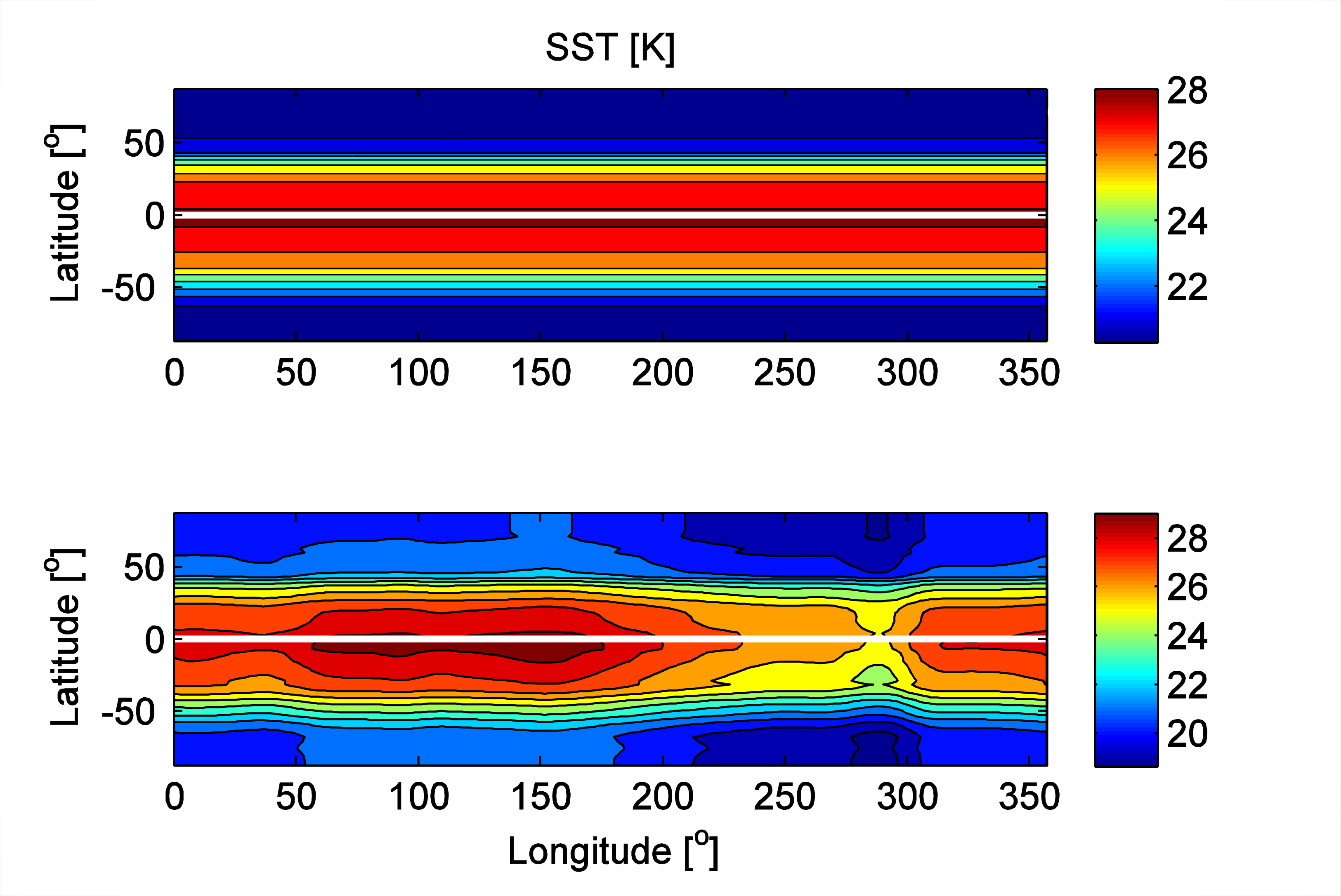
Effects of Zonal Asymmetries on Mean Tropical Climate and its Variability

