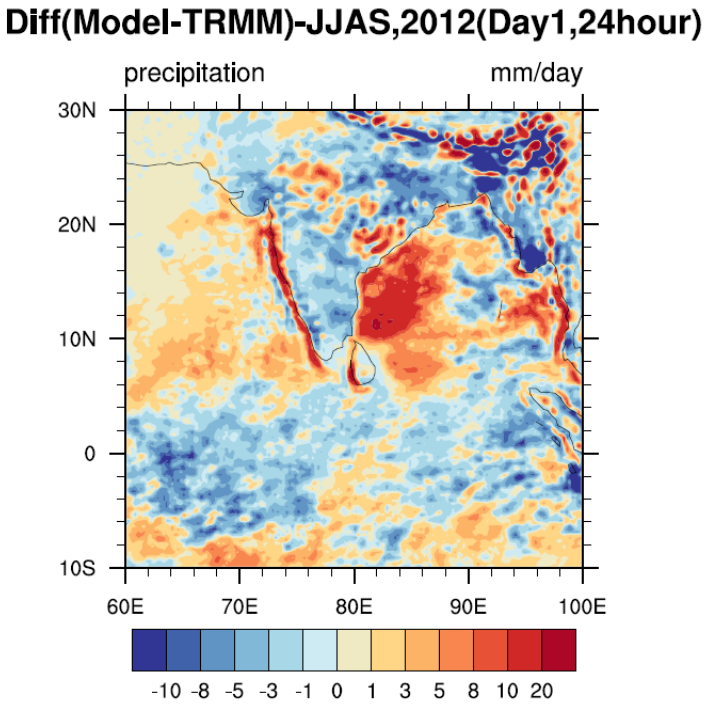


Day-1, 12-18 GMT

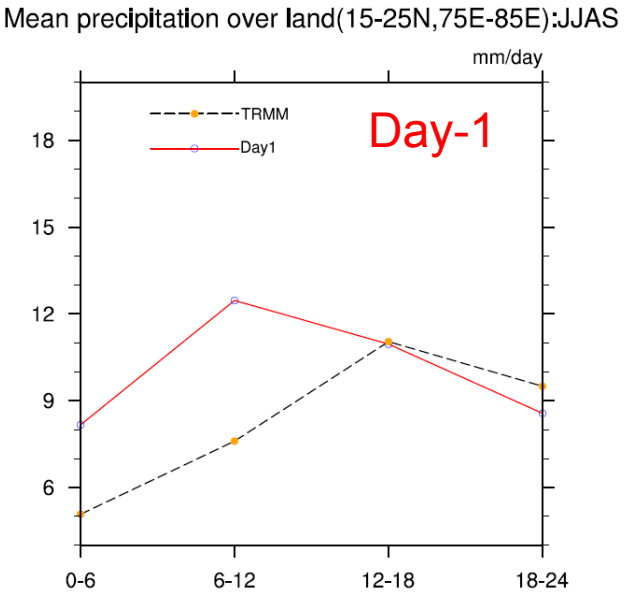


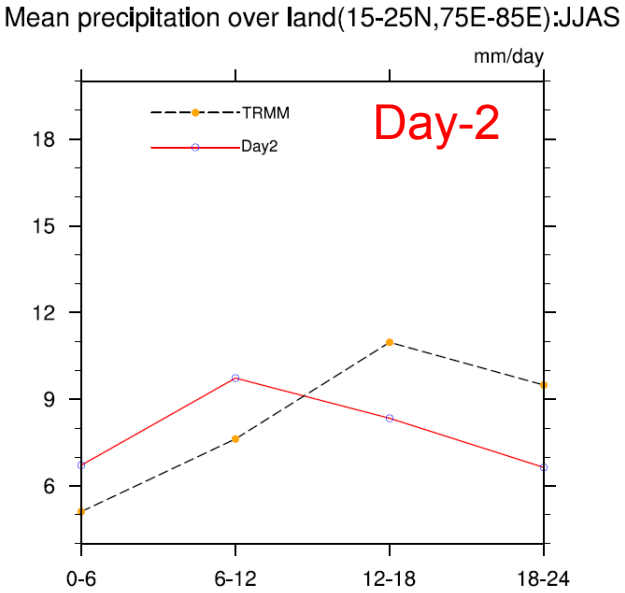


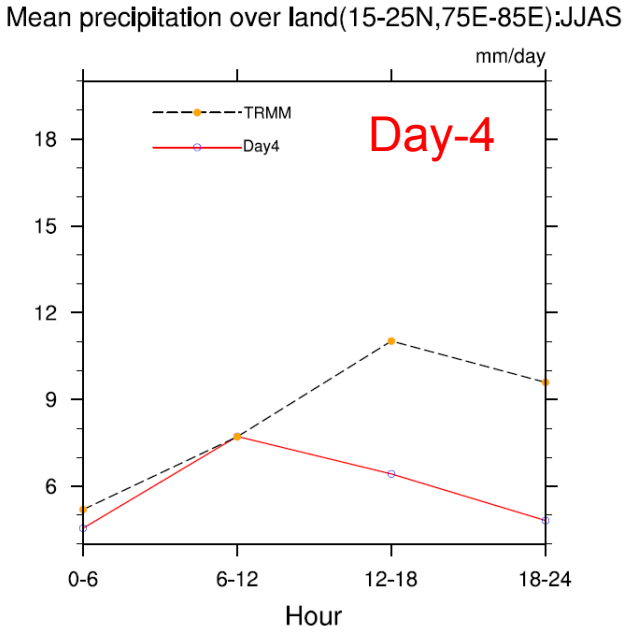
Day-1, 18-24 GMT

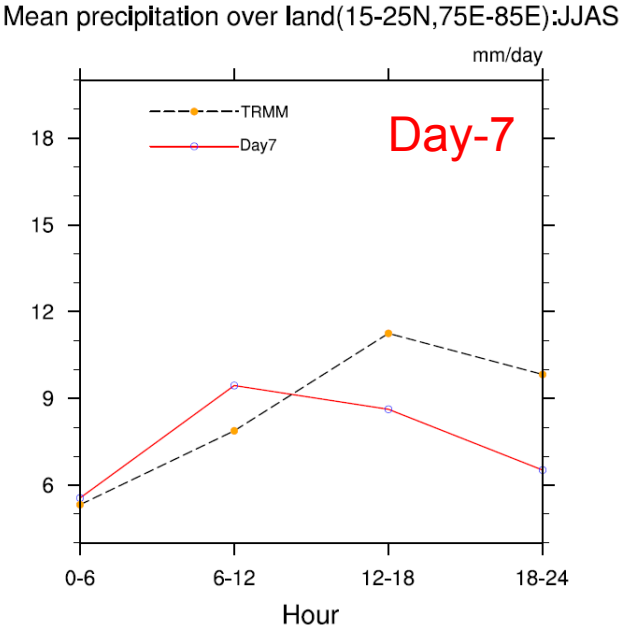


Diurnal Cycle over Central India, Land

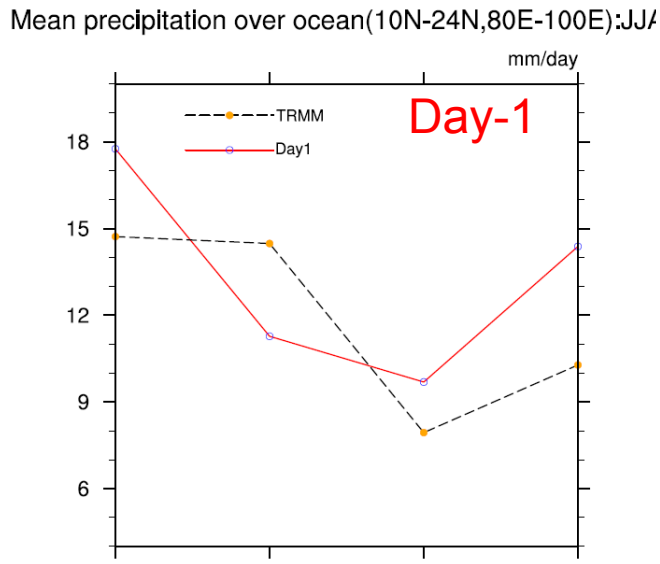


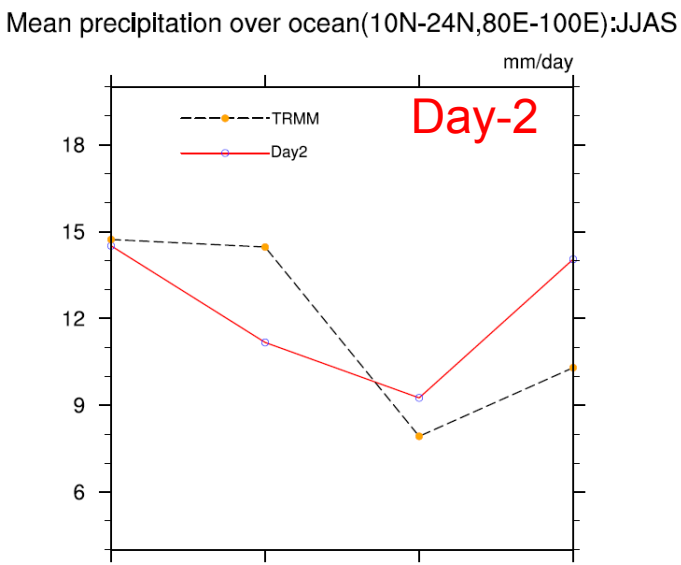


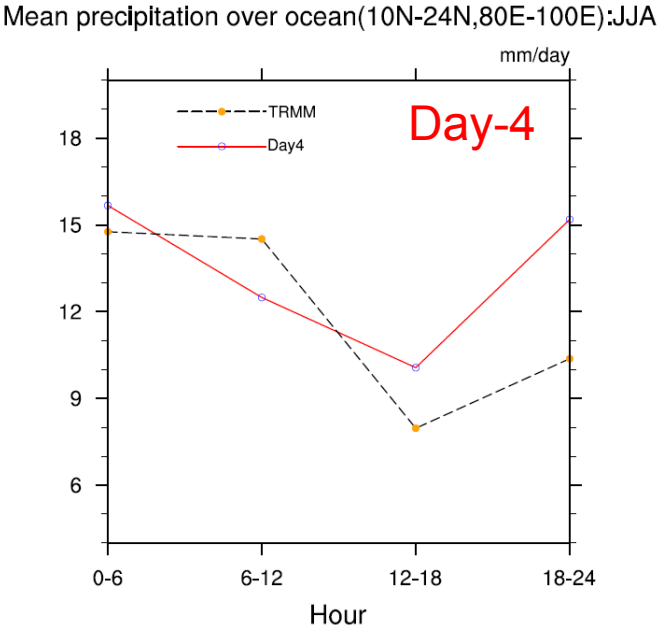


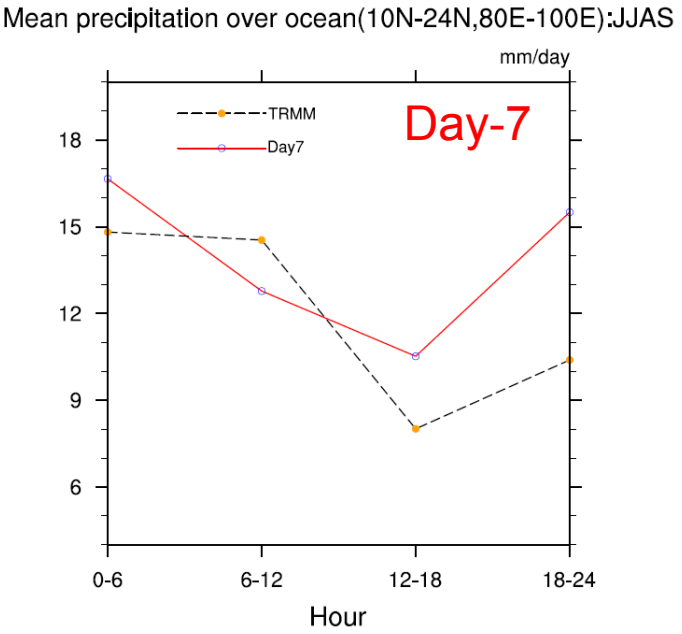


Diurnal Cycle over North-Central BoB

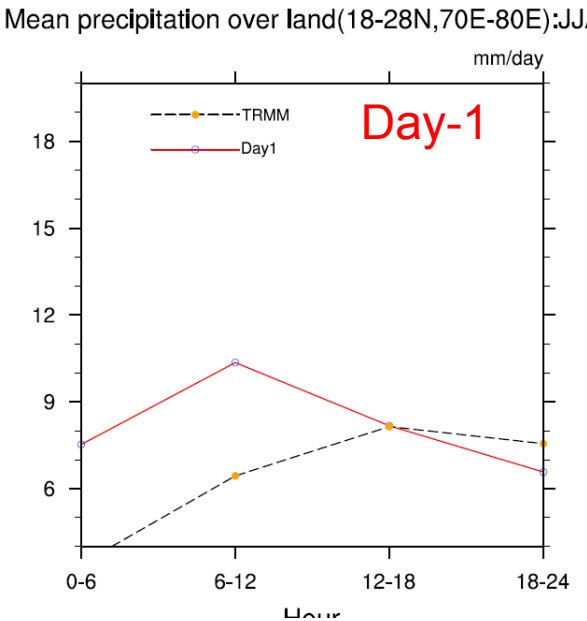


