The origin and mechanism of winter depressions over Saudi Arabia

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The University of Hawaii, 01st Dec, 2004

Outline

- **Brief climatological overview (Chakraborty et al. 2004)**
- **Interannual variability of moisture flux (Chakraborty et al. 2004)**
- **Winter time transients and analysis of G-ANAL (JMA)**
- **Preliminary results from MM5 simulations**
- **Future work**

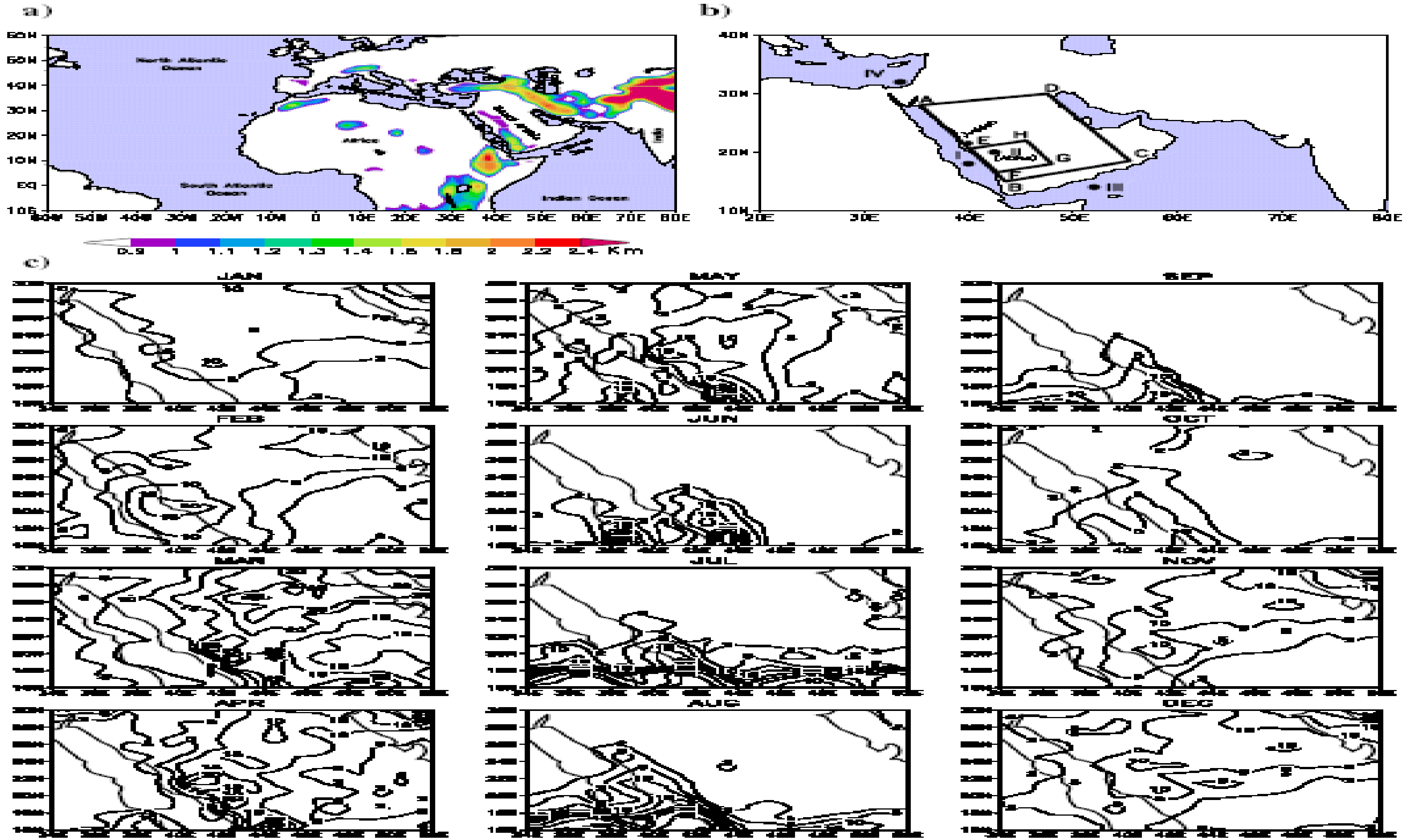
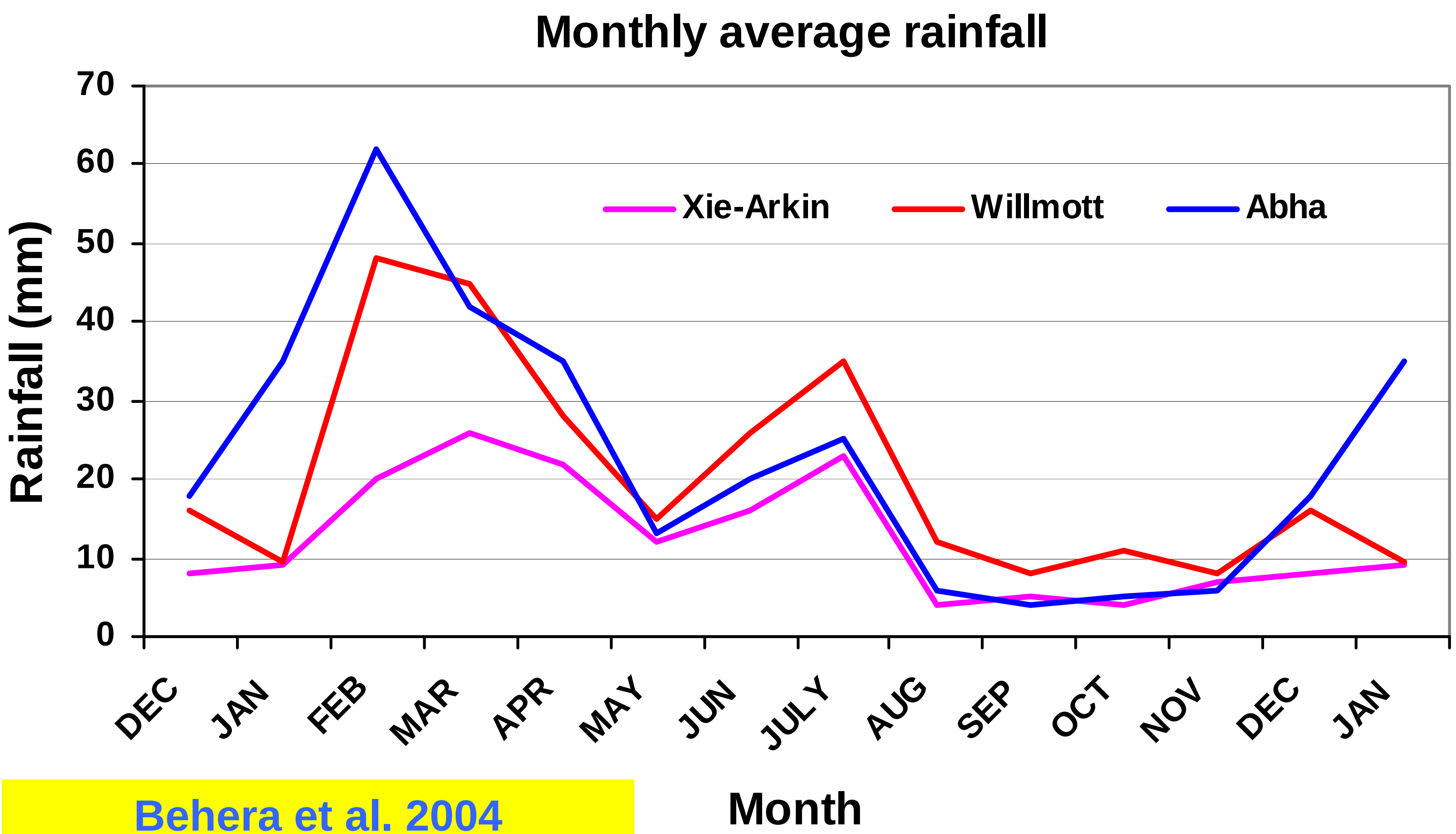


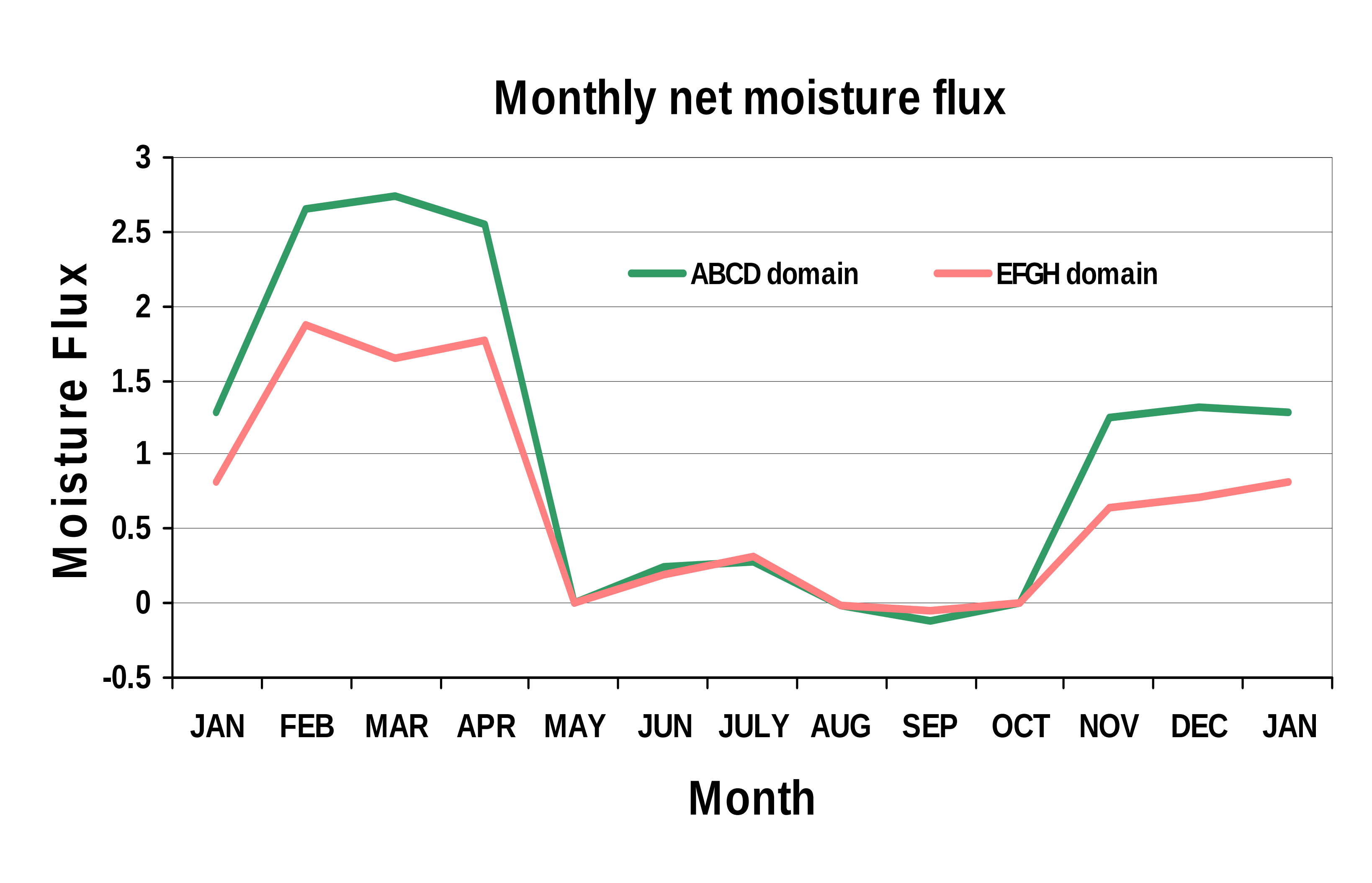
Fig. 1. (a) Diagram showing the adjacent seas of Saudi Arabia along with topography, (b) The domain of selected regions studied in this paper (Area I: over Red Sea; Area II: over Abha; Area III: over Arabian Sea and Area IV: over Mediterranean Sea) and (c) a map of climatological precipitation (in mm) from Xie-Arkin over Saudi Arabia.