Stipo Sentic, University of Notre Dame du Lac

Third Split Workshop in Atmospheric Physics and Oceanography, Croatia, 2011

Introduction

- NCAR Community Atmosphere Model 3
- T42 horizontal resolution (2.8^o x 2.8^o), and 26 vertical levels
- Perpetual March 21 insolation and ozone
- 5-year aquaplanet simulation with idealized SST boundary conditions
- First 3 months excluded

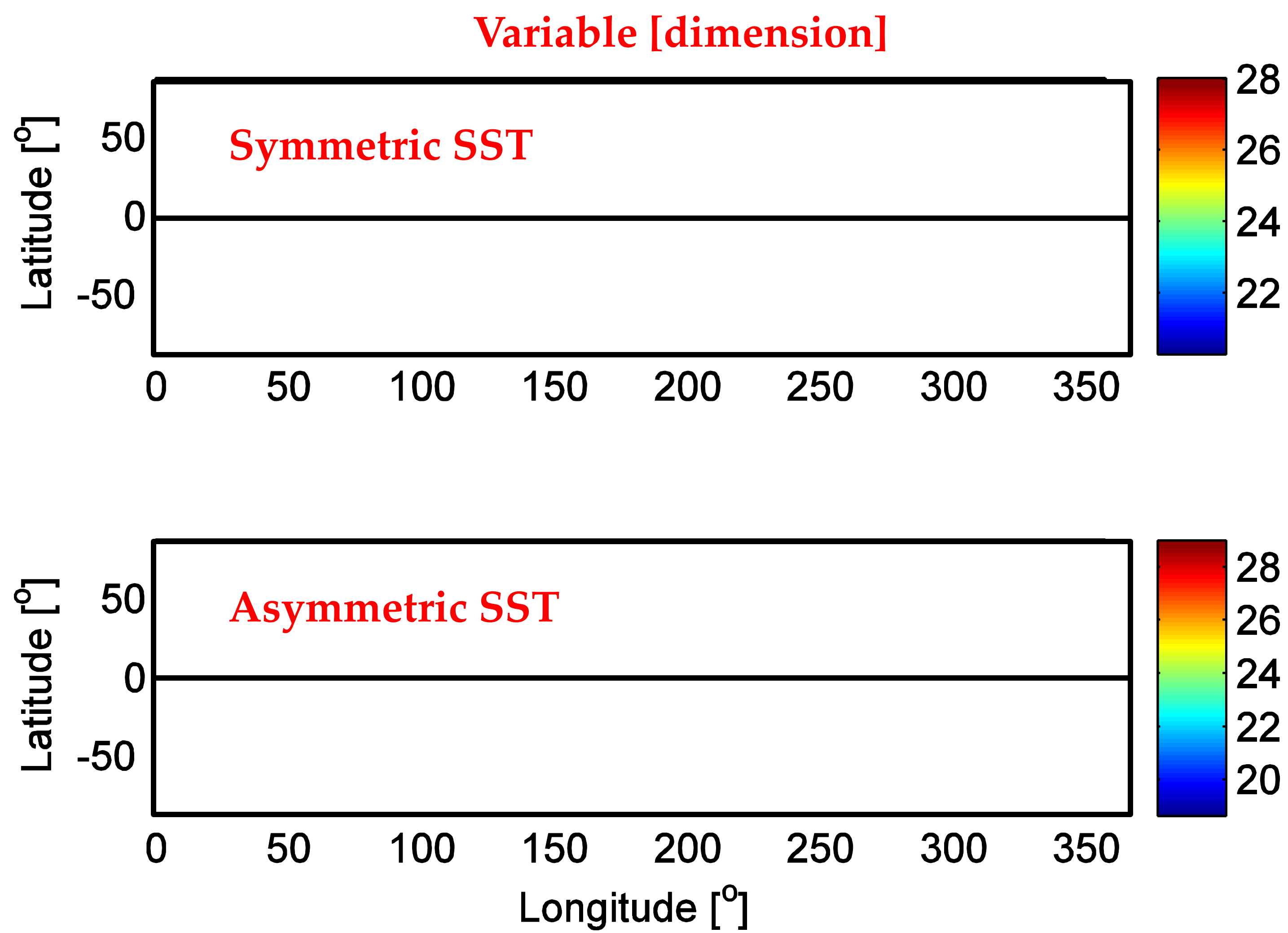

SST [K]
Latitude [°]
50
0
-50
0
50
100
150
200
250
300
350
28
26
24
22
Latitude [°]
50
0
-50
0
50
100
150
200
250
300
350
Longitude [°]
28
26
24
22
20