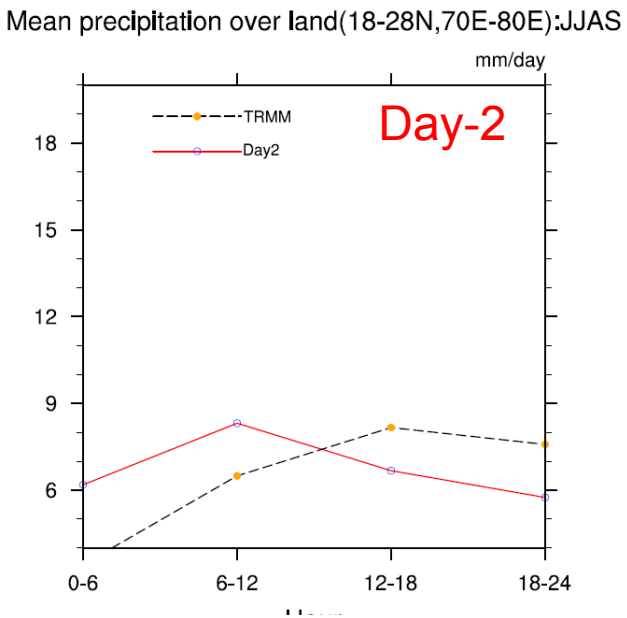


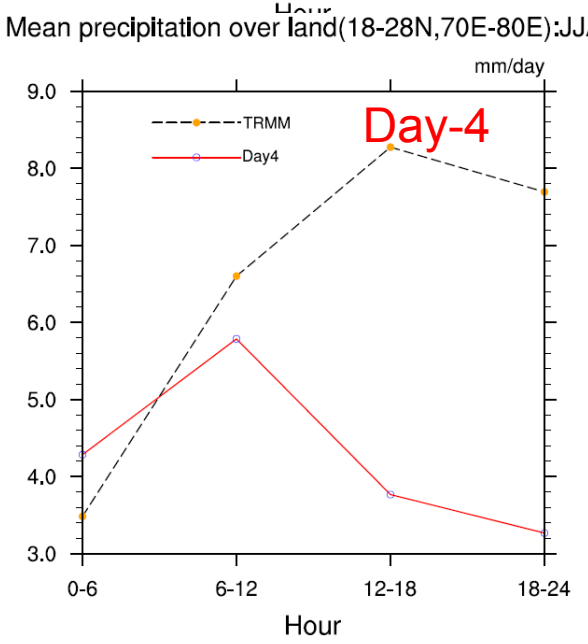


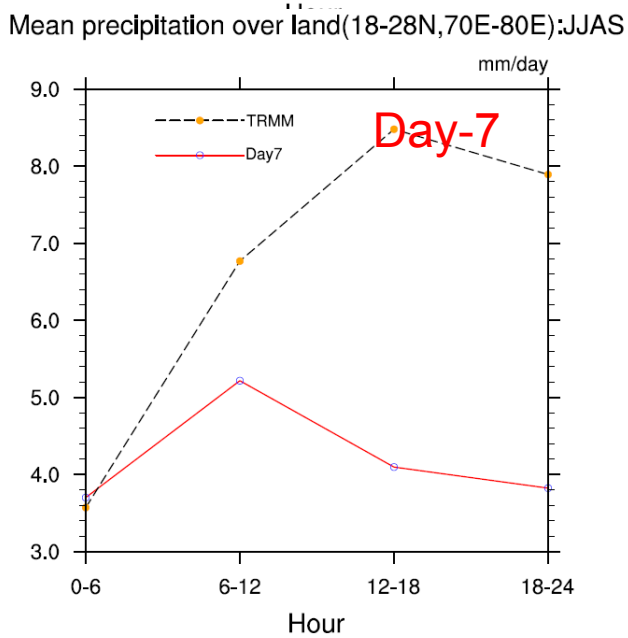


Diurnal Cycle, North-West India

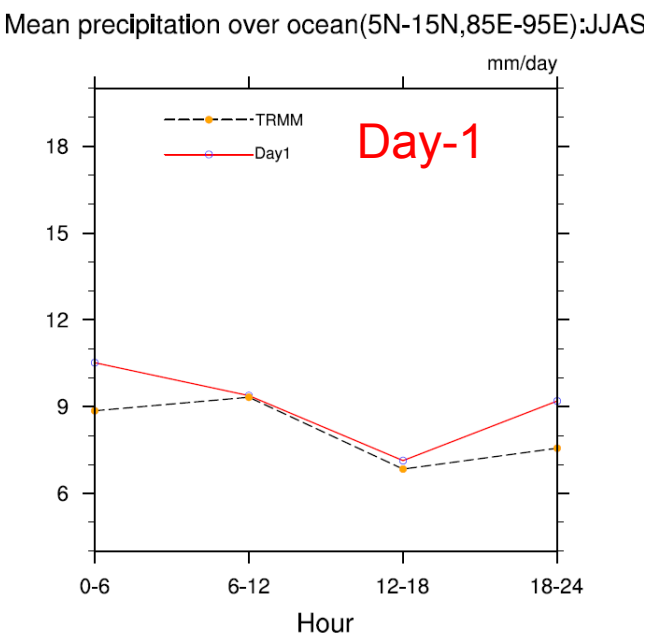


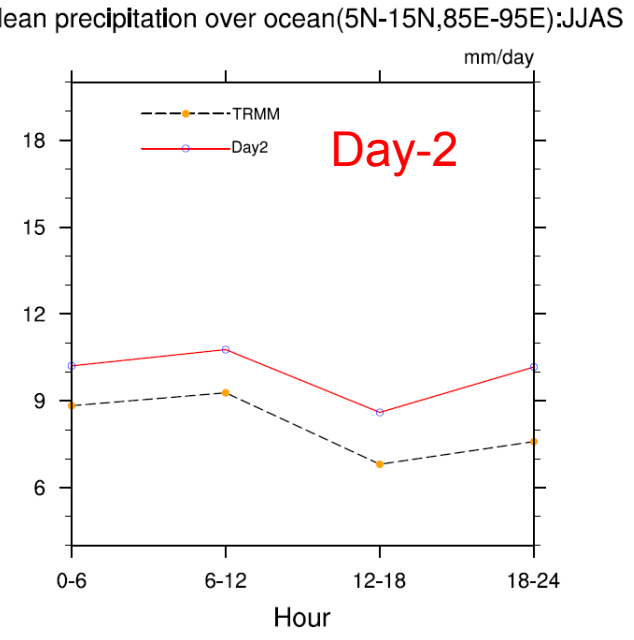


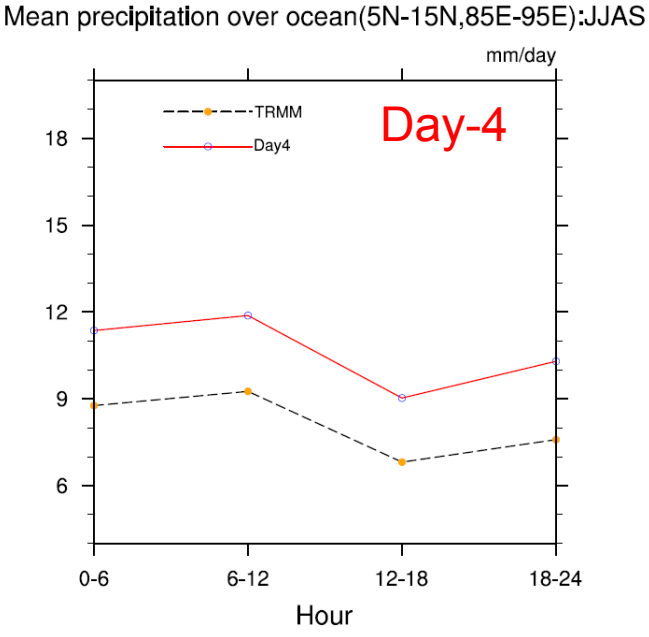


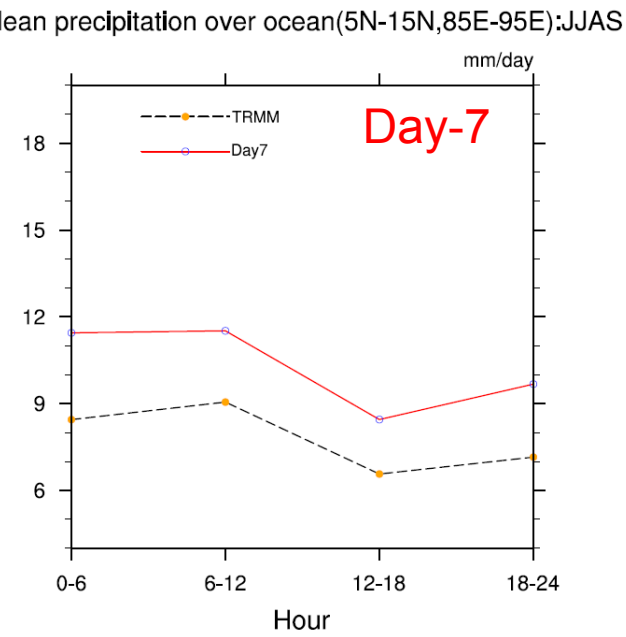


Diurnal Cycle over South-Central BoB

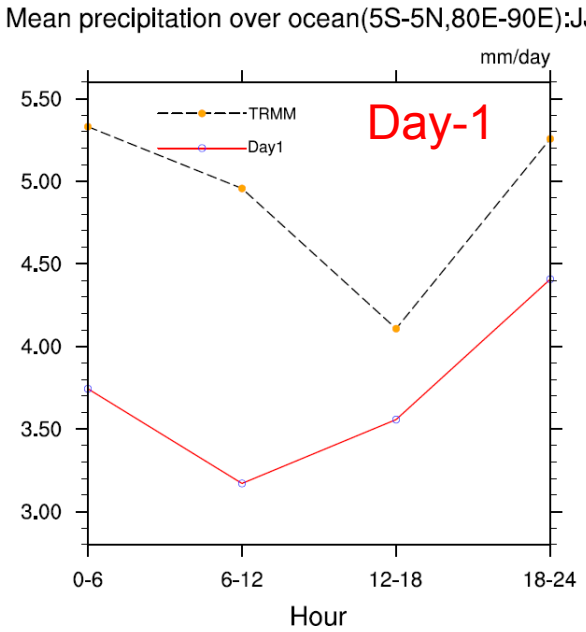


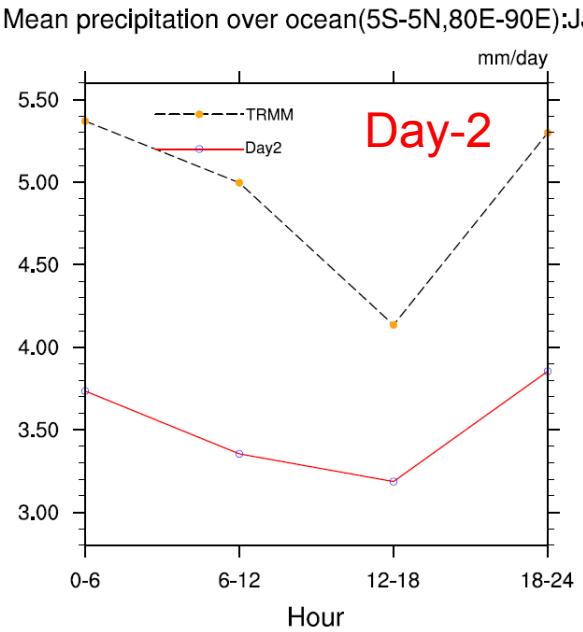


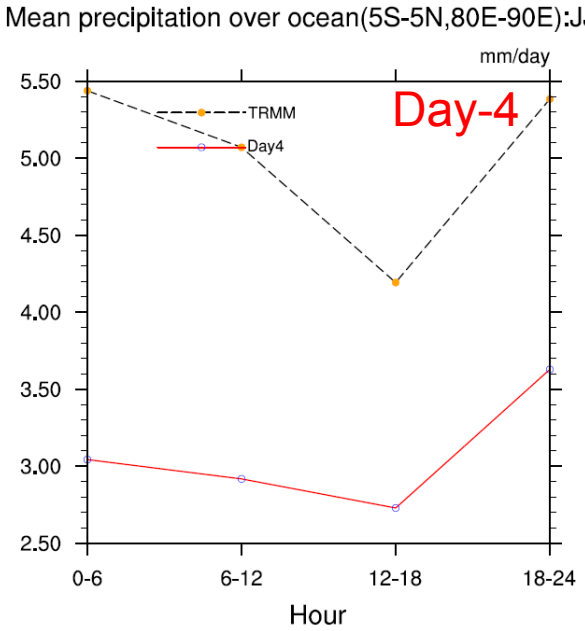


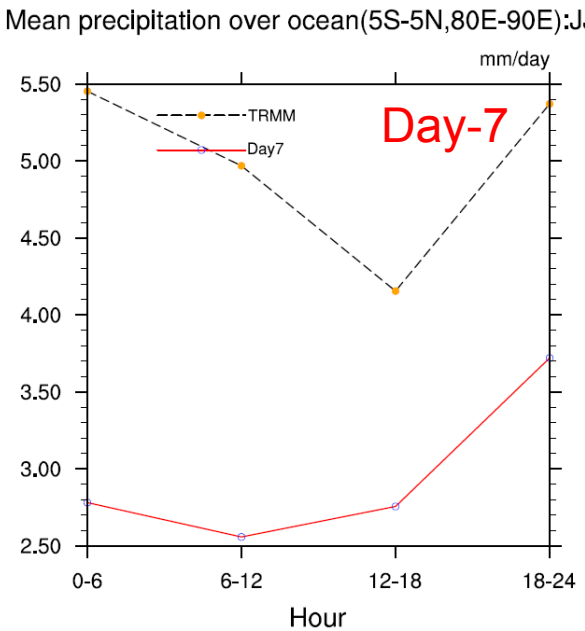