Semi-annual rainfall signal

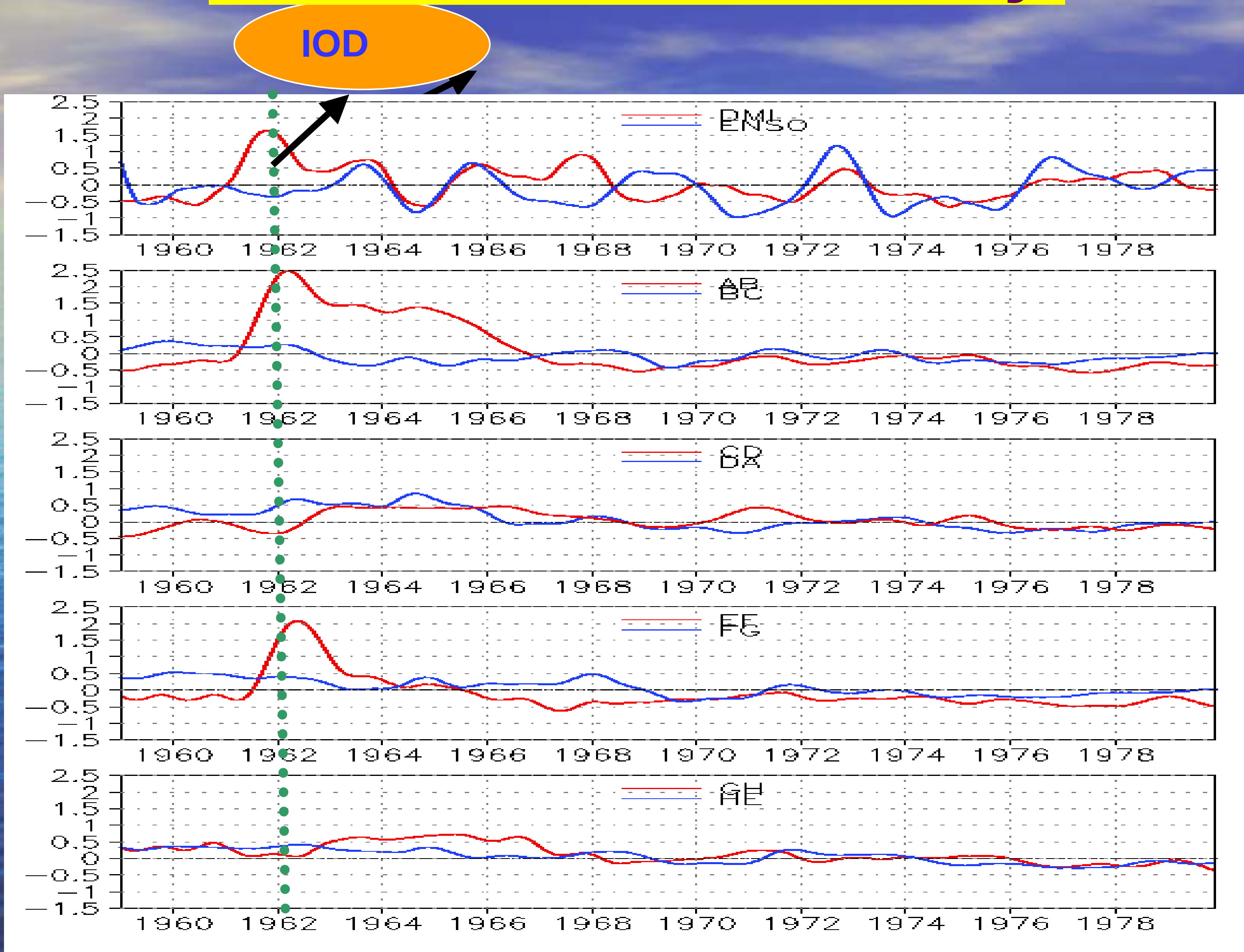


Behera et al. 2004

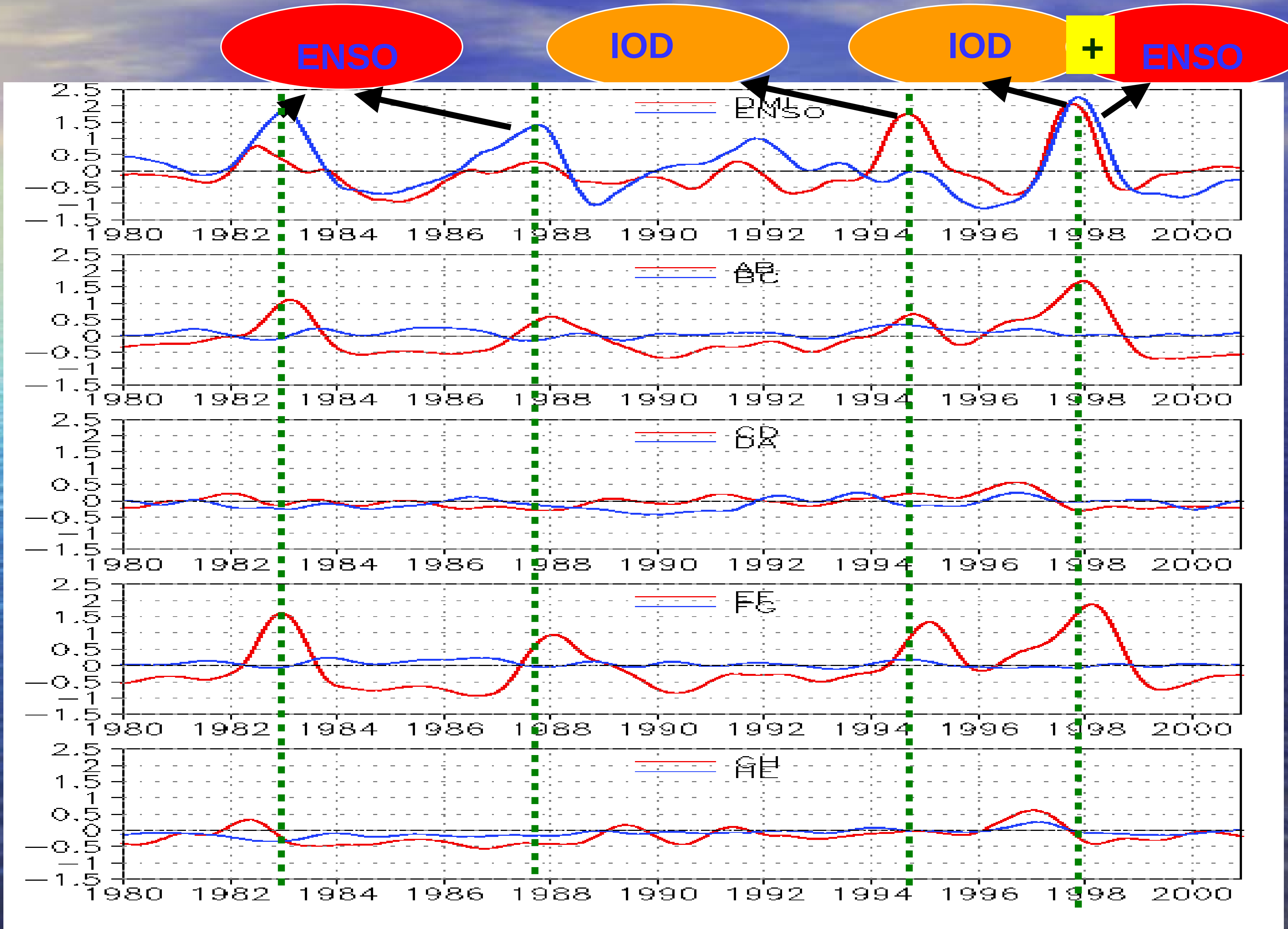
Seasonal Variability

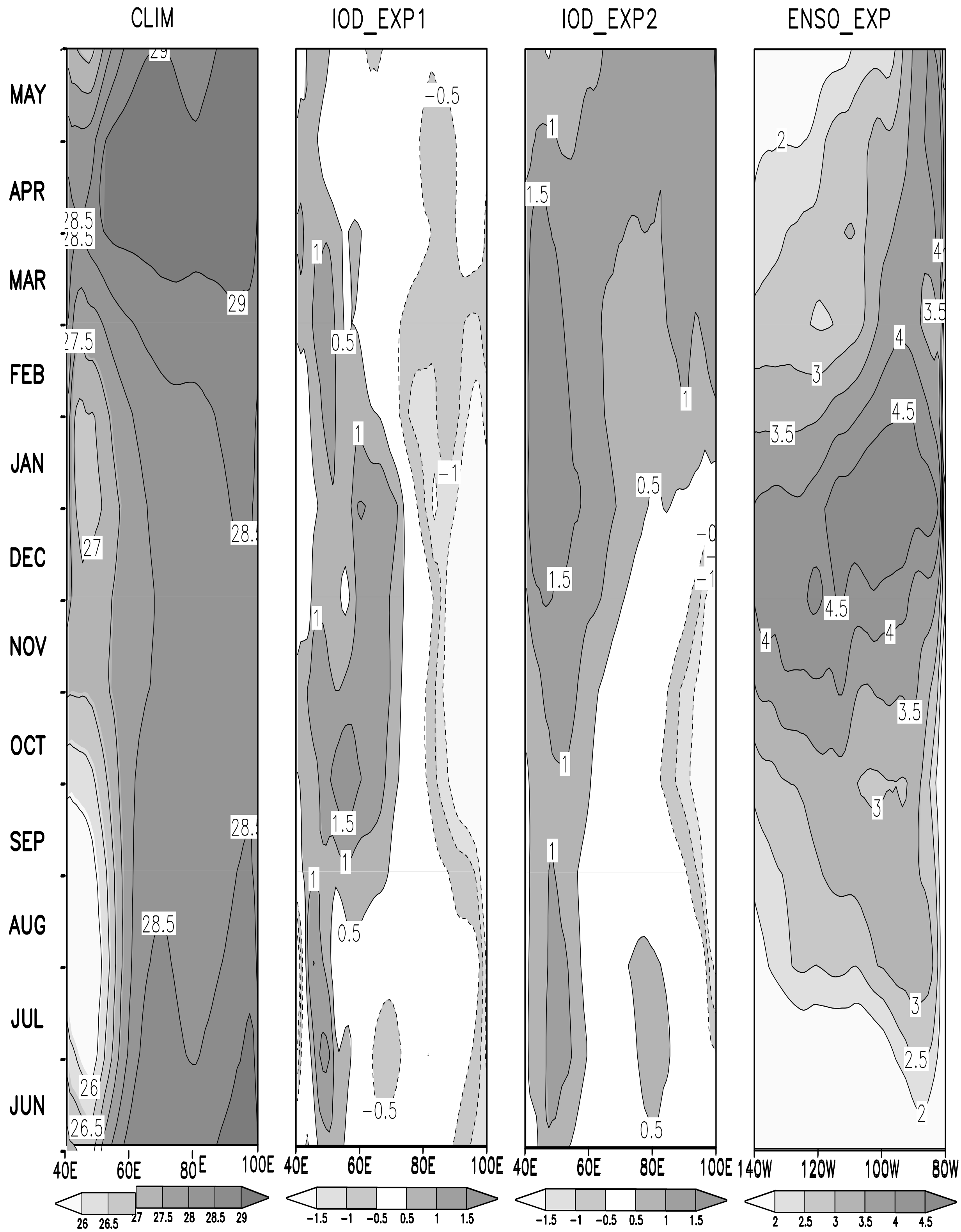


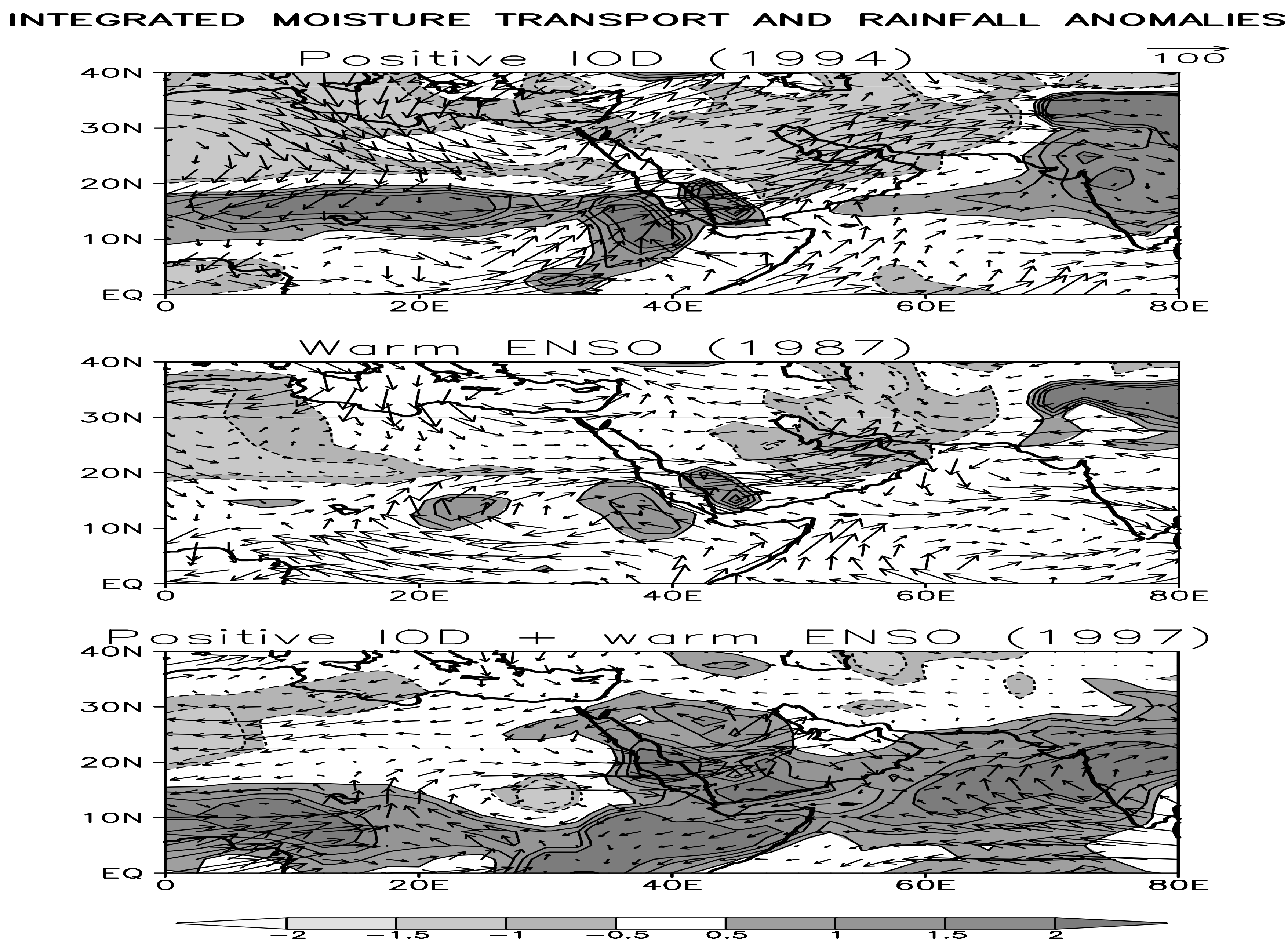
Interannual Variability



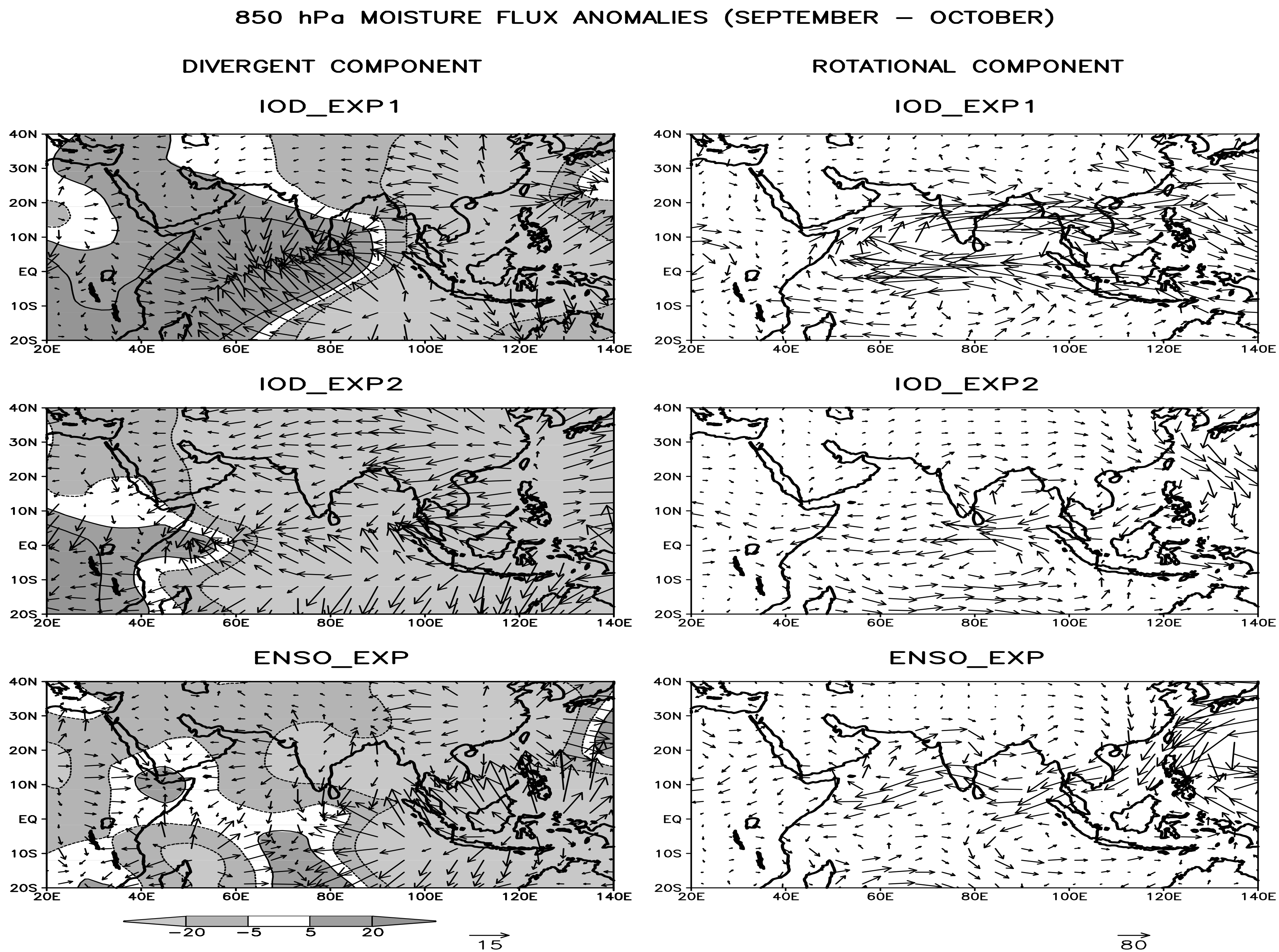
Interannual Variability



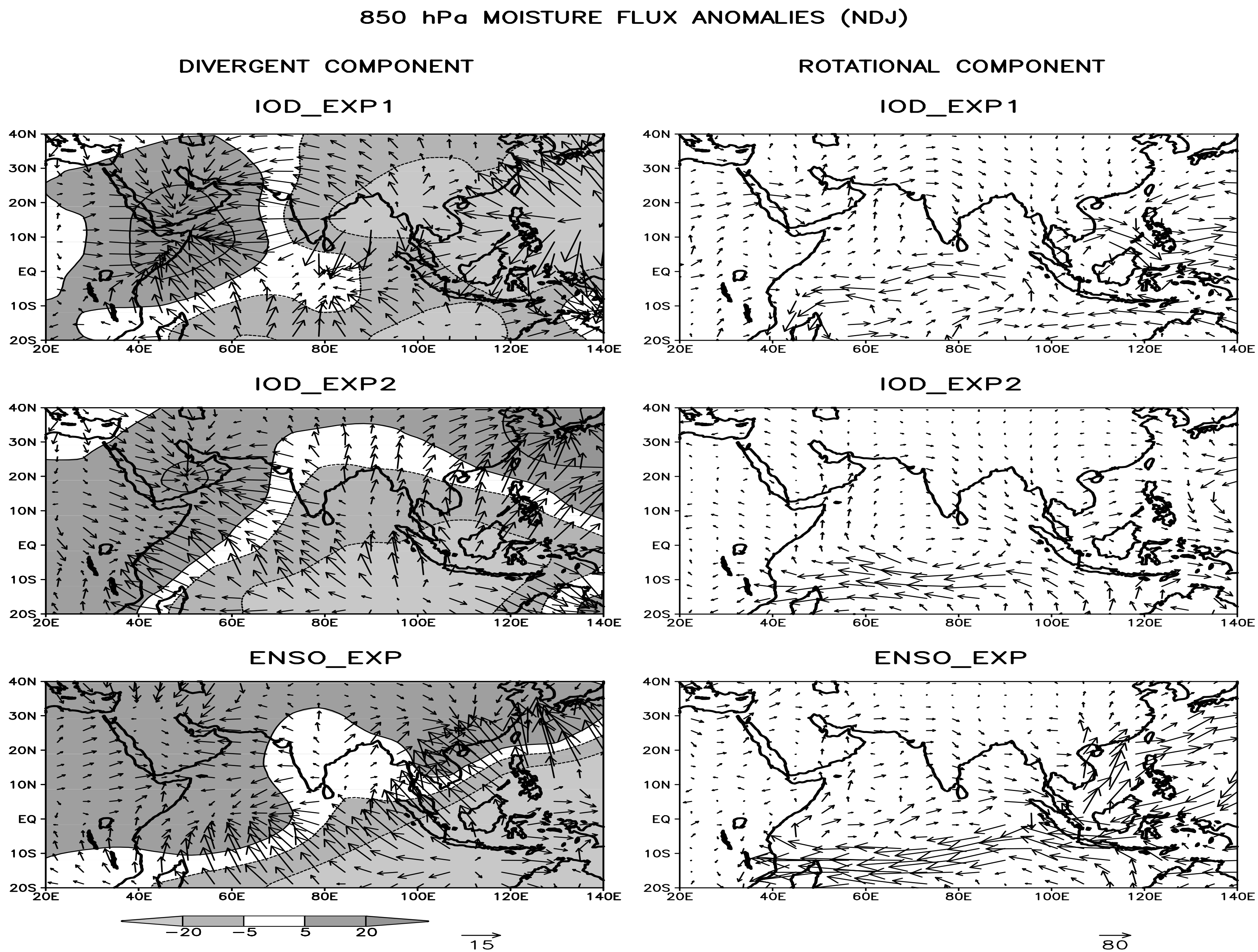

CLIM
IOD_EXP1
IOD_EXP2
ENSO_EXP
MAY
APR
MAR
FEB
JAN
DEC
NOV
OCT
SEP
AUG
JUL
JUN
40E
60E
80E
100E
140W
120W
100W
80W
26 26.5 27 27.5 28 28.5 29
−1.5 −1 −0.5 0.5 1 1.5
−1.5 −1 −0.5 0.5 1 1.5
2 2.5 3 3.5 4 4.5

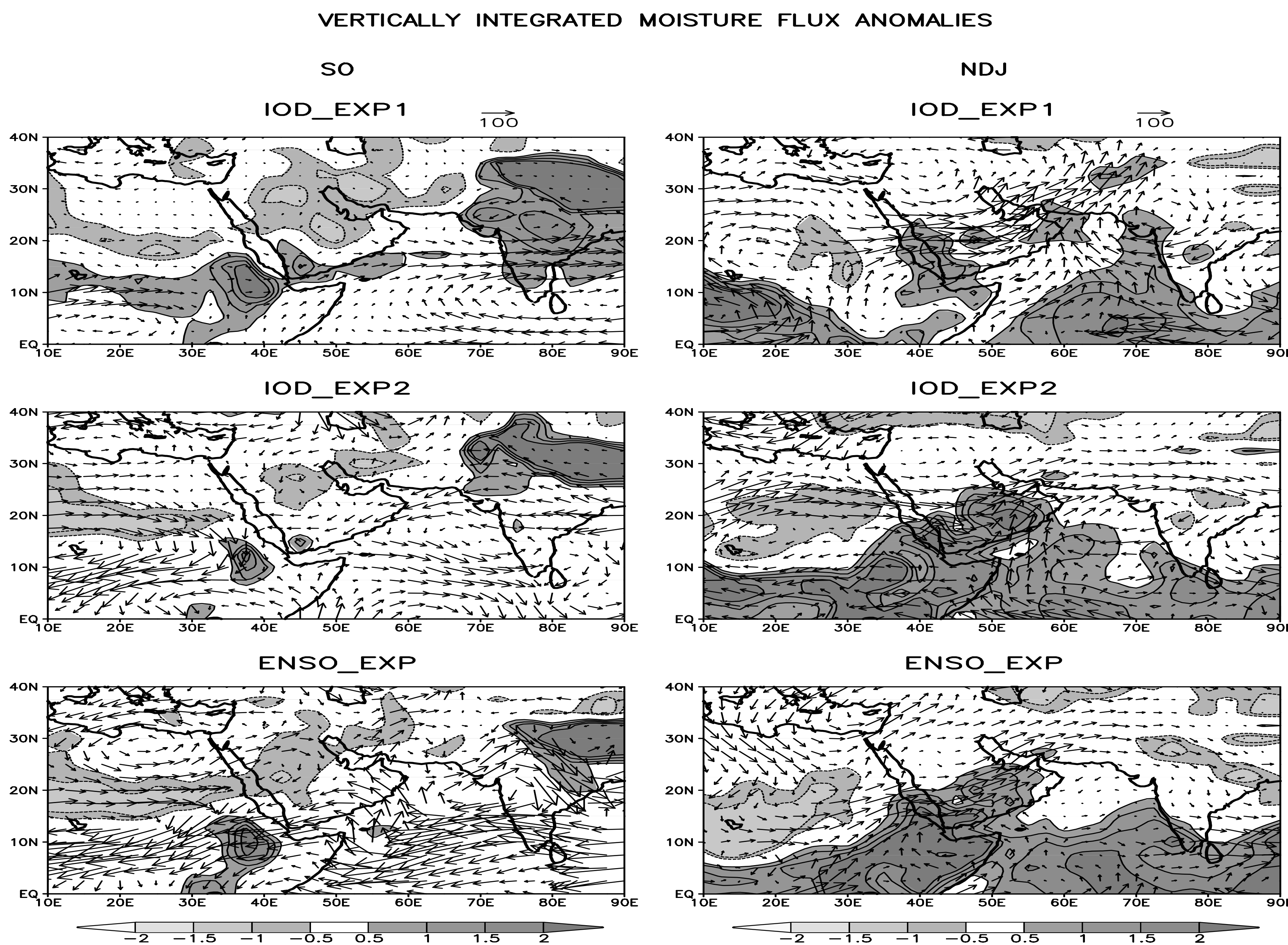


INTEGRATED MOISTURE TRANSPORT AND RAINFALL ANOMALIES
Positive IOD (1994)
100
40N
30N
20N
10N
EQ
0
20E
