Importance of Land Surface Processes in Simulating the Mean Rainfall

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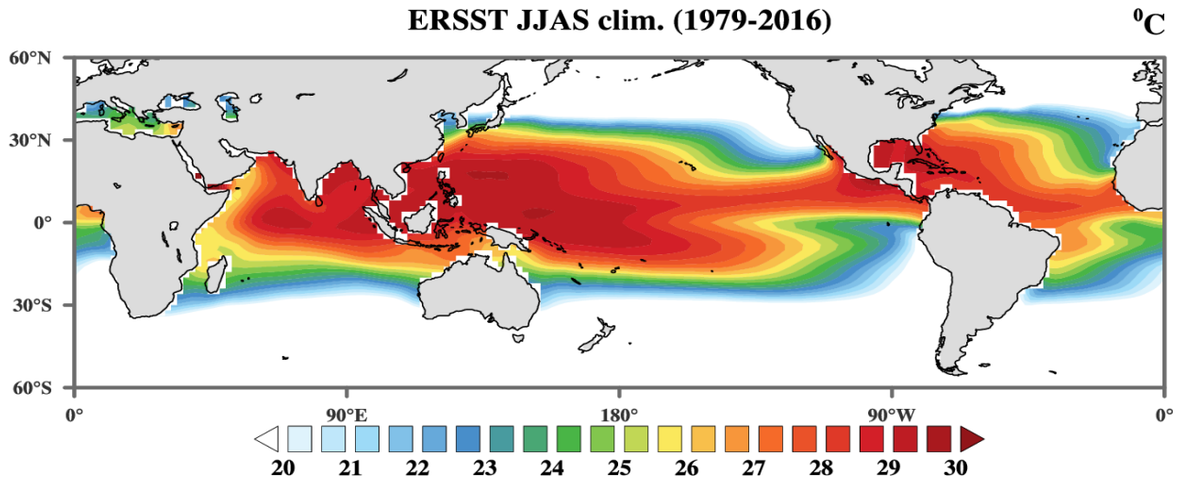
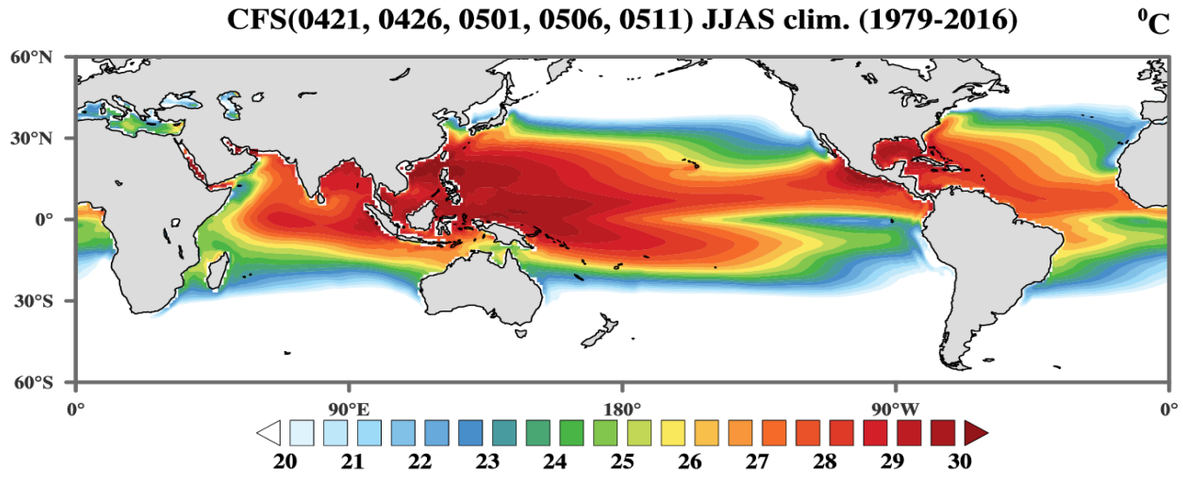
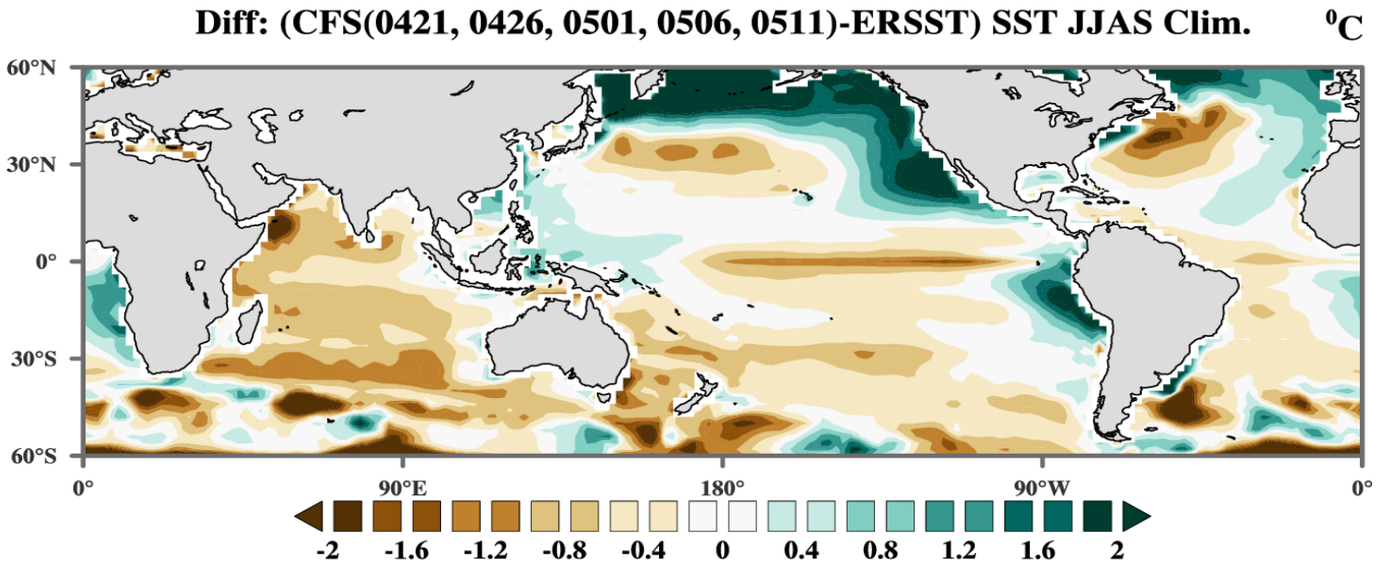
SST Climatology

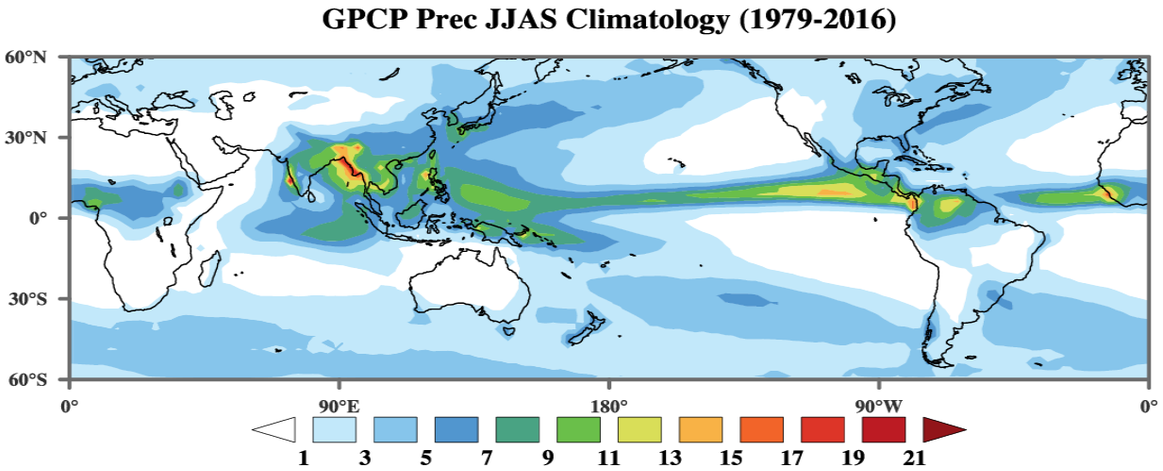


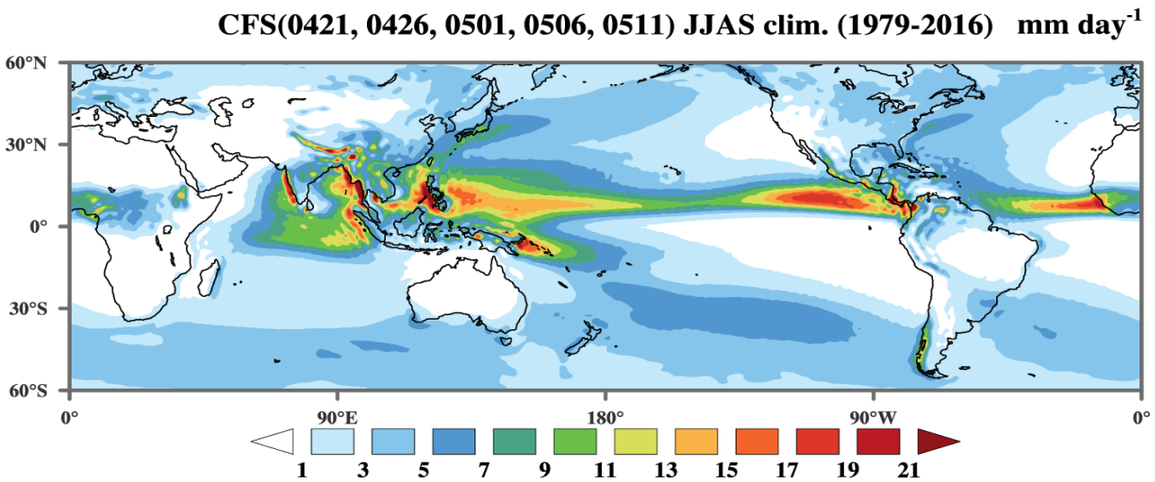


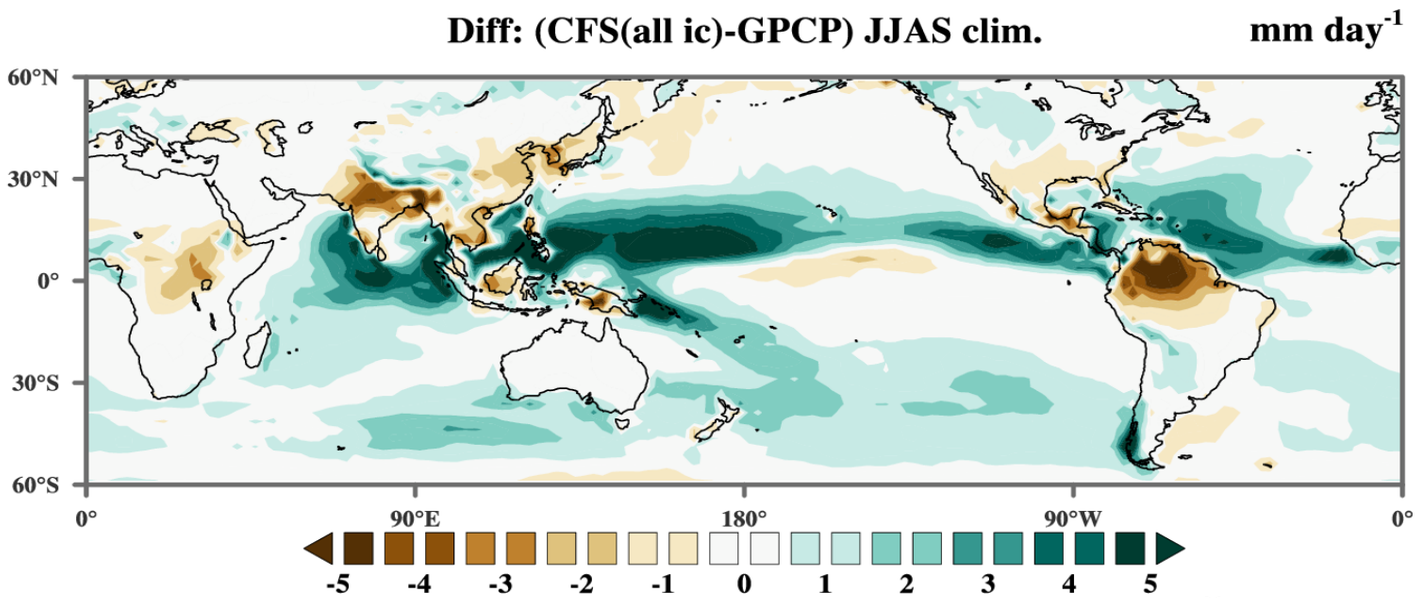


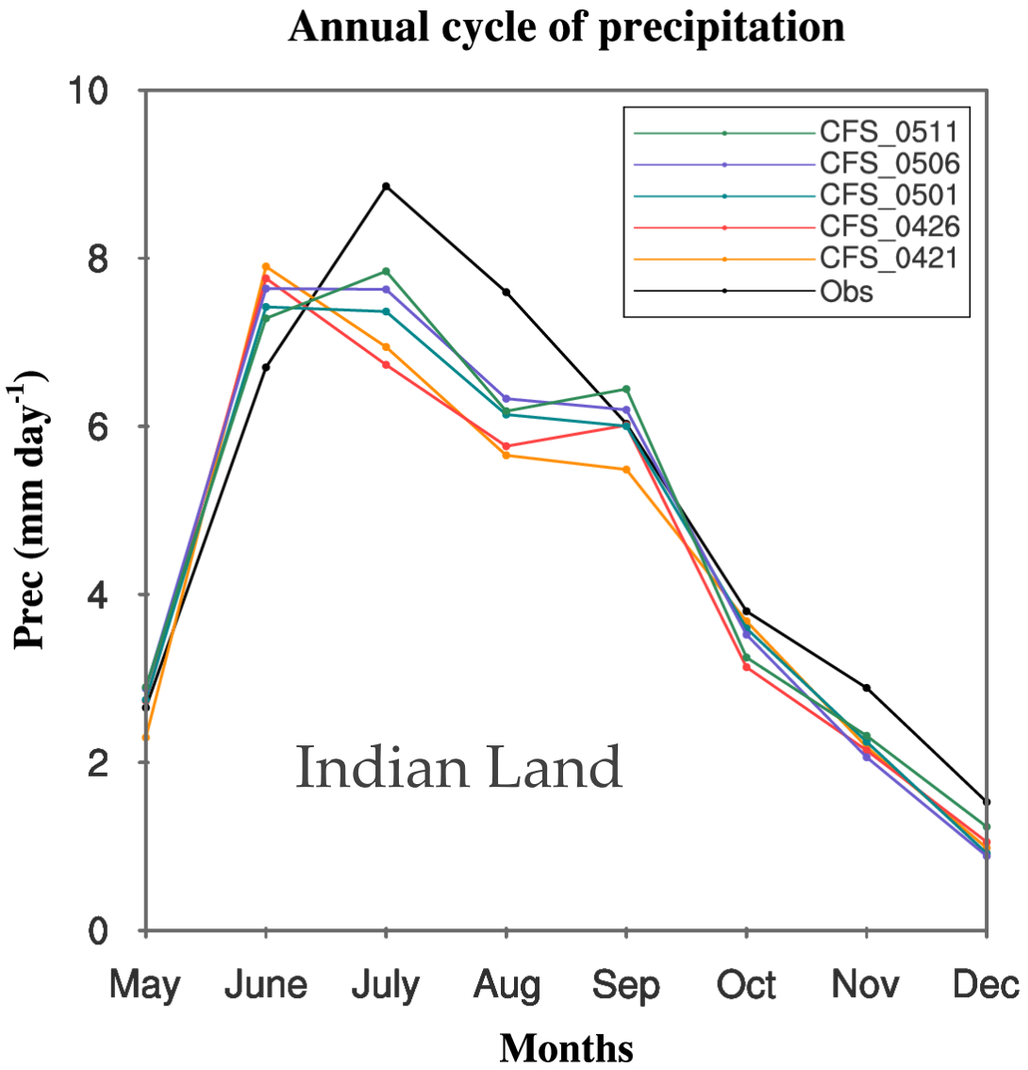
- Cold Bias in SST is primarily south of 45N
- Warm bias over far north Pacific and Atlantic
- This implies stronger hemispherical temp difference in the model than observed.