Diurnal Cycle, Equatorial Indian Ocean

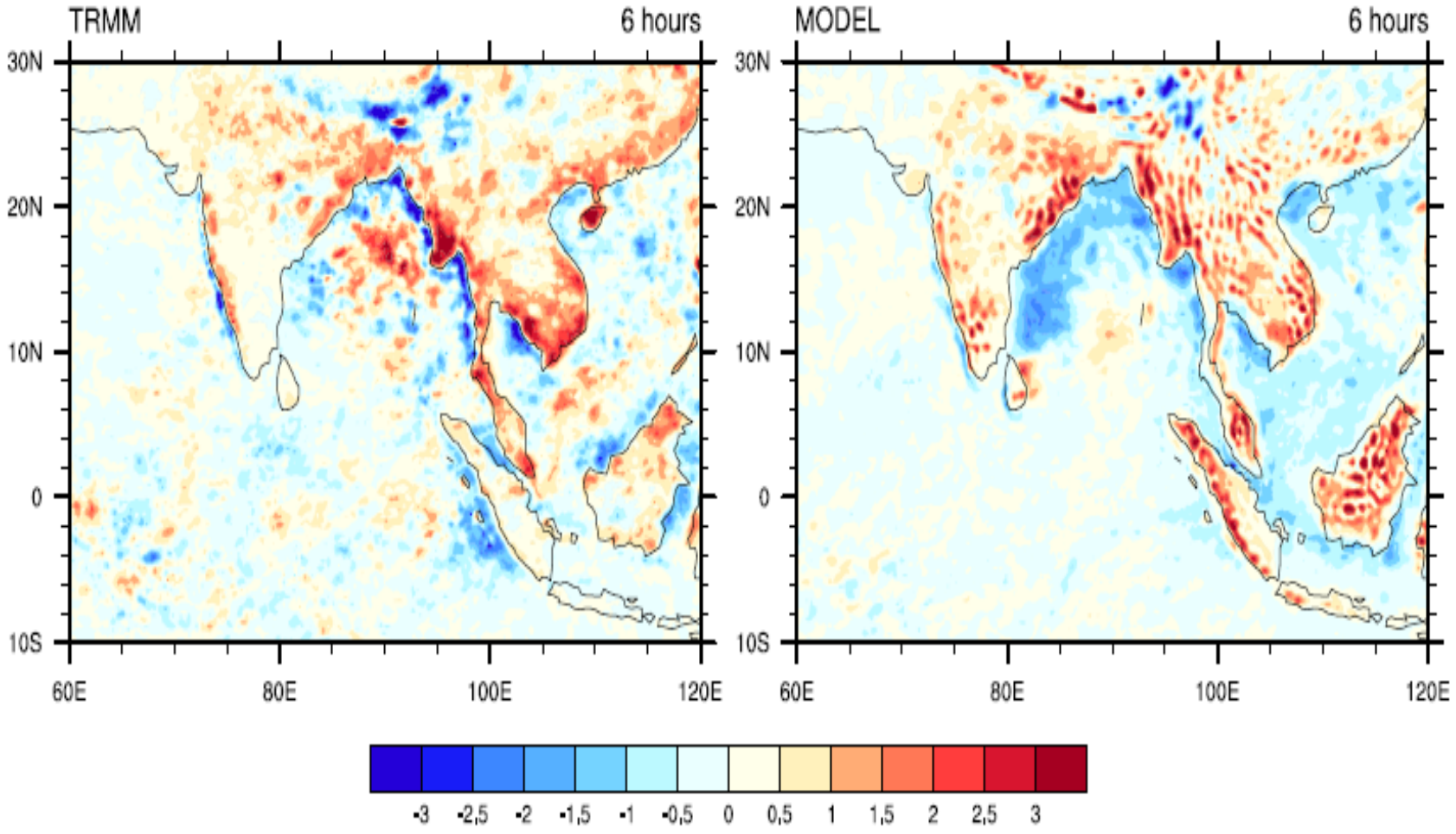


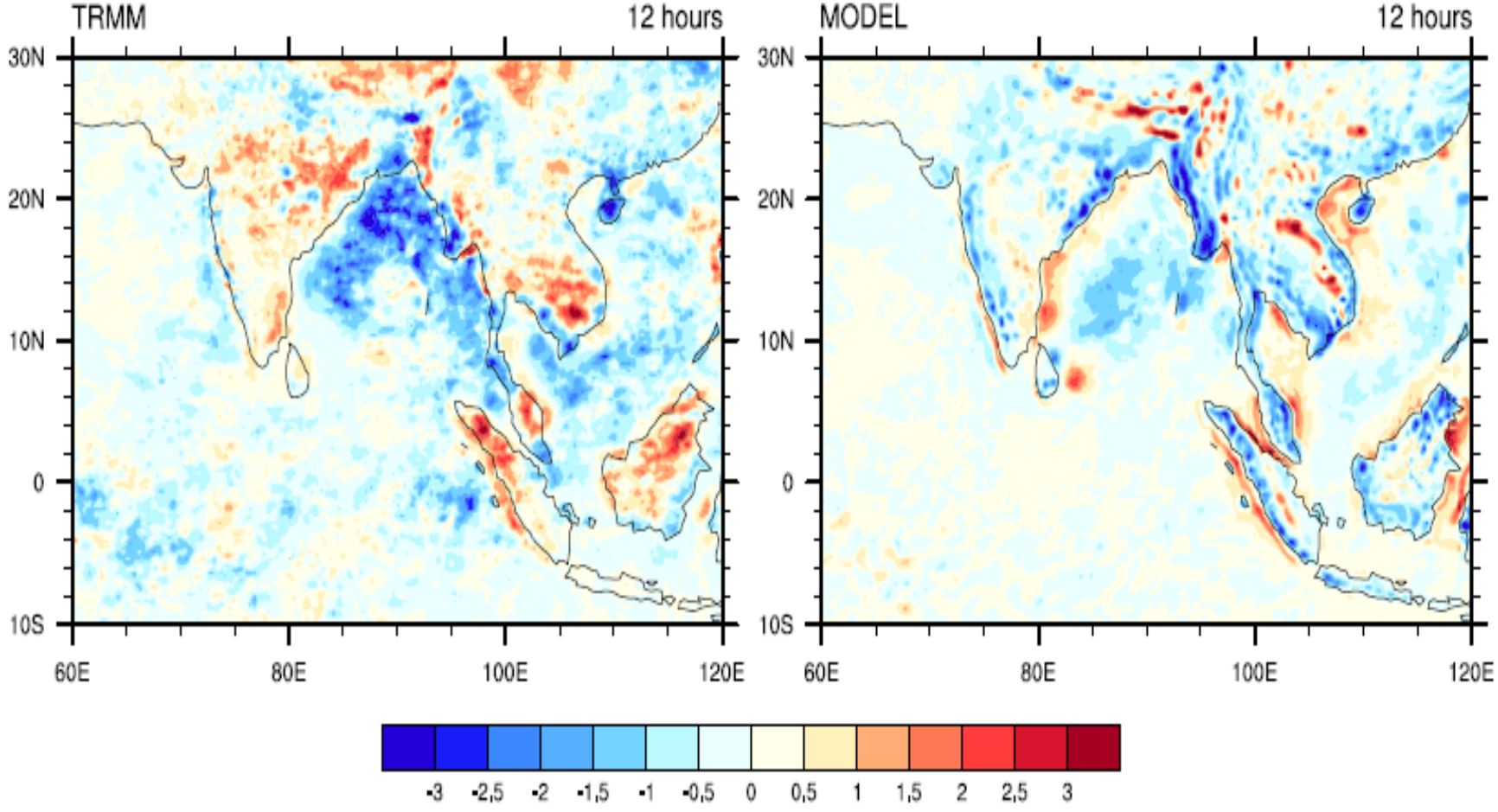




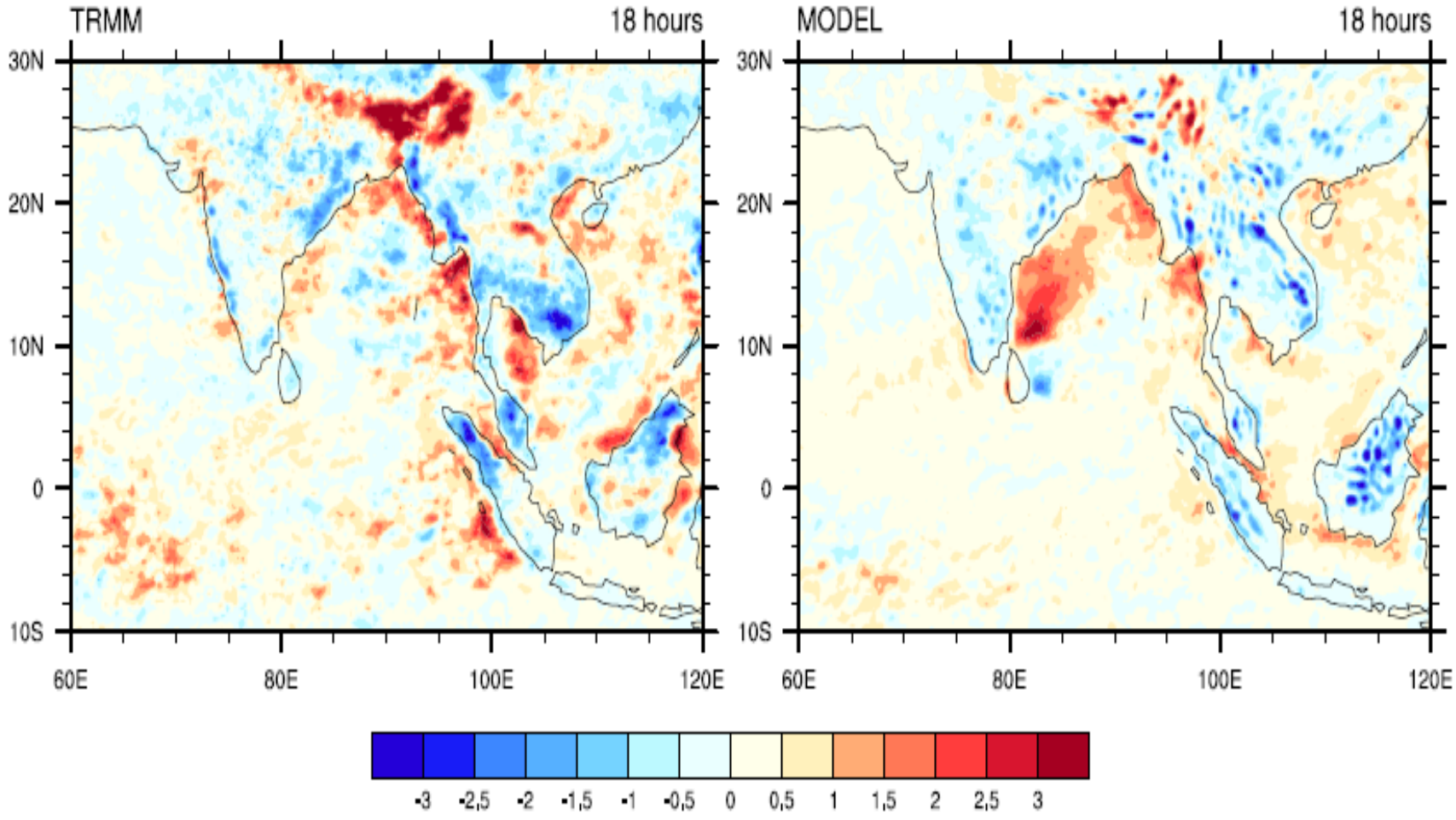


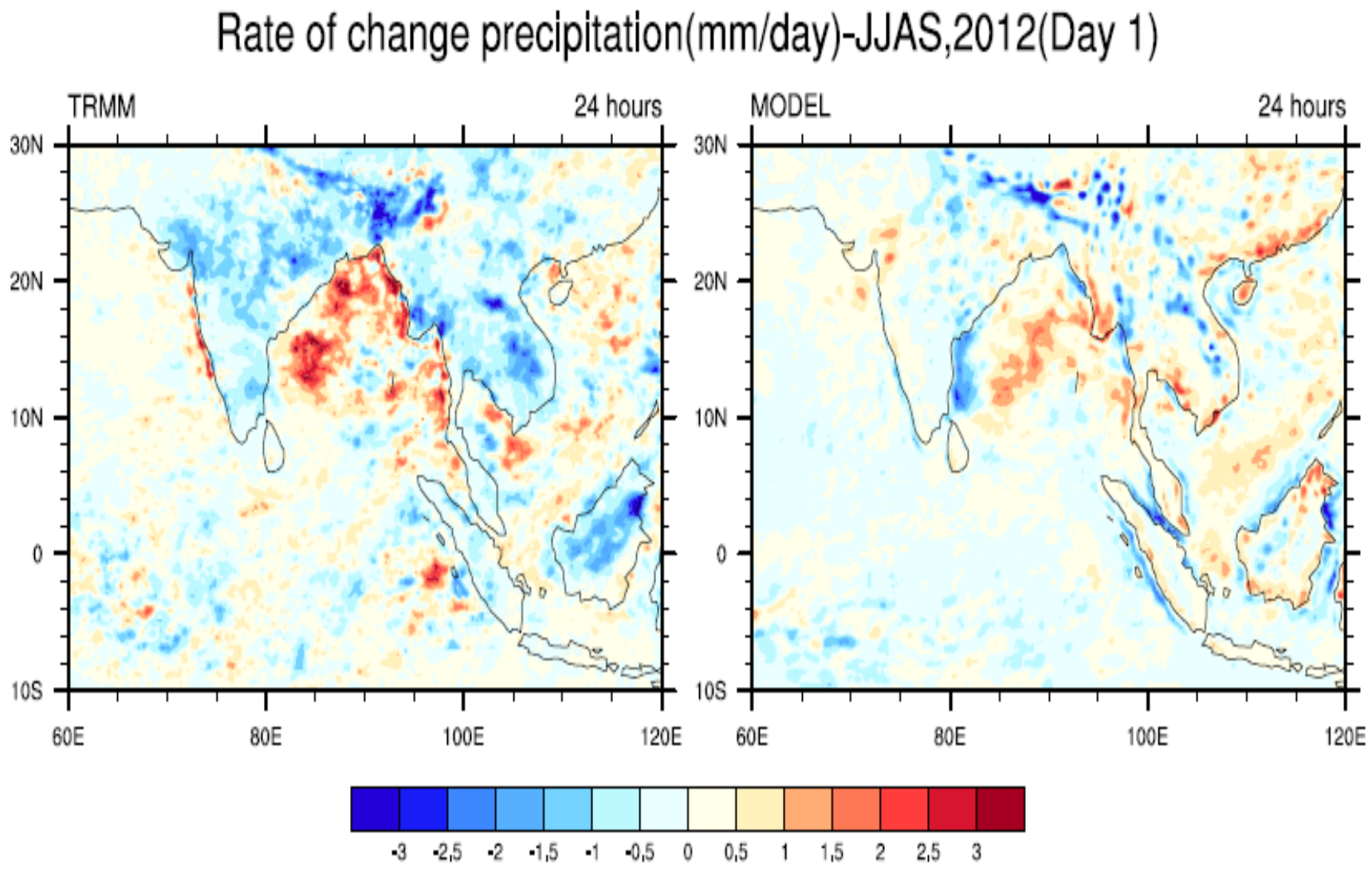
Rate of change precipitation(mm/day)-JJAS,2012(Day 1)

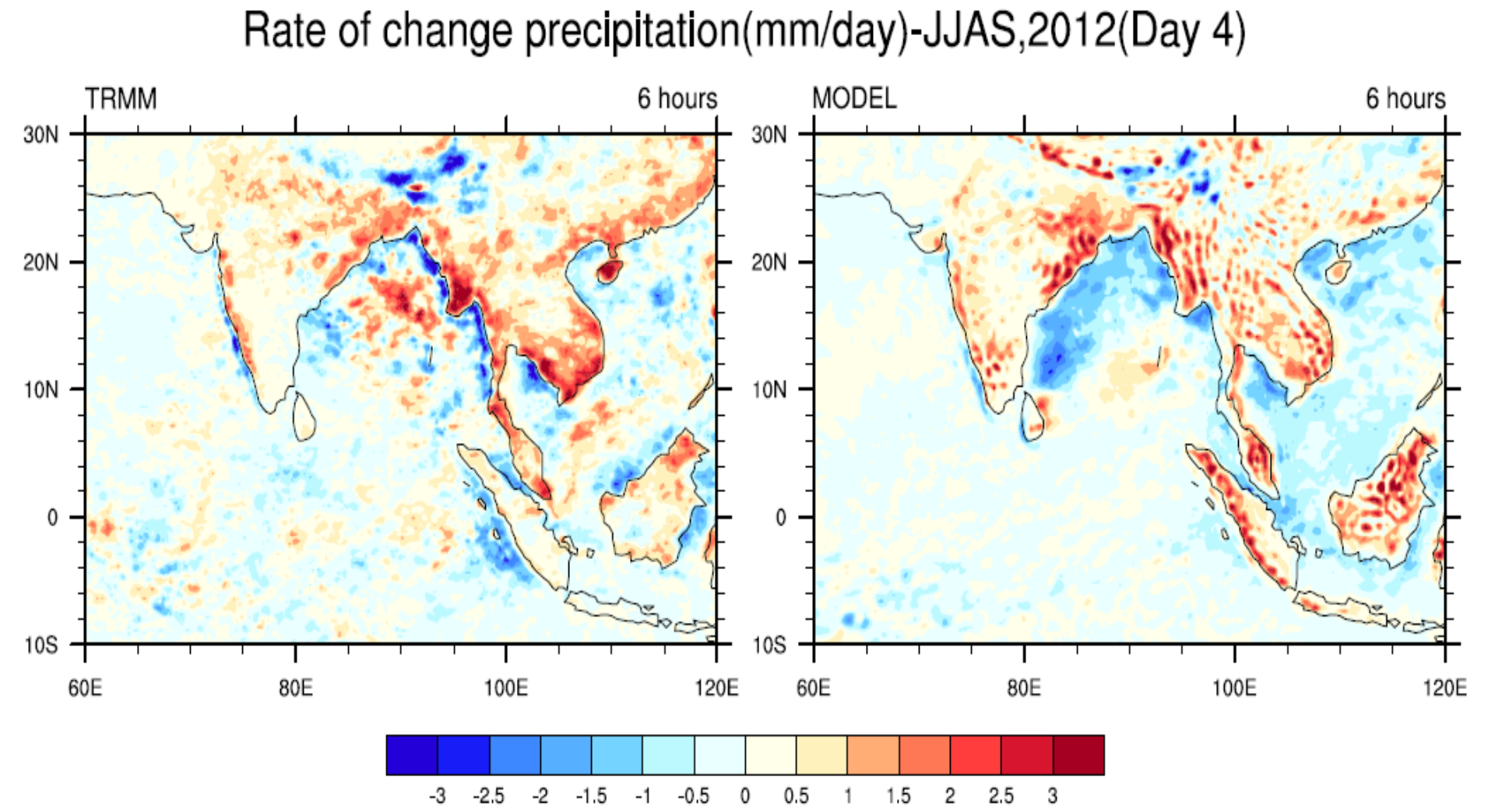


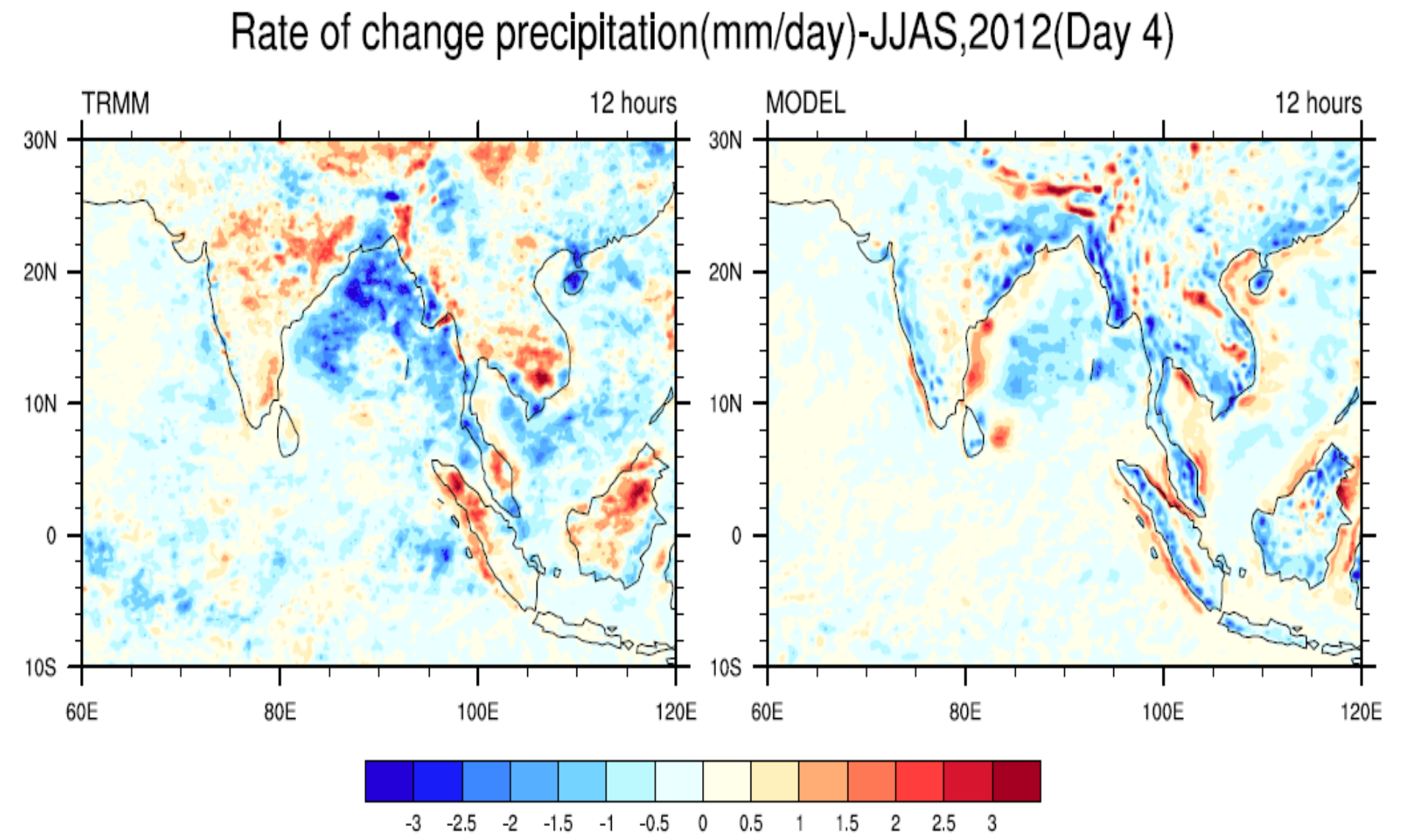

Rate of change precipitation(mm/day)-JJAS,2012(Day 1)
TRMM
12 hours
MODEL
12 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2,5
-2
-1,5
-1
-0,5
0
0,5
1
1,5
2
2,5
3