40E
60E
80E
Warm ENSO (1987)
Positive IOD + warm ENSO (1997)
−2
−1.5
−1
−0.5
0.5
1
1.5
2

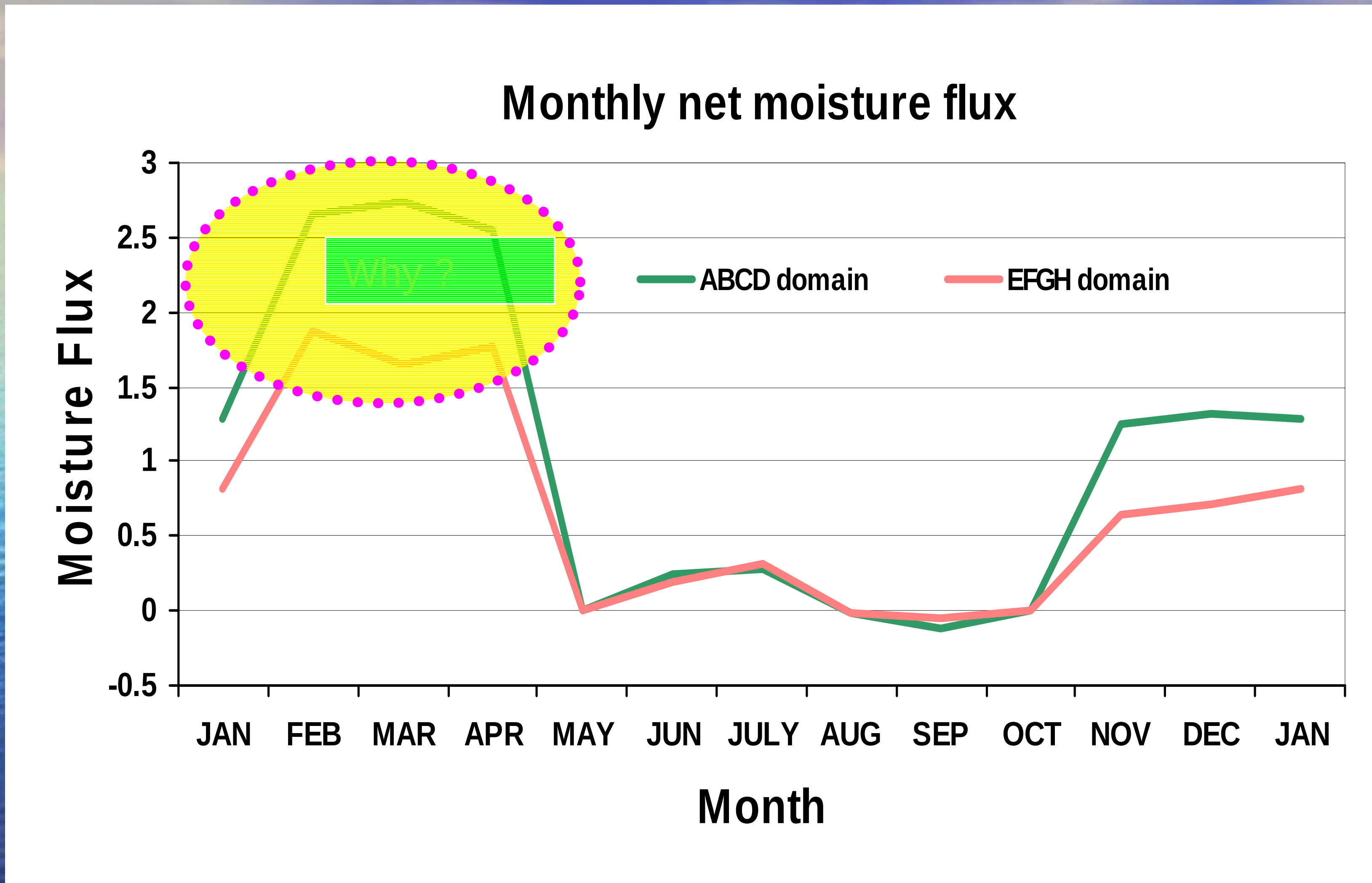


850 hPa MOISTURE FLUX ANOMALIES (SEPTEMBER – OCTOBER)
DIVERGENT COMPONENT
ROTATIONAL COMPONENT
IOD_EXP1
IOD_EXP2
ENSO_EXP
40N
30N
20N
10N
EQ
10S
20S
20E
40E
60E
80E
100E
120E
140E
−20
−5
5
20
15
80


850 hPa MOISTURE FLUX ANOMALIES (NDJ)
DIVERGENT COMPONENT
ROTATIONAL COMPONENT
IOD_EXP1
IOD_EXP2
ENSO_EXP
40N
30N
20N
10N
EQ
10S
20S
20E
40E
60E
80E
100E
120E
140E
−20
−5
5
20
15
80

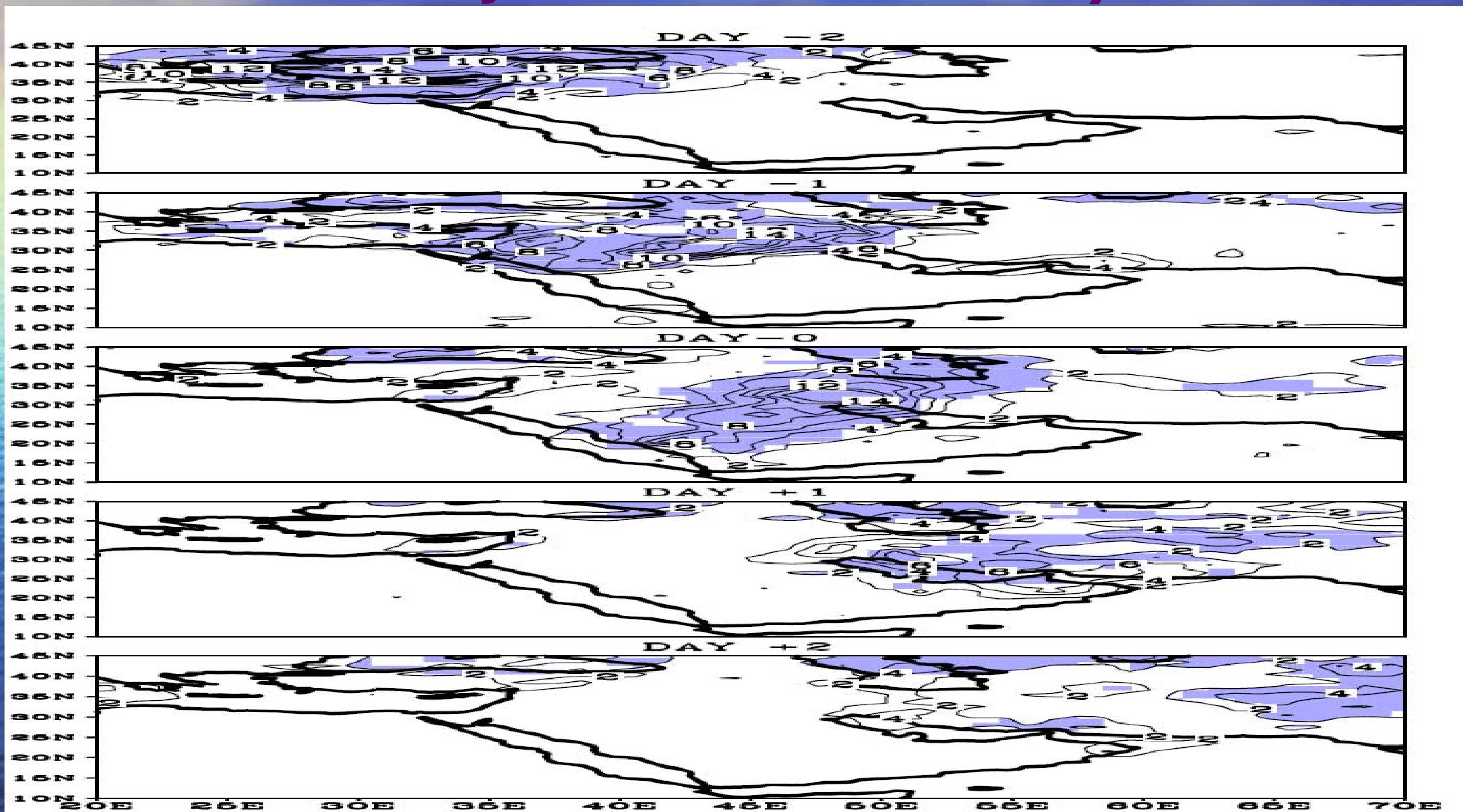

VERTICALLY INTEGRATED MOISTURE FLUX ANOMALIES
SO
NDJ
IOD_EXP1
IOD_EXP2
ENSO_EXP
100
40N
30N
20N
10N
EQ
10E
20E
30E
40E
50E
60E
70E
80E
90E
−2
−1.5
−1
−0.5
0.5
1
1.5
2