Rainfall Climatology, JJAS

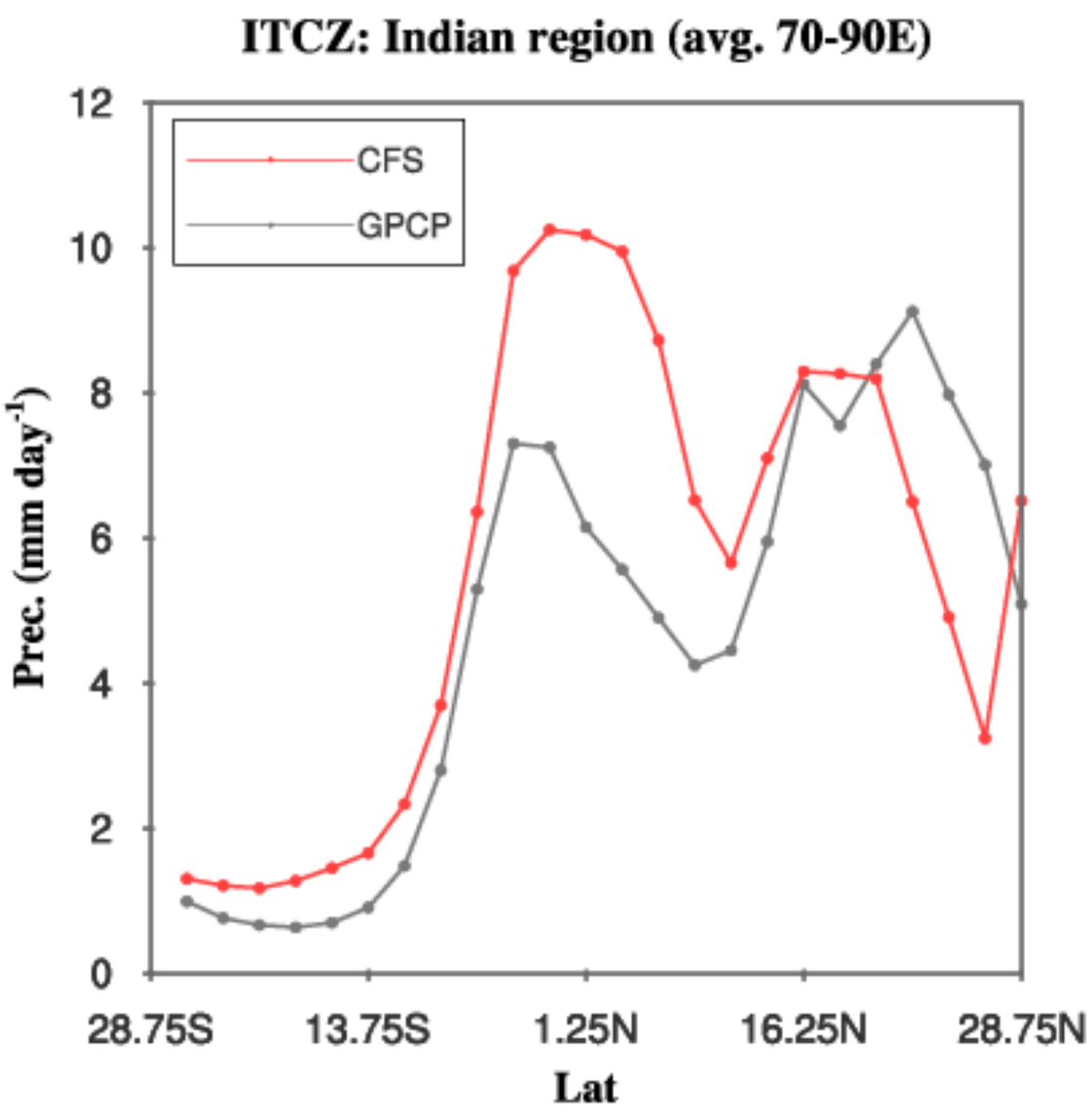


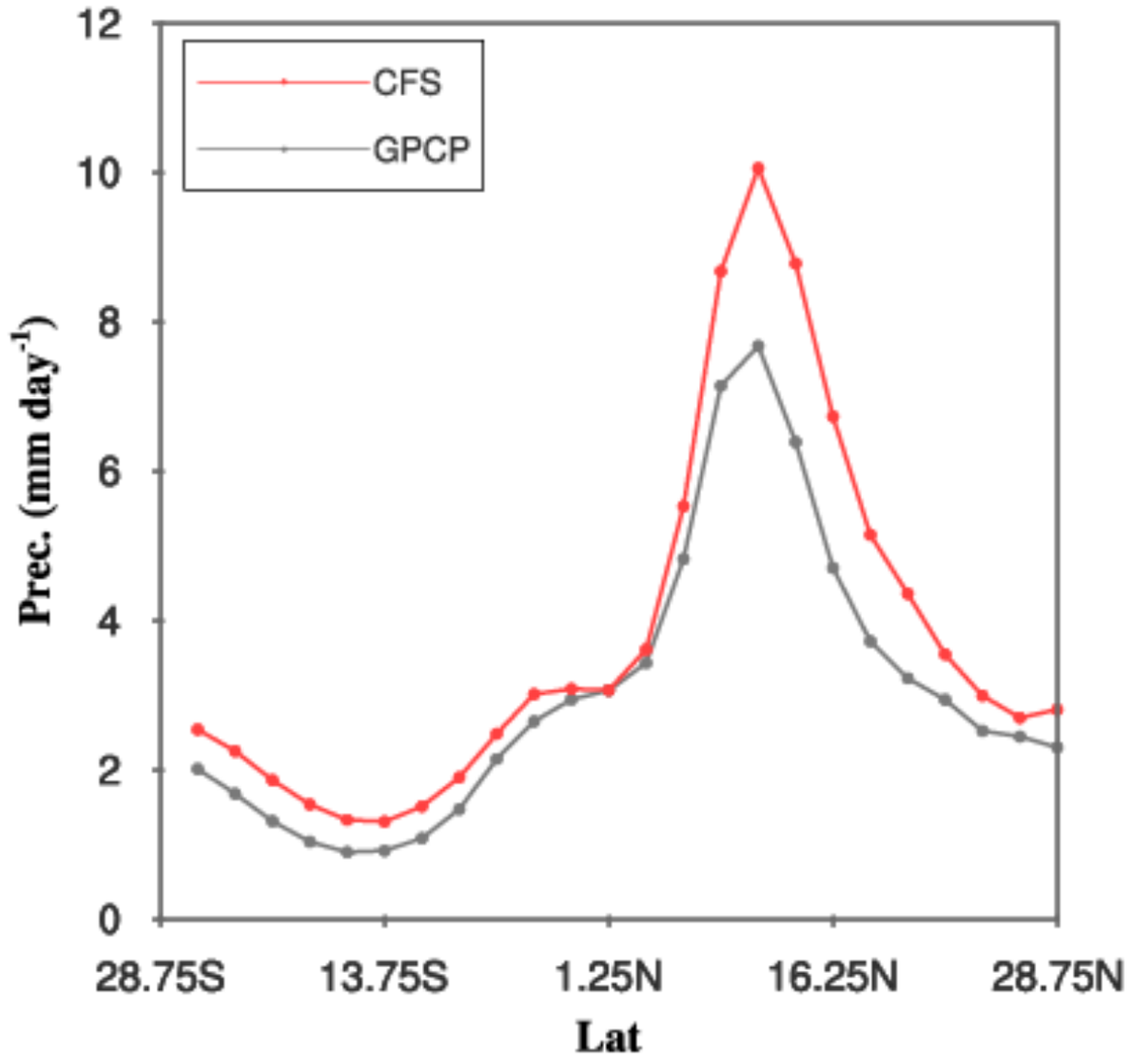






- Oceanic ITCZ too strong
- Dry bias primarily over land





- Zonal mean ITCZ location is similar to that observed
- The mean ITCZ is stronger than observed!
- ITCZ over India is to the south of observed and weaker
- Indian Ocean ITCZ is stronger than observed
- ITCZ does not move poleward if there is land

ITCZ as Energy Flux Equator

$S - L - O = \partial_y < \bar{vh} >$

$E = S - L - O$ is net energy to the atmosphere

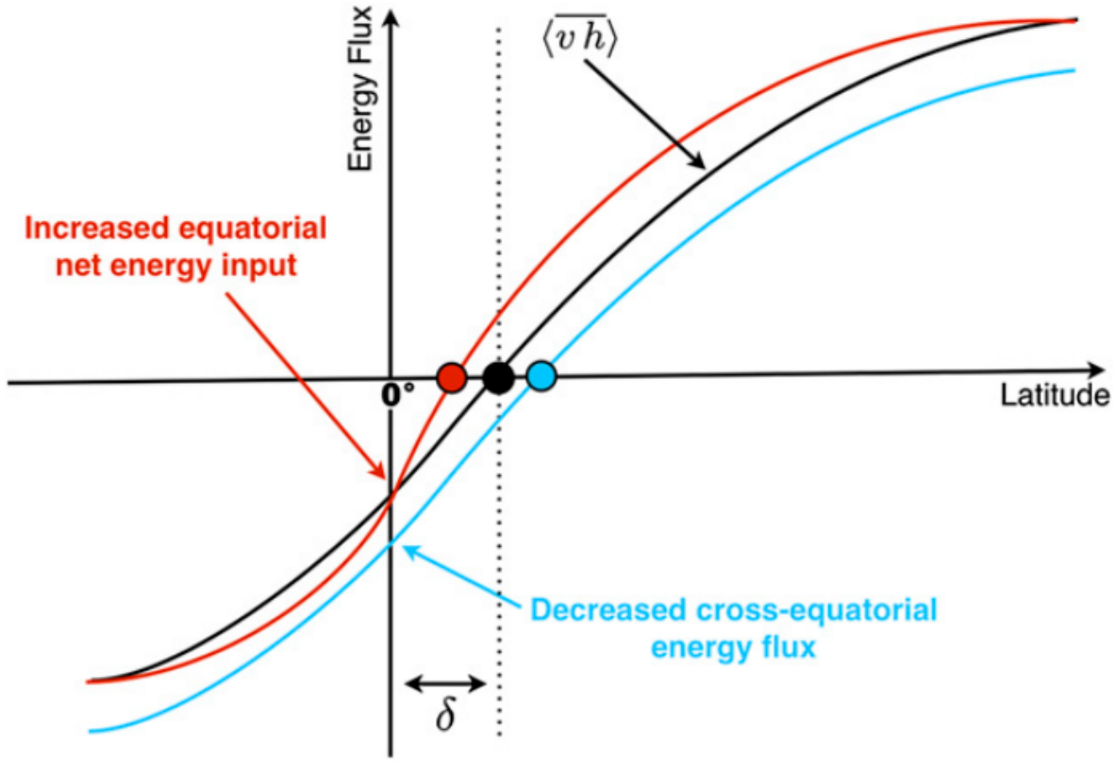
$h = C_p T + Lq + gz$

$< \bar{vh} >$ is vertically integrated and zonal mean meridional h transport

$$0 \approx \langle \overline{vh} \rangle_\delta = \langle \overline{vh} \rangle_0 + a \partial_y \langle \overline{vh} \rangle_0 \delta ,$$

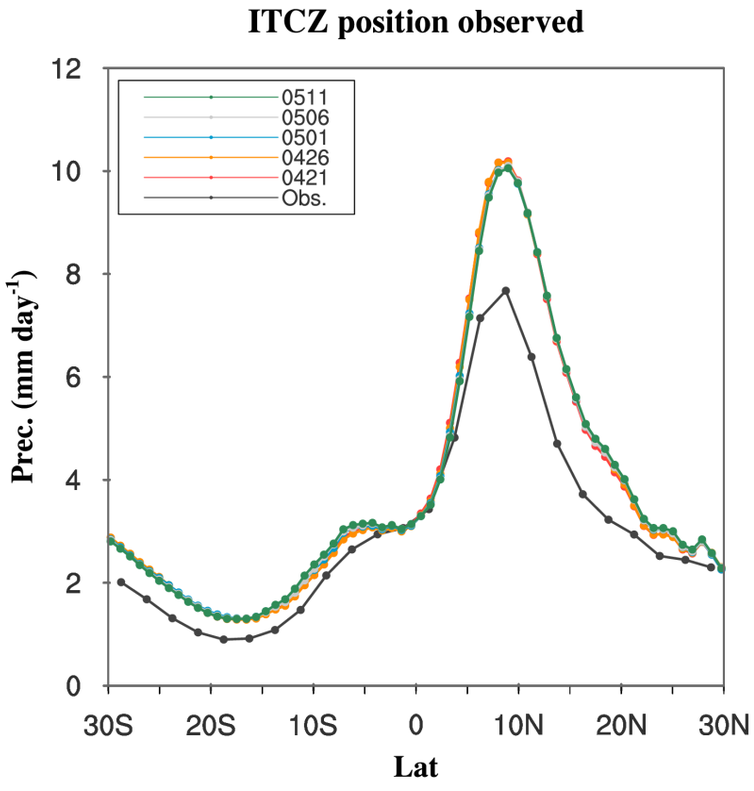
$$\delta \approx -\frac{1}{a} \frac{\langle \overline{vh} \rangle_0}{\mathcal{S}_0 - \mathcal{L}_0 - \mathcal{O}_0}.$$

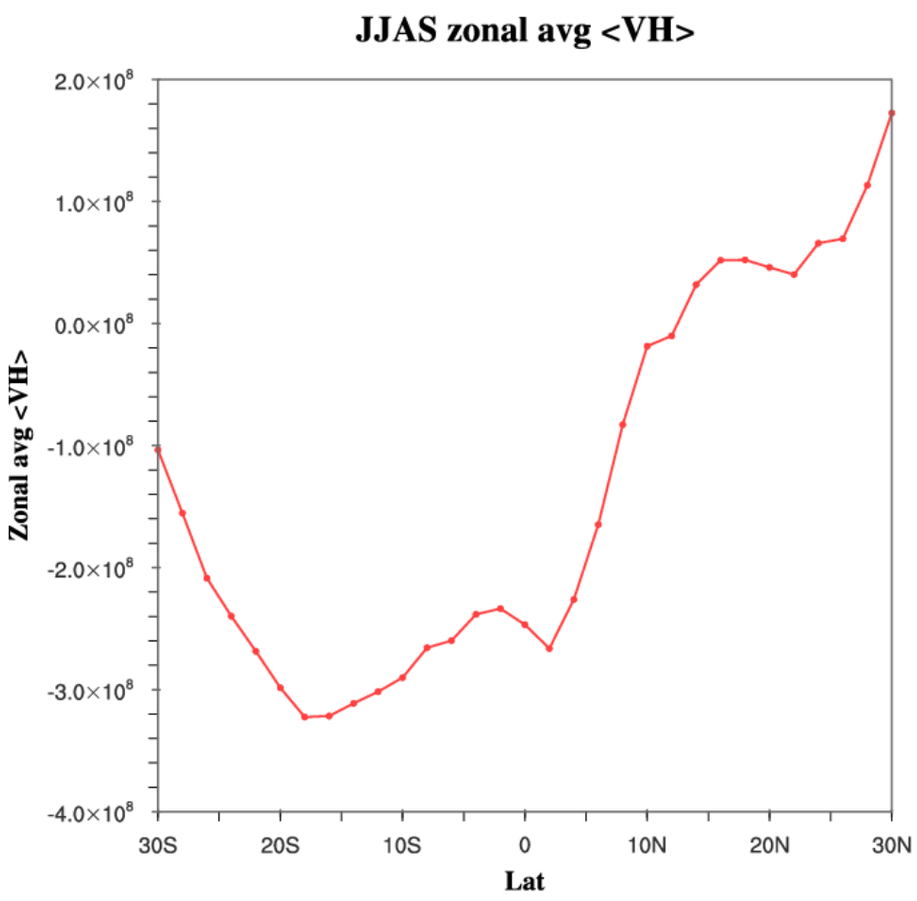
ITCZ location

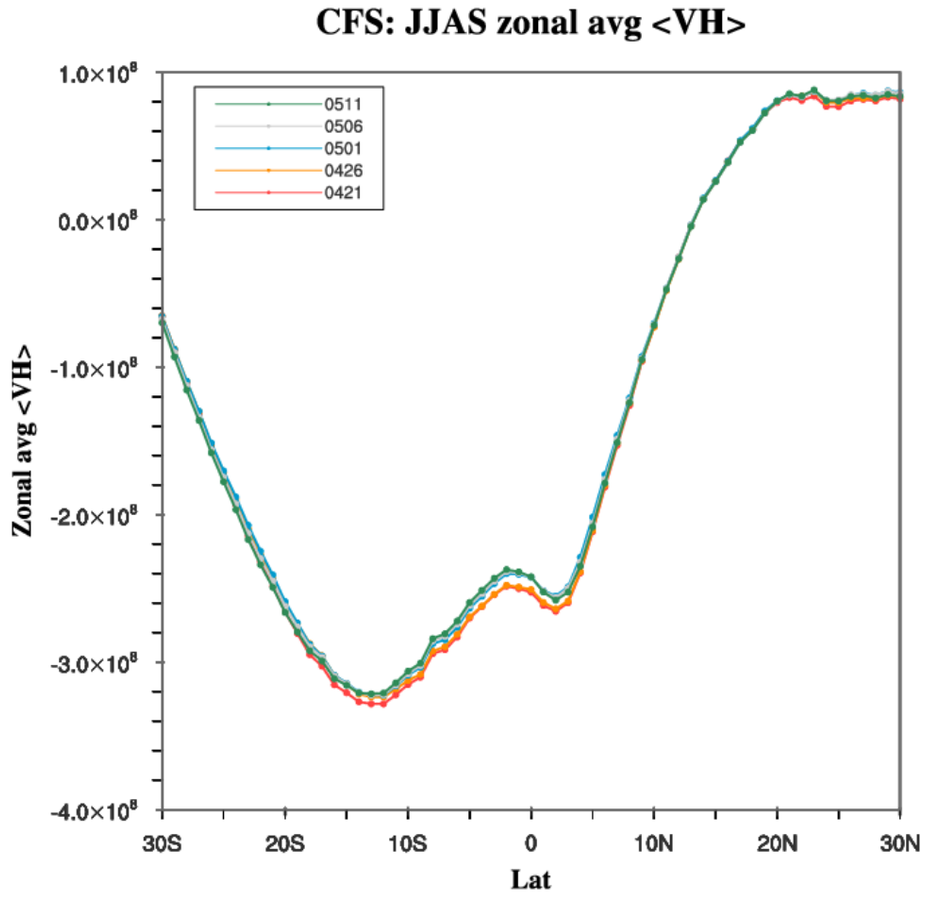


Bischoff and Schneider (2014)

MSE Flux, Zonal Mean







India: JJAS

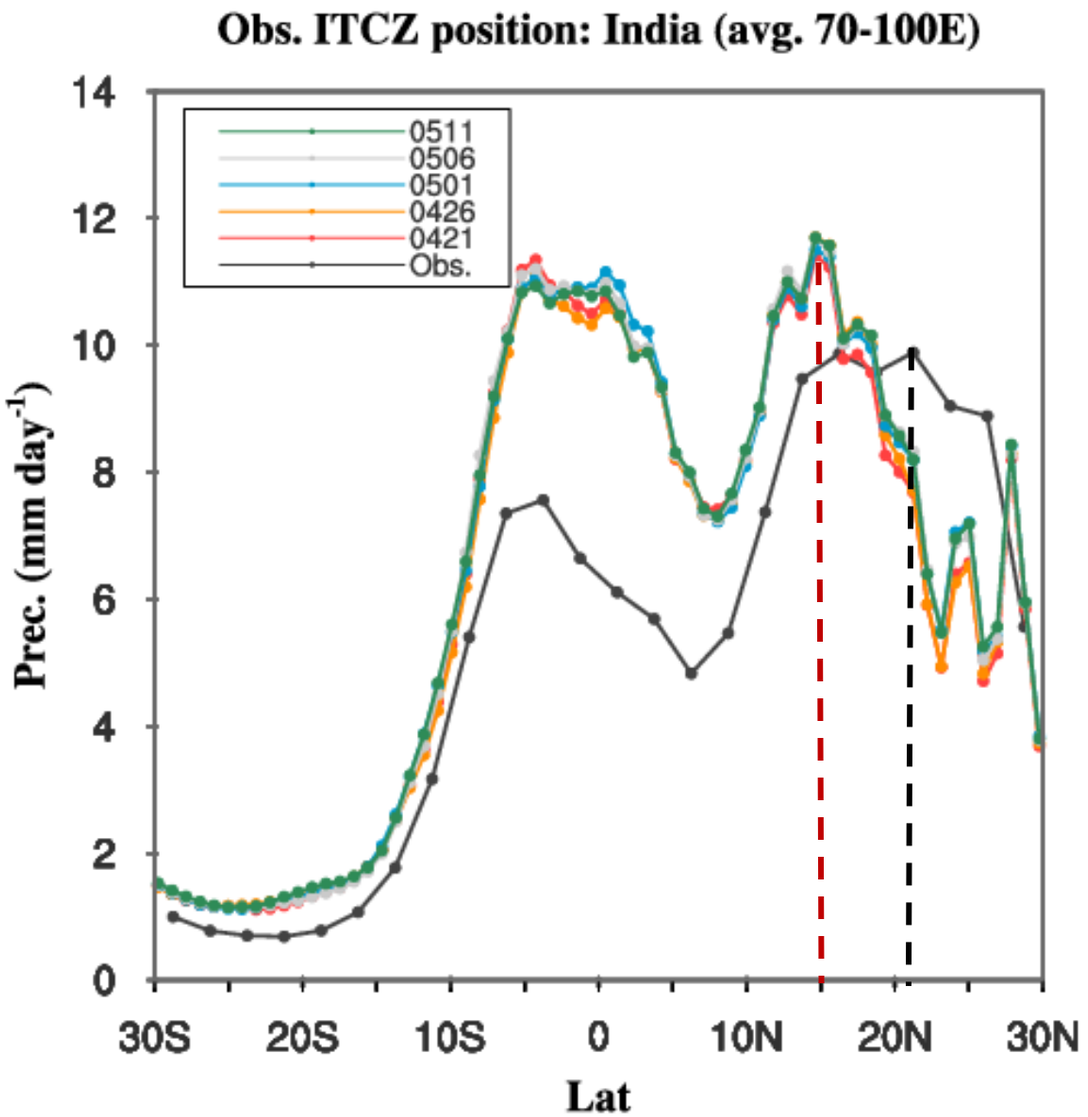
1. δ_o observed:

Observation (GPCP) ~ **21N**

CFS ~ **15N**

- Oceanic TCZ enhanced and Continental TCZ remains southward

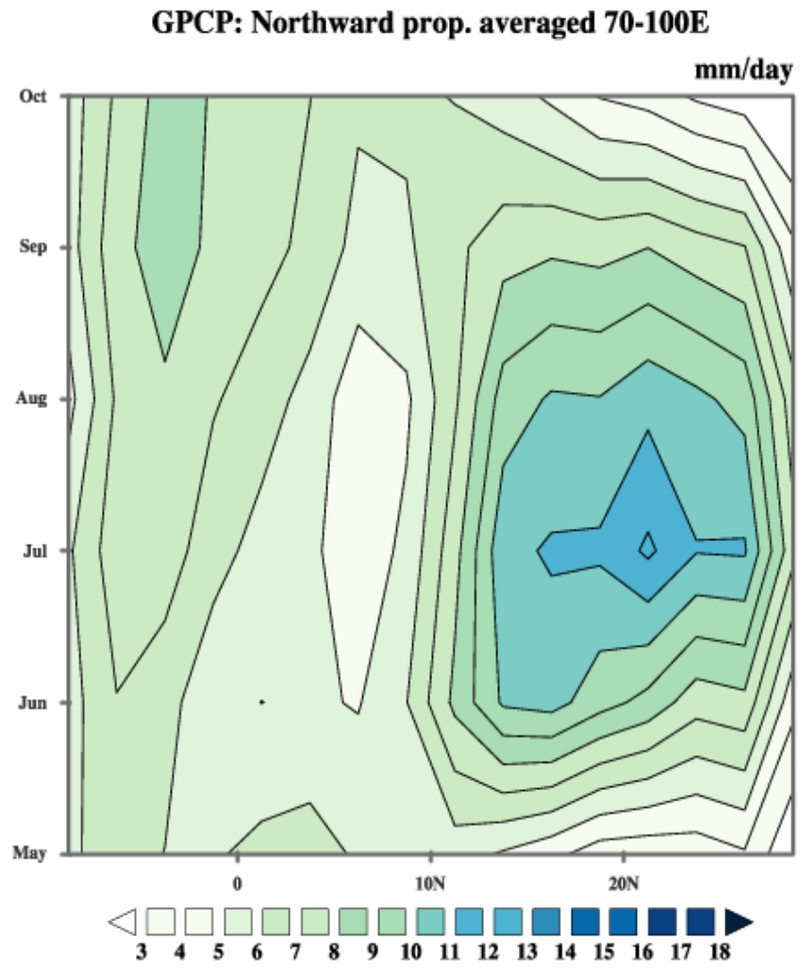
~10 N

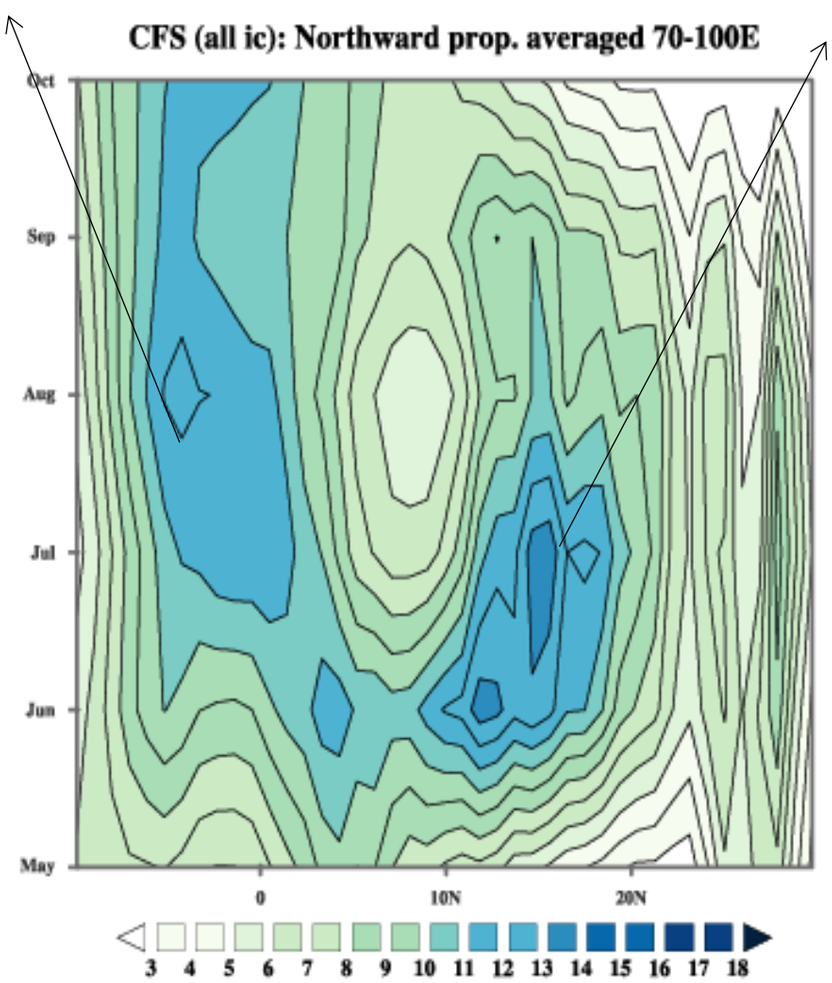


Why northward migration of continental TCZ is restricted to ocean in CFSv2??