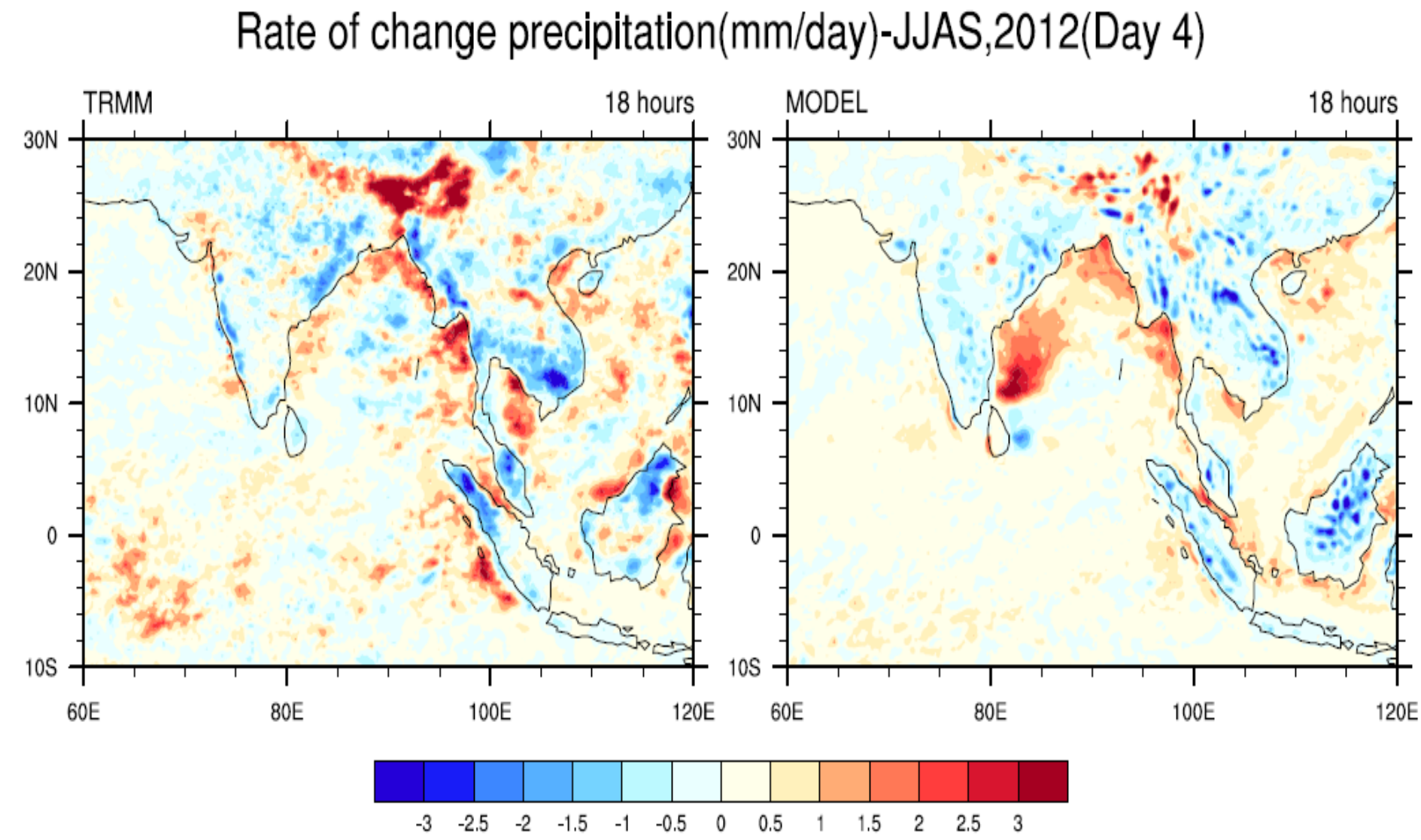
Rate of change precipitation(mm/day)-JJAS,2012(Day 1)

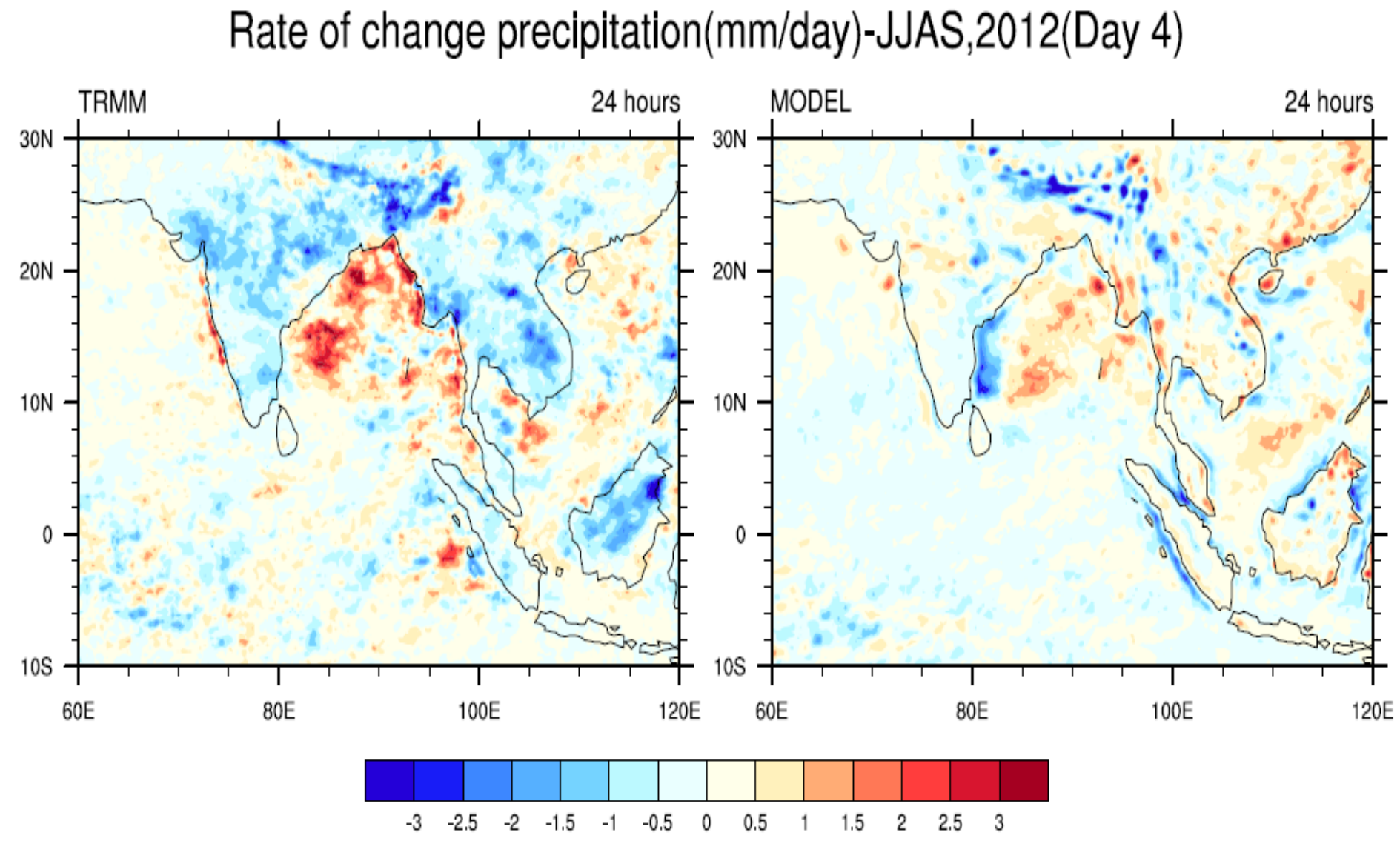


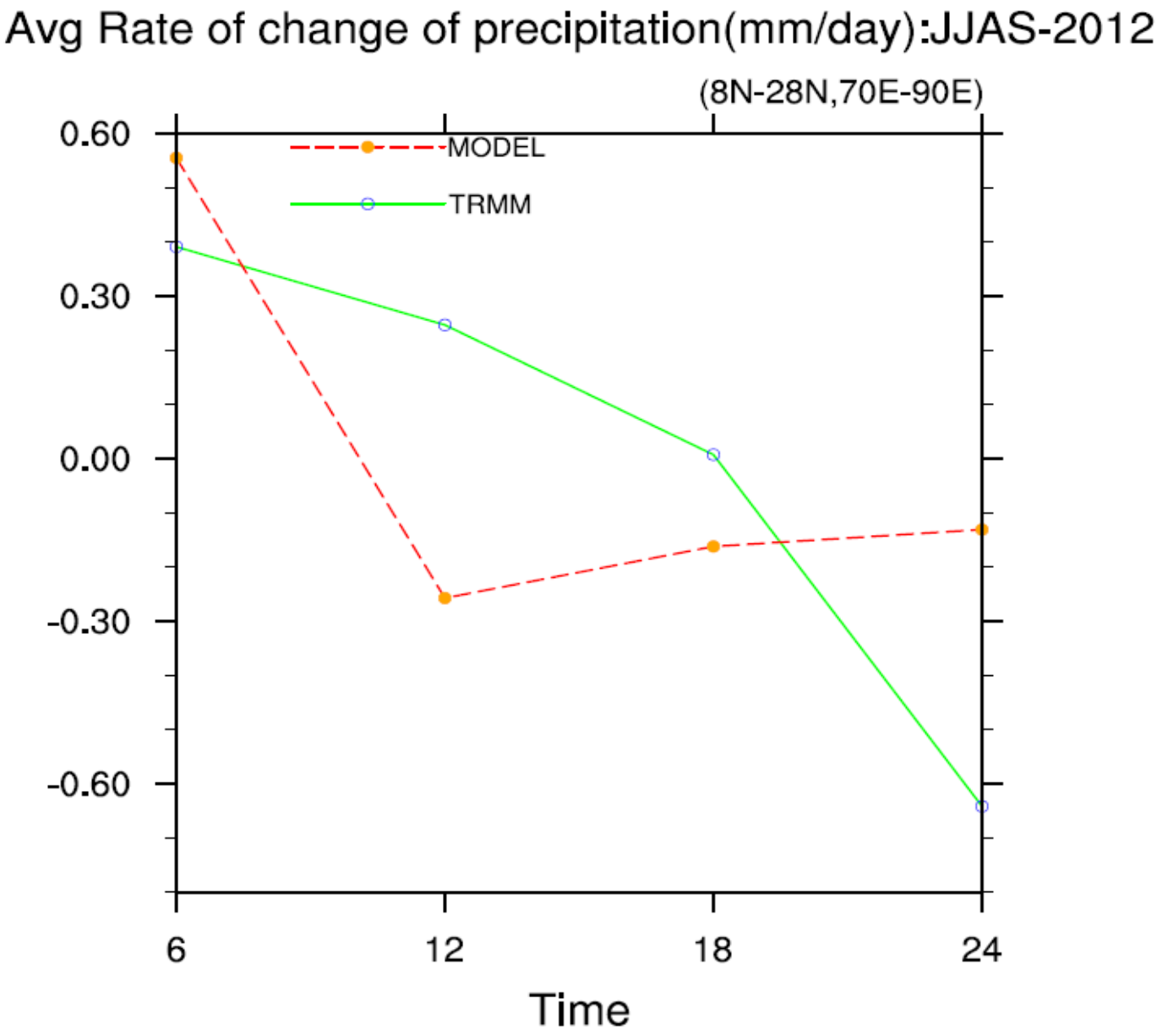

Rate of change precipitation(mm/day)-JJAS,2012(Day 1)
TRMM
24 hours
MODEL
24 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2,5
-2
-1,5
-1
-0,5
0
0,5
1
1,5
2
2,5
3

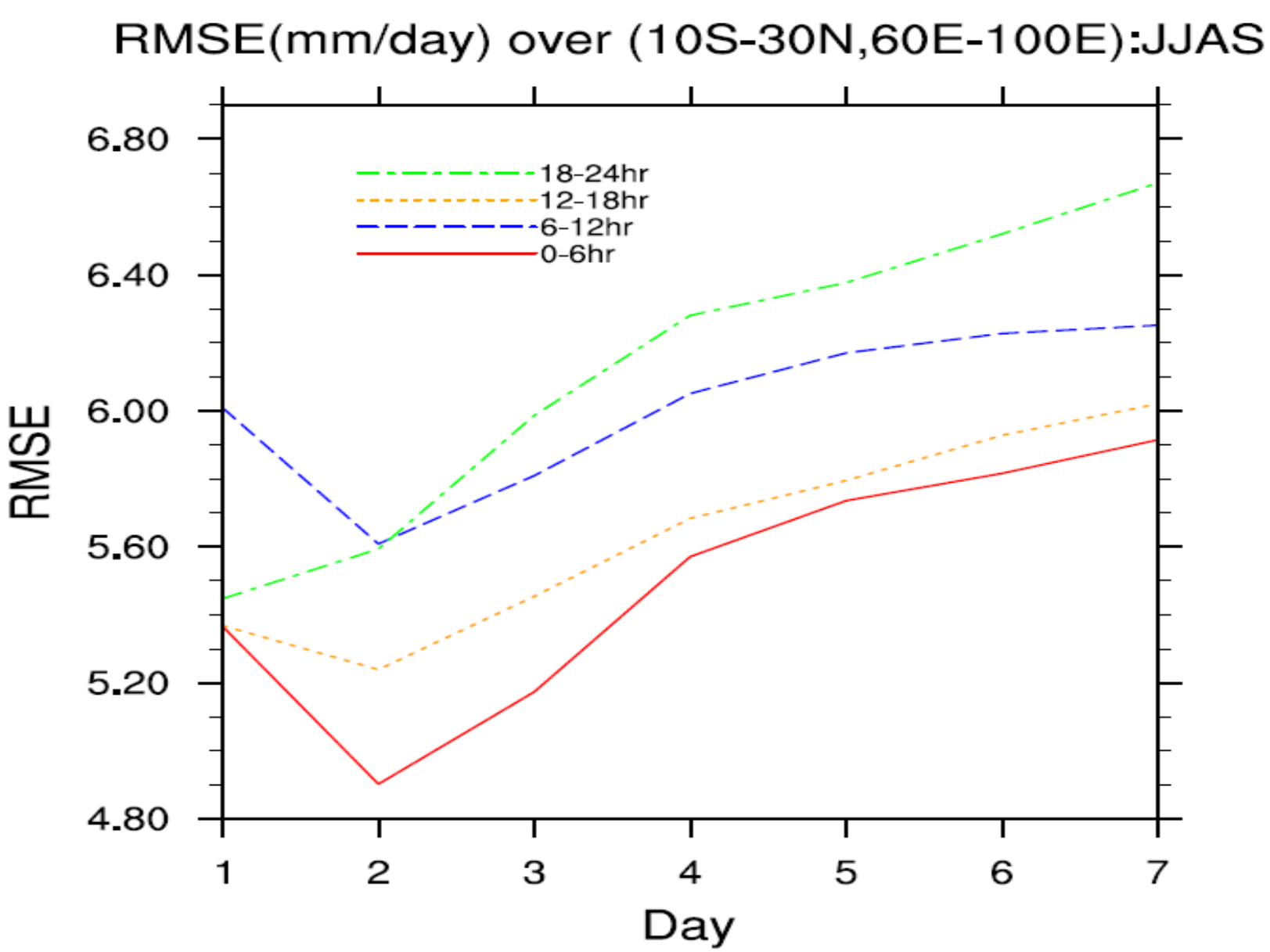

Rate of change precipitation(mm/day)-JJAS,2012(Day 4)
TRMM
6 hours
MODEL
6 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3