Seasonal Variability

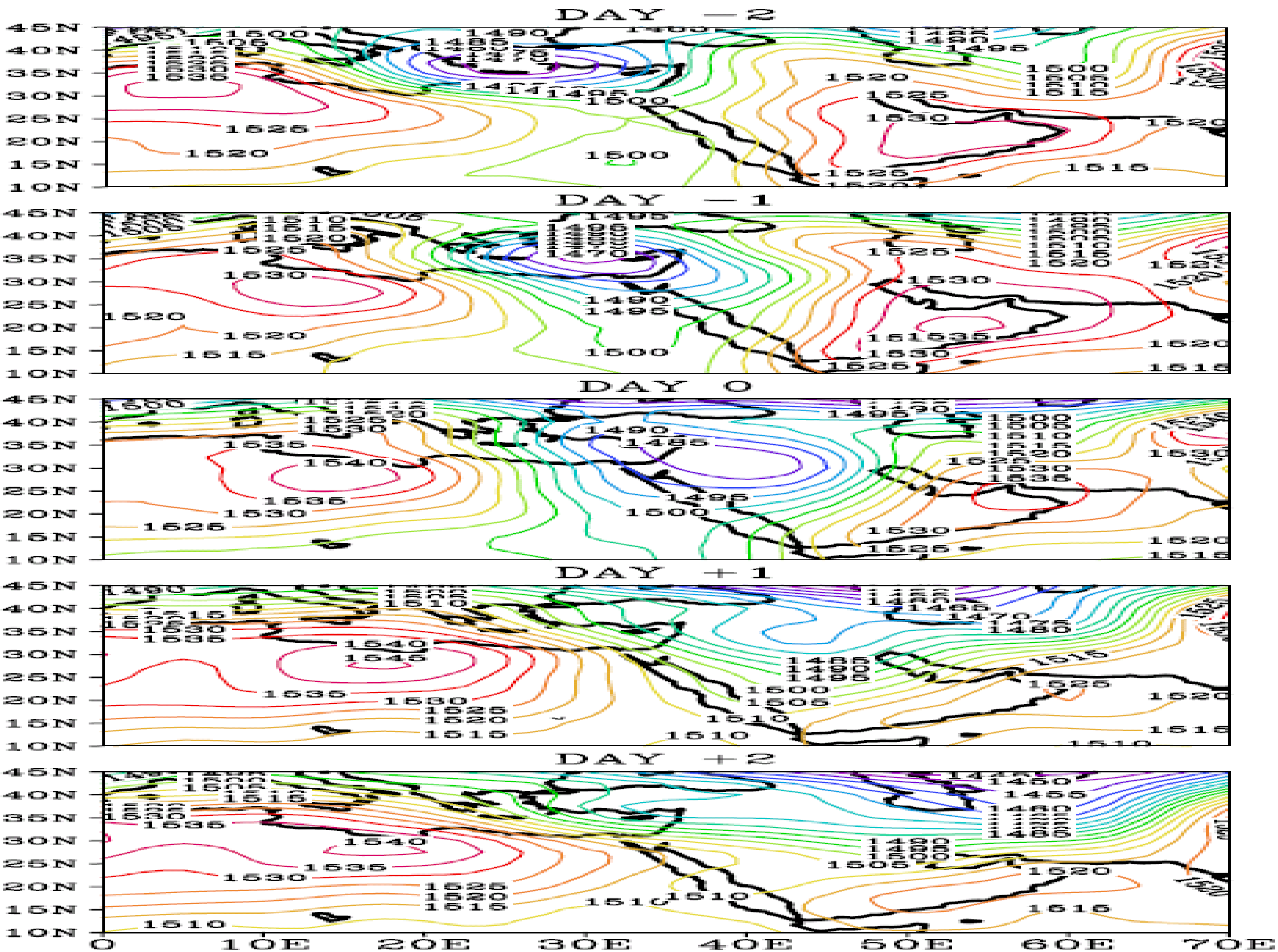


Precipitation from winter disturbances

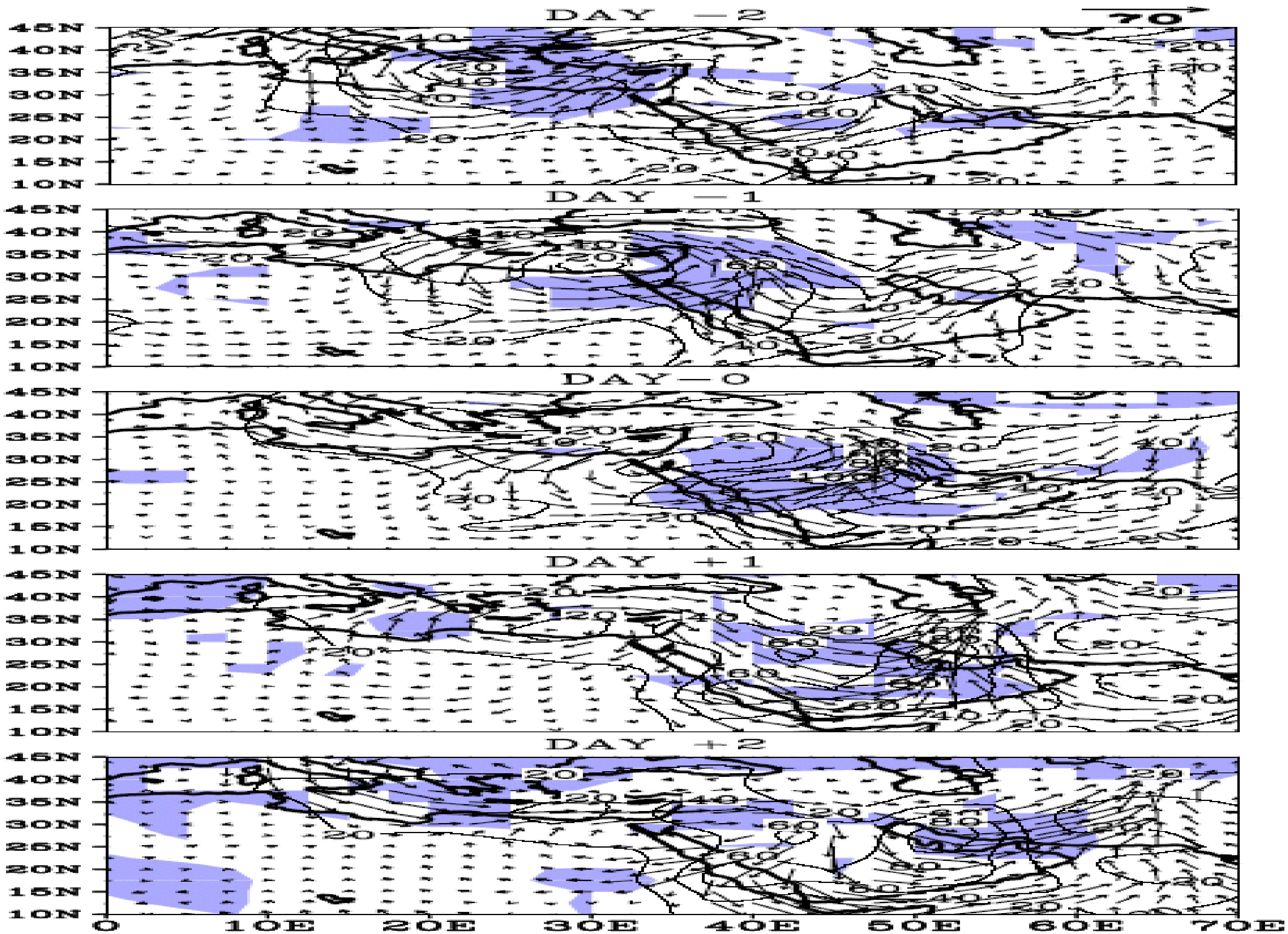
Mujumdar et. al. 2004)