Oceanic TCZ enhanced

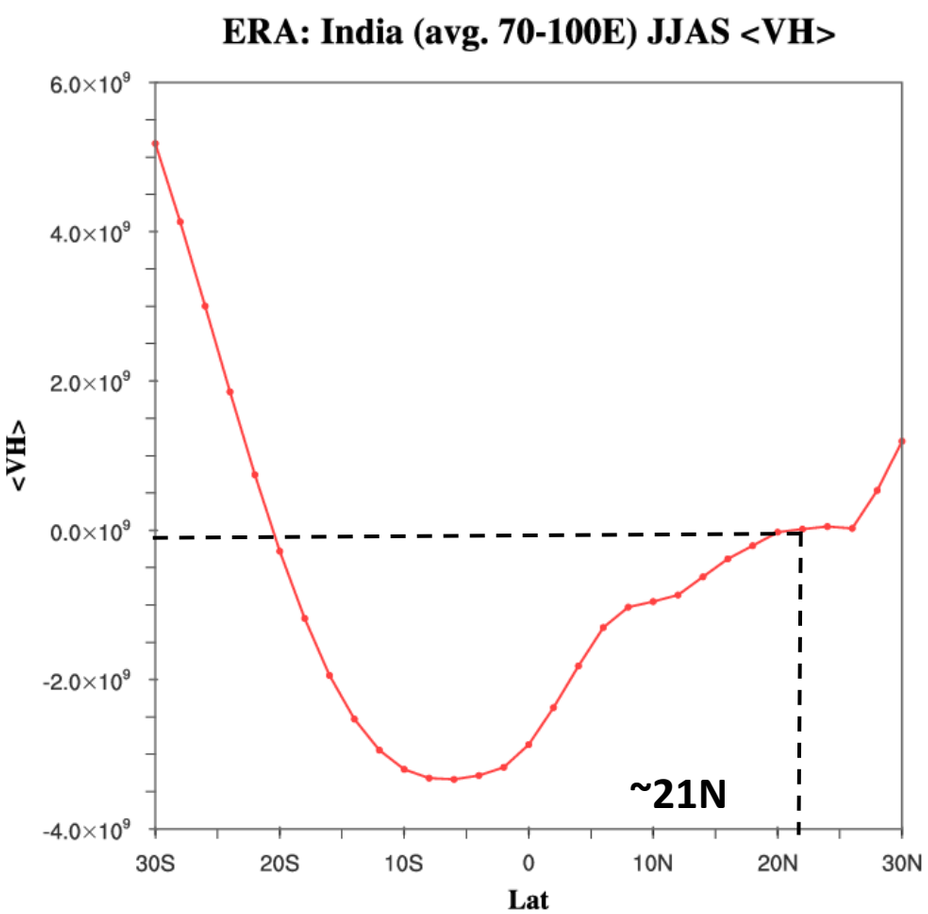
Continental TCZ squeezed

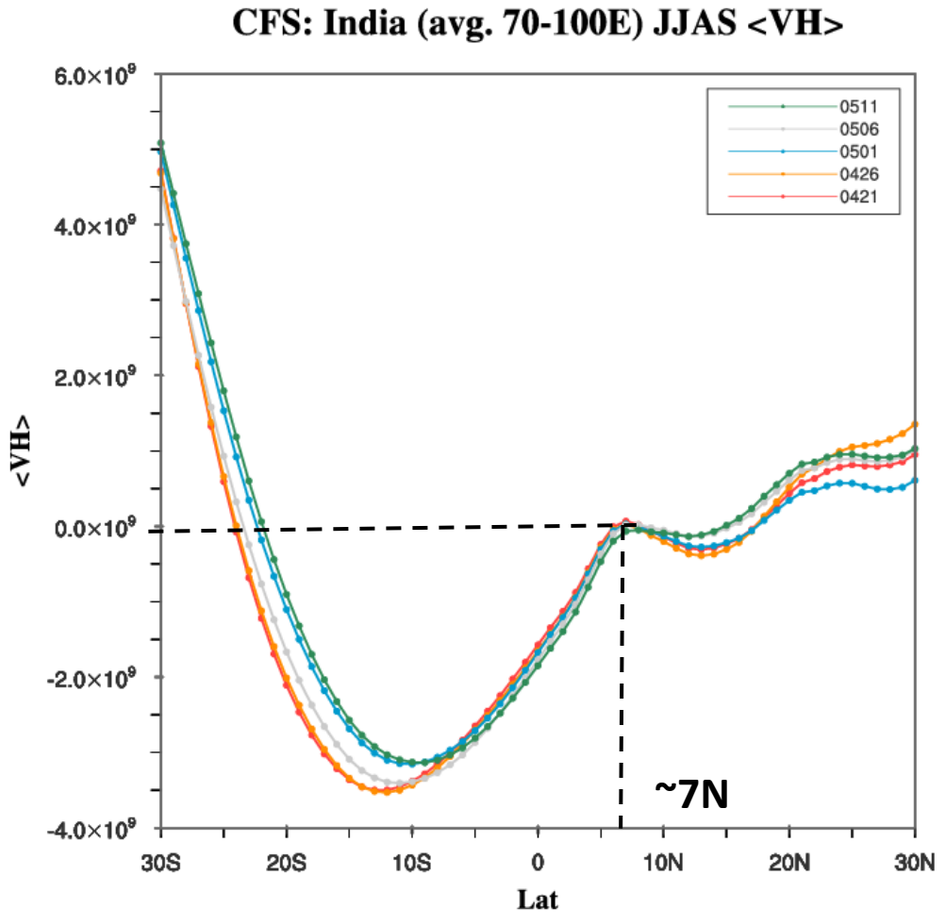




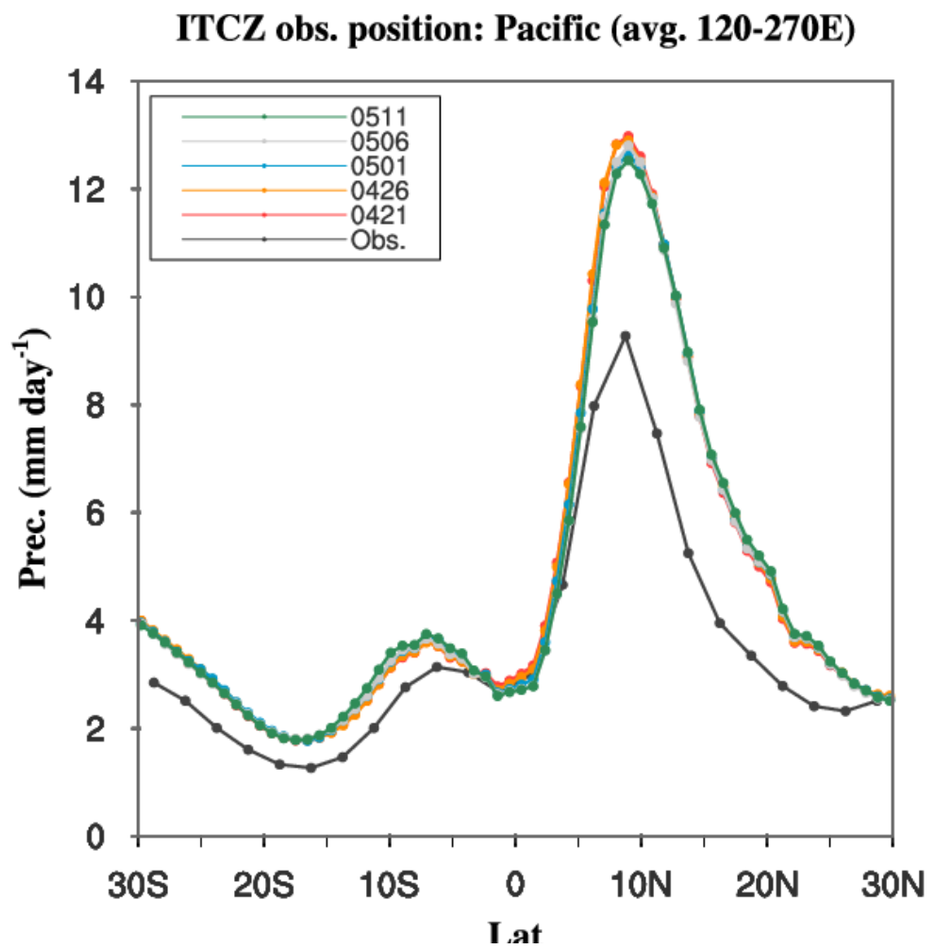
MSE Flux over Indian Longitude

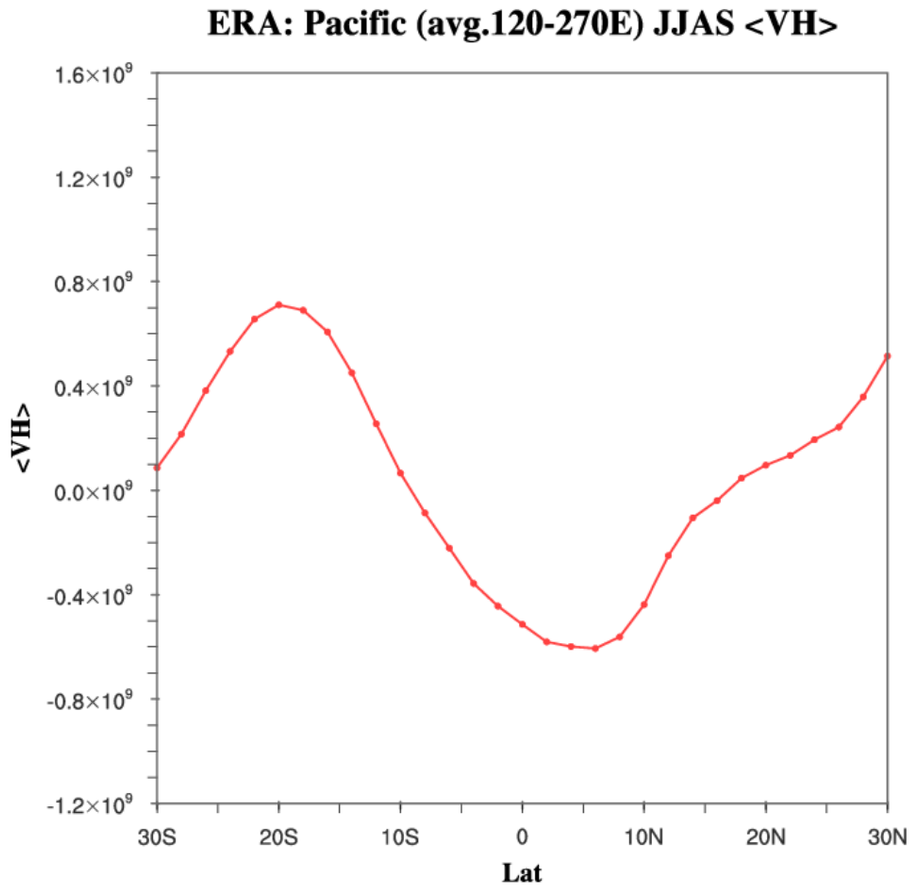
ITCZ position ~ <vh> changes sign



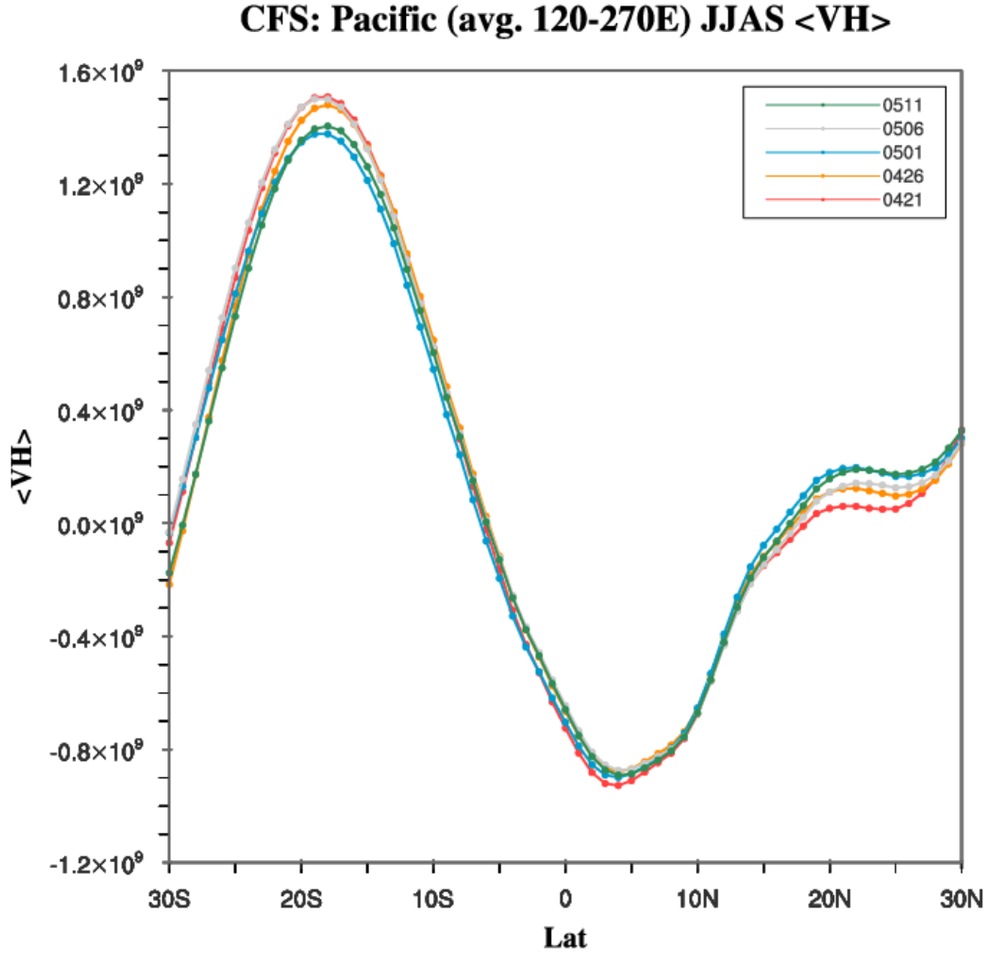


MSE Flux, Pacific



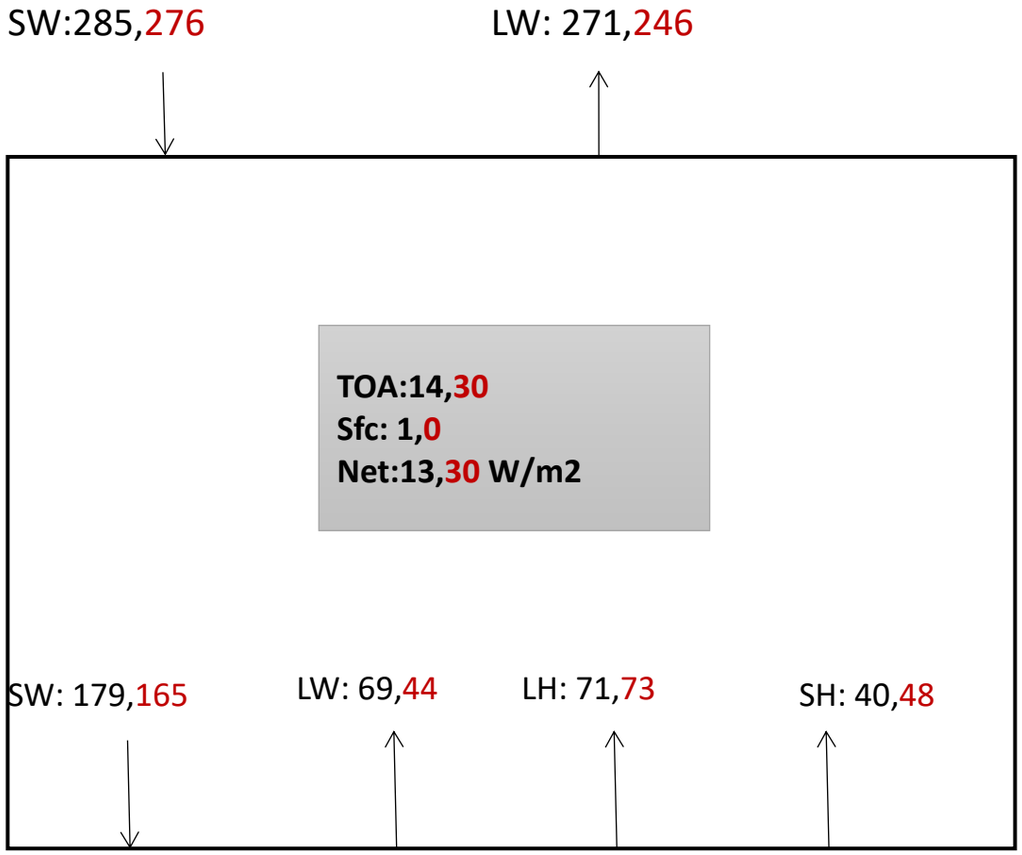


Stronger circulation in CFSv2

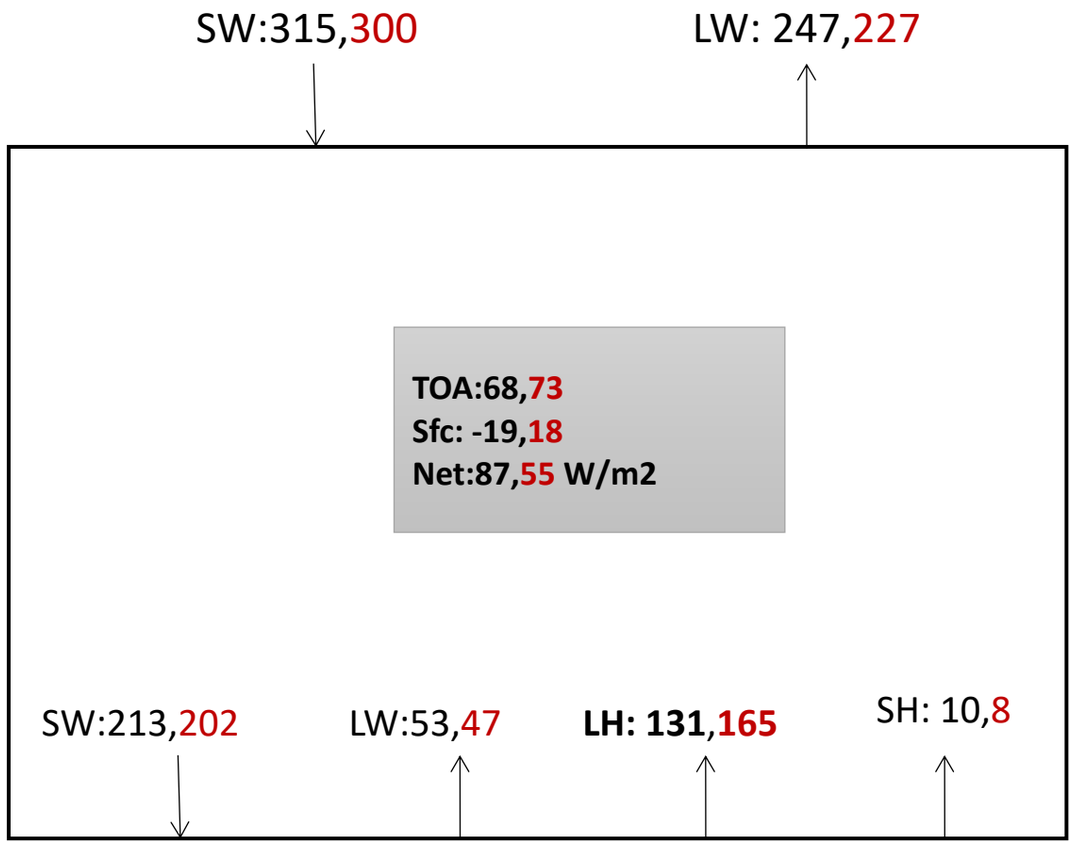


Atmospheric Energy Budget

Indian land (8-28N,70-90E): JJAS