Introduction

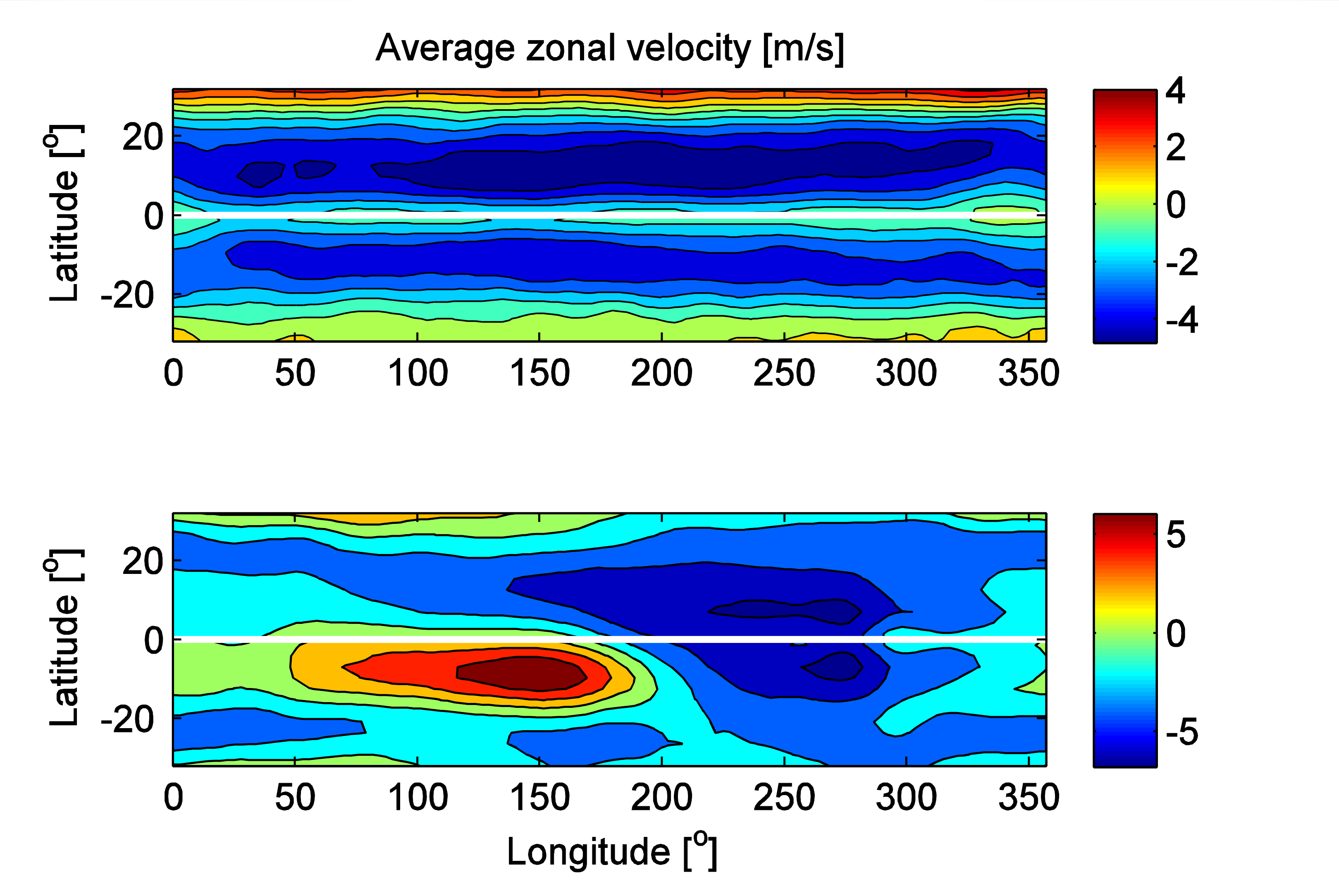
- Uncoupled from ocean (Kiranmayi and Maloney, 2010)
- Extratropical forcing
- Wind induced fluxes important
- Quarter meridional SST gradient zonally asymmetric simulation
- Zonal average (zonally symmetric) of the same