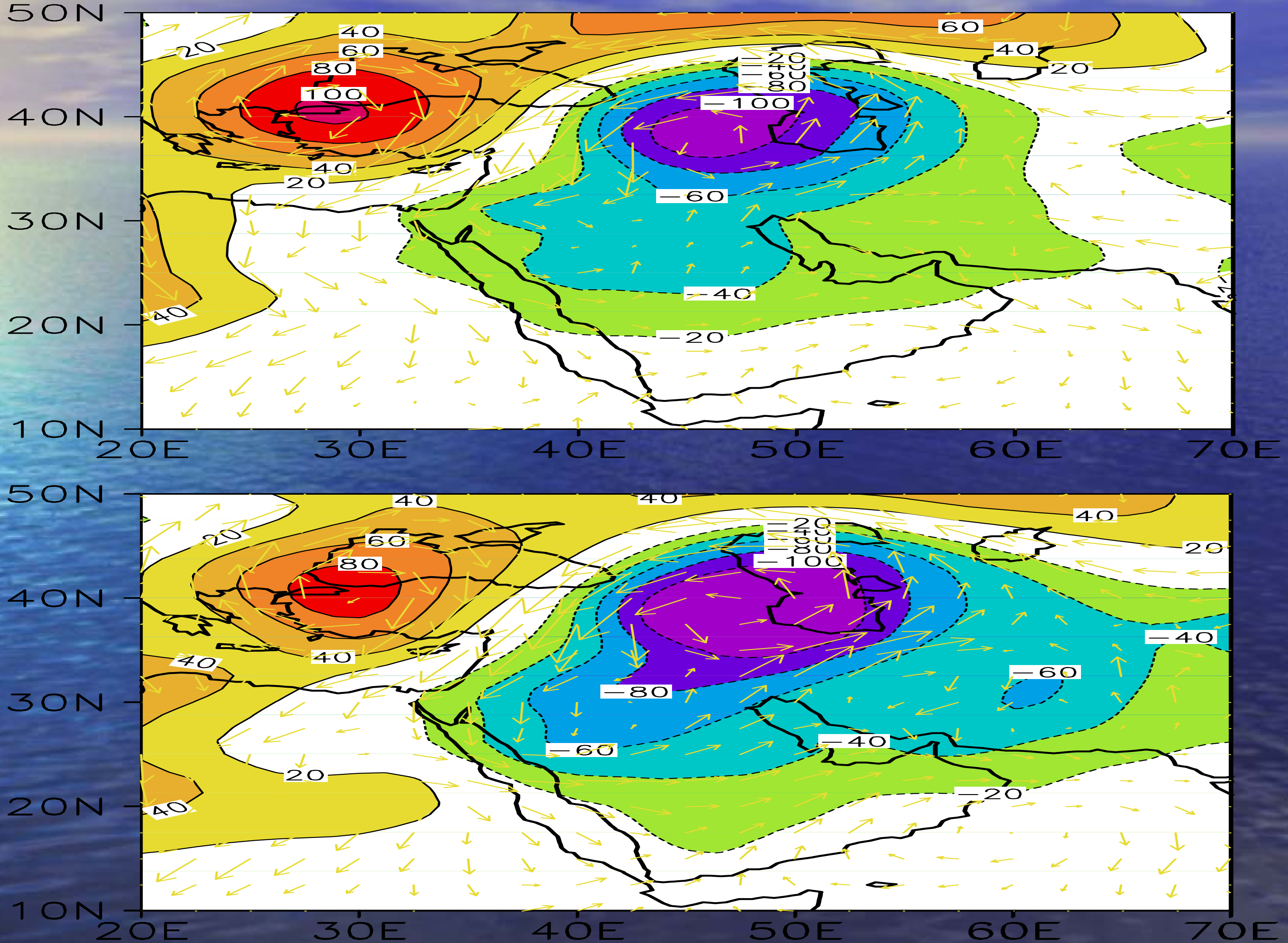
850 hPa Geo-potential anomalies



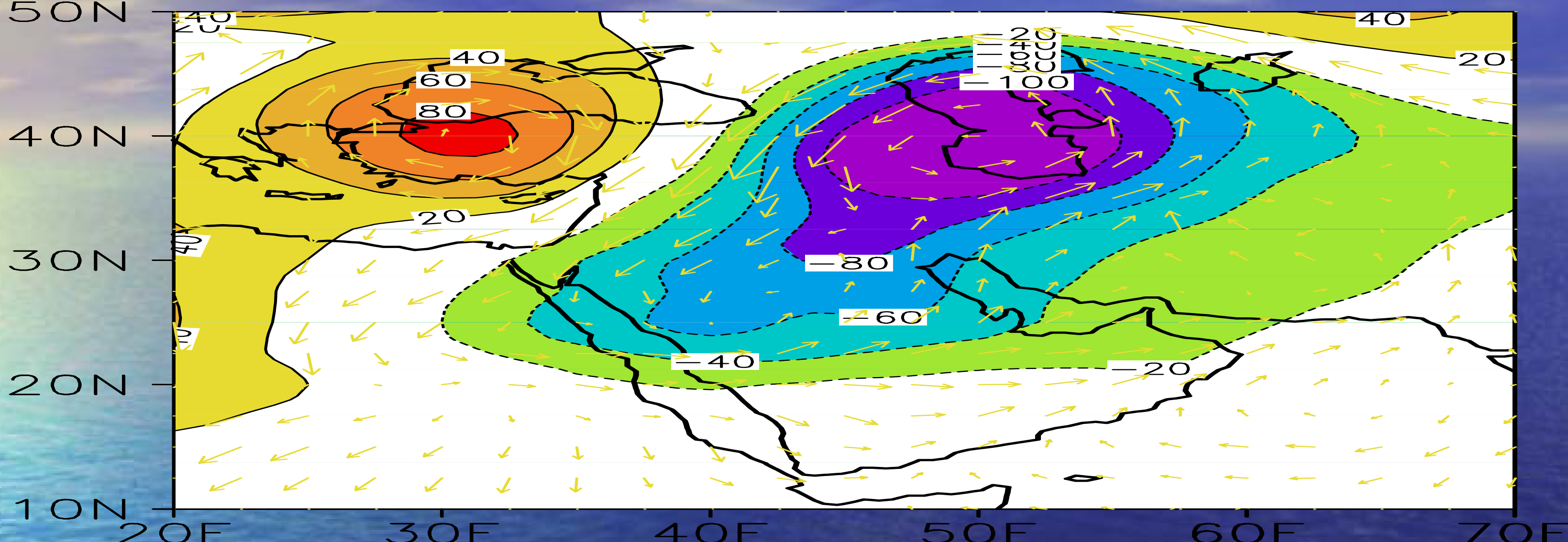
Moisture flux anomalies

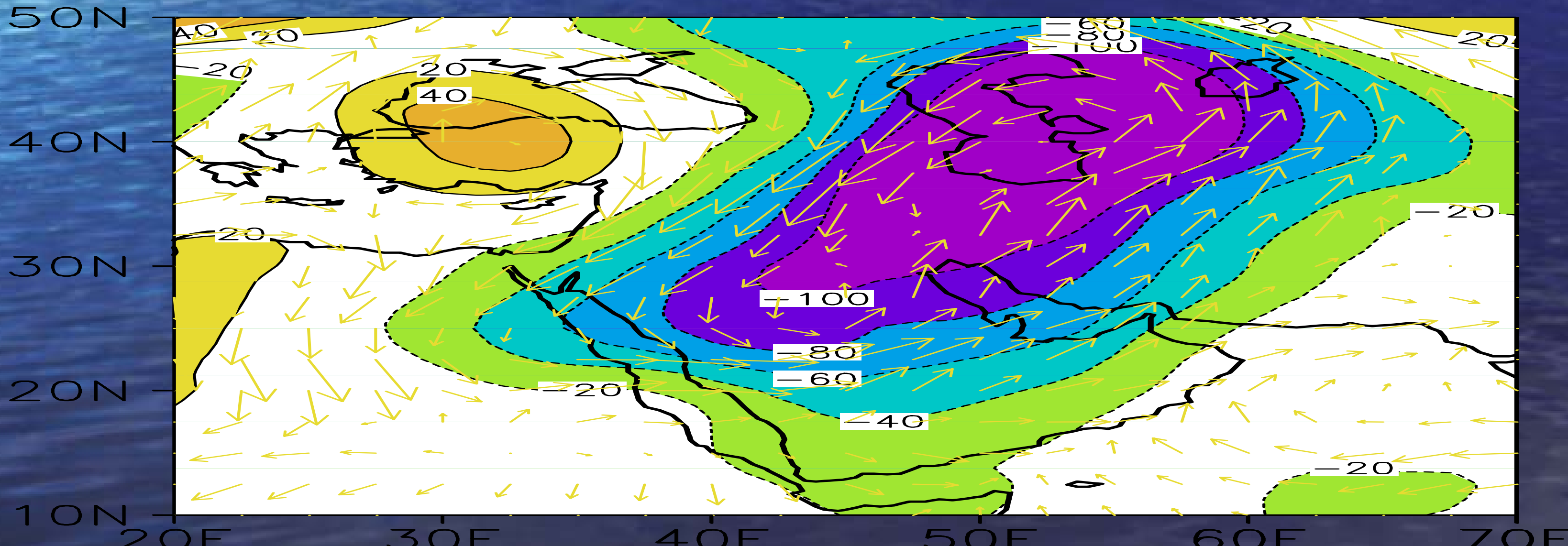


Type-1

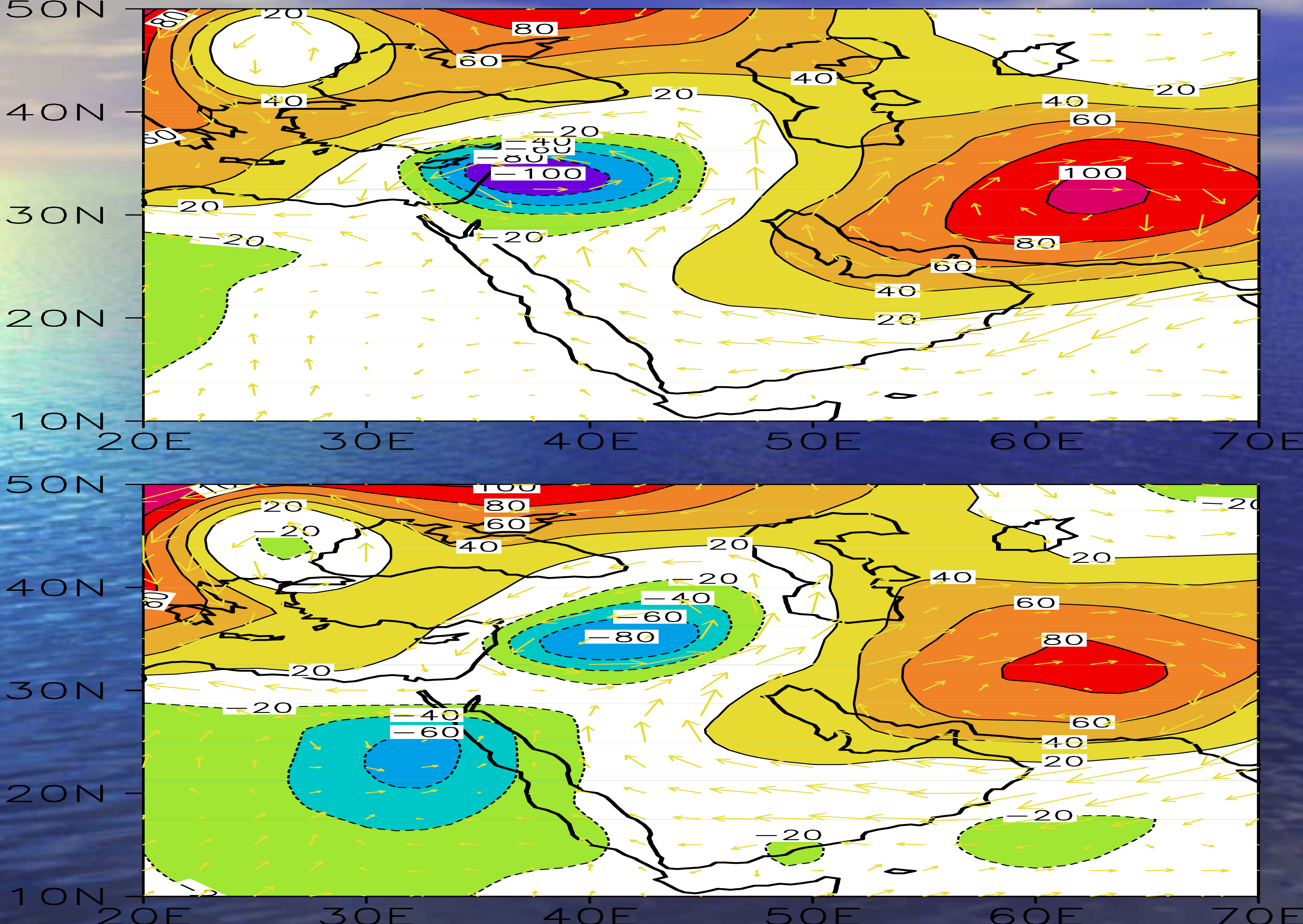


Type-1

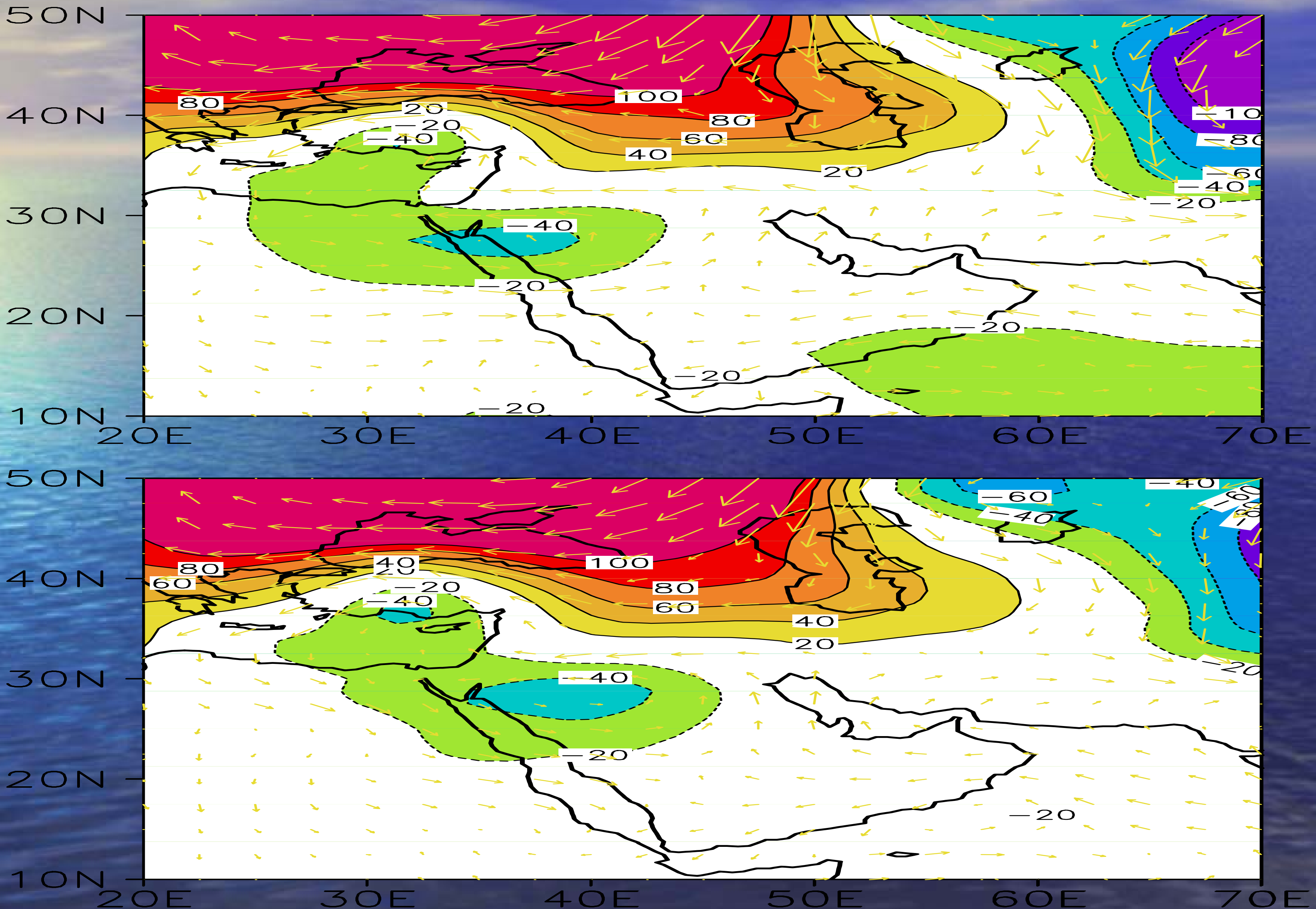

50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E
40
60
80
20
−100
−80
−60
−40
−20


50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E
20
40
−100
−80
−60
−40
−20

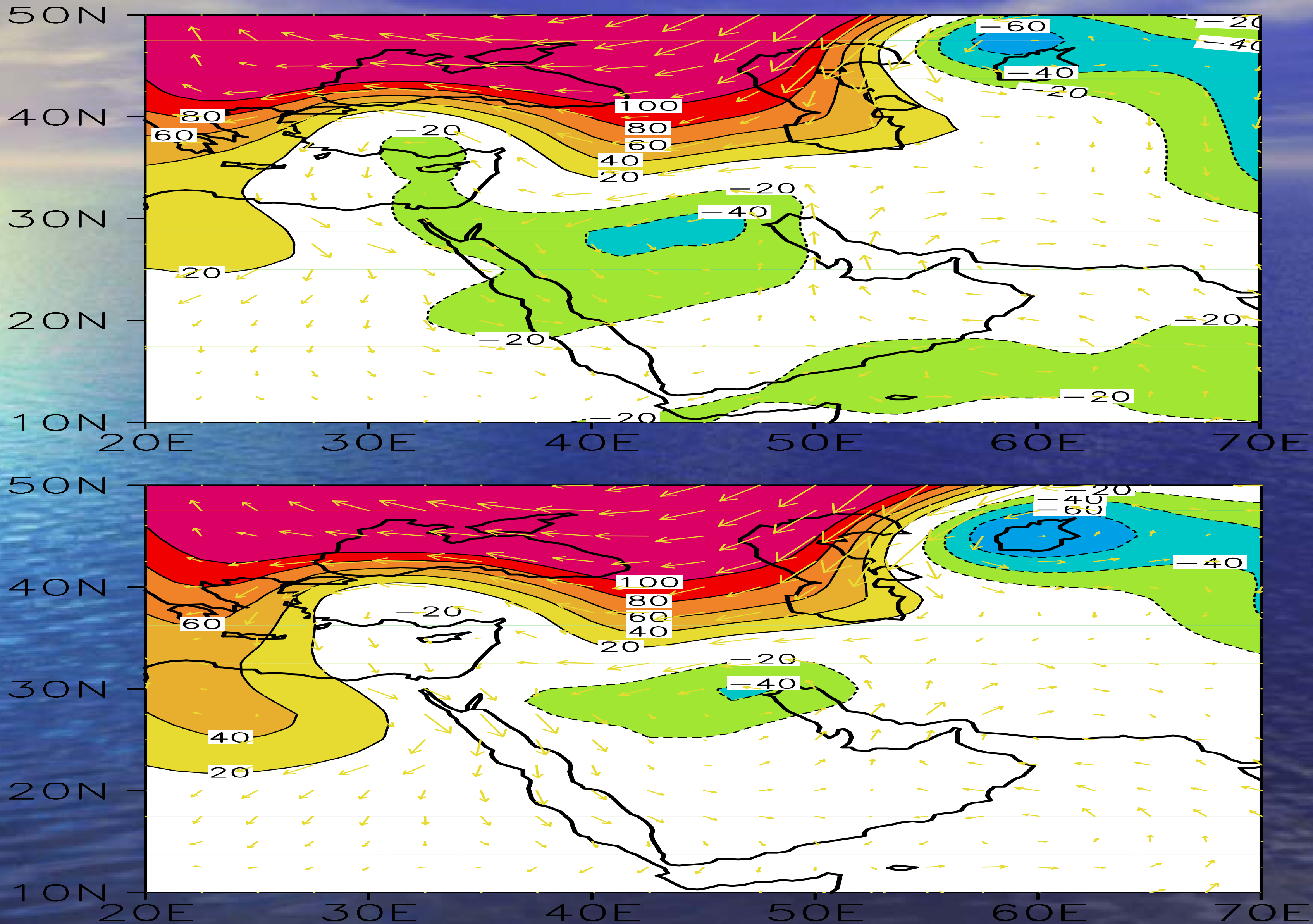
Type-2


50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E
80
60
40
20
−20
−40
−60
−80
−100
100

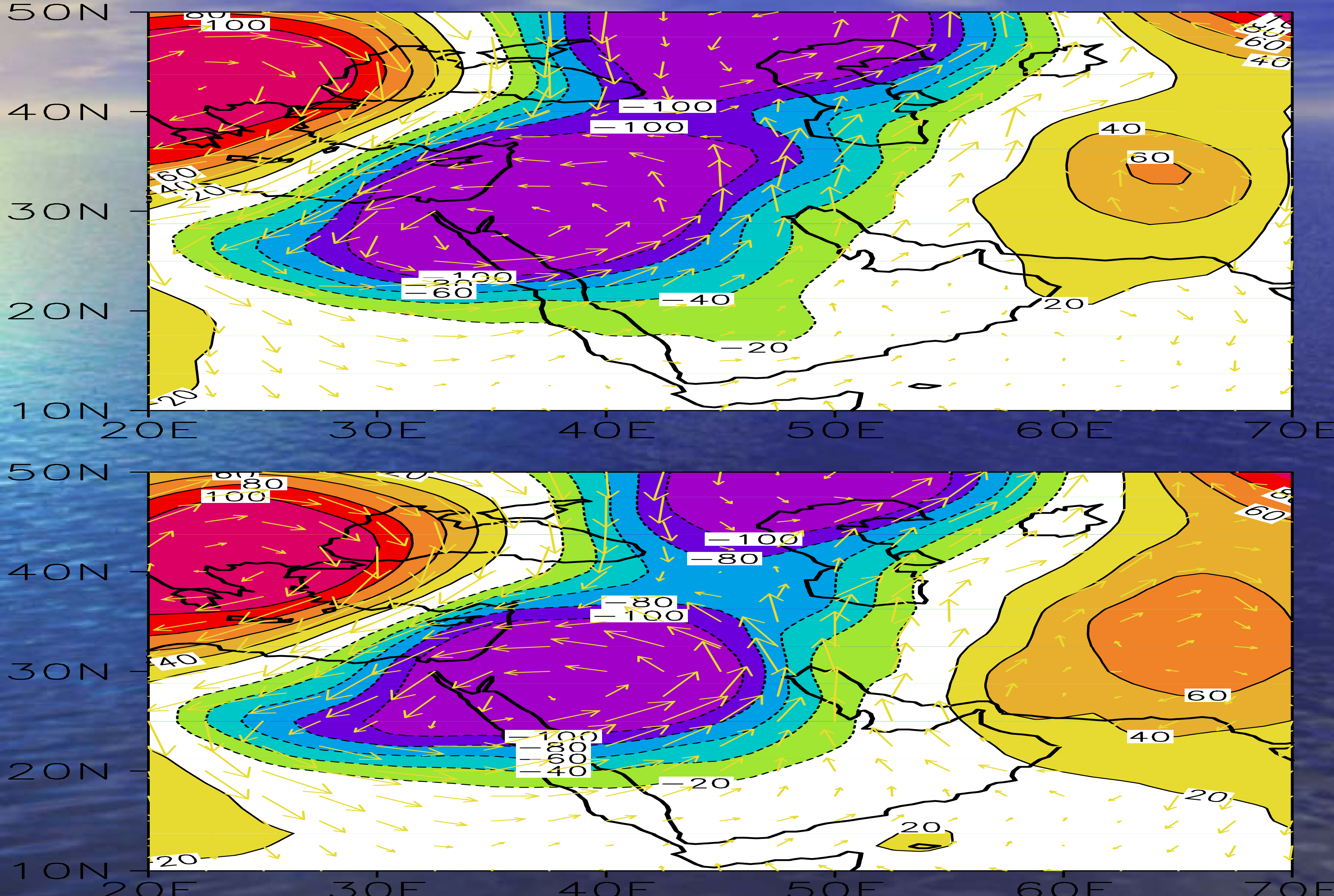
Type-2



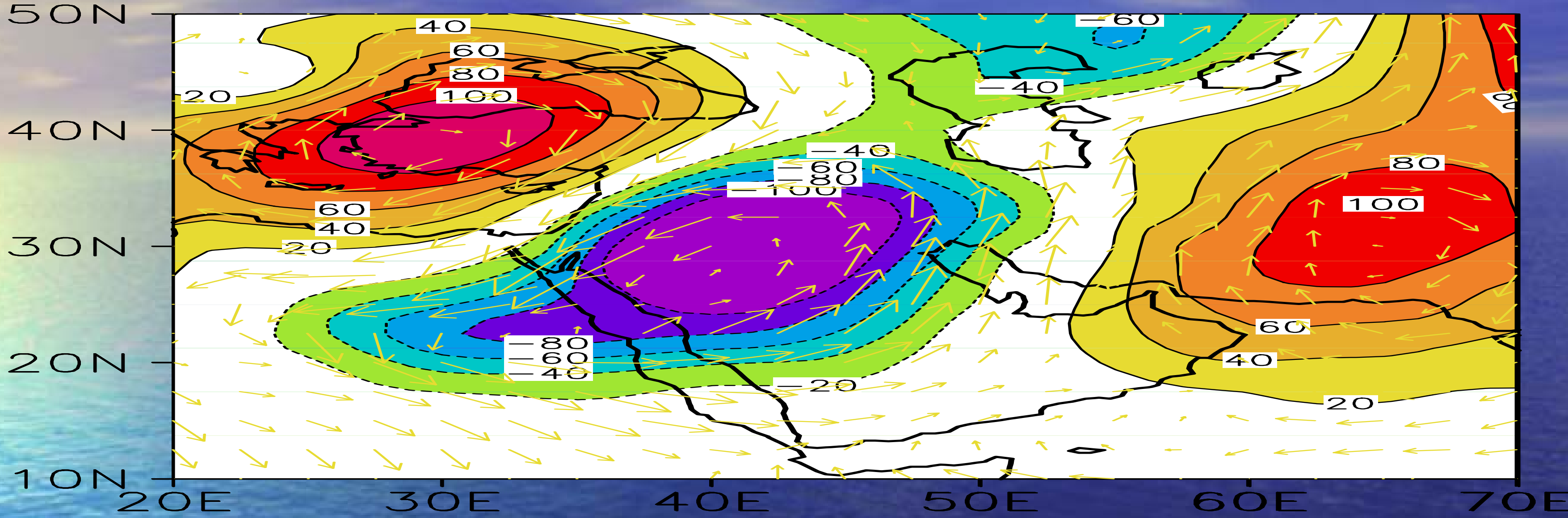
Type-2


50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E
100
80
60
40
20
−20
−40
−60