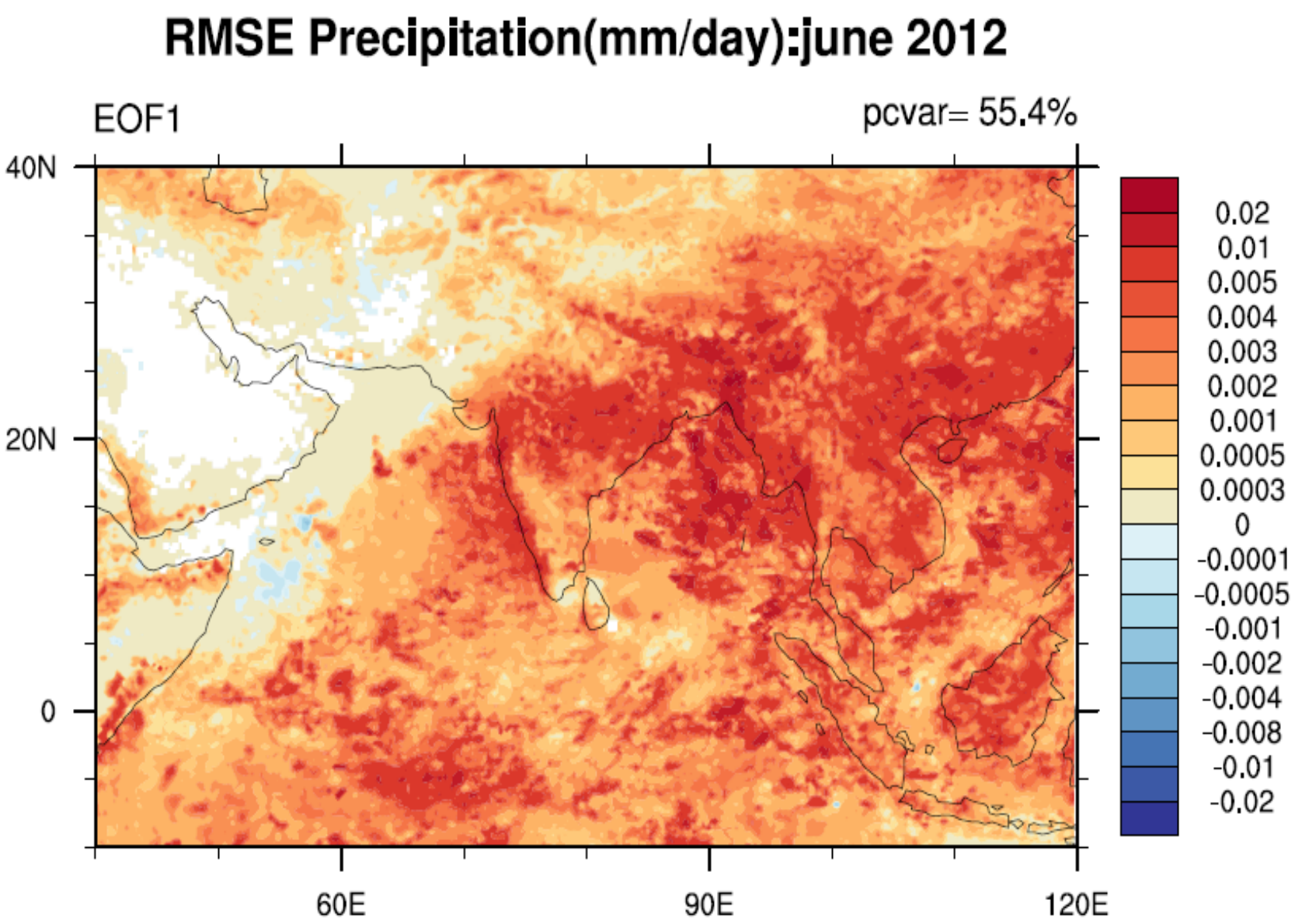

Rate of change precipitation(mm/day)-JJAS,2012(Day 4)
TRMM
12 hours
MODEL
12 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3

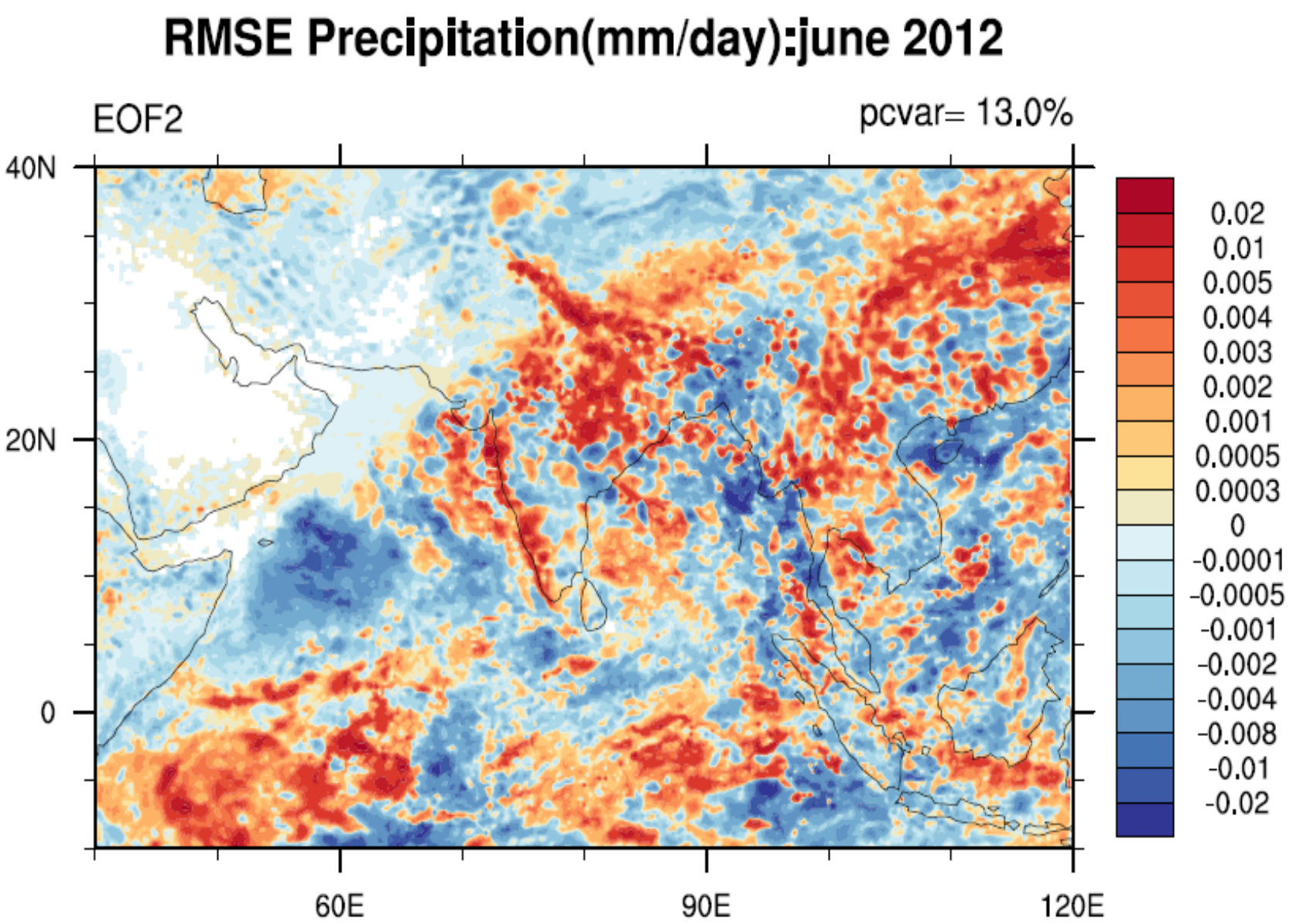

Rate of change precipitation(mm/day)-JJAS,2012(Day 4)
TRMM
18 hours
MODEL
18 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3

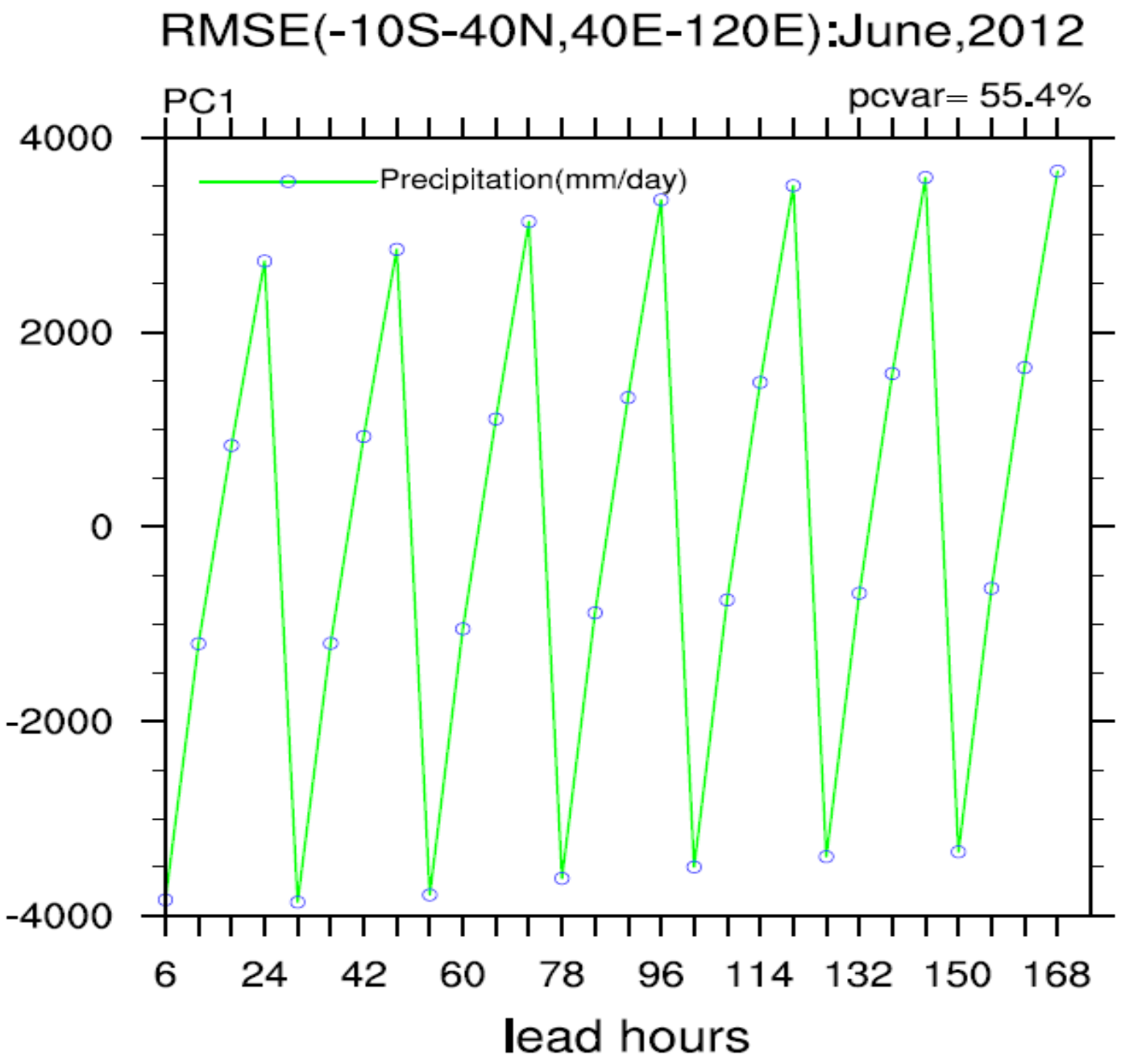

Rate of change precipitation(mm/day)-JJAS,2012(Day 4)
TRMM
24 hours
MODEL
24 hours
30N
20N
10N
0
10S
60E
80E
100E
120E
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3

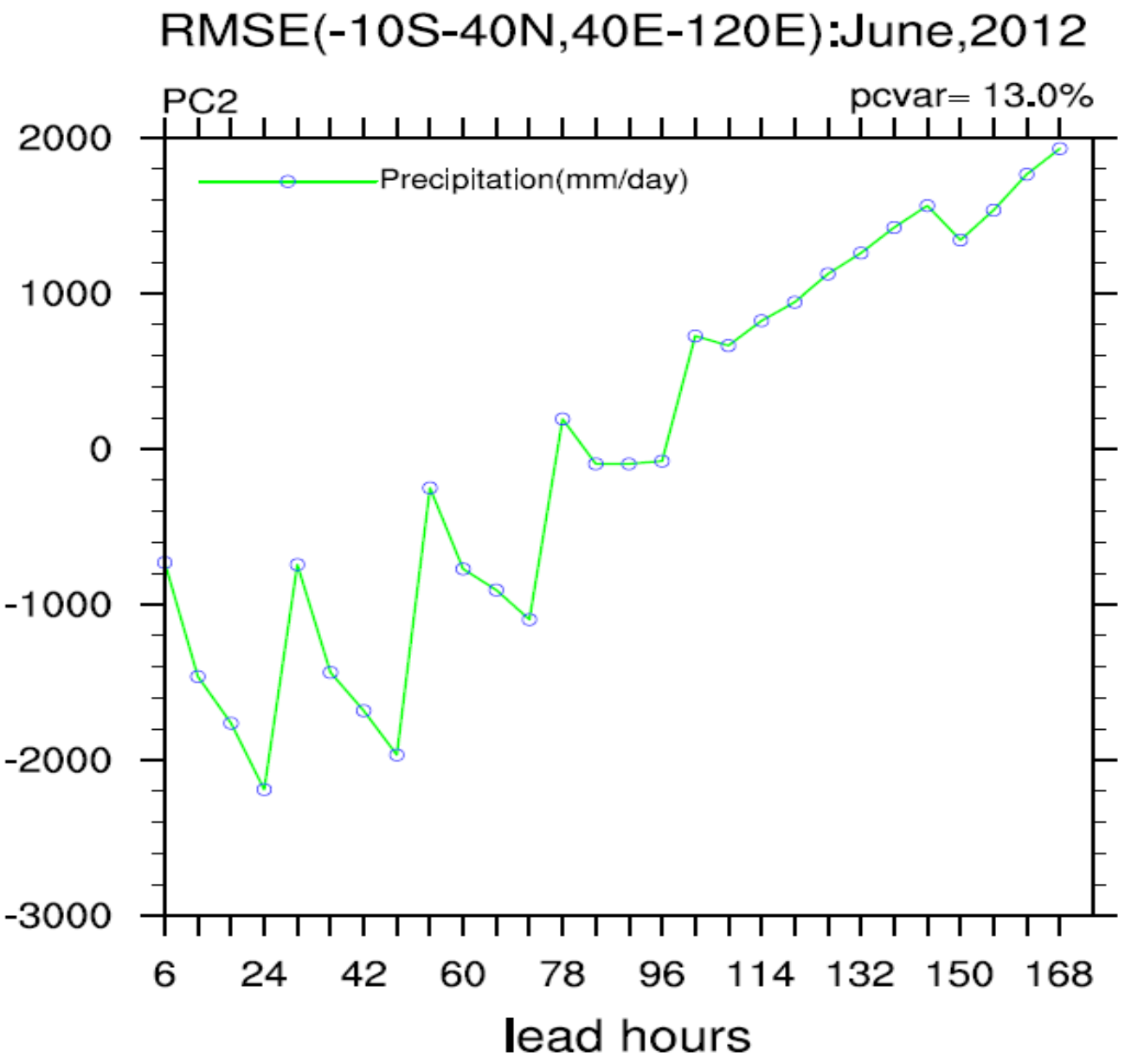

Avg Rate of change of precipitation(mm/day):JJAS-2012
(8N-28N,70E-90E)
MODEL
TRMM
0.60
0.30
0.00
-0.30
-0.60
6
12
18
24
Time

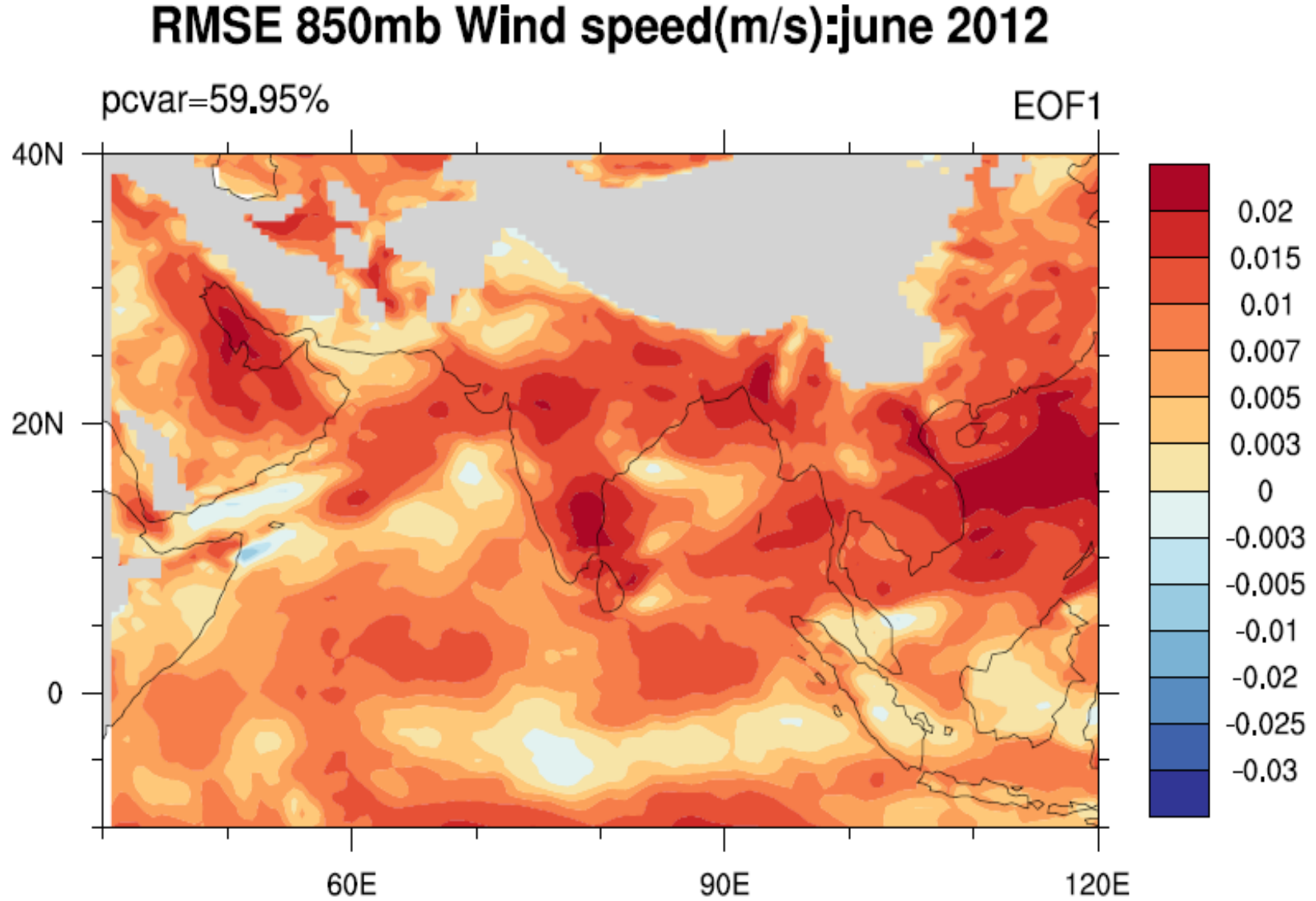

RMSE(mm/day) over (10S-30N,60E-100E):JJAS
18-24hr
12-18hr
6-12hr
0-6hr
6.80
6.40
6.00
5.60
5.20
4.80
RMSE
1
2
3
4
5
6
7
Day