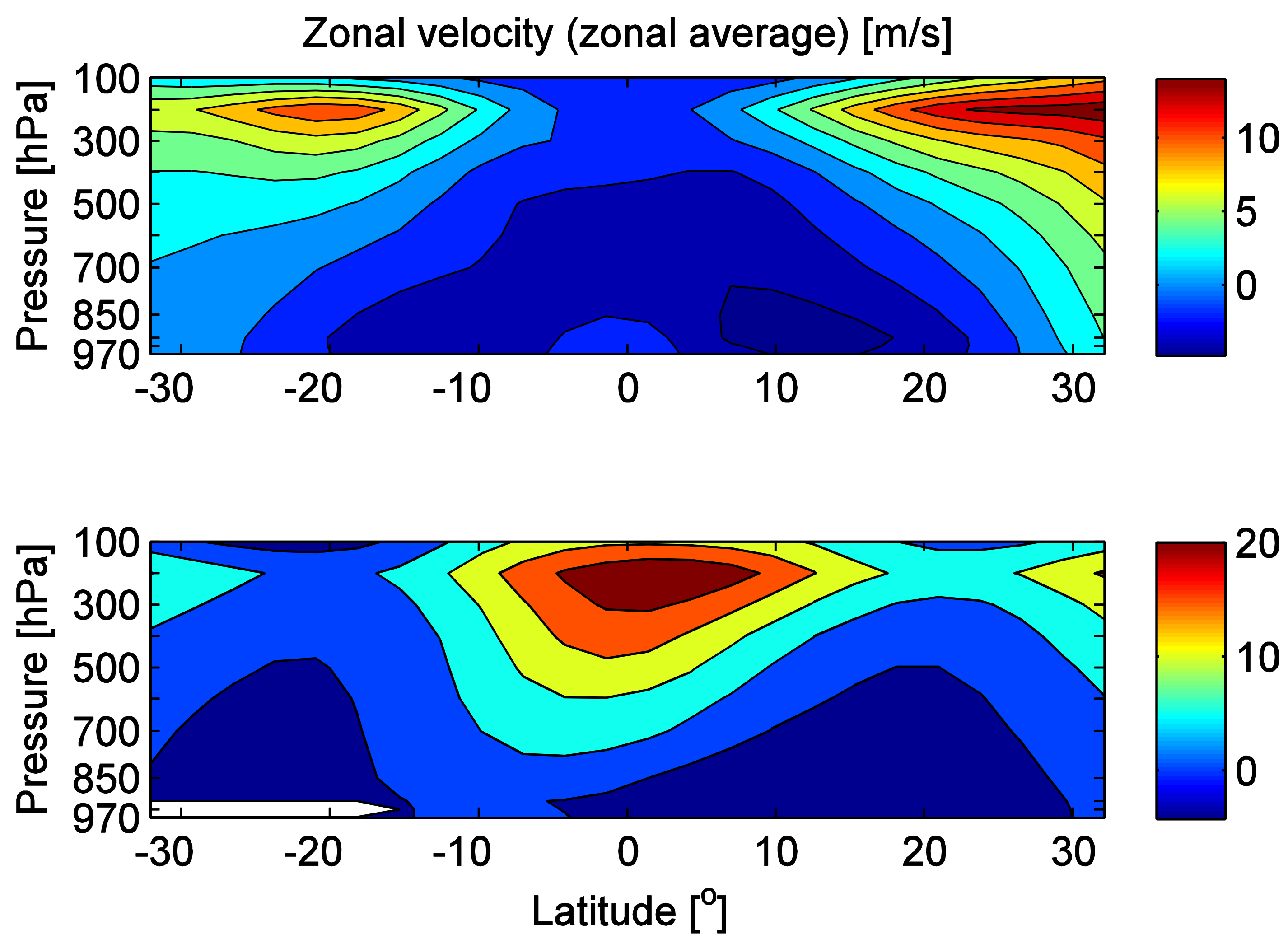
Introduction

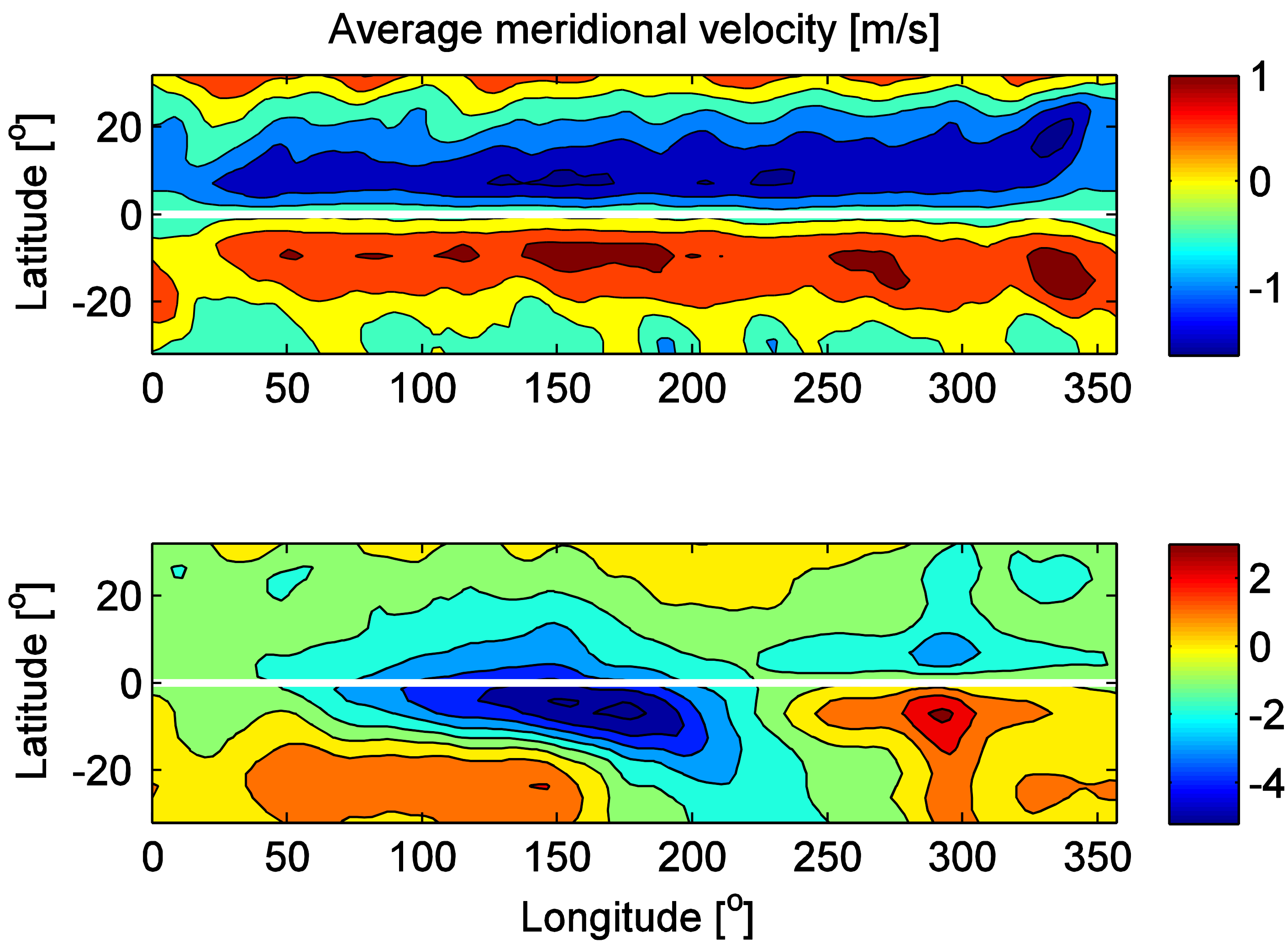
- Hypothesis:
  Zonally asymmetric model -> weak or negative GMS in regions of increased SST
- Outline: mean climate, NGMS, conclusions