Indian ocean (10S-25N,70-100E): JJAS

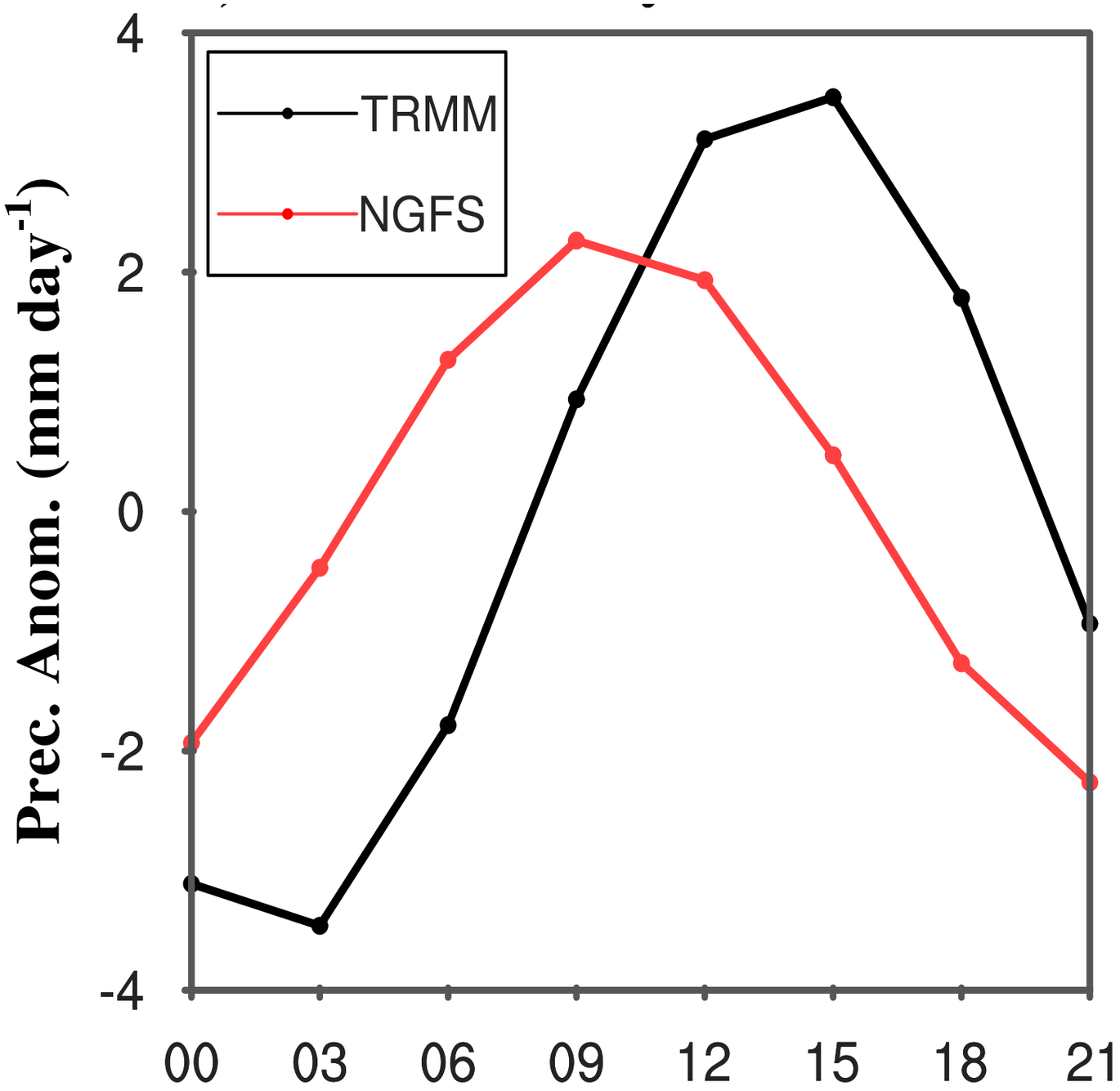


Excess energy$_{net}$ over land still less rainfall

Deficit energy$_{net}$ over ocean still more rainfall

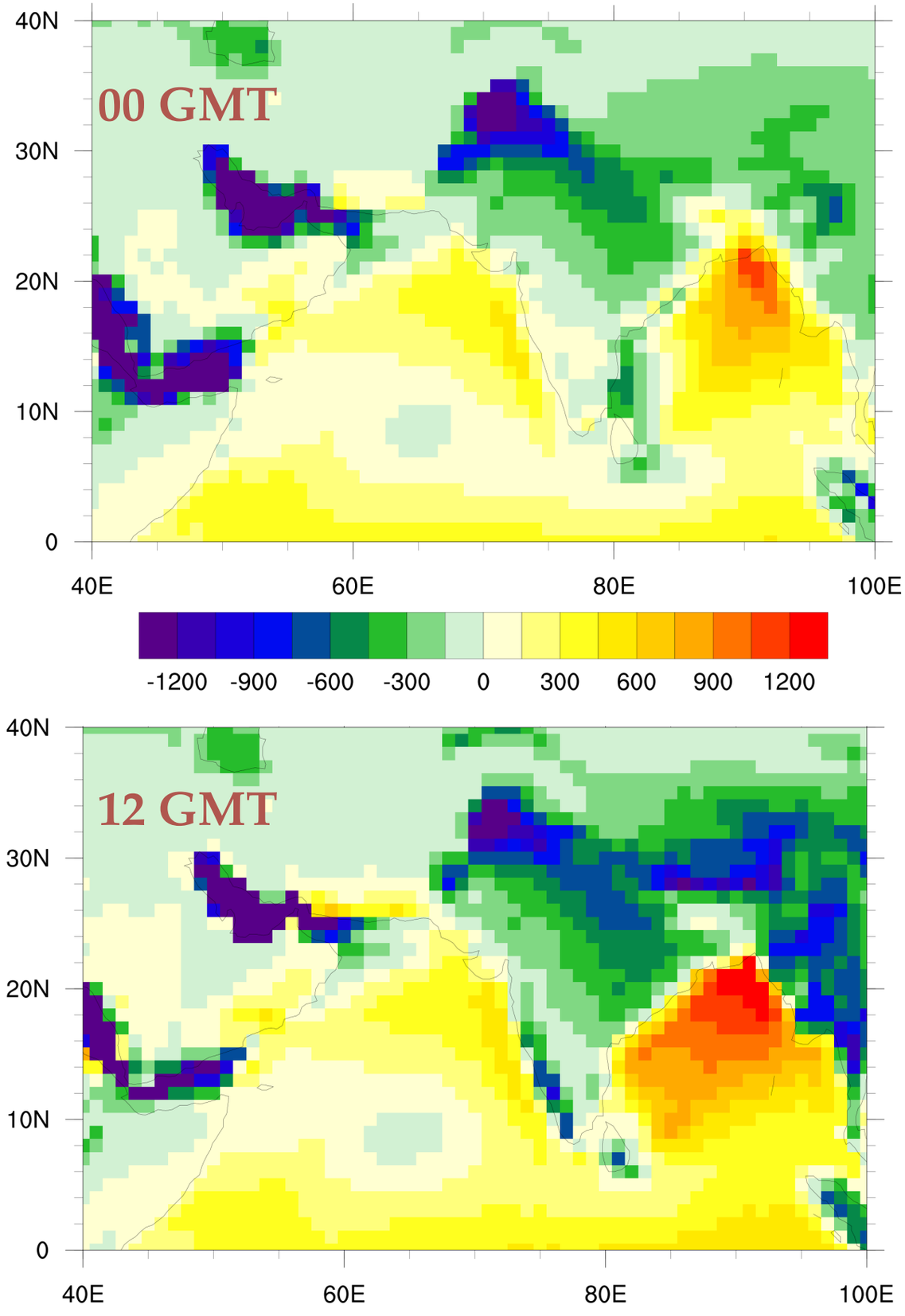
Phase shift????

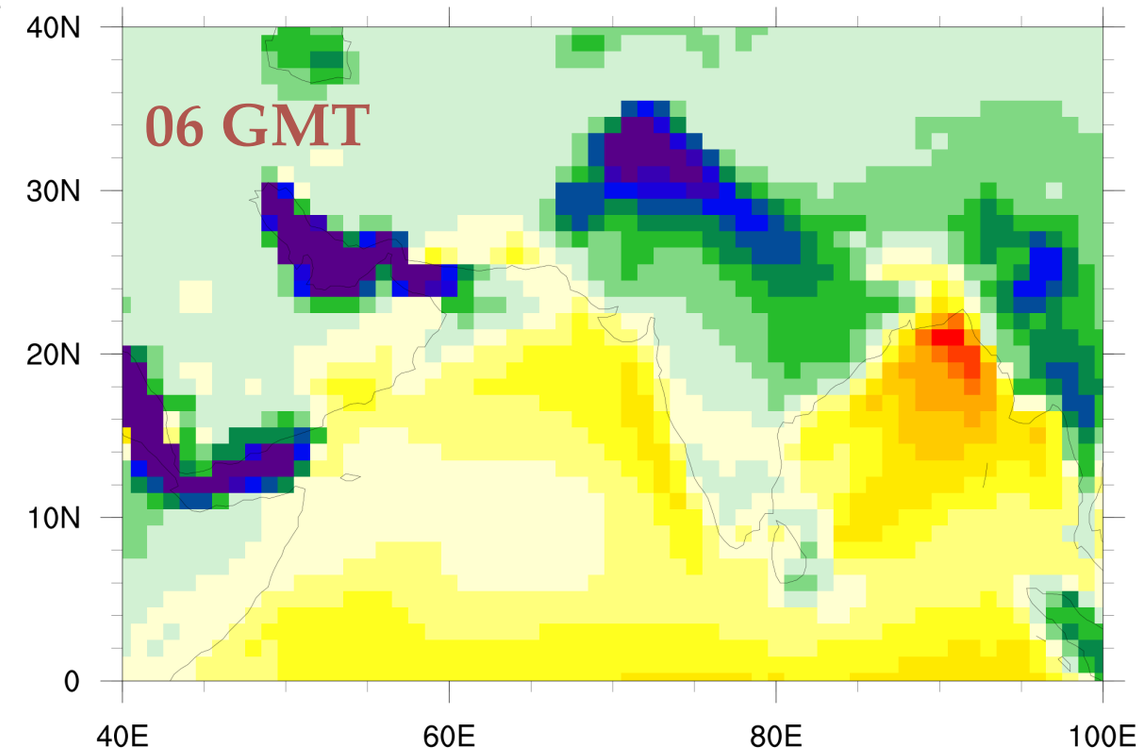
Black: ERA, Red: CFS

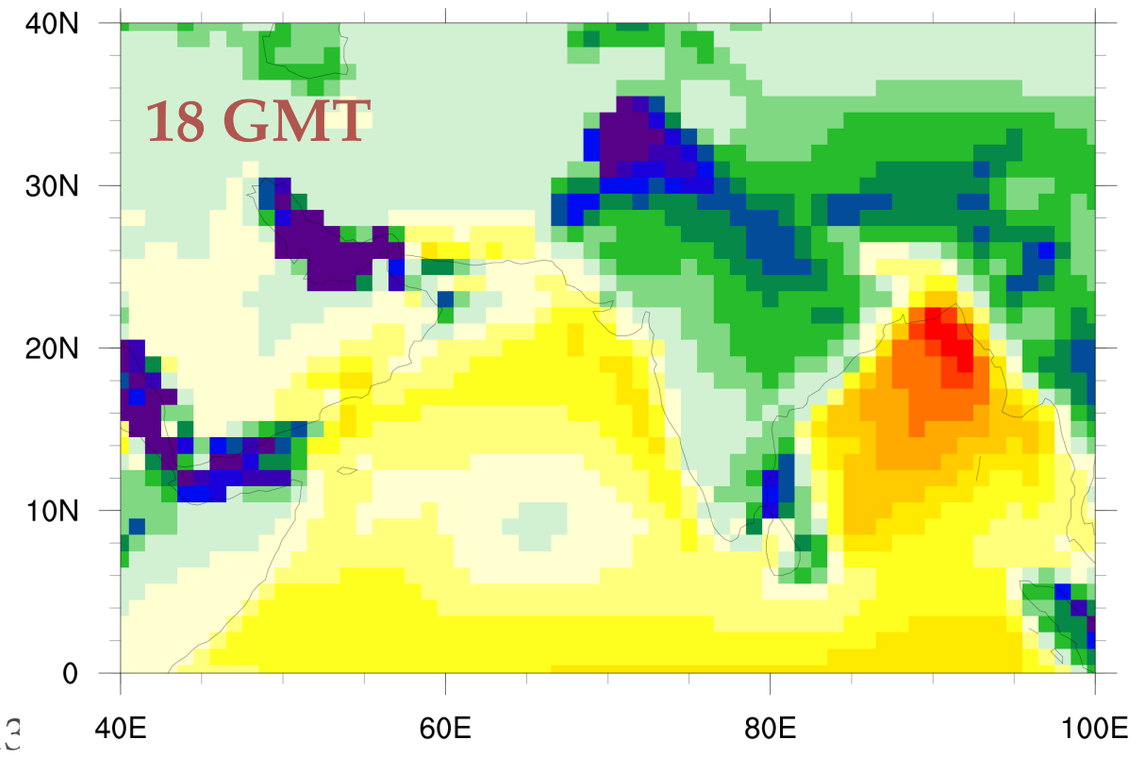


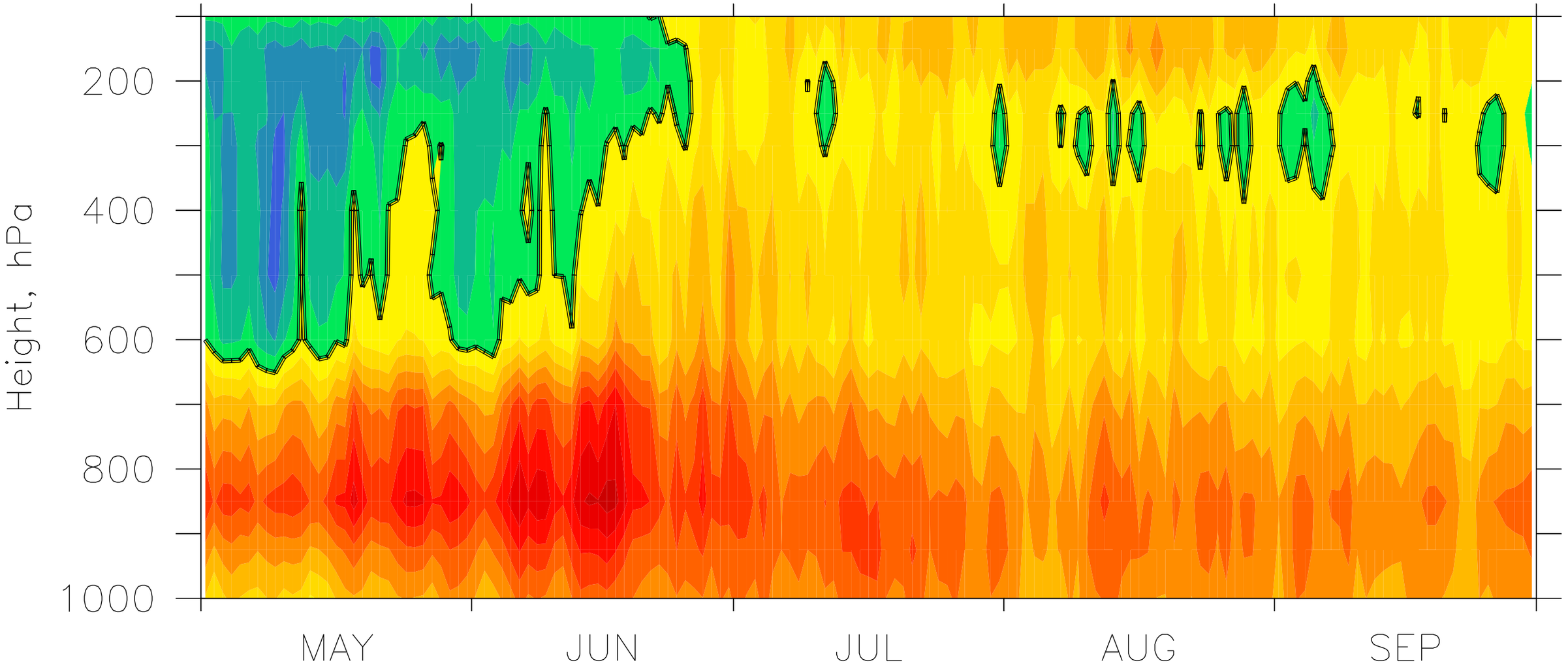
- Diurnal Cycle of Rainfall is too early in model than observed.
- This can result in error in daily mean net energy.