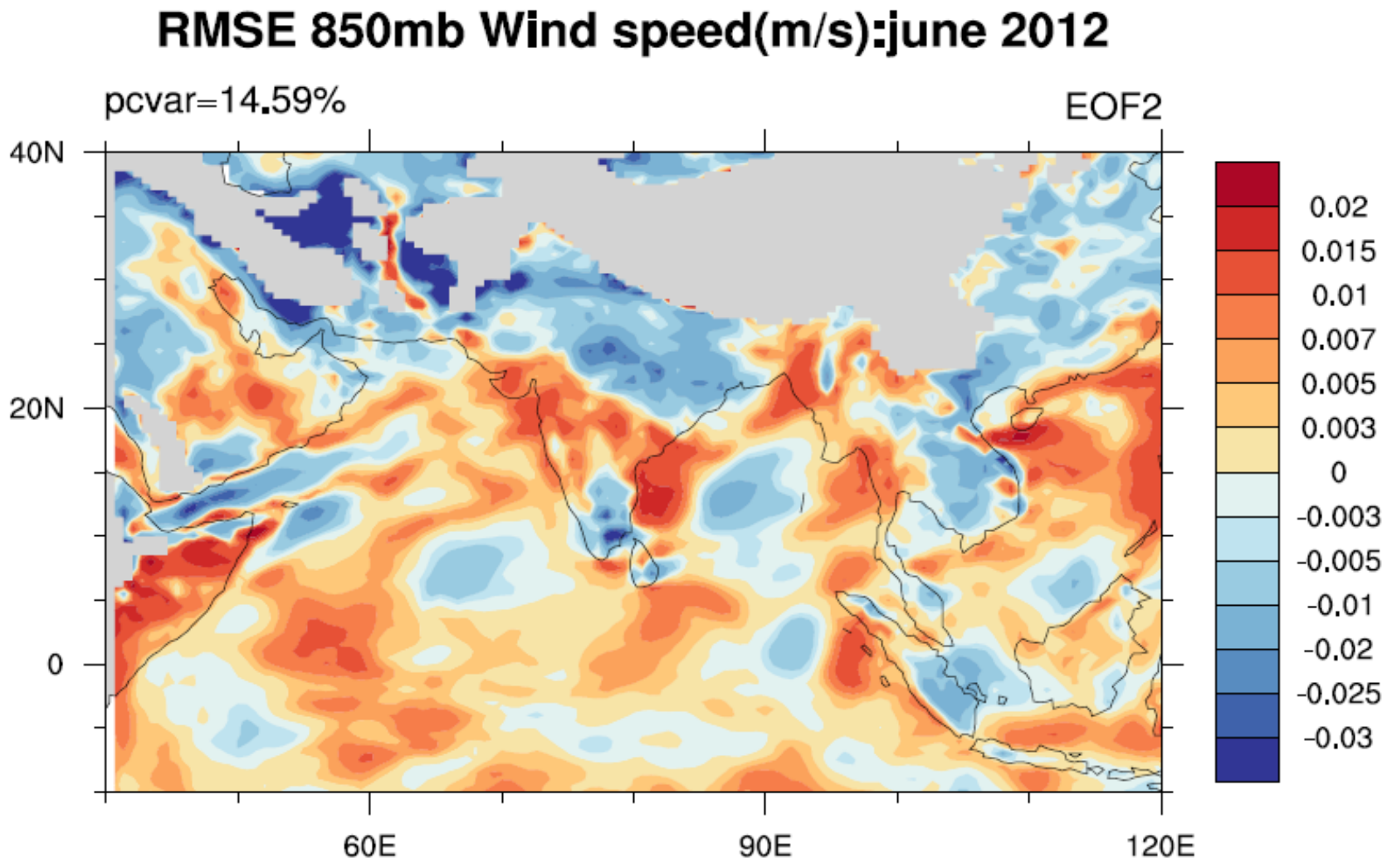

RMSE Precipitation(mm/day):june 2012
EOF1
pcvar= 55.4%
40N
20N
0
60E
90E
120E
0.02
0.01
0.005
0.004
0.003
0.002
0.001
0.0005
0.0003
0
-0.0001
-0.0005
-0.001
-0.002
-0.004
-0.008
-0.01
-0.02

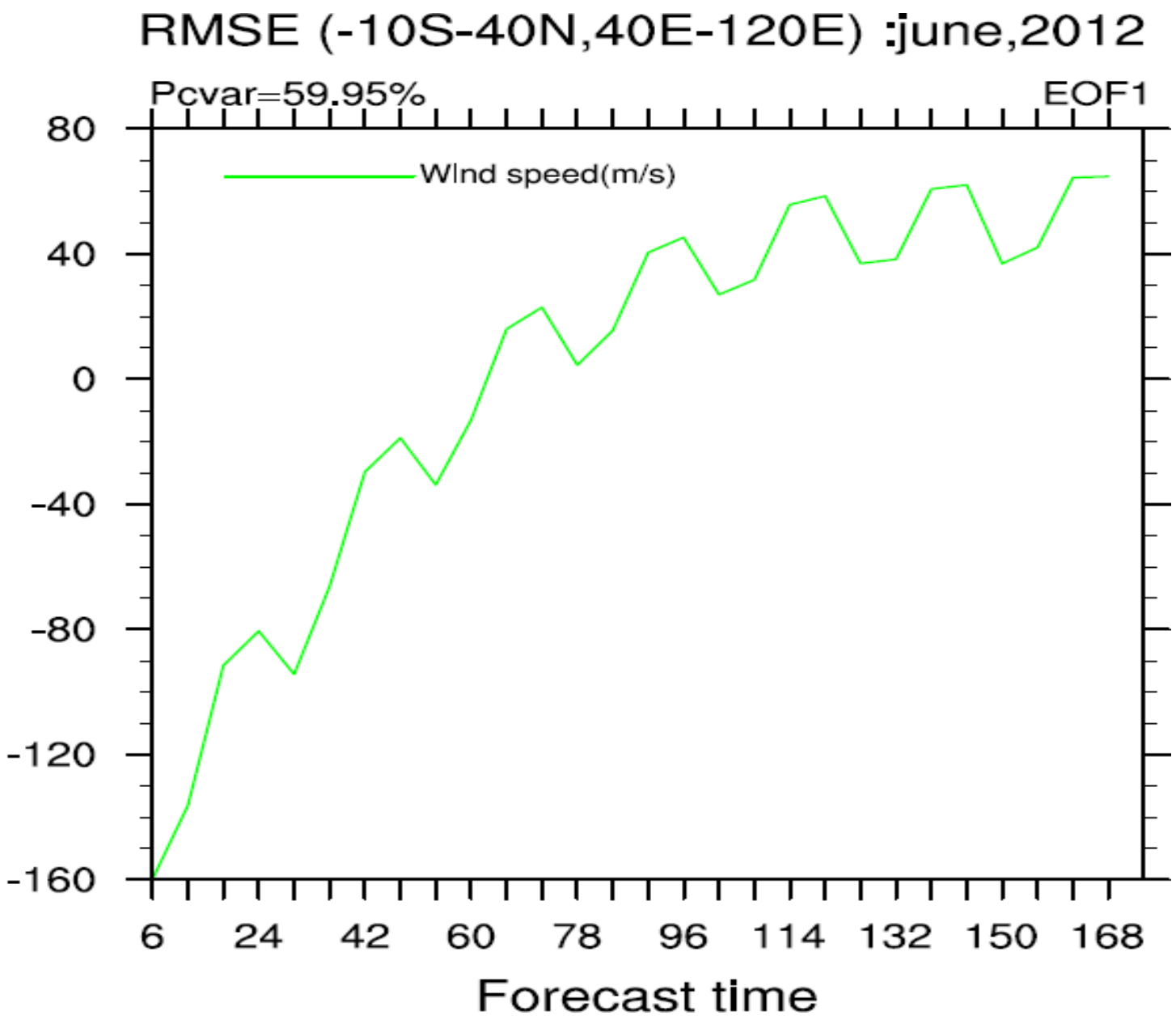

RMSE Precipitation(mm/day):june 2012
EOF2
pcvar= 13.0%
40N
20N
0
60E
90E
120E
0.02
0.01
0.005
0.004
0.003
0.002
0.001
0.0005
0.0003
0
-0.0001
-0.0005
-0.001
-0.002
-0.004
-0.008
-0.01
-0.02

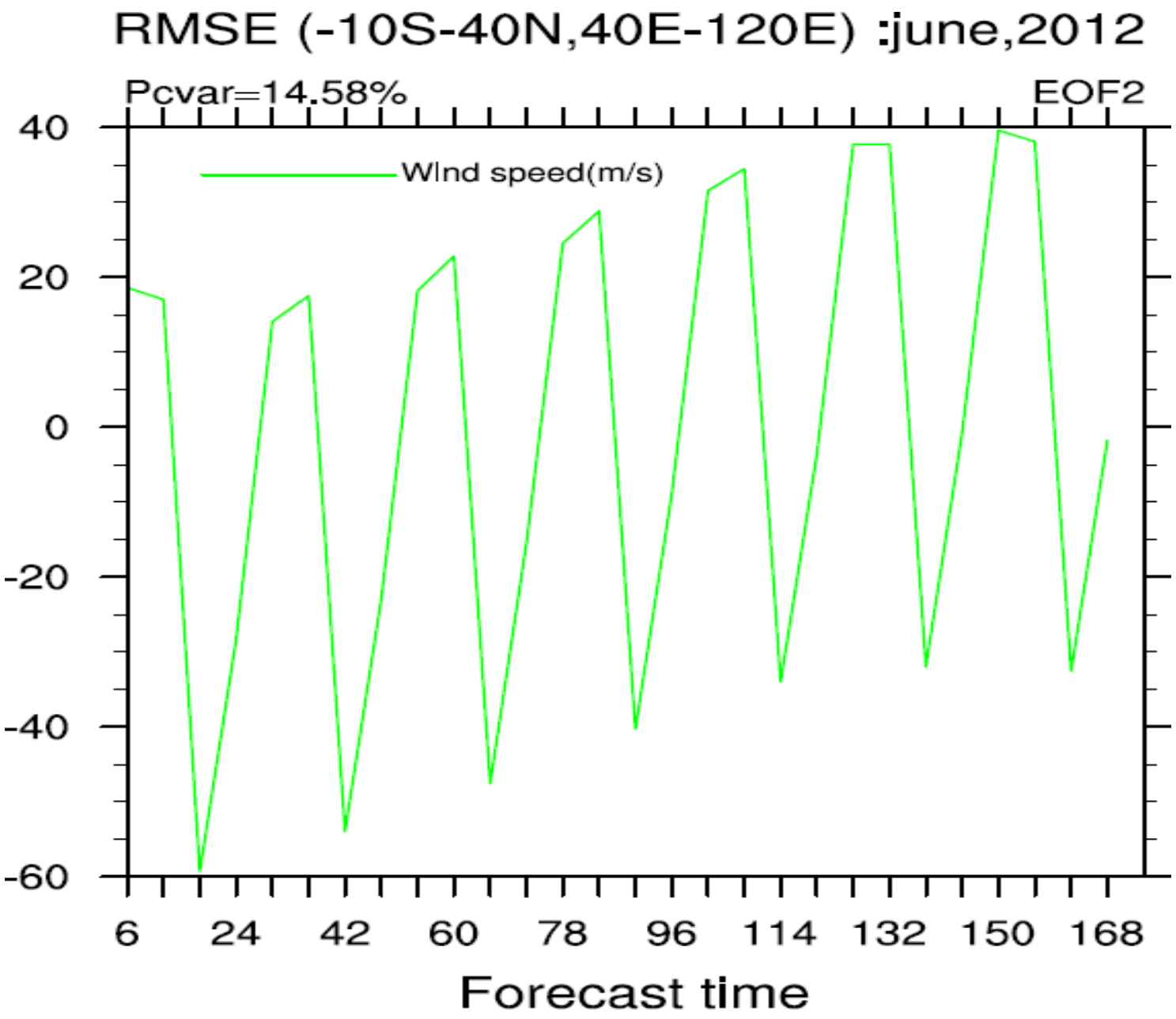

RMSE(-10S-40N,40E-120E):June,2012
PC1
pcvar= 55.4%
Precipitation(mm/day)
4000
2000
0
-2000
-4000
6
24
42
60
78
96
114
132
150
168
lead hours


RMSE(-10S-40N,40E-120E):June,2012
PC2
pcvar= 13.0%
Precipitation(mm/day)
2000
1000
0
-1000
-2000
-3000
6
24
42
60
78
96
114
132
150
168
lead hours

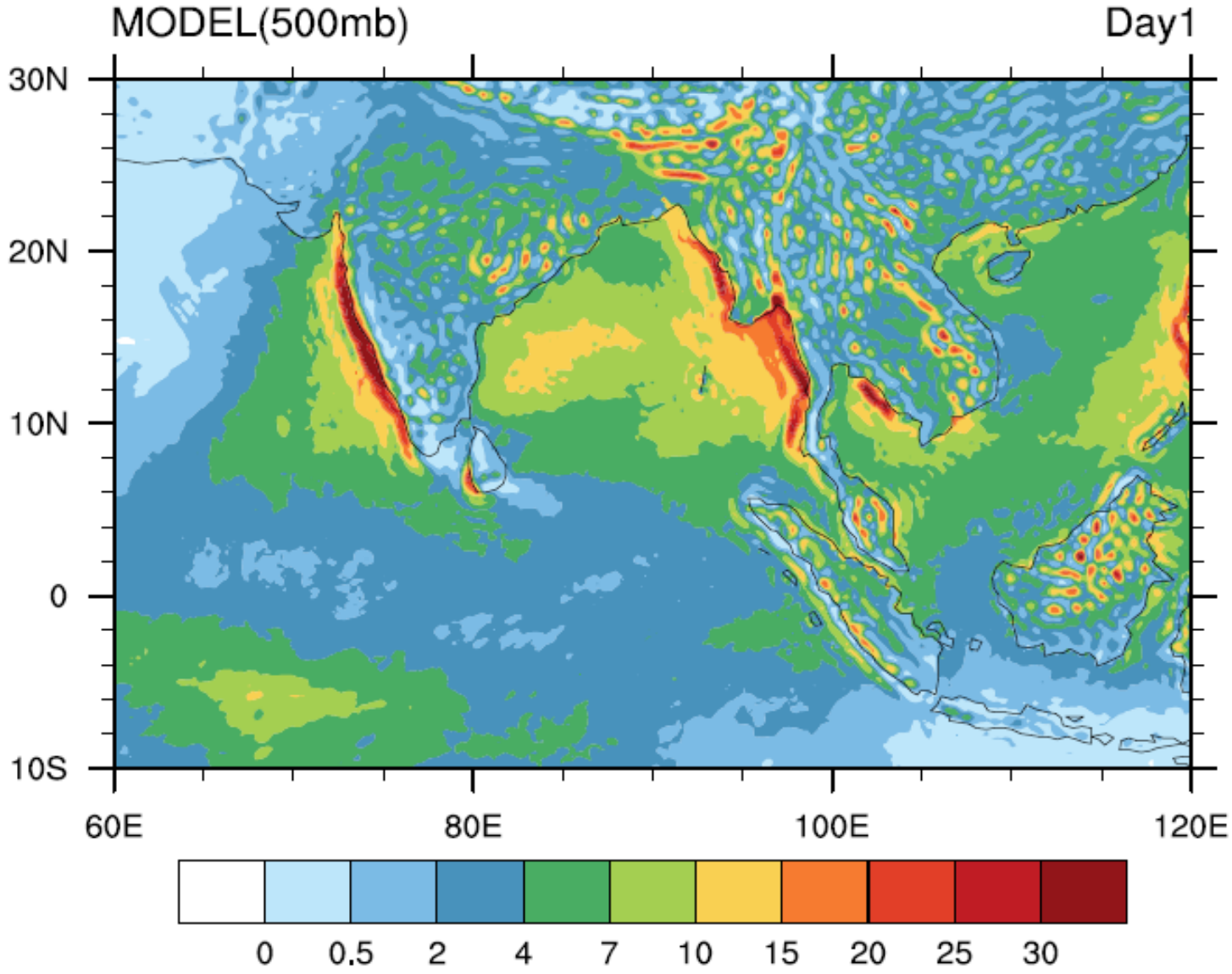

RMSE 850mb Wind speed(m/s):june 2012
pcvar=59.95%
EOF1
40N
20N
0
60E
90E
120E
0.02
0.015
0.01
0.007
0.005
0.003
0
-0.003
-0.005
-0.01
-0.02
-0.025
-0.03