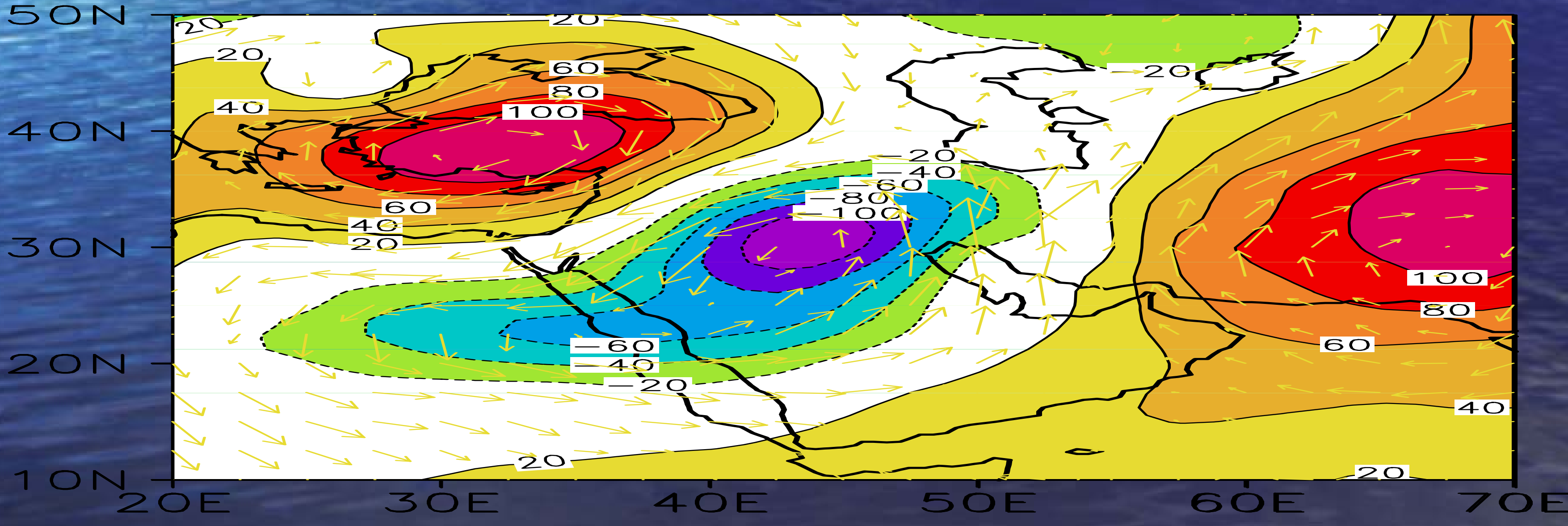
Type-3


50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E
100
−100
−100
−60
−40
−20
40
60
20
−100
−80
−80
−100
−100
−80
−60
−40
−20
80
100
40
60
40
20
20
20

Type-3



50N
40N
30N
20N
10N
20E
30E
40E
50E
60E
70E



50N
40N
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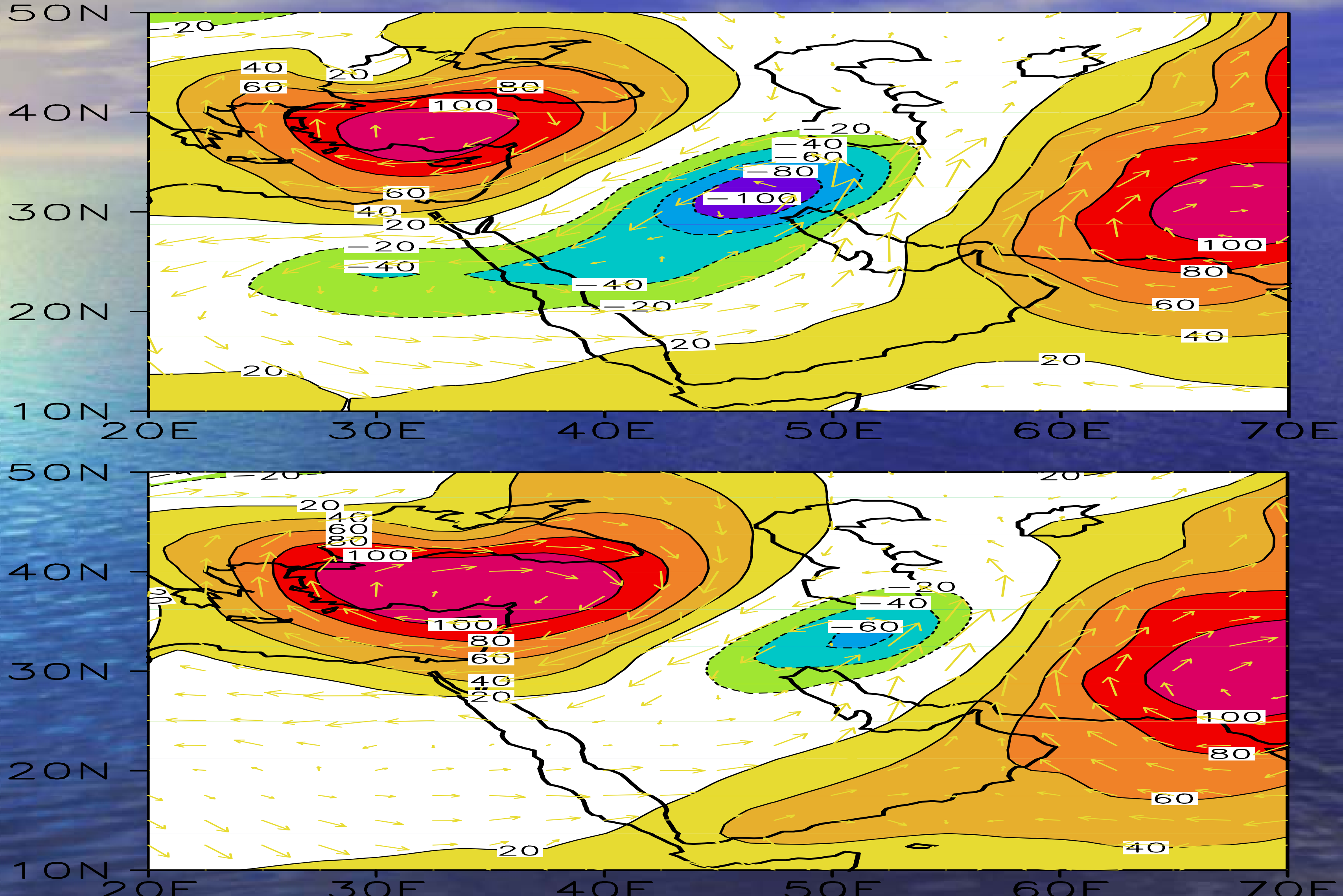
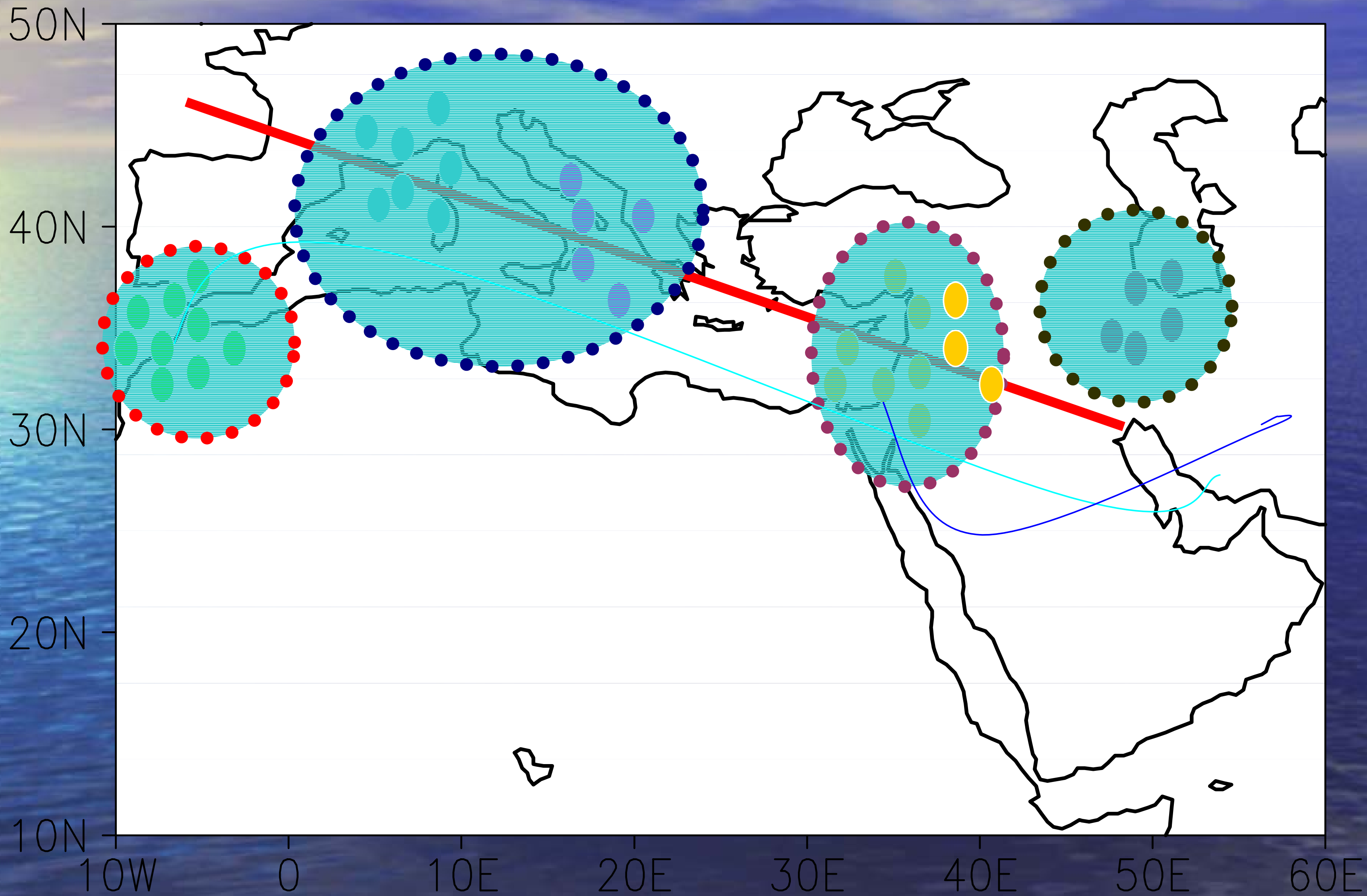
20N
10N
20E
30E
40E
50E
60E
70E

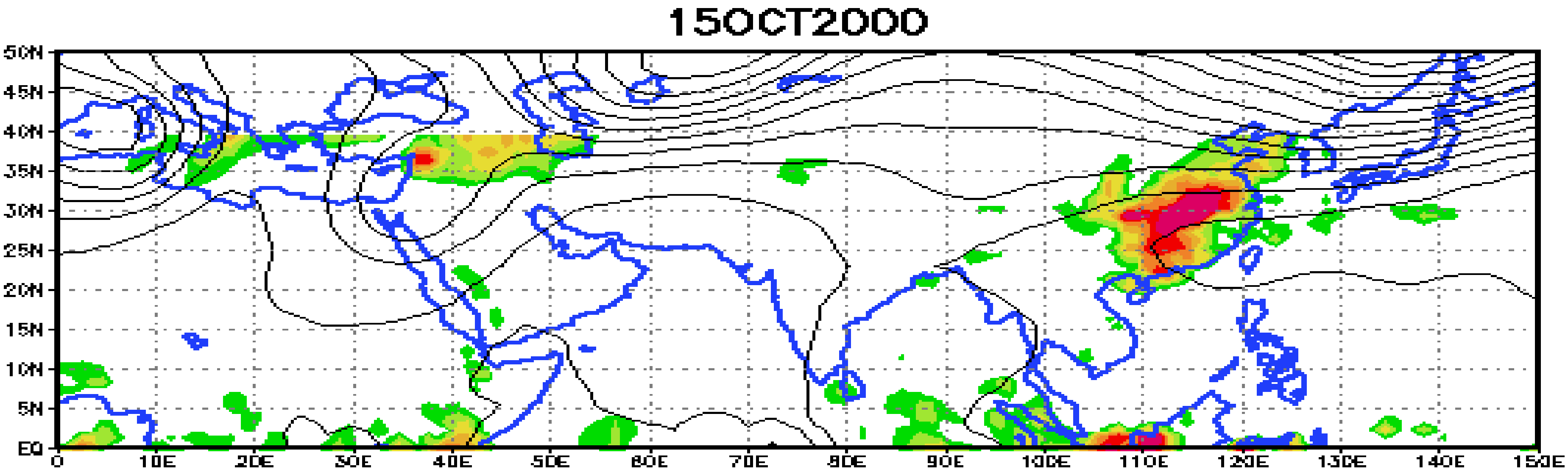
Type-3



G-ANAL
(JMA, 1.25X1.25)
(6 years: 1999 – 2004)

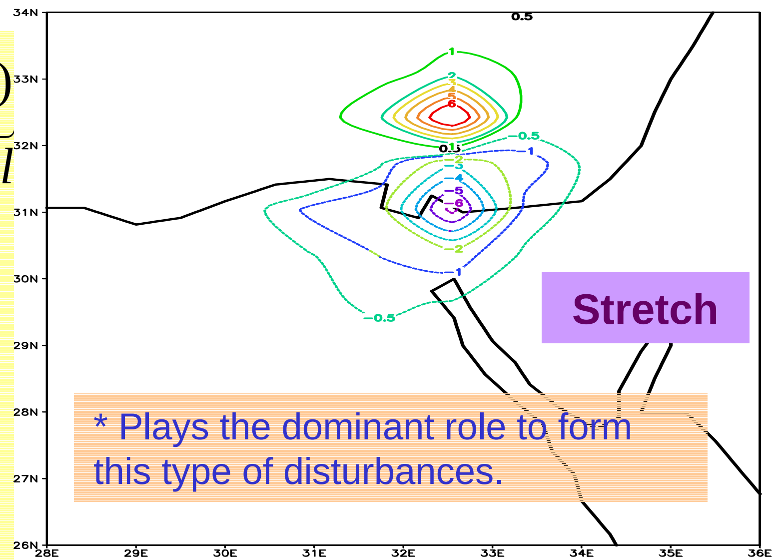


500 hPa Geopotential Height and Rainfall Animations – Note the influence of propagating western disturbances on the rainfall variability over Saudi Arabia