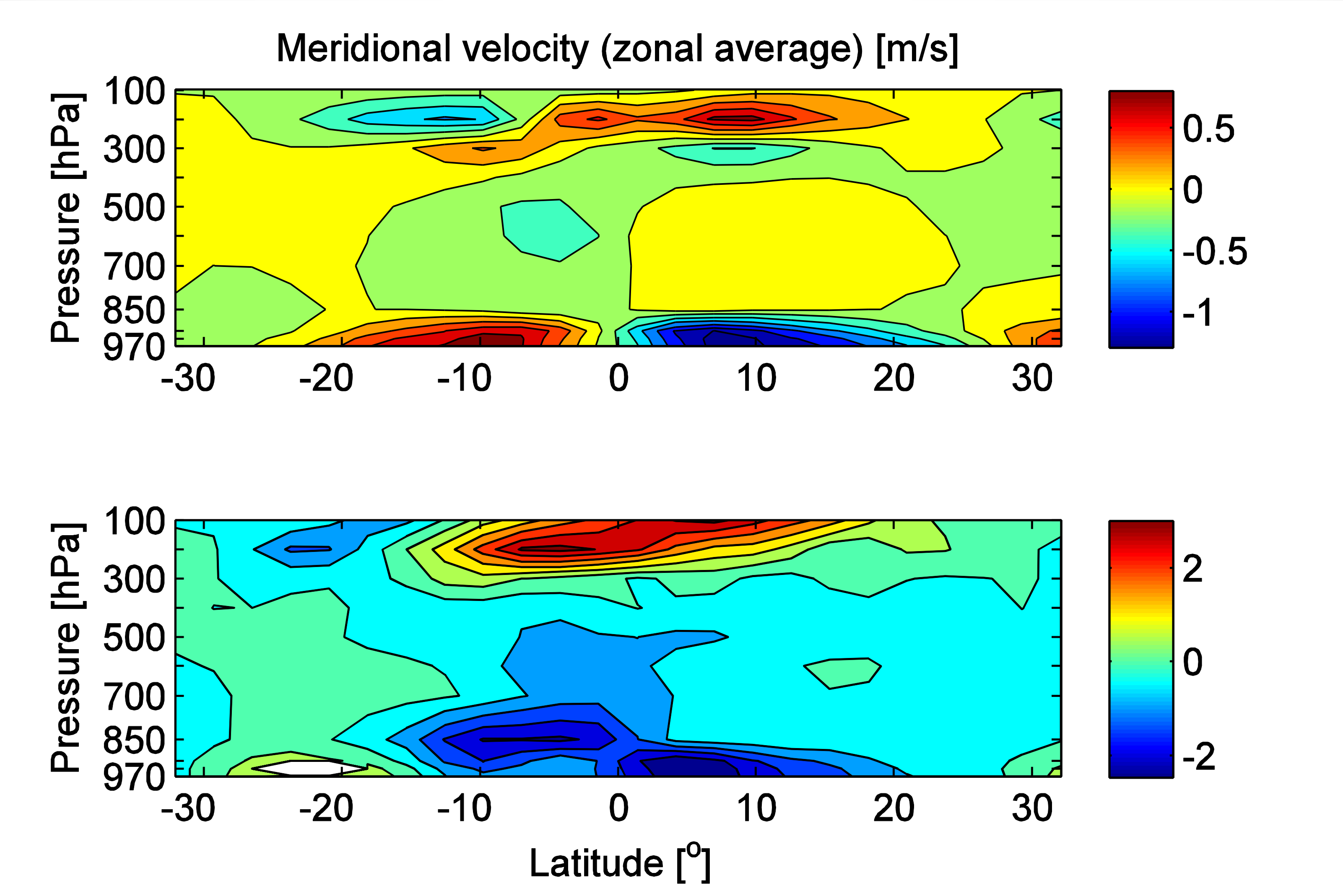
Variable [dimension]
Symmetric SST
Asymmetric SST
Latitude [°]
50
0
-50
0
50
100
150
200
250
300
350
28
26
24
22
20
Longitude [°]


Average zonal velocity [m/s]
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
4
2
0
-2
-4
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [o]
5
0
-5