CAPE at Surface, CFSv2 minus Obs



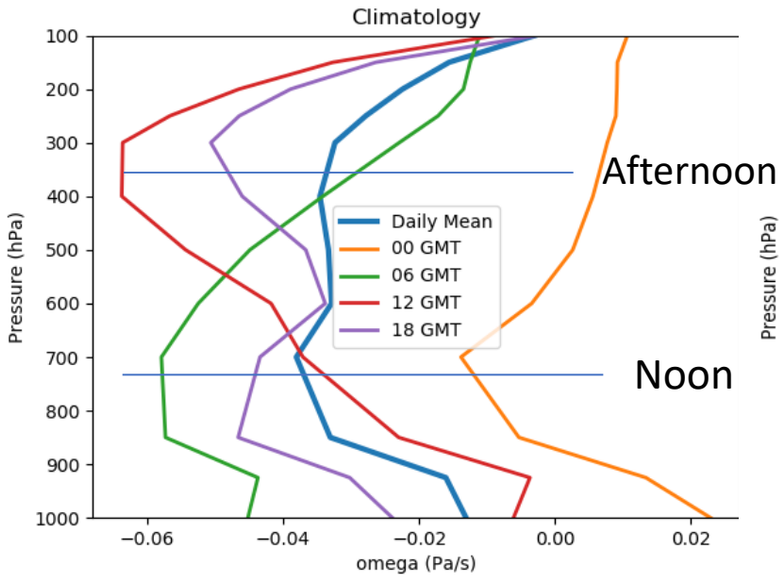


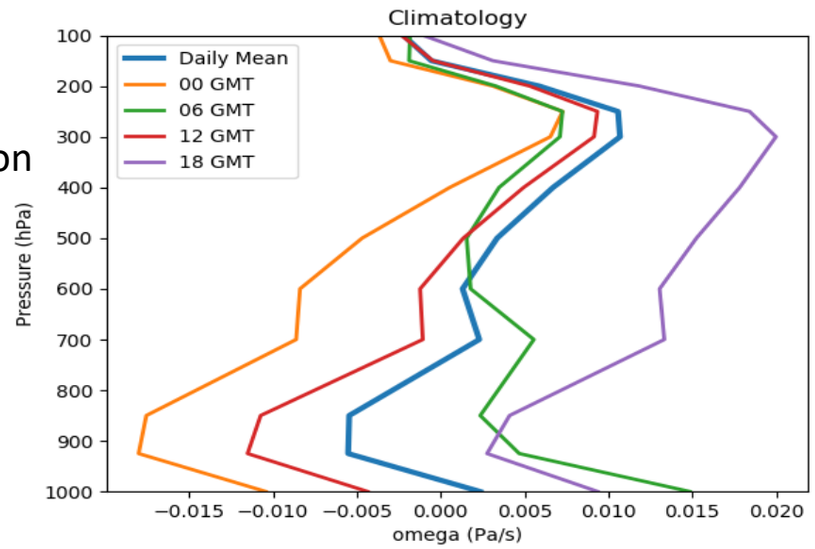


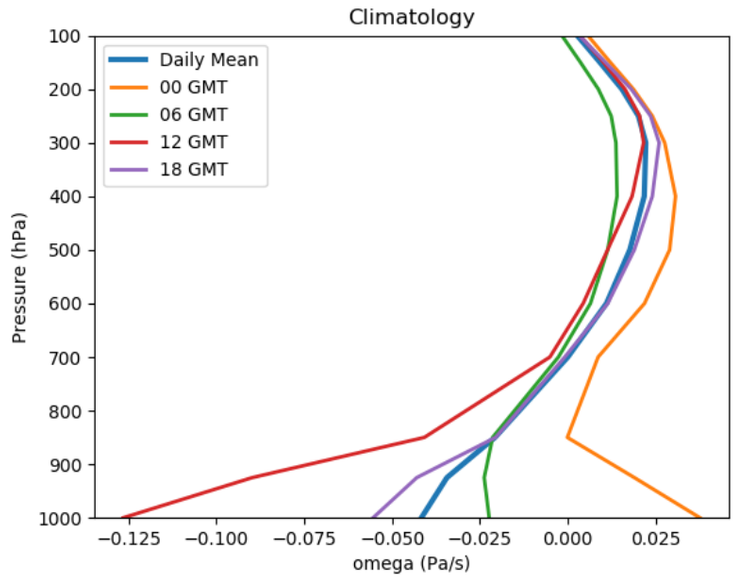

Height, hPa
200
400
600
800
1000
MAY
JUN
JUL
AUG
SEP

Diurnal Cycle of Vertical Velocity, Climatology

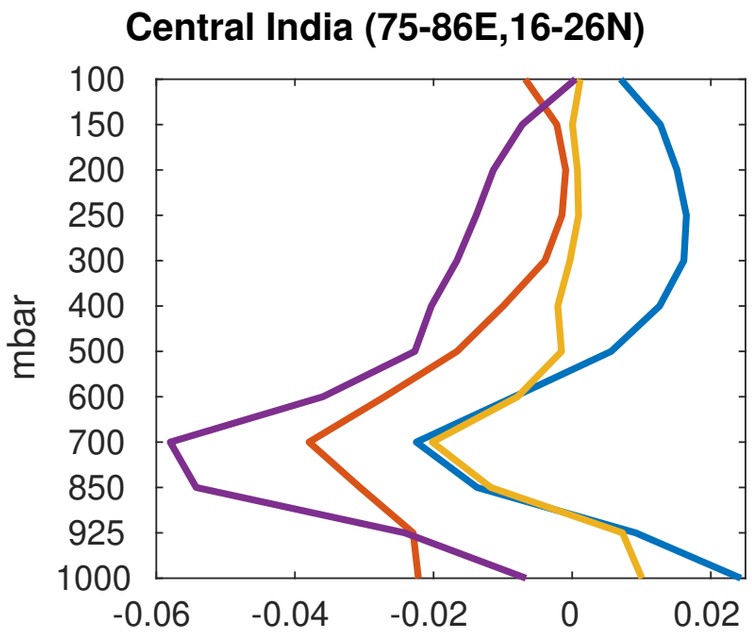
Observed

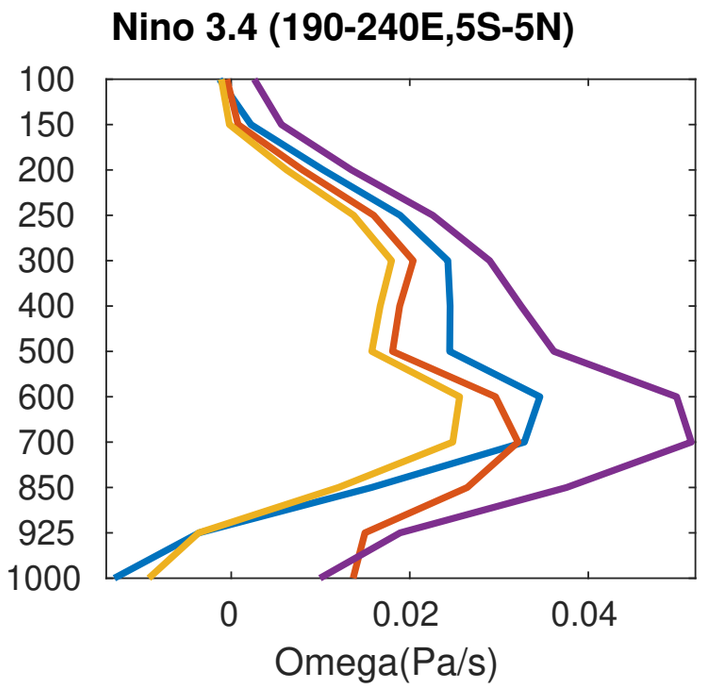


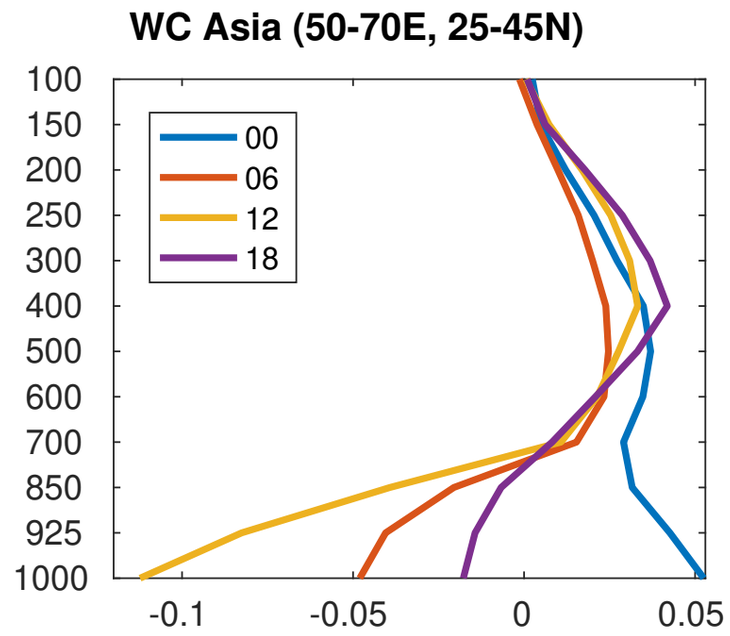




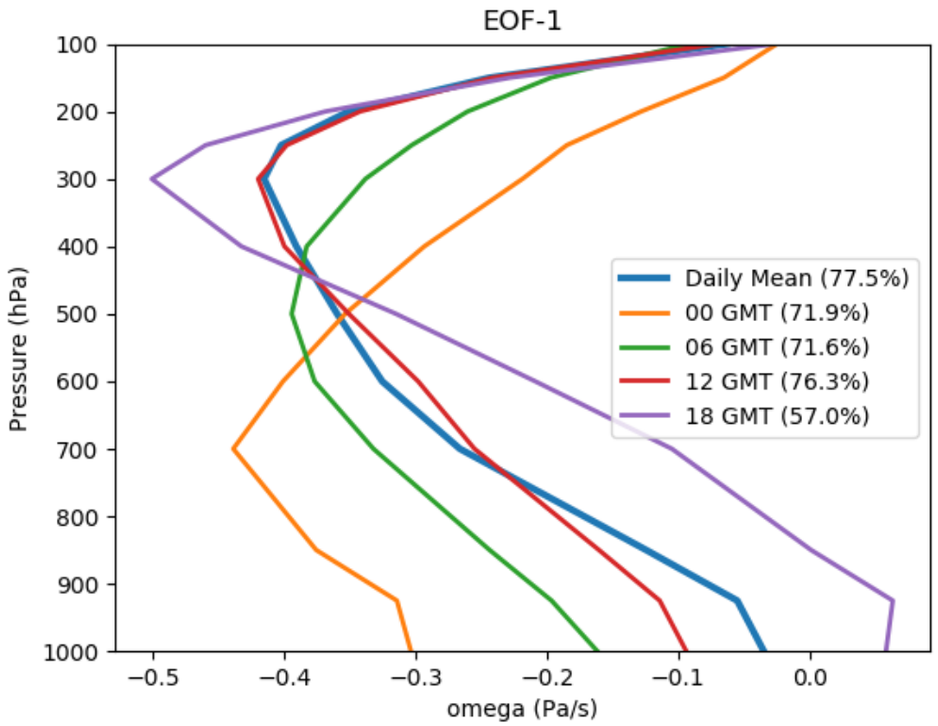
CFSv2

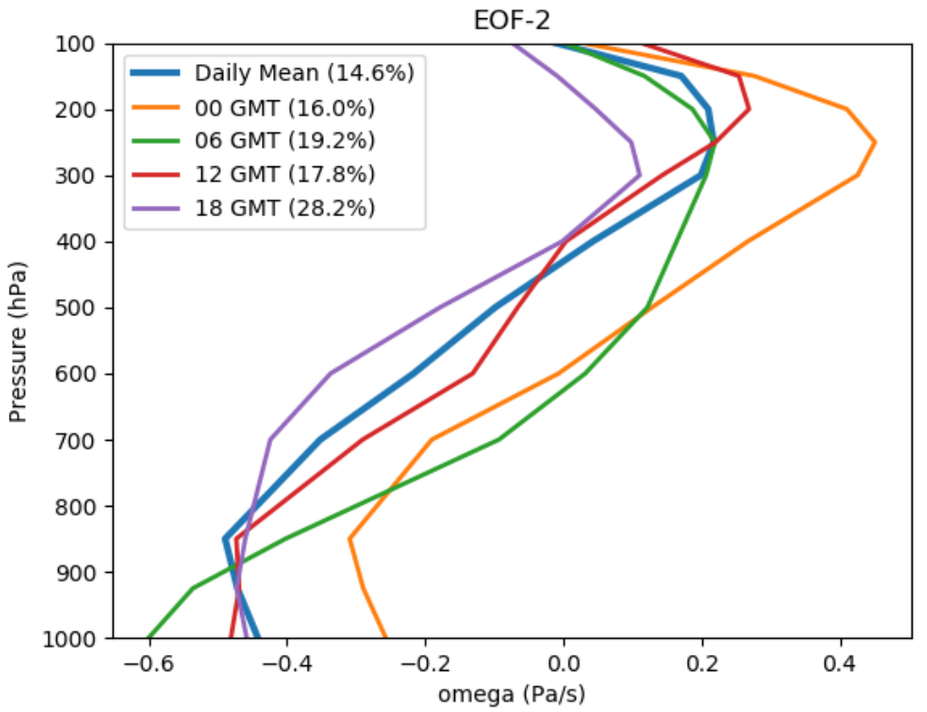


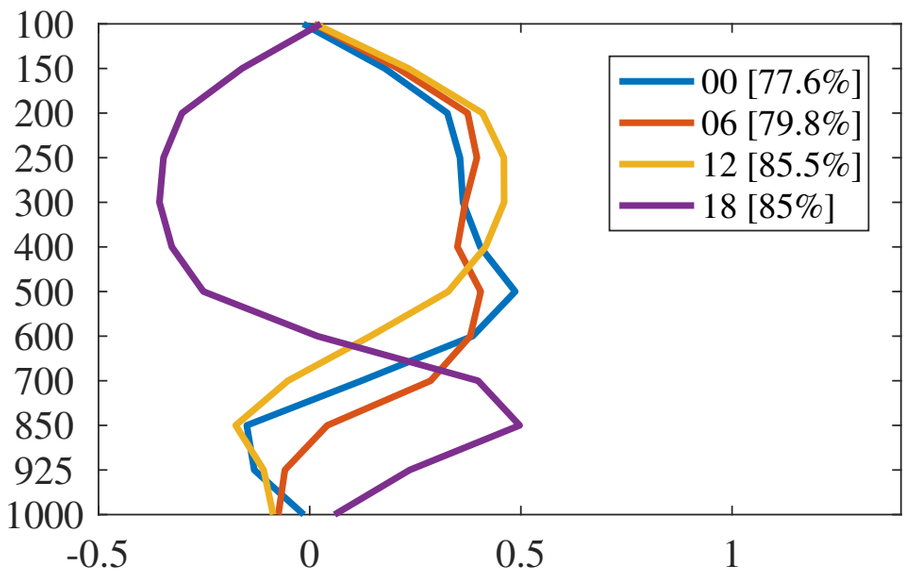


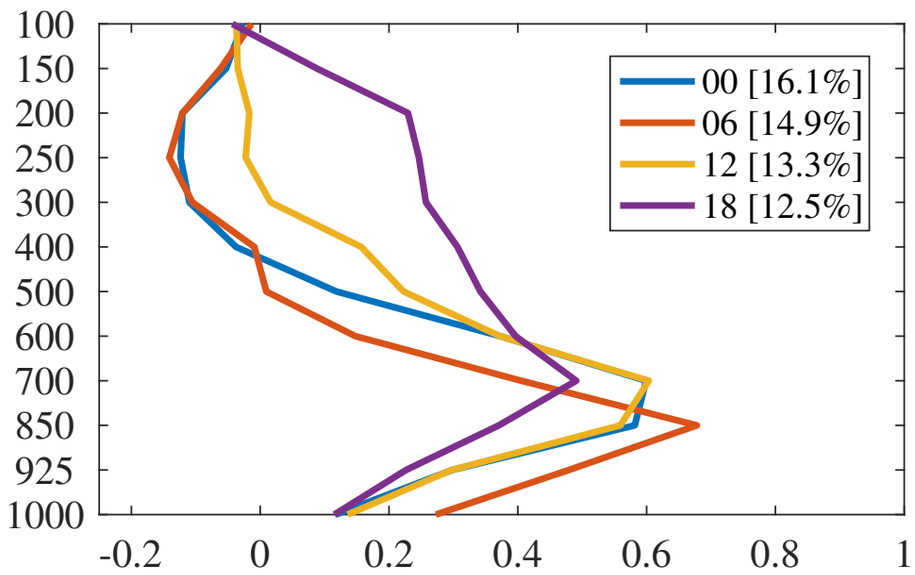


Modes of Vertical Velocity Profile

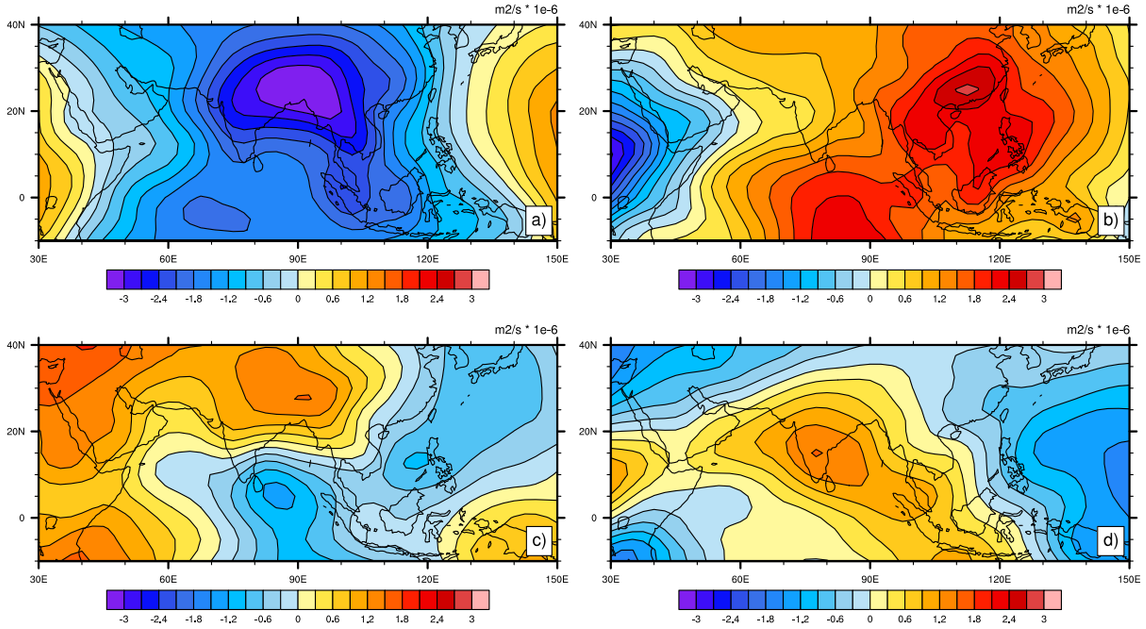


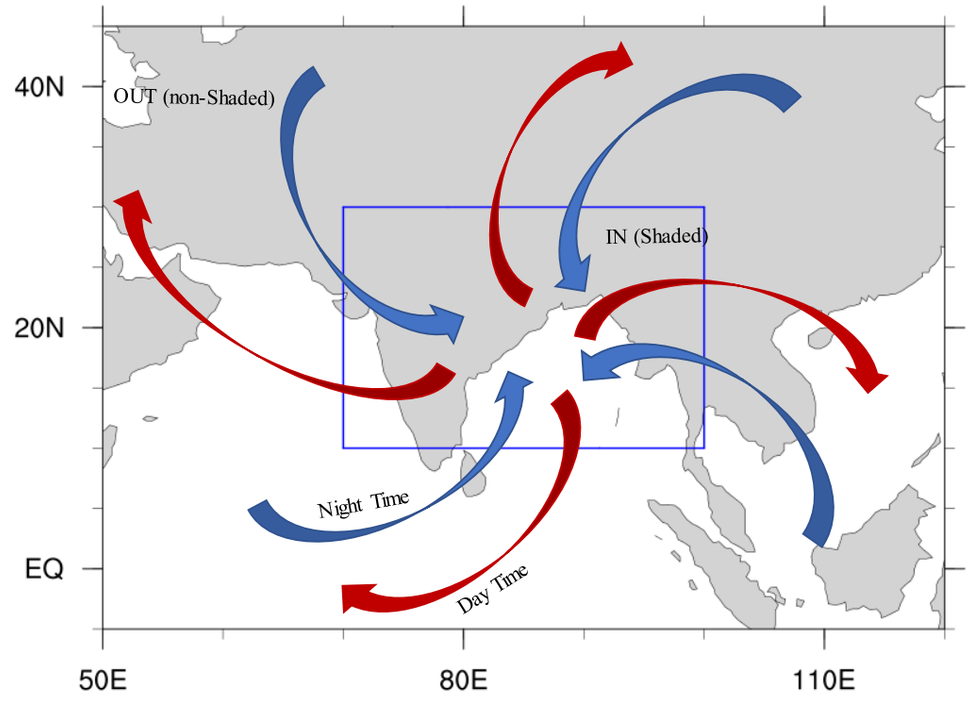




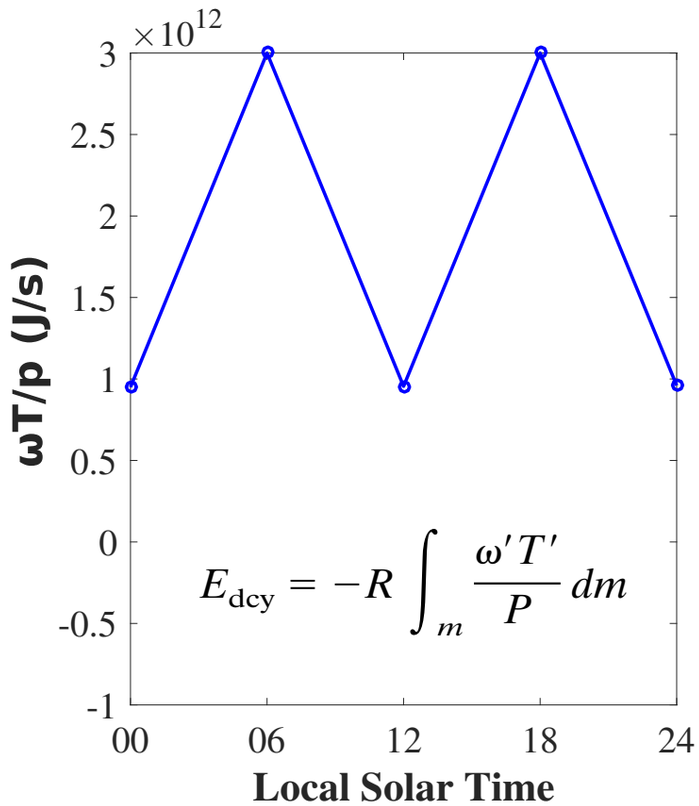


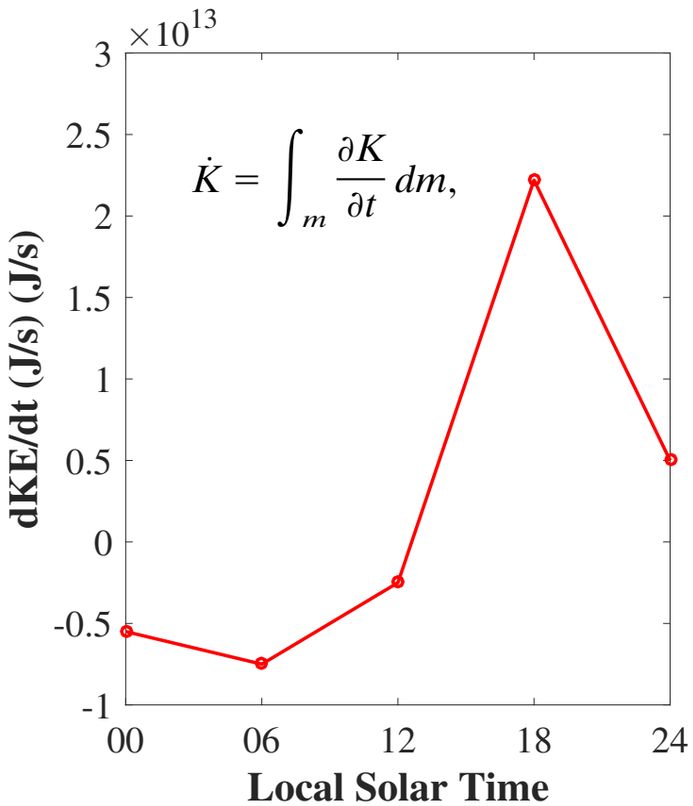
Continental Scale Diurnal Cycle





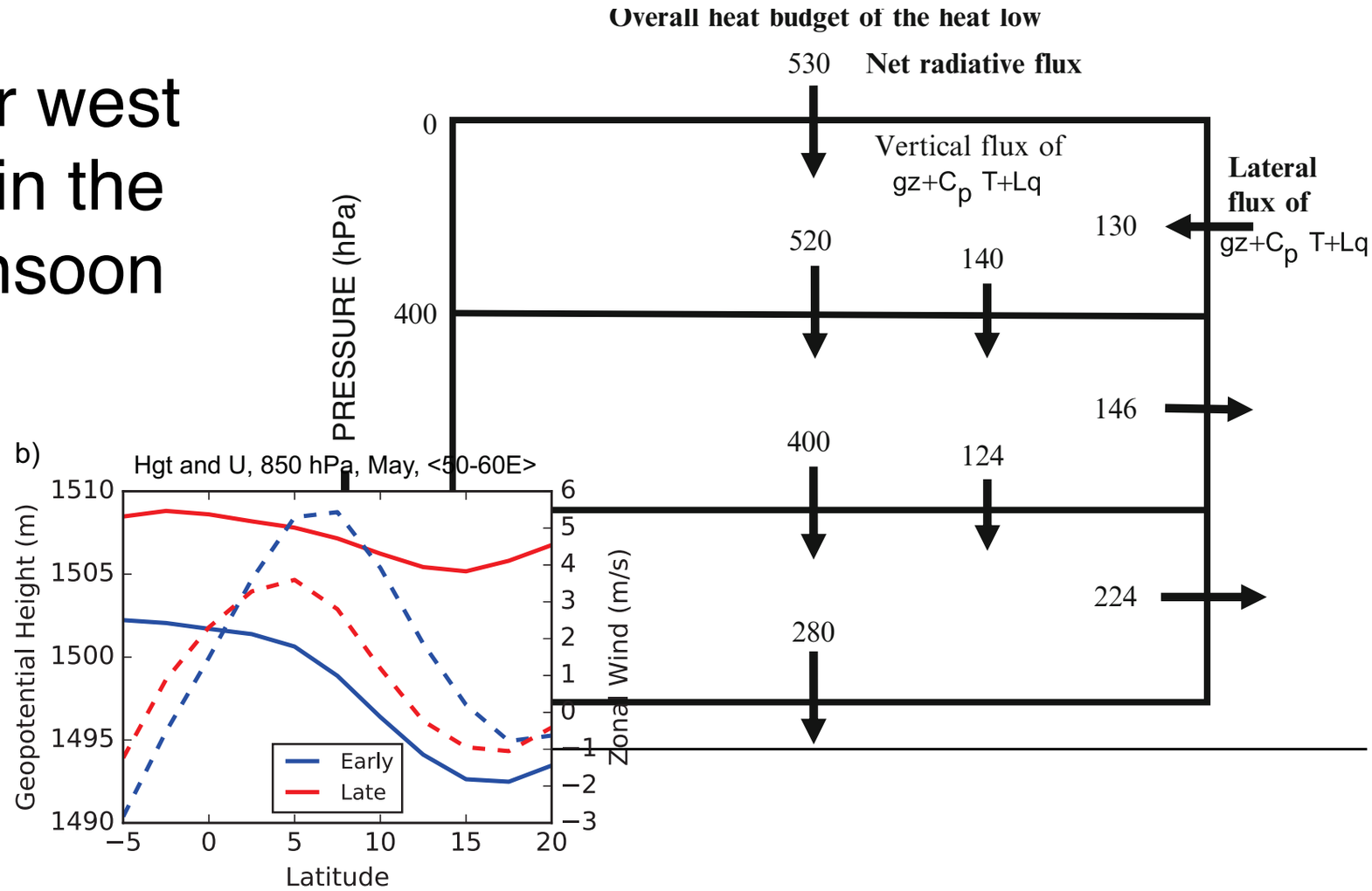
- W', T' are diurnal component of vertical pressure velocity and temperature. The mass integration is over a 3D domain.
- Asian Summer Monsoon Experiences Continental Scale Diurnal Cycle of Divergent Circulation (Krishnamurti and Kishtawal (2000, Mon Weather Rev), Chakraborty and Krishnamurti (2010, J Climate)).

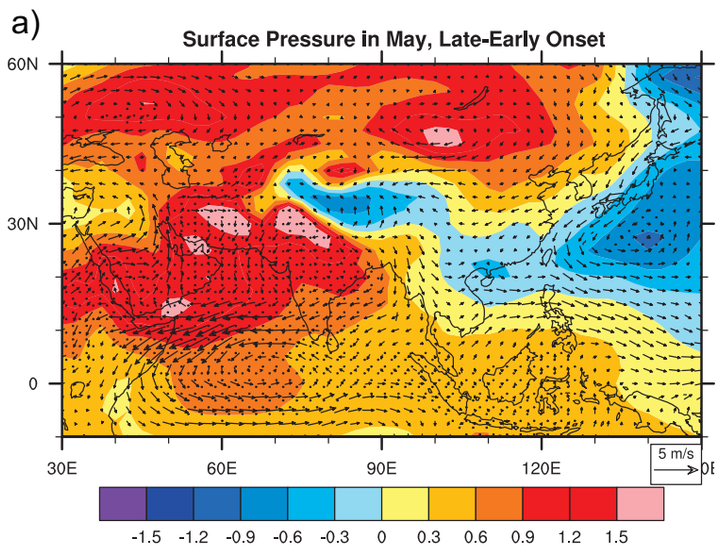


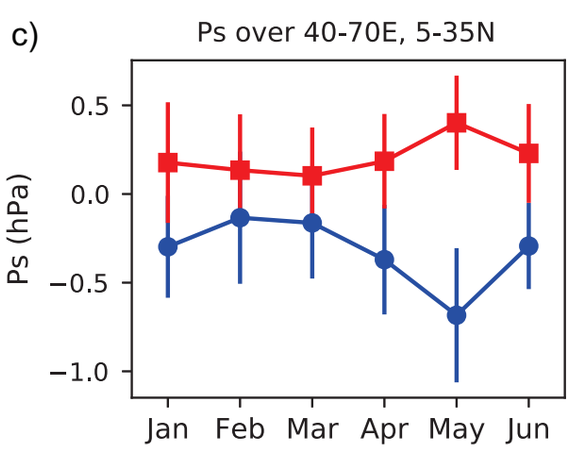


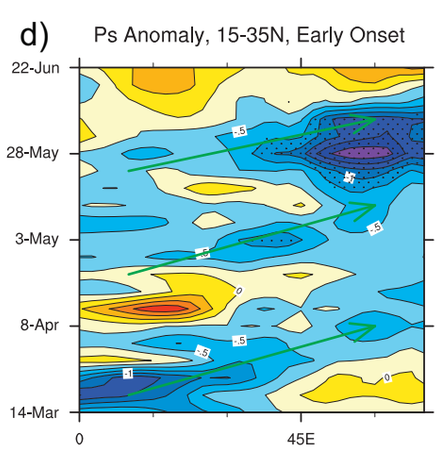
Remote Impact

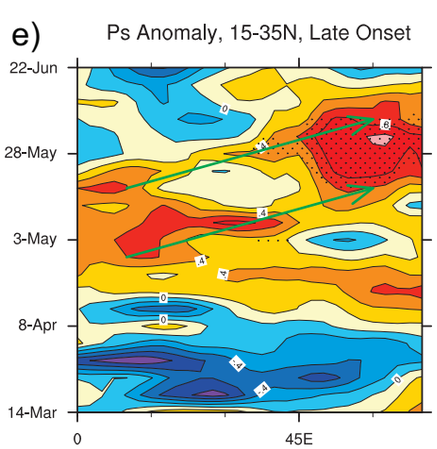
Energy balance over west central Asia Crucial in the Onset Phase of Monsoon