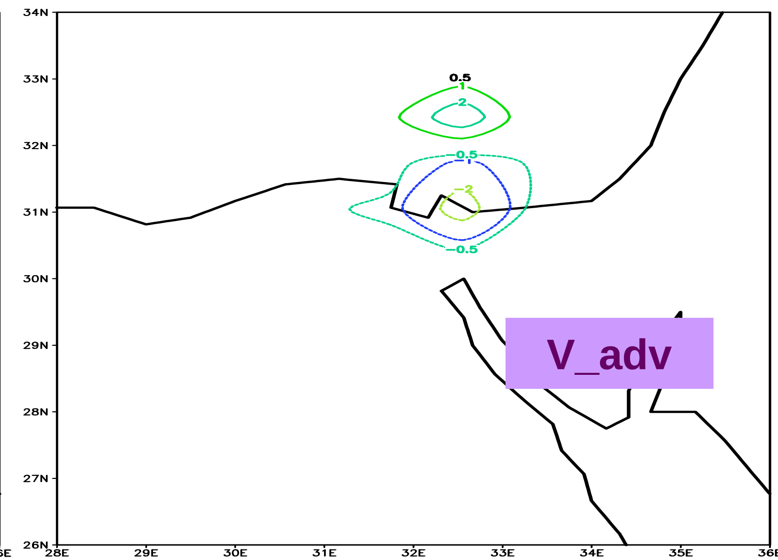


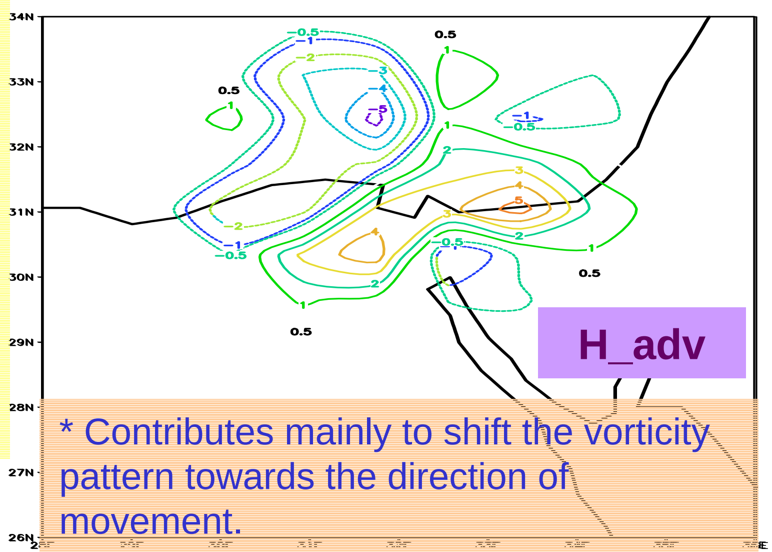
Vorticity Budget (900hPa)

$$\frac{\partial\varsigma}{\partial t}=\underbrace{-\vec{V}_h\bullet\vec{\nabla}_h(\varsigma+f)}_{Horizontal\ Advection}-\underbrace{\omega\frac{\partial\varsigma}{\partial p}}_{Vertical\ Advection}\underbrace{-(\varsigma+f)\vec{\nabla}_h\bullet\vec{V}_h}_{Stretching}\underbrace{-\hat{k}\bullet\left(\frac{\partial\vec{V}_h}{\partial p}\times\vec{\nabla}_h\right)}_{Tilting}+\underbrace{D_\varsigma}_{Frictional}$$

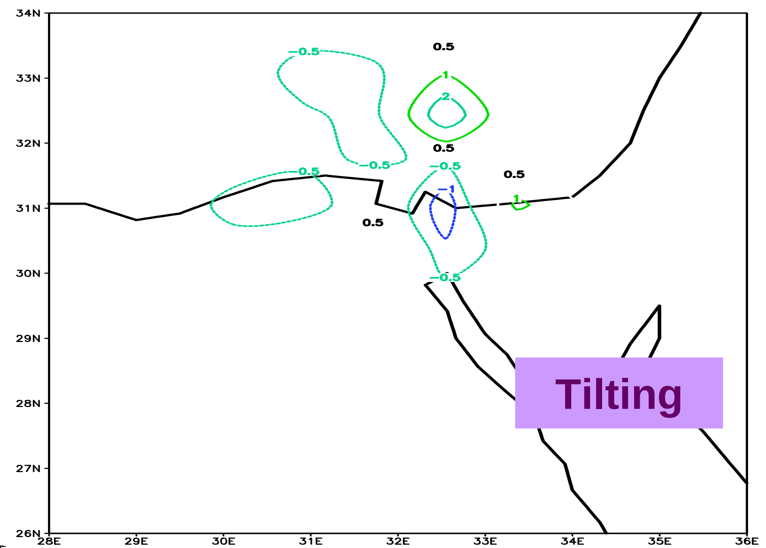


* Plays the dominant role to form this type of disturbances.





* Contributes mainly to shift the vorticity pattern towards the direction of movement.

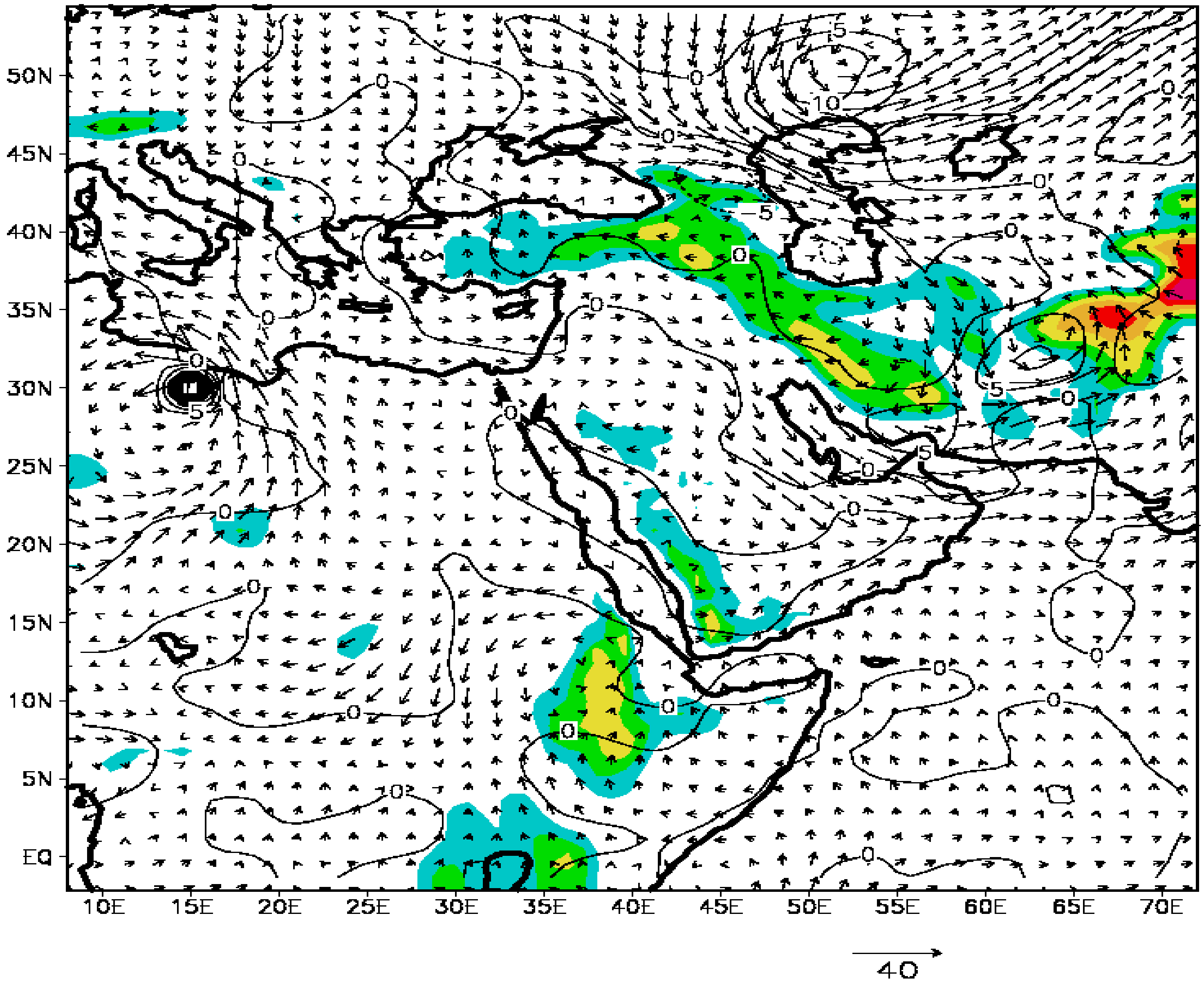


MM5 Simulation

- MM_run1 (90km resolution)
- MM_run2 (30km resolution)

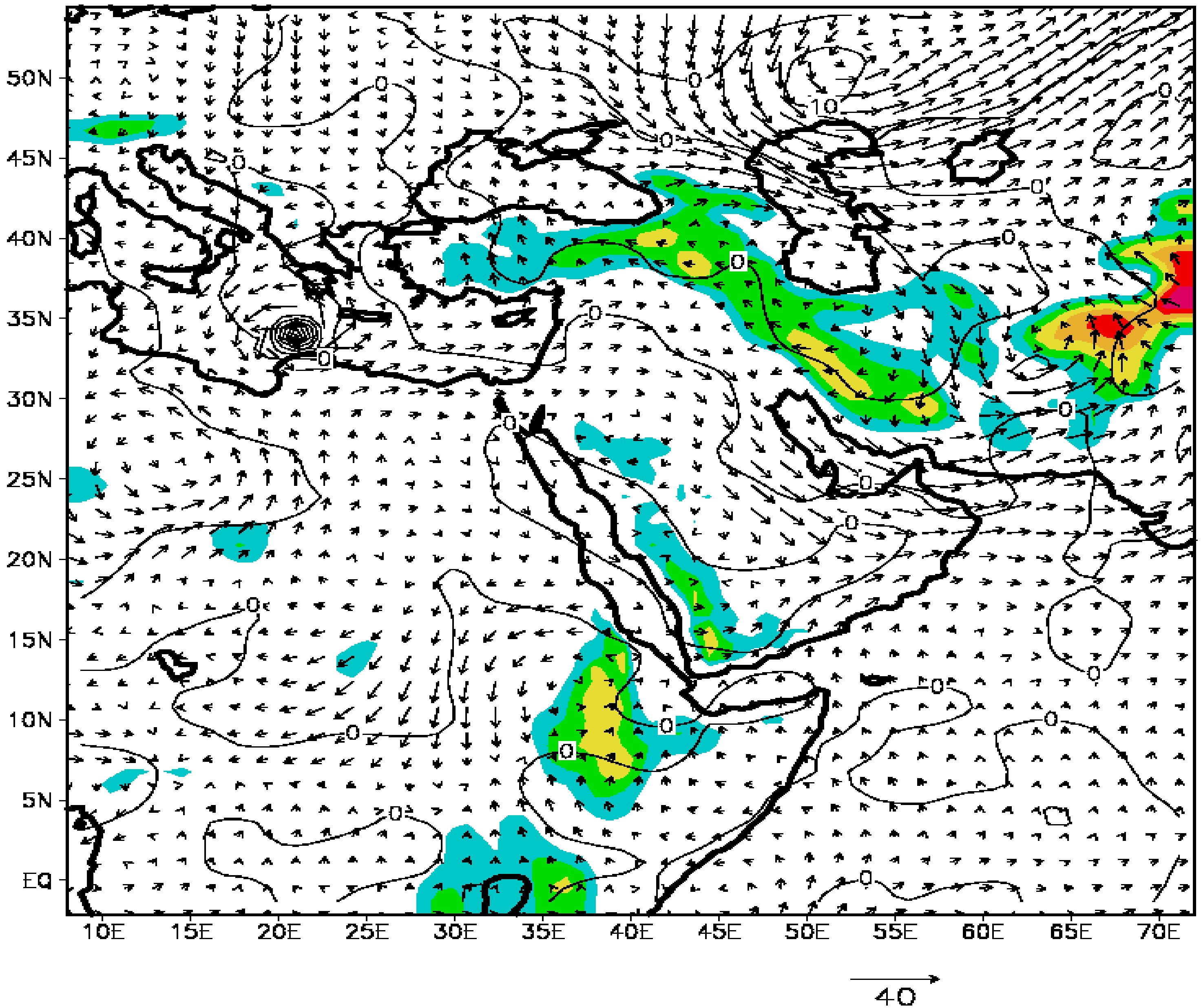
Simple ice physics, Kuo cumulus scheme, Bulk PBL fluxes, no multi layer soil temperature model, no shallow convection

MM_run1 (00hr)



50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
10E
15E
20E
25E
30E
35E
40E
45E
50E
55E
60E
65E
70E
40

MM_run1 (36hr)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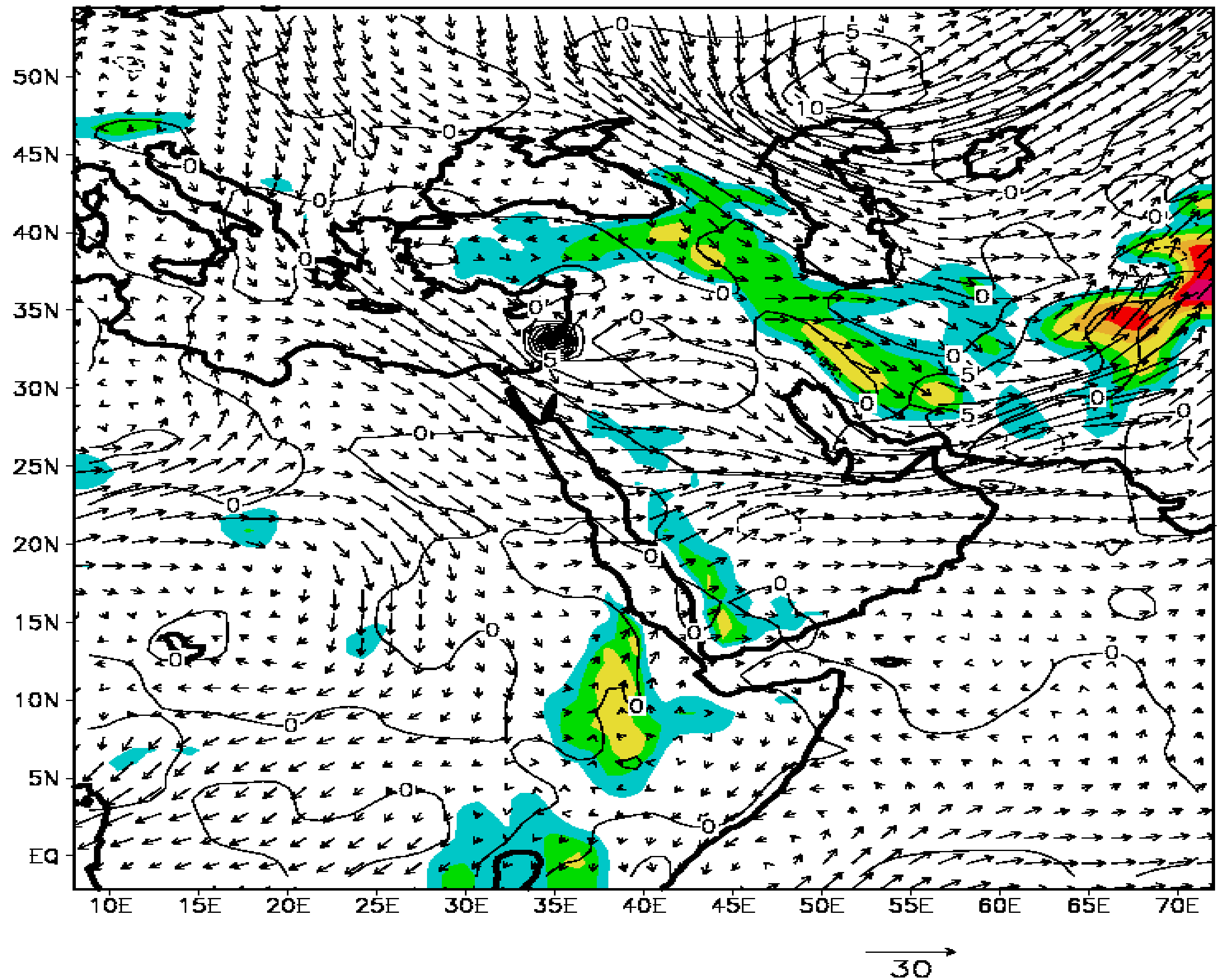
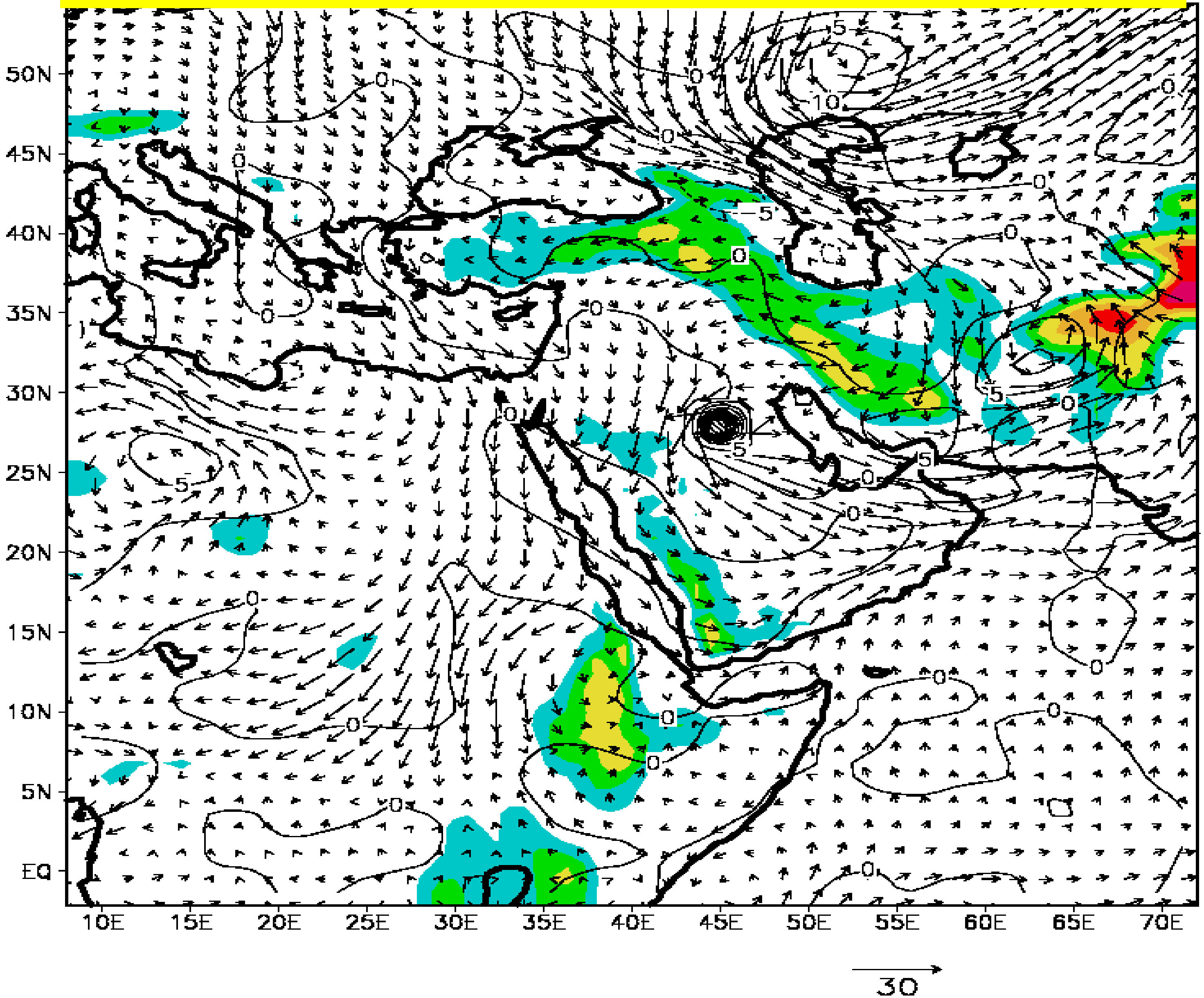
20N
15N
10N
5N
EQ
10E
15E
20E
25E
30E
35E
40E
45E
50E
55E
60E
65E
70E
40