RMSE 850mb Wind speed(m/s):june 2012
pcvar=14.59%
EOF2
40N
20N
0
60E
90E
120E
0.02
0.015
0.01
0.007
0.005
0.003
0
-0.003
-0.005
-0.01
-0.02
-0.025
-0.03

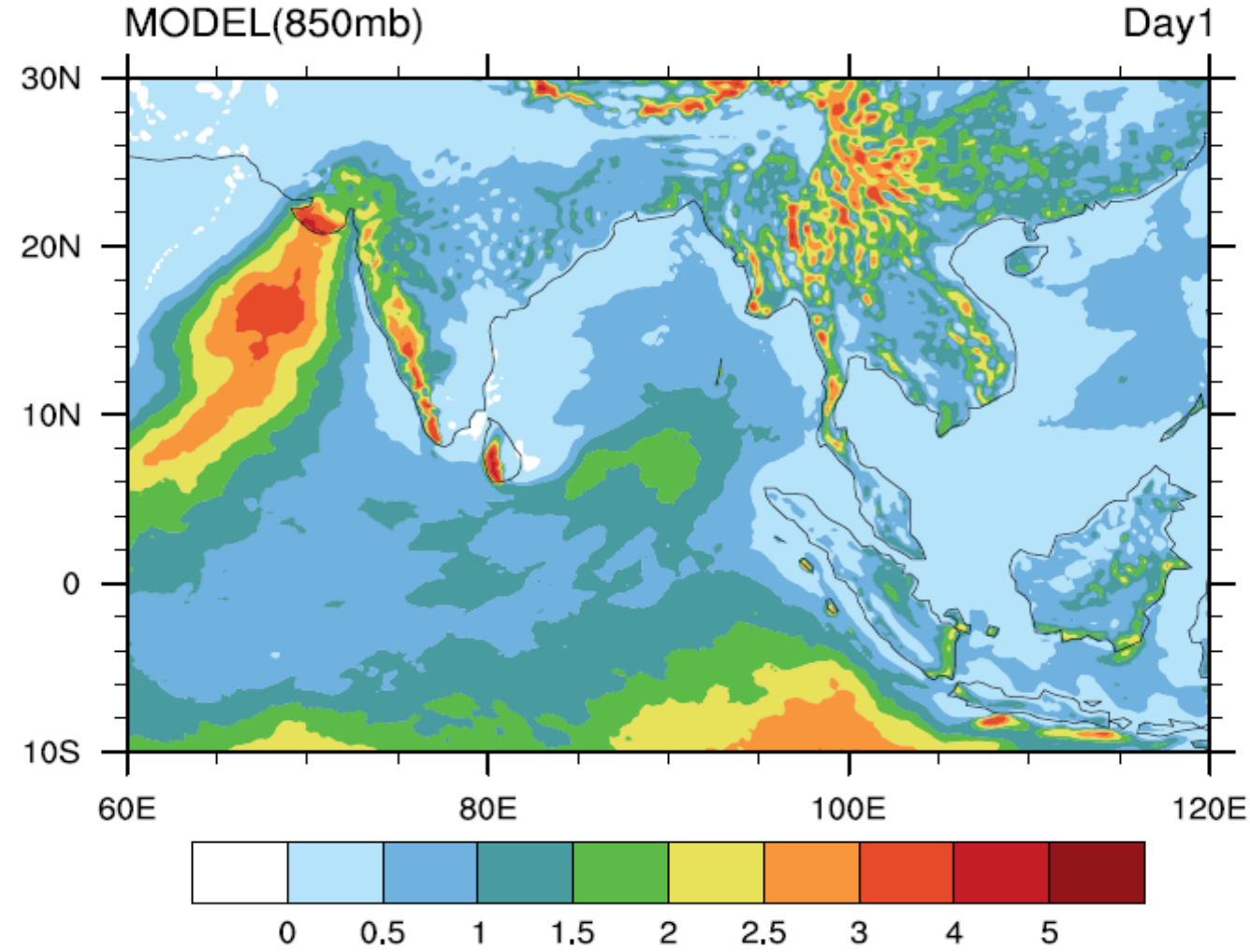

RMSE (-10S-40N,40E-120E) :june,2012
Pcvar=59.95%
EOF1
Wind speed(m/s)
80
40
0
-40
-80
-120
-160
6
24
42
60
78
96
114
132
150
168
Forecast time

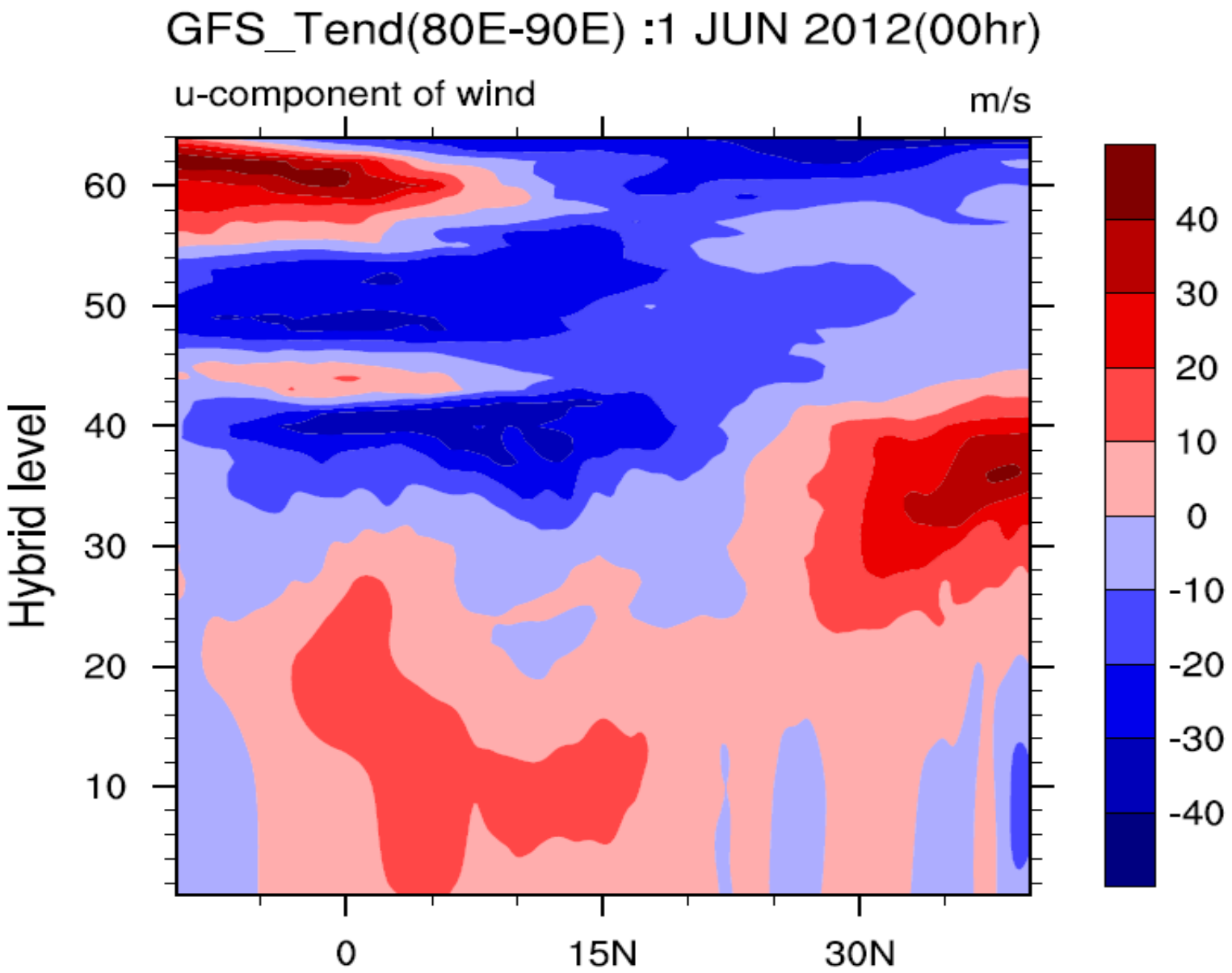

RMSE (-10S-40N,40E-120E) :june,2012
Pcvar=14.58%
EOF2
Wlnd speed(m/s)
40
20
0
-20
-40
-60
6
24
42
60
78
96
114
132
150
168
Forecast time

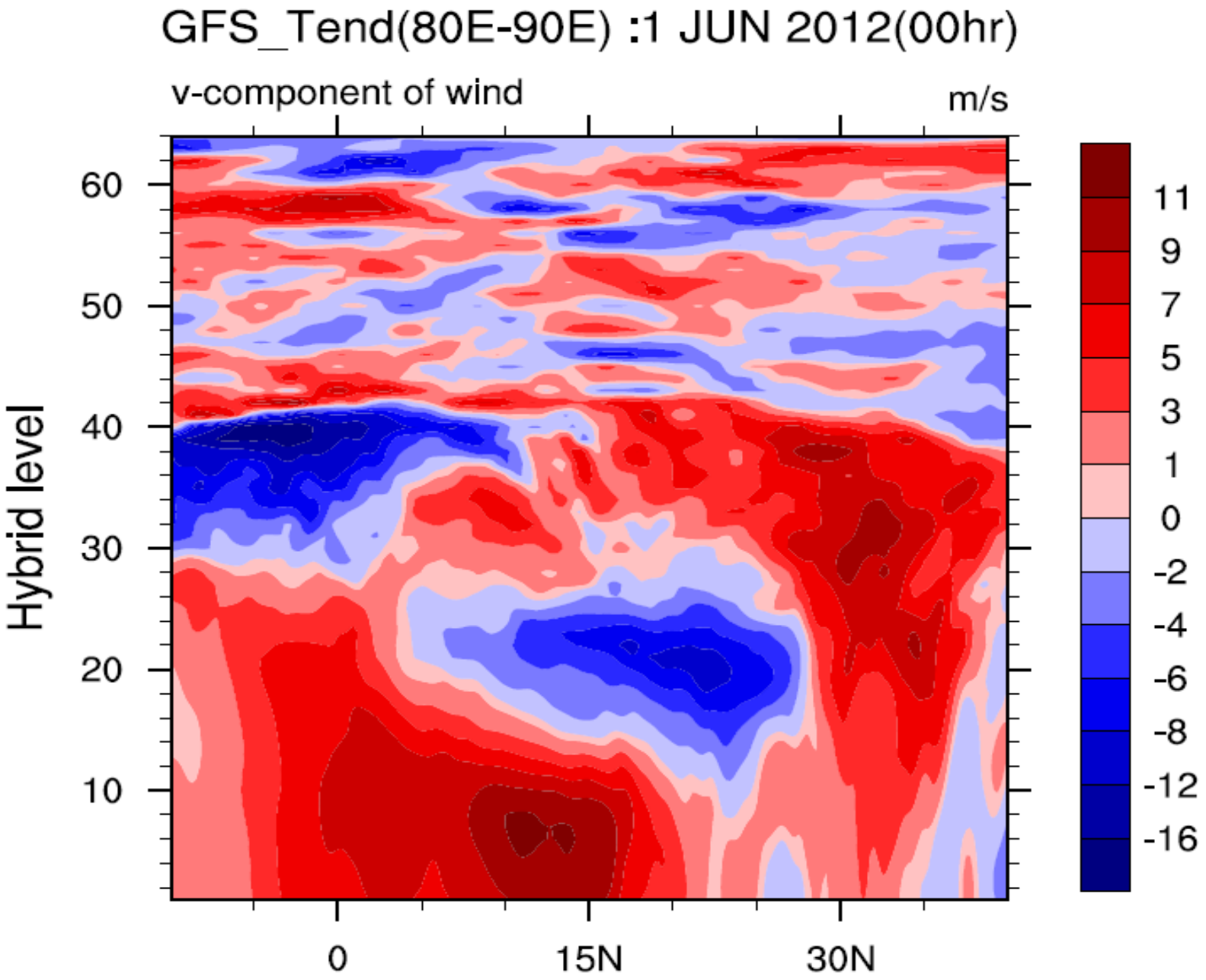
Mean Deep convective heating(K/day):JJAS-2012