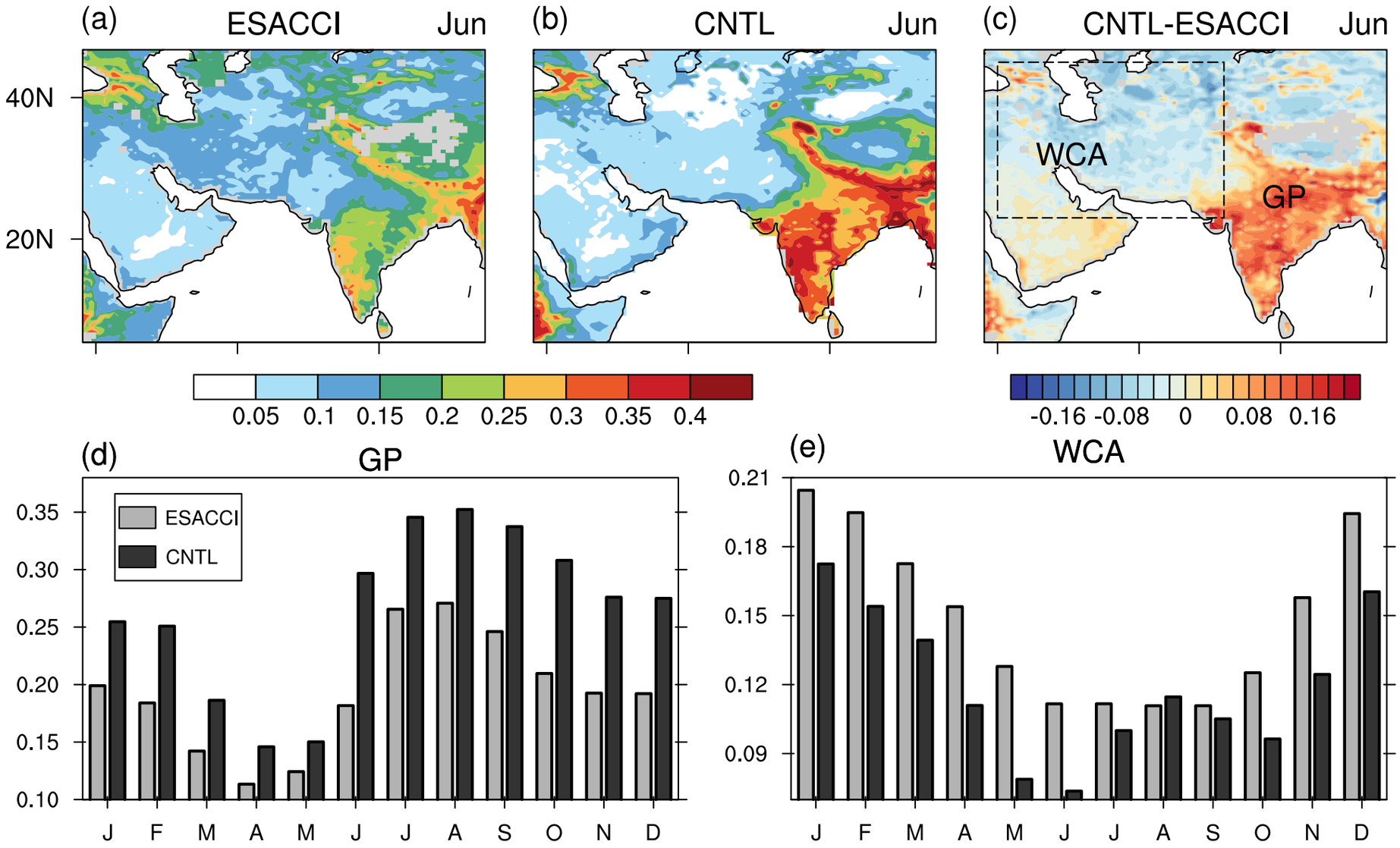






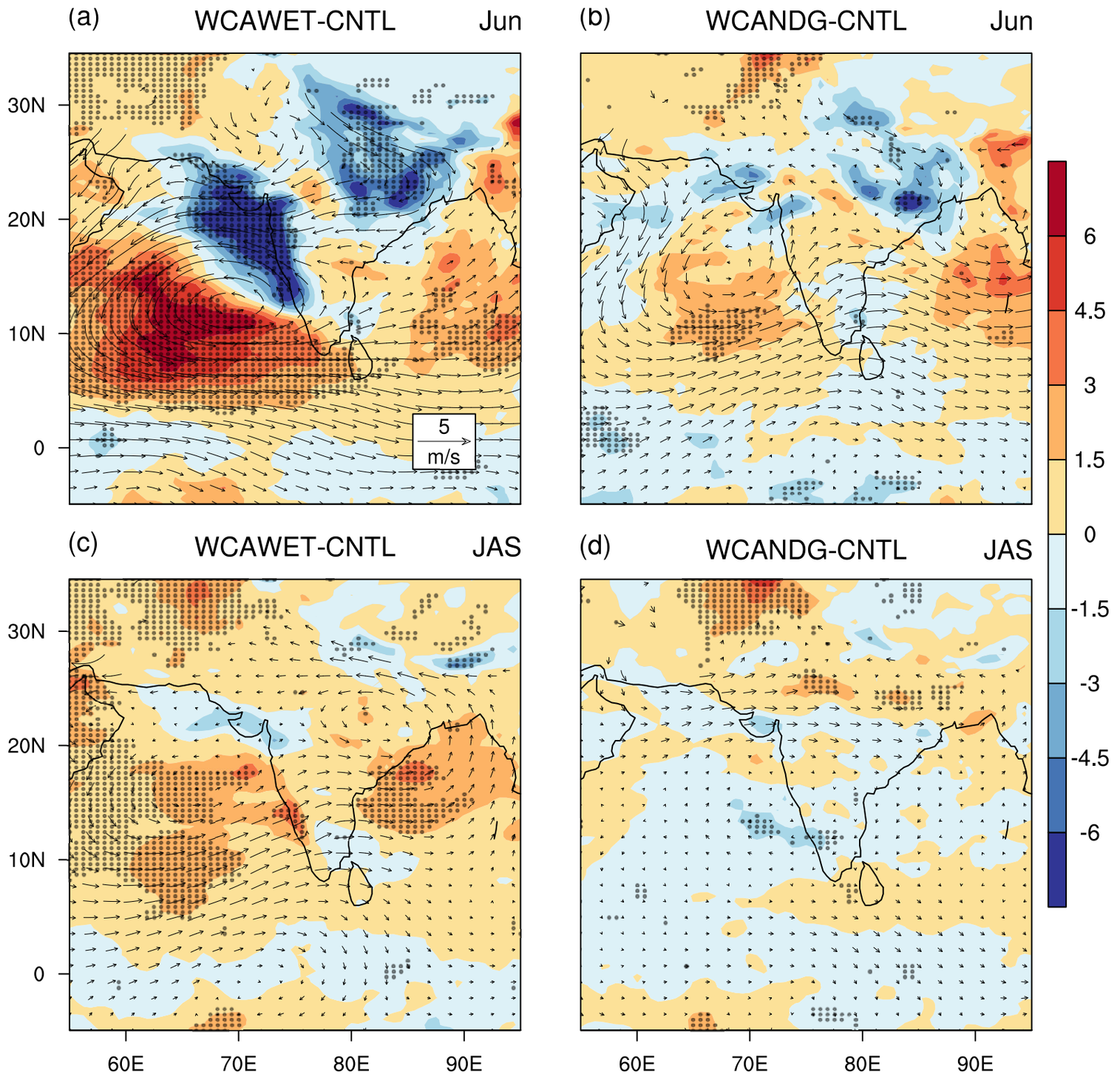




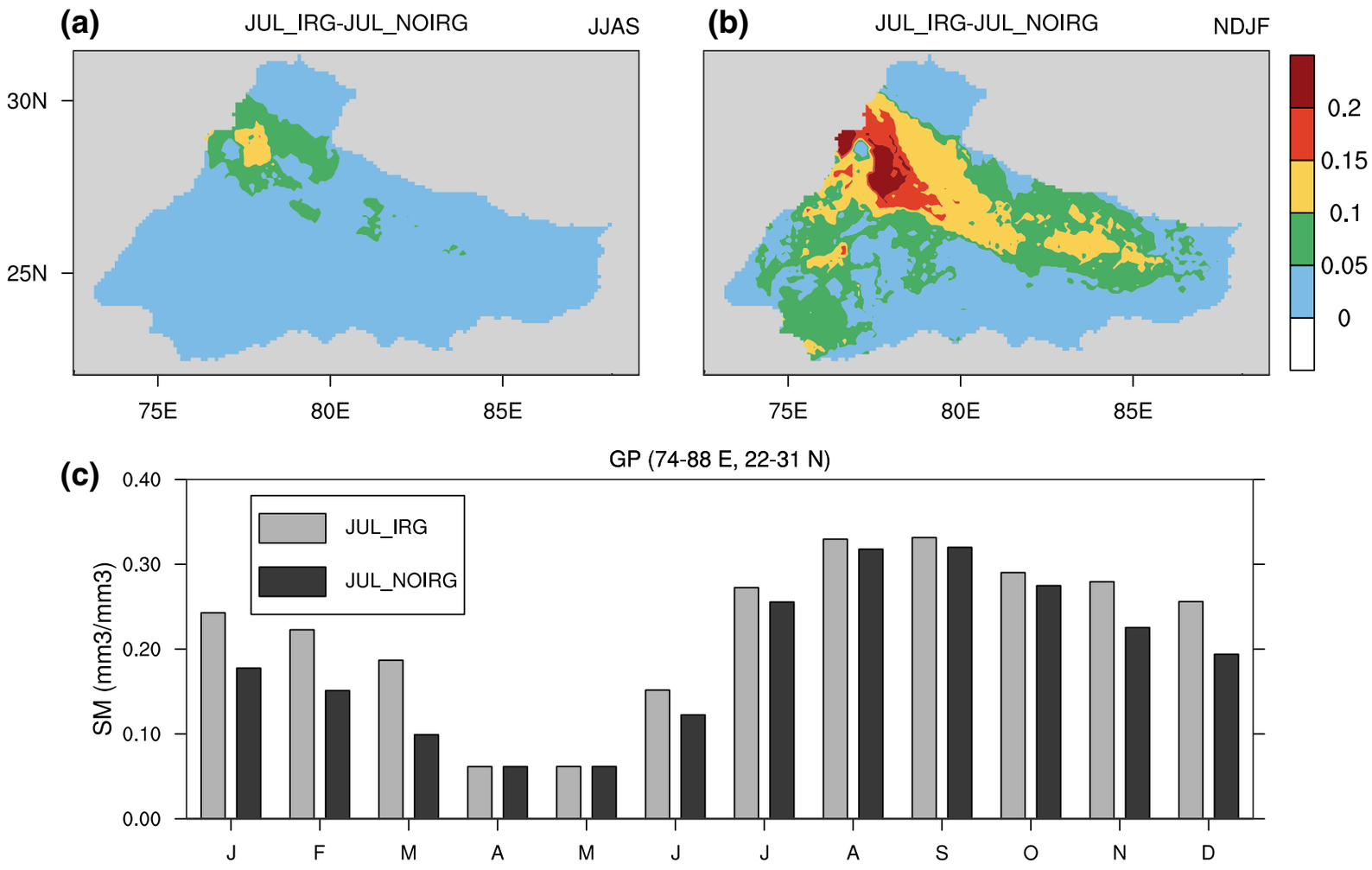

(a)
ESACCI
Jun
(b)
CNTL
Jun
(c)
CNTL-ESACCI
Jun
40N
20N
WCA
GP
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4
-0.16 -0.08 0 0.08 0.16
(d)
GP
ESACCI
CNTL
0.35
0.30
0.25
0.20
0.15
0.10
J F M A M J J A S O N D
(e)
WCA
0.21
0.18
0.15
0.12
0.09
J F M A M J J A S O N D

Model Simulation with West Soil Moisture over West Central Asia

Decrease in rainfall over central India when WCA soil moisture is saturated.

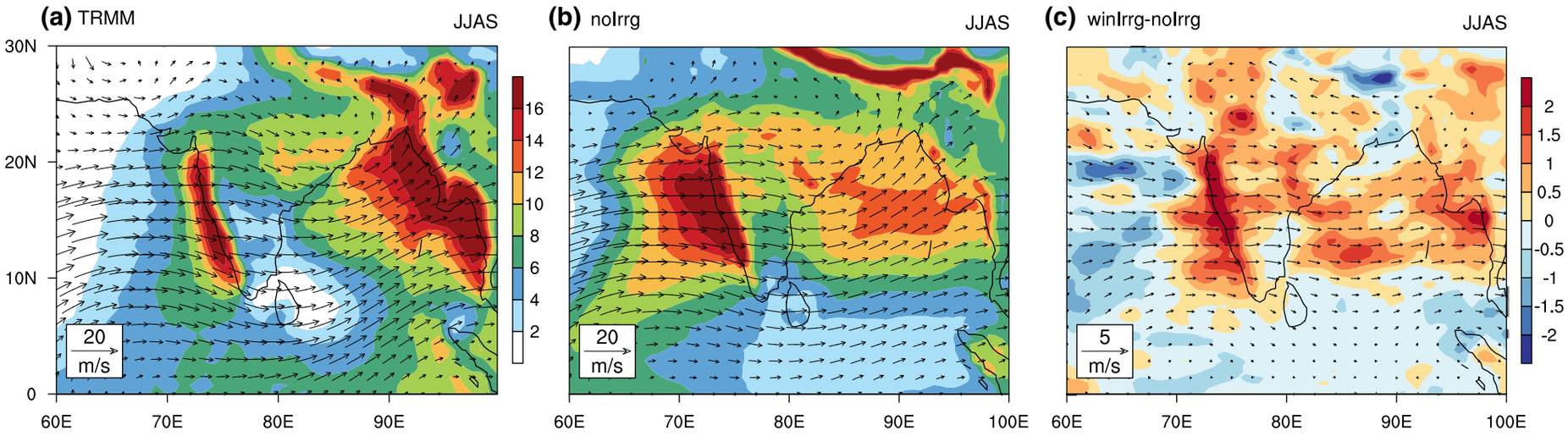


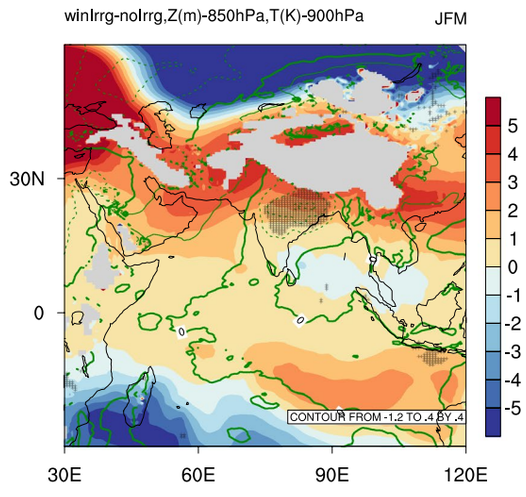
Impact of Irrigation

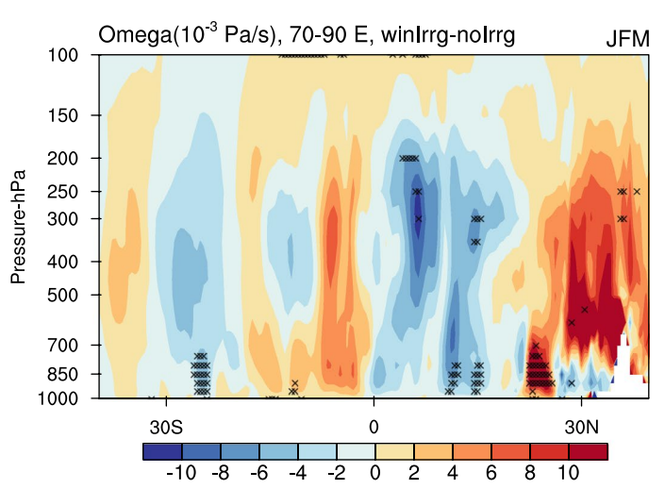


Agrawal et al. (2019, Clim Dyn)