MM_run1 (72hr)

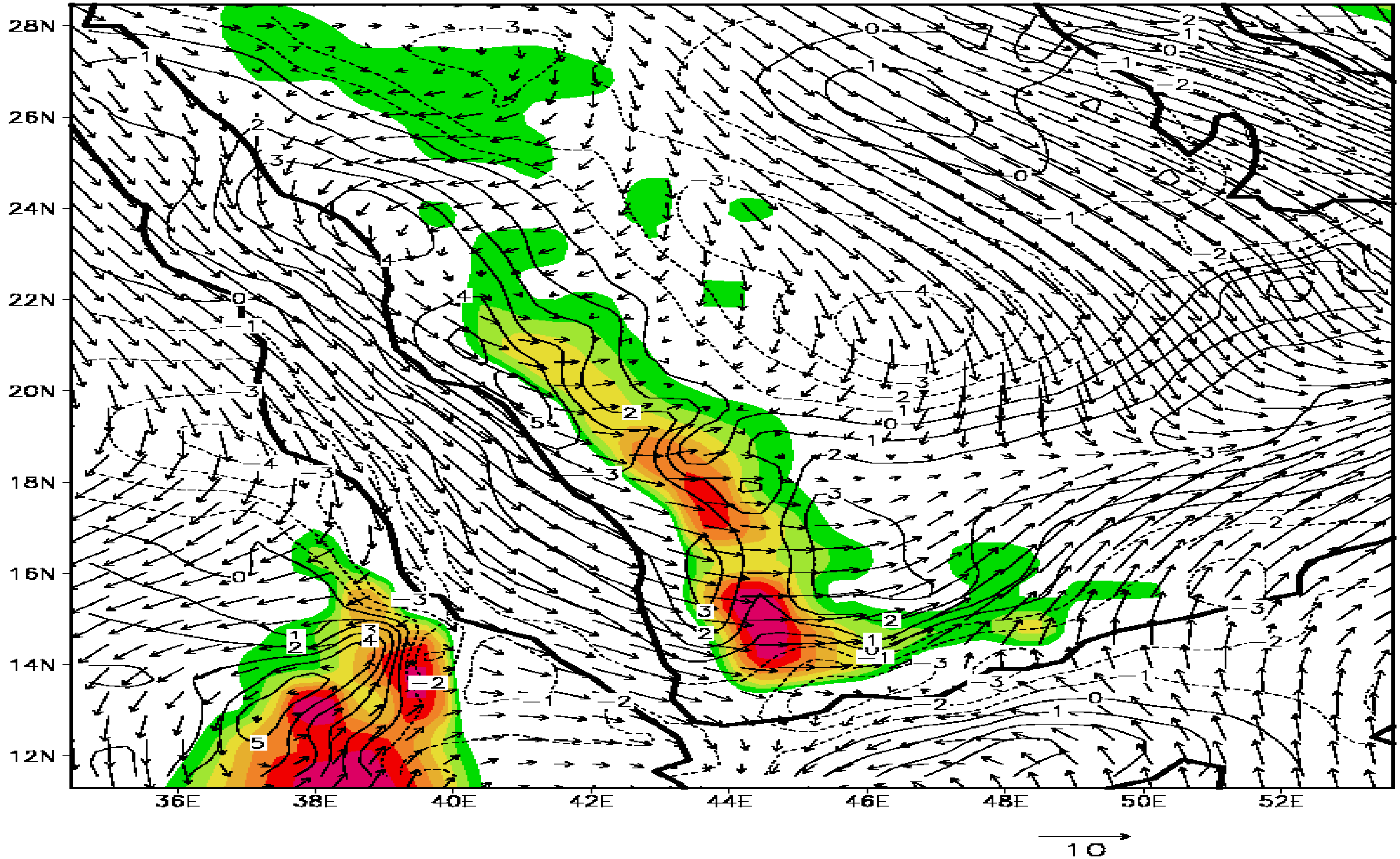


50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
10E
15E
20E
25E
30E
35E
40E
45E
50E
55E
60E
65E
70E
30

MM_run1 (108hr)

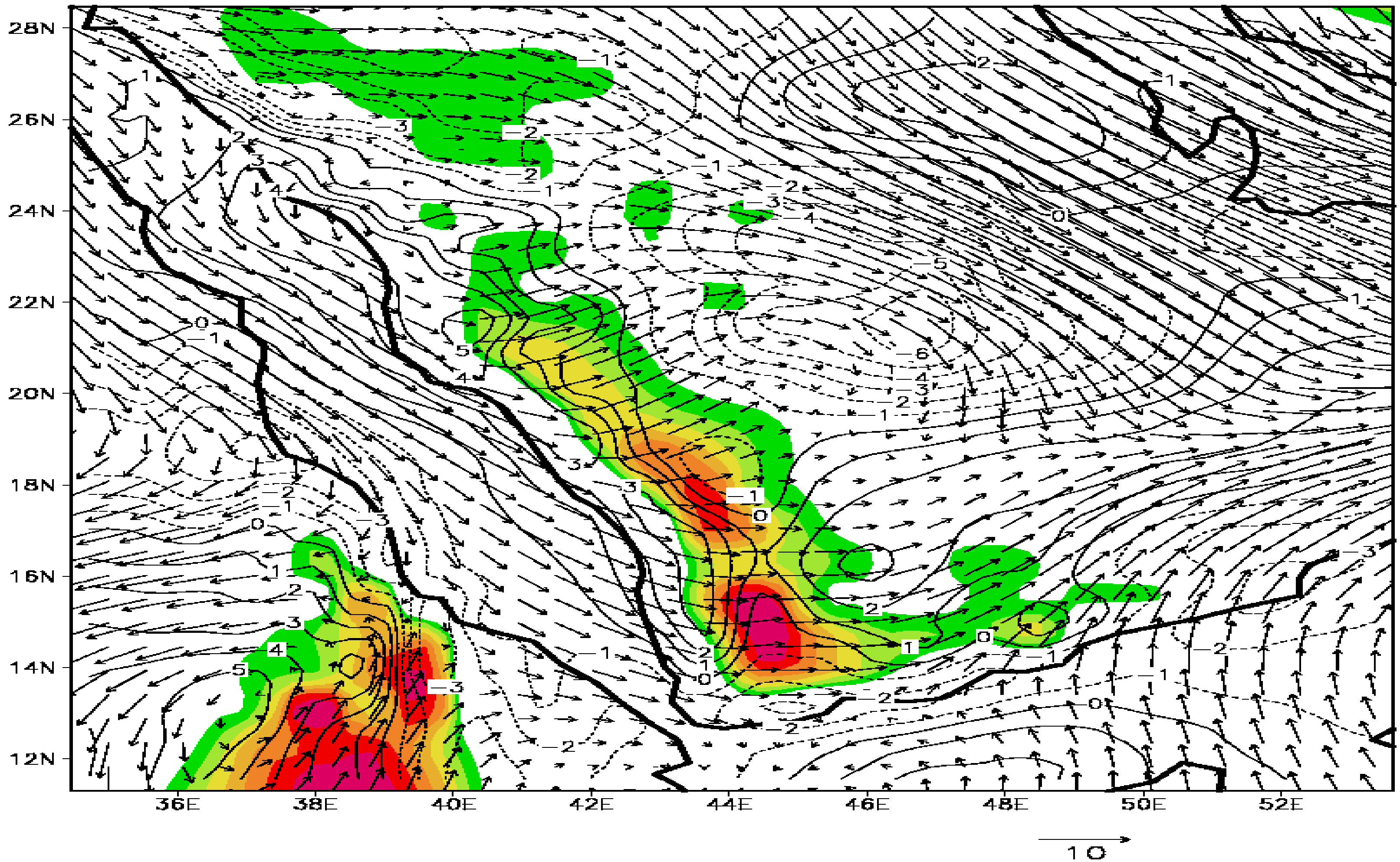


MM_run2 (36hr)



28N
26N
24N
22N
20N
18N
16N
14N
12N
36E
38E
40E
42E
44E
46E
48E
50E
52E
10

MM_run2 (72hr)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20N
18N
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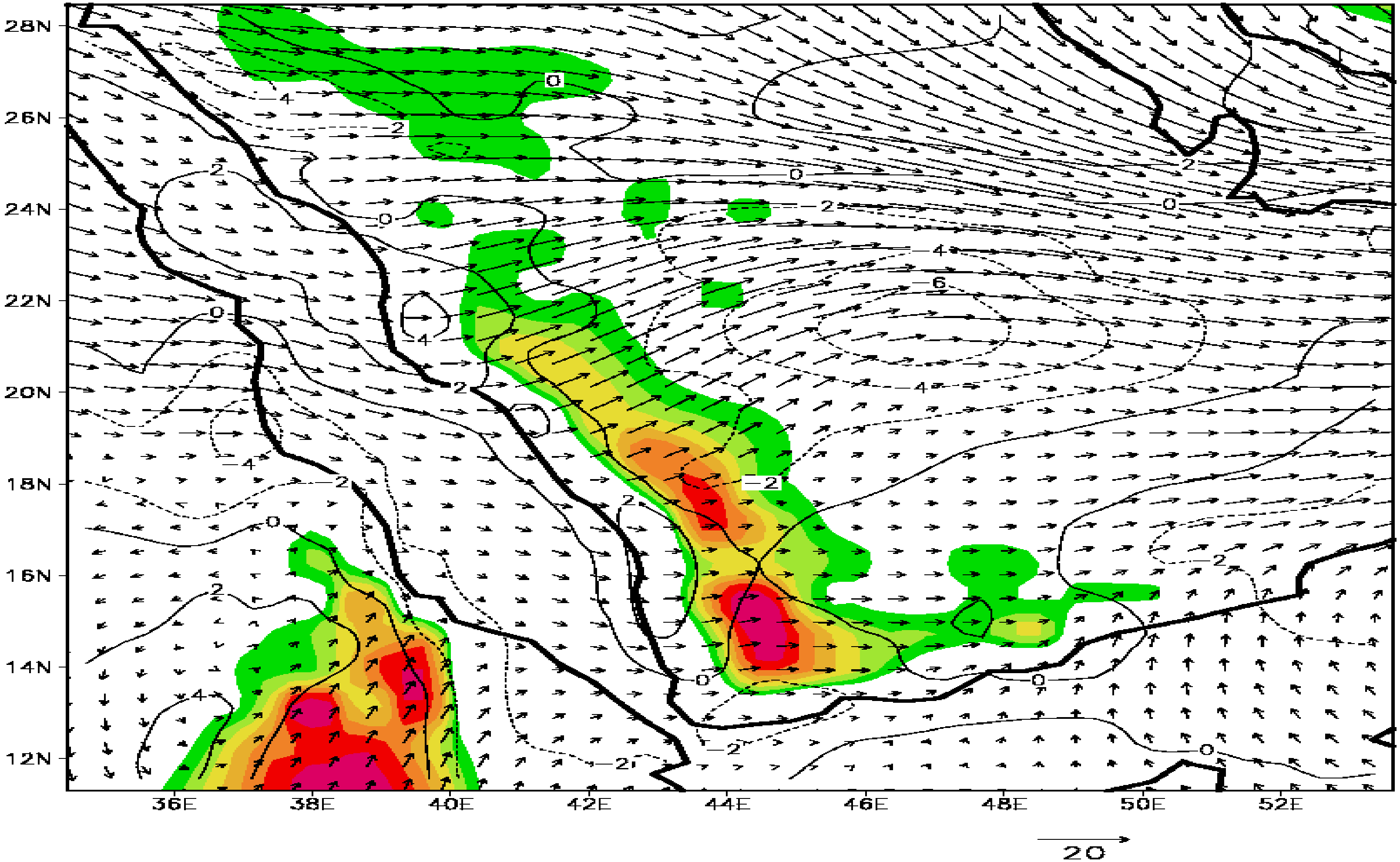
14N
12N
36E
38E
40E
42E
44E
46E
48E
50E
52E
10

MM_run2 (108hr)



Conclusions

- Semi-annual signal for moisture flux.
- Interannual variability of moisture flux due to tropical climatic signals like IOD and ENSO.
- Winter transients triggers Arabian Cyclone (??).
- Stretching and horizontal advection terms are the major contributors to the vorticity dynamics of the cyclone. Vertical advection and tilting terms are relatively weak.
- The horizontal advection term contributes mainly to shift the vorticity pattern toward the direction of the movement of the disturbance and does not contribute to amplify the vorticity.
- The stretching term plays the dominant role for this type of disturbance development..
- The distribution of horizontal advection term simply represents the fact that the vortex is advected by the north-westerly wind.

Future Work

- Details structure and their classifications.

- In order to understand the mechanism of development and propagation, high resolution MM5 sensitivity study for all kinds of disturbances by switching on-off (a) condensational heating, (b) surface sensible heat flux and (c) surface latent heat flux .

- How they are related to NAO, IOD and ENSO ?

Thank you

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