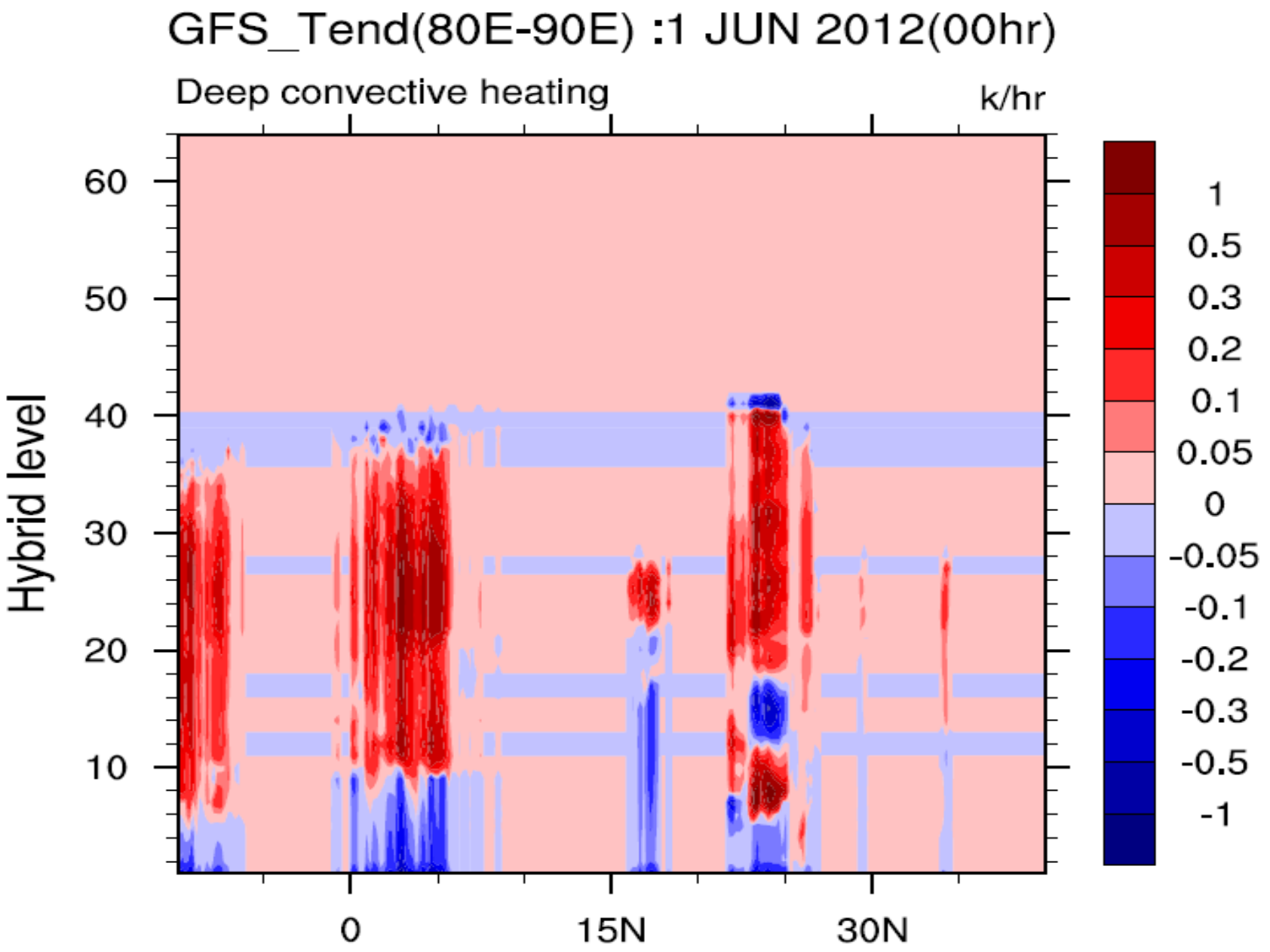


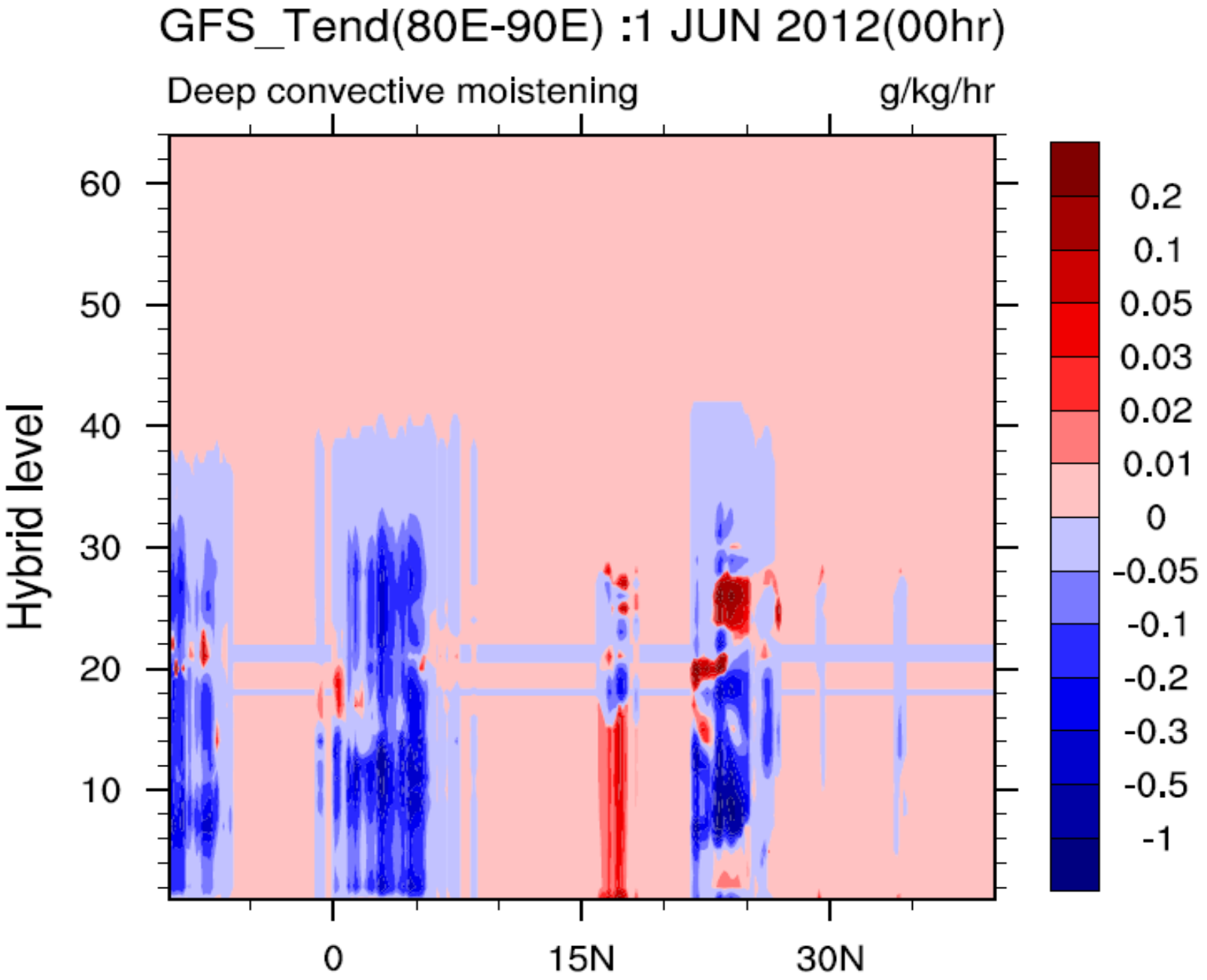
Mean Shallow convective heating(K/day):JJAS-2012

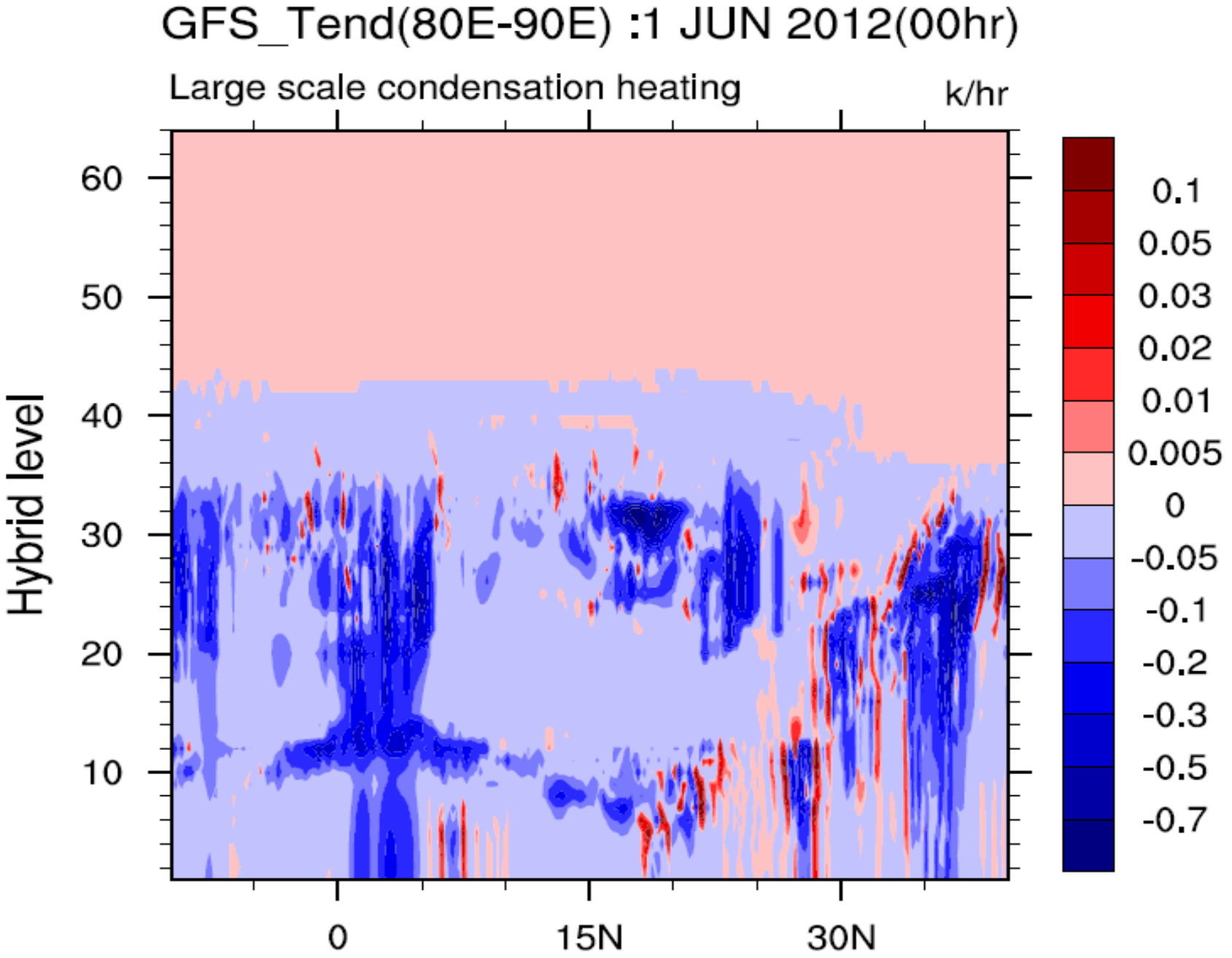


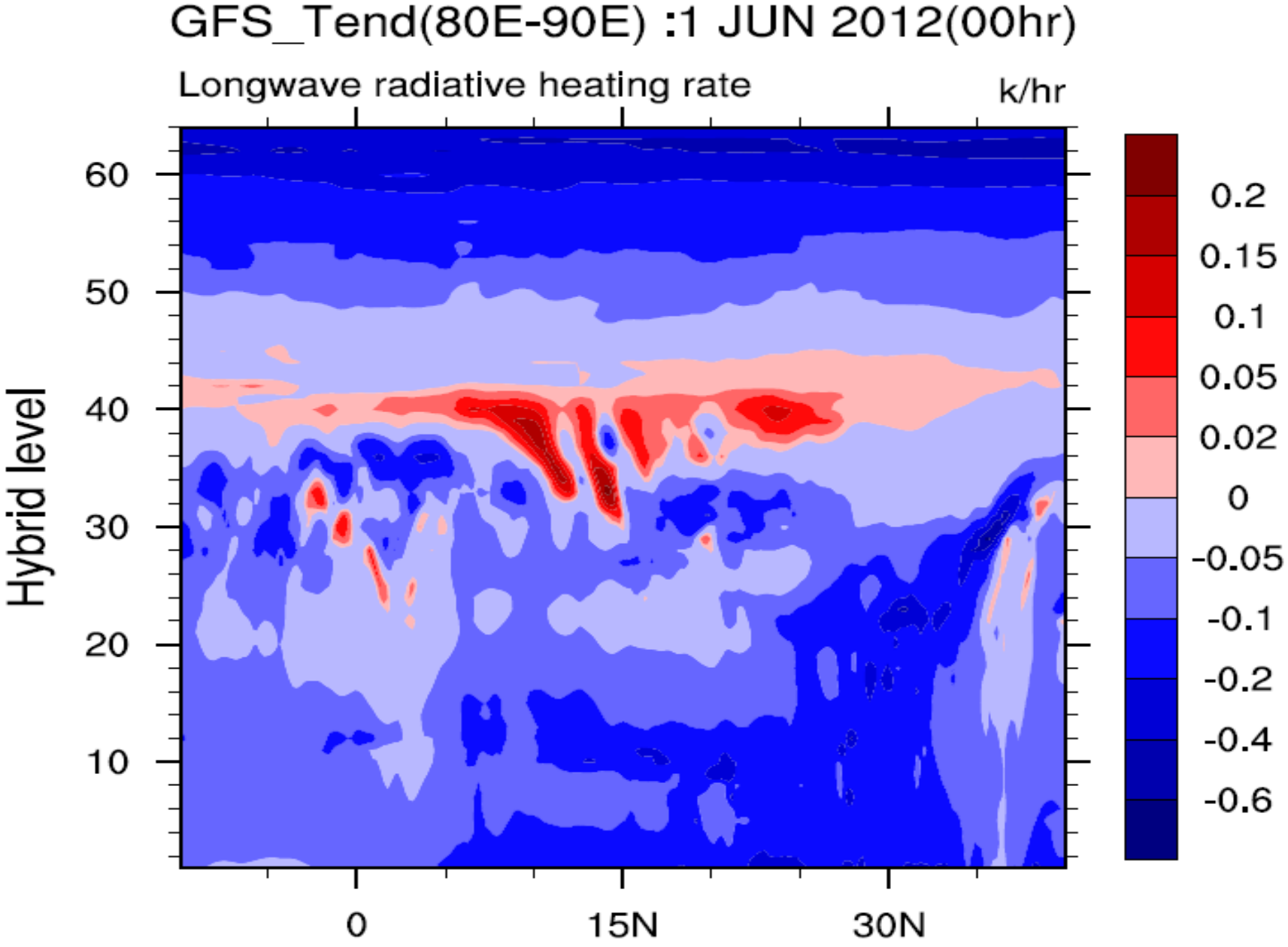

GFS_Tend(80E-90E) :1 JUN 2012(00hr)
u-component of wind
m/s
Hybrid level
60
50
40
30
20
10
0
15N
30N
40
30
20
10
0
-10
-20
-30
-40


GFS_Tend(80E-90E) :1 JUN 2012(00hr)
v-component of wind
m/s
Hybrid level
60
50
40
30
20
10
0
15N
30N
11
9
7
5
3
1
0
-2
-4
-6
-8
-12
-16


GFS_Tend(80E-90E) :1 JUN 2012(00hr)
Deep convective heating
k/hr
Hybrid level
60
50
40
30
20
10
0
15N
30N
1
0.5
0.3
0.2
0.1
0.05
0
-0.05
-0.1
-0.2
-0.3
-0.5
-1


GFS_Tend(80E-90E) :1 JUN 2012(00hr)
Deep convective moistening
g/kg/hr
Hybrid level
60
50
40
30
20
10
0
15N
30N
0.2
0.1
0.05
0.03
0.02
0.01
0
-0.05
-0.1
-0.2
-0.3
-0.5
-1


GFS_Tend(80E-90E) :1 JUN 2012(00hr)
Large scale condensation heating
k/hr
Hybrid level
60
50
40
30
20
10
0
15N
30N
0.1
0.05
0.03
0.02
0.01
0.005
0
-0.05
-0.1
-0.2
-0.3
-0.5
-0.7


GFS_Tend(80E-90E) :1 JUN 2012(00hr)
Longwave radiative heating rate
k/hr
Hybrid level
60
50
40
30
20
10
0
15N
30N
0.2
0.15
0.1
0.05
0.02
0
-0.05
-0.1
-0.2
-0.4
-0.6

Conclusions

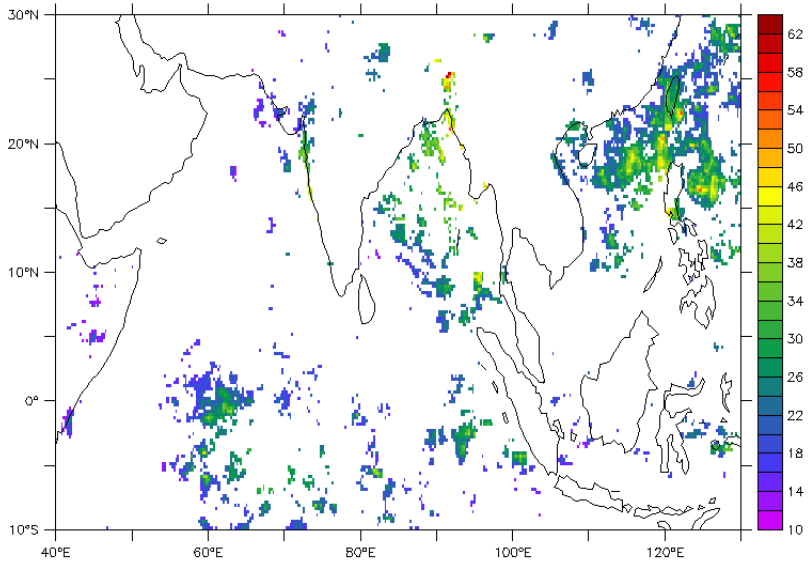
- High error in precipitation is noticed over land during first 12 hours of forecast. This is possibly because of lack in precipitation initialization in the model.
- Error in spatial pattern in mean precipitation is low over ocean than that over land. However, the rate of decrease of error over ocean is larger than over land.
- Unlike that over land, error over ocean at long lead time is confined to over regions with large day-to-day variability but low mean in precipitation. This possibly indicates lack in air-sea coupling in the model.
- Large error is noticed is precipitation diurnal cycle over Indian land and Bay of Bengal. Most of the bias in the model can be attributed to the error in diurnal cycle in model precipitation.

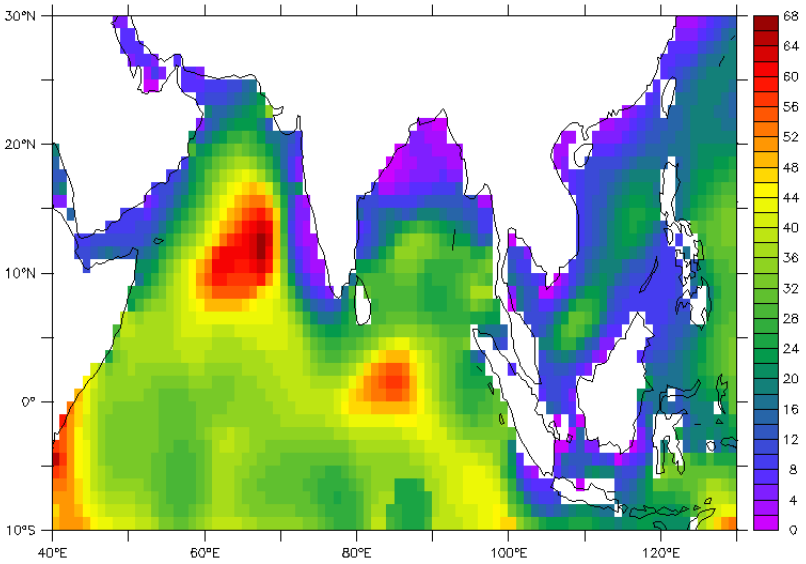
Future Work

- Implement the correction terms inside the model.
- Model simulation for JJAS2012 and compare the forecast skill with control.

THANK YOU

Regions with Low Mean and High Std



Need for coupling?

JJAS Mean MLD (m), Levitus Climatology