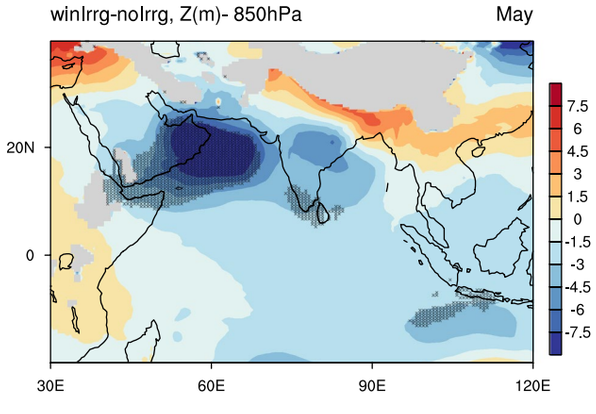
Effect of Winter Irrigation

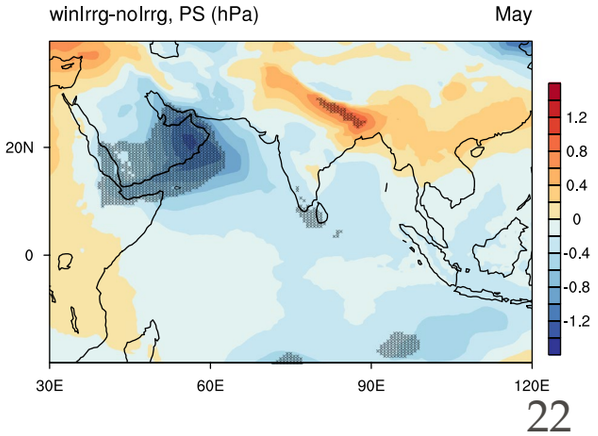


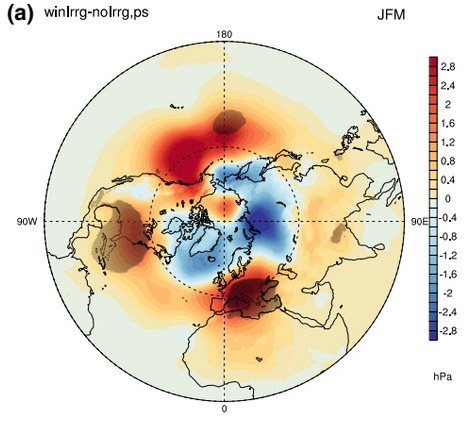


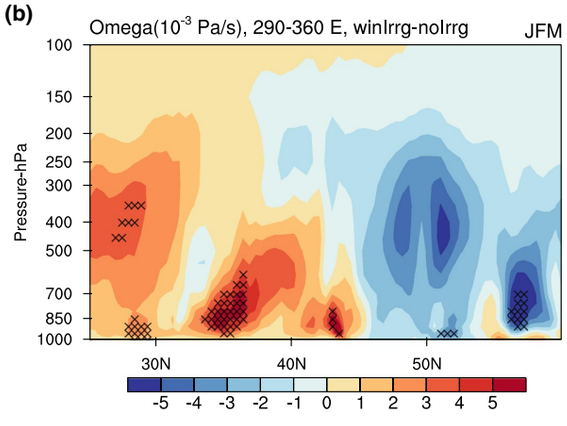


+ve NAO Signal

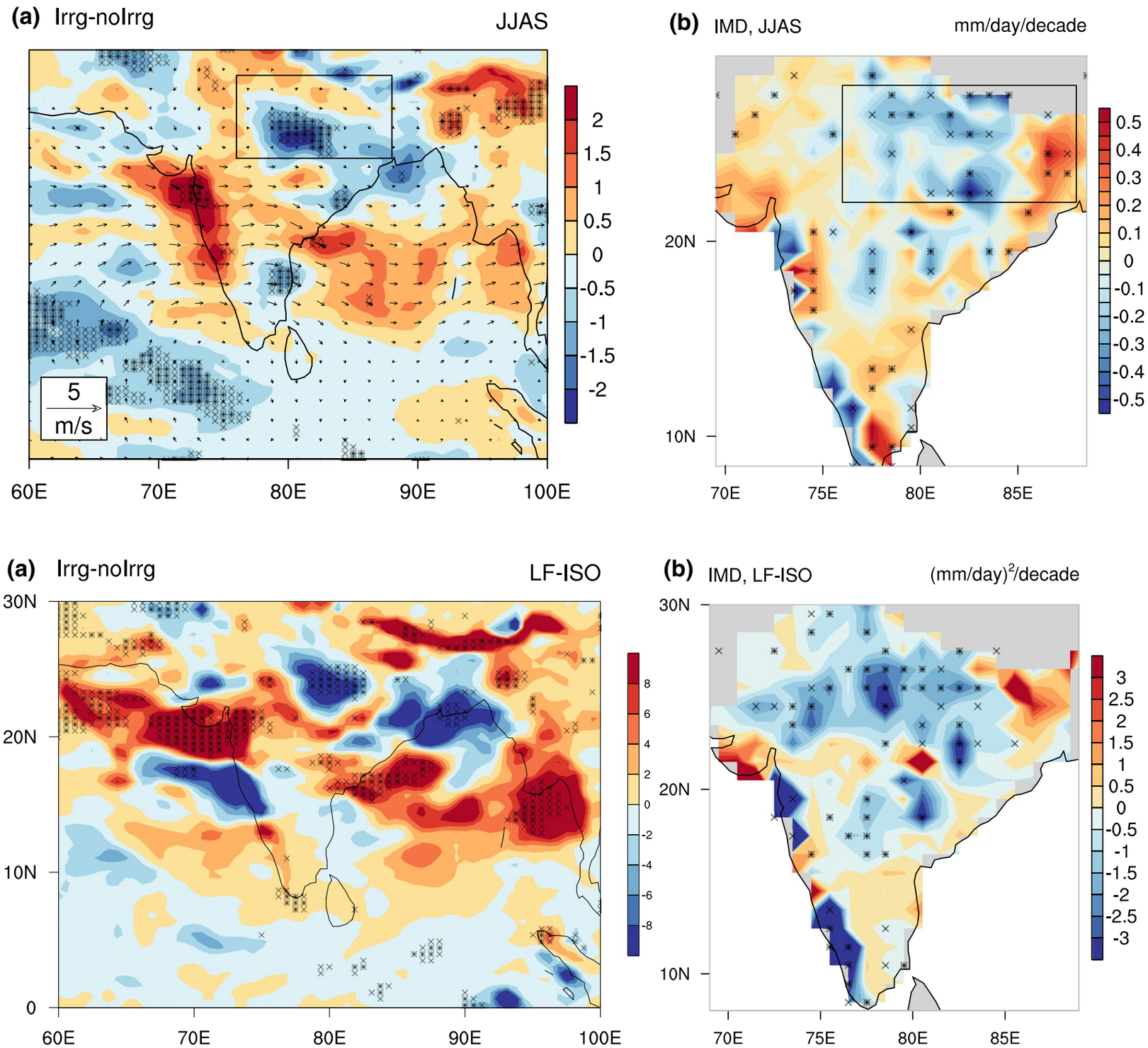




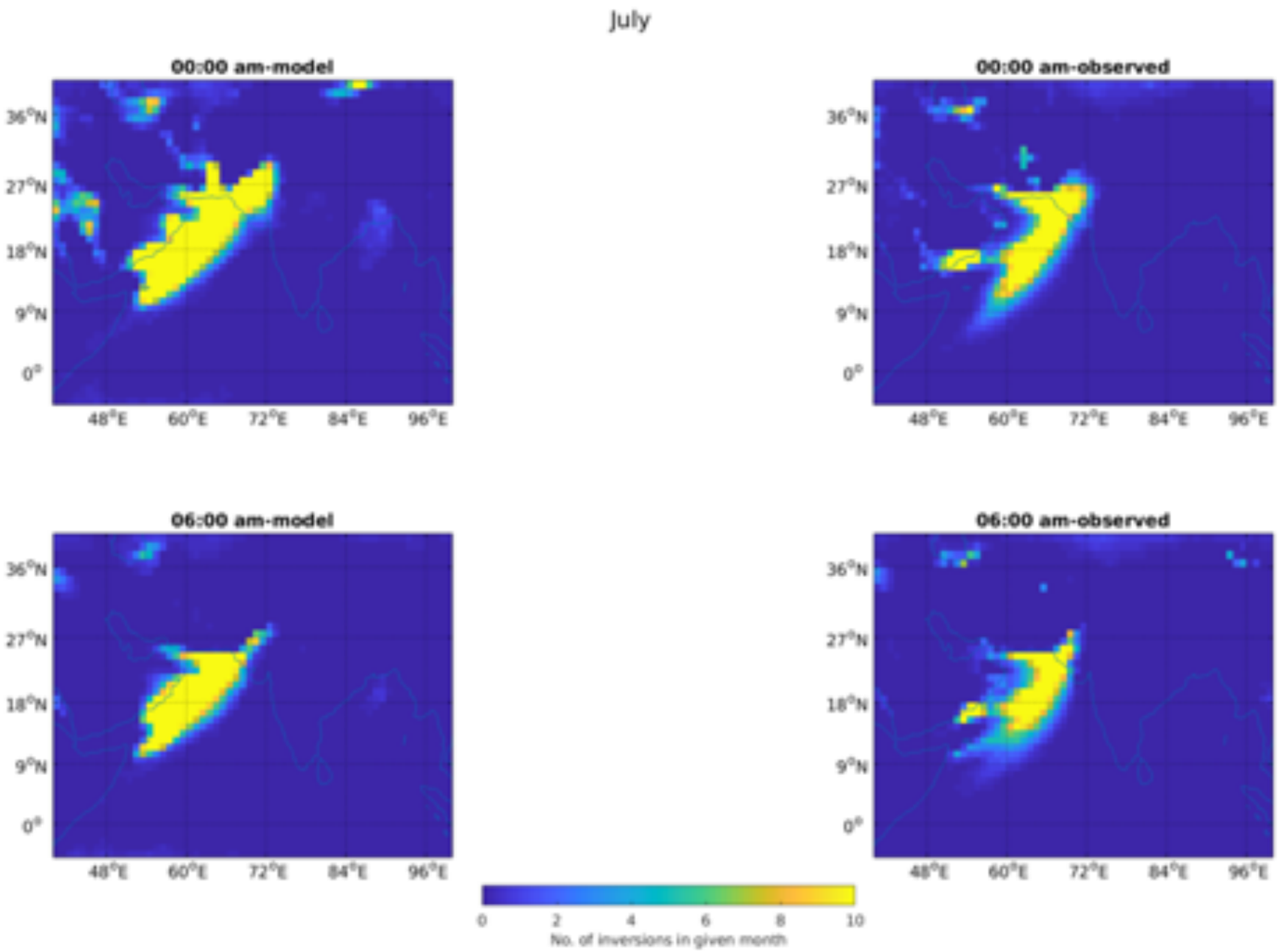




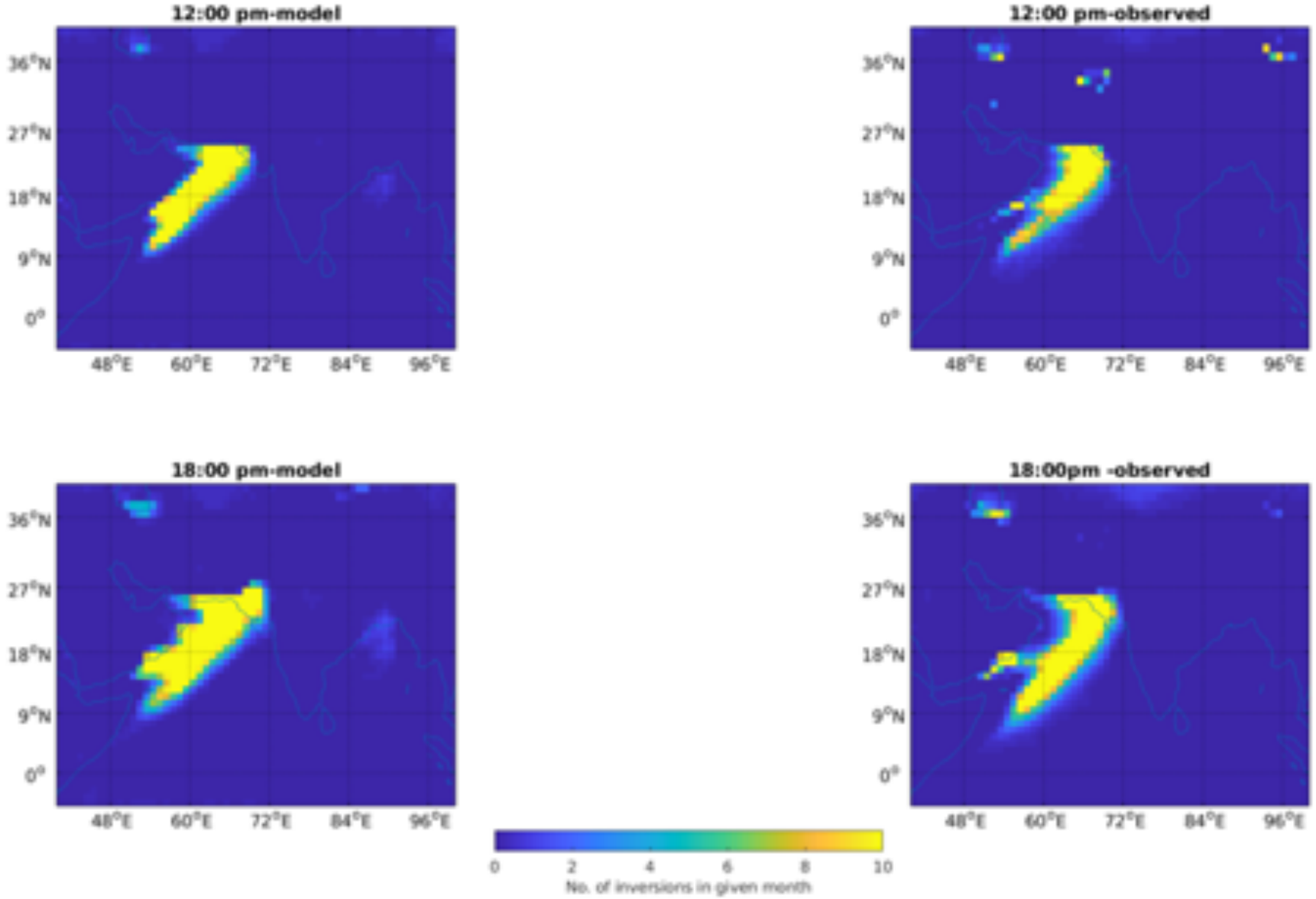
Annual Irrigation



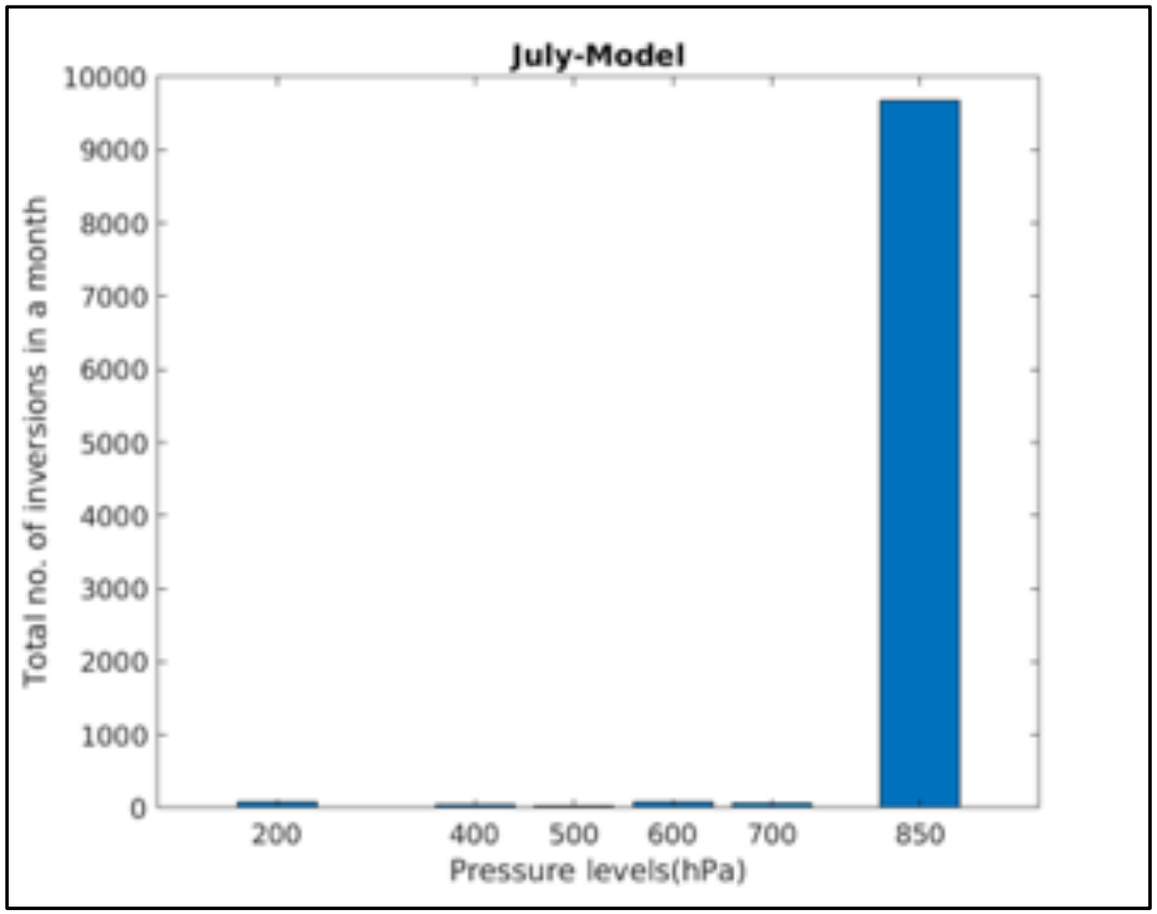
Temperature Inversions

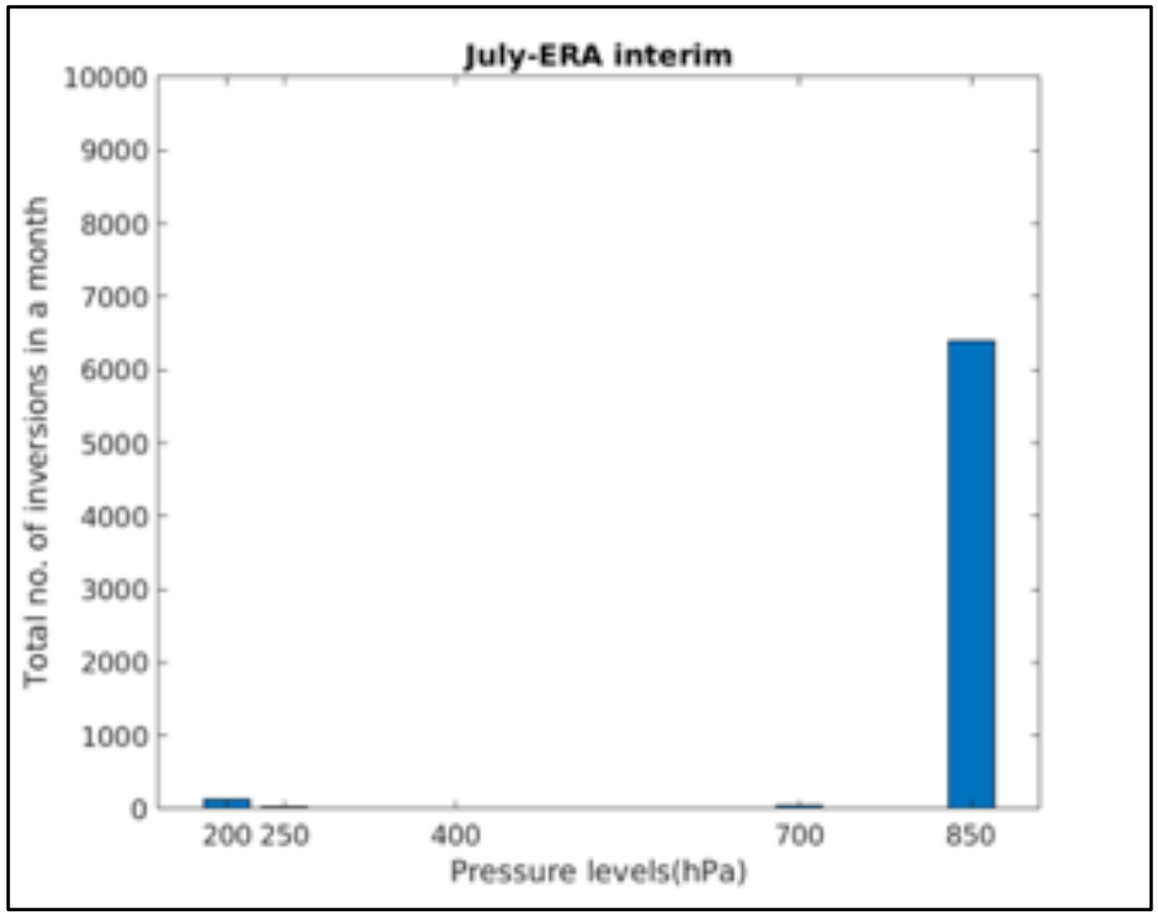


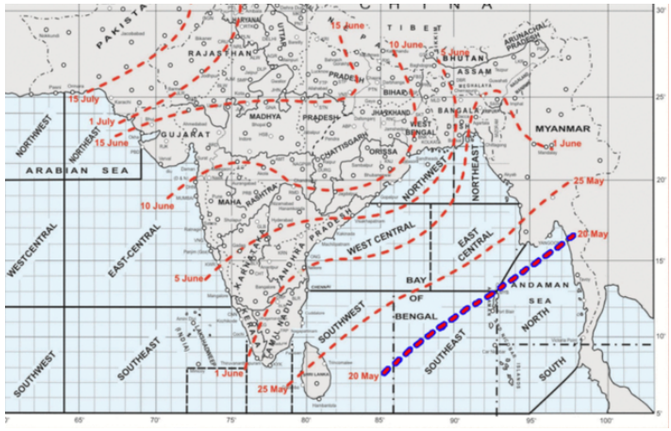
July

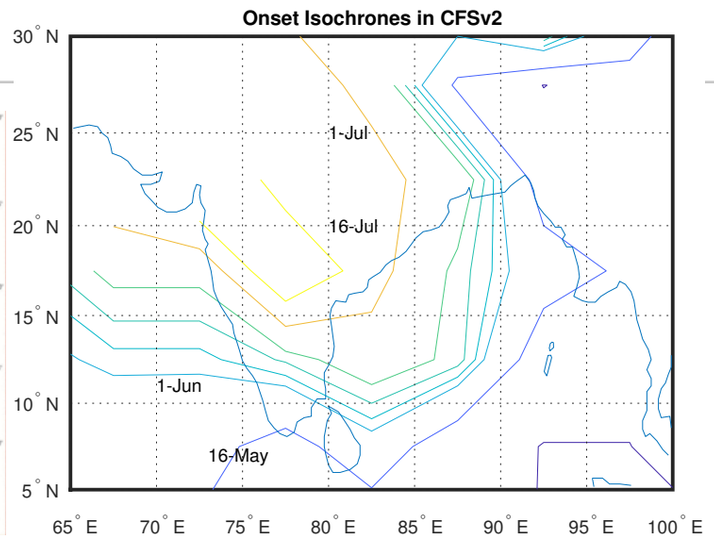

12:00 pm-model
12:00 pm-observed
18:00 pm-model
18:00pm -observed
36°N
27°N
18°N
9°N
0°
48°E
60°E
72°E
84°E
96°E
0
2
4
6
8
10
No. of inversions in given month

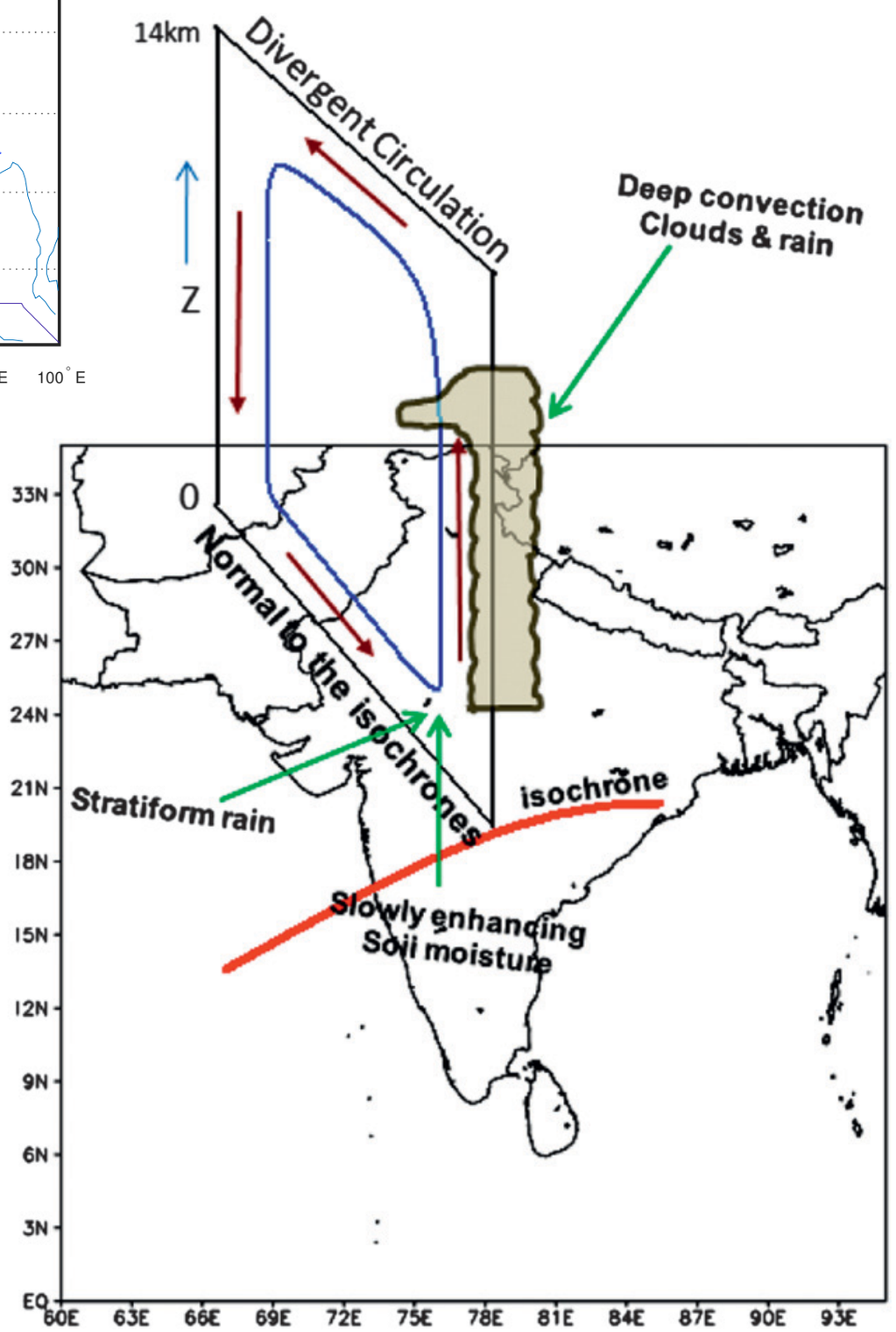
Frequency of Inversions






PAKISTAN
CHINA
TIBET
RAJASTHAN
BHUTAN
ASSAM
MYANMAR
GUJARAT
MADHYA PRADESH
ARABIAN SEA
BAY OF BENGAL
ANDAMAN SEA
NORTHWEST
WESTCENTRAL
EAST-CENTRAL
SOUTHWEST
SOUTHEAST
15 June
10 June
1 July
15 July
25 May
20 May
5 June
1 June


Onset Isochrones in CFSv2
30° N
25° N
20° N
15° N
10° N
5° N
65° E
70° E
75° E
80° E
85° E
90° E
95° E
100° E
1-Jul
16-Jul
1-Jun
16-May


14km
Divergent Circulation
Deep convection
Clouds & rain
Z
0
Normal to the isochrones
Stratiform rain
isochrone
Slowly enhancing
Soil moisture
33N
30N
27N
24N
21N
18N
15N
12N
9N
6N
3N
EQ
60E
63E
66E
69E
72E
75E
78E
81E
84E
87E
90E
93E