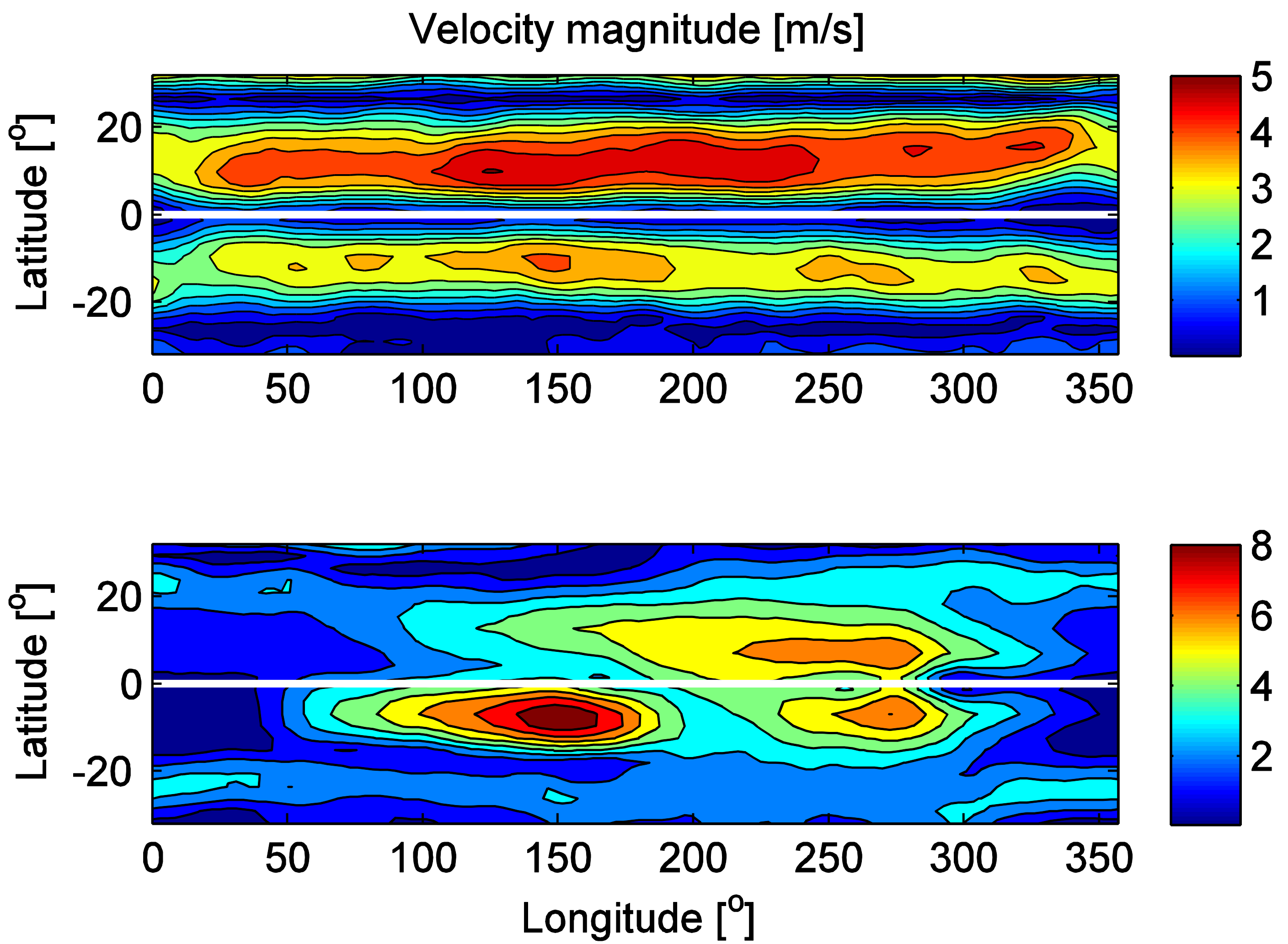

Zonal velocity (zonal average) [m/s]
Pressure [hPa]
100
300
500
700
850
970
-30
-20
-10
0
10
20
30
10
5
0
Pressure [hPa]
100
300
500
700
850
970
-30
-20
-10
0
10
20
30
Latitude [^{o}]
20
10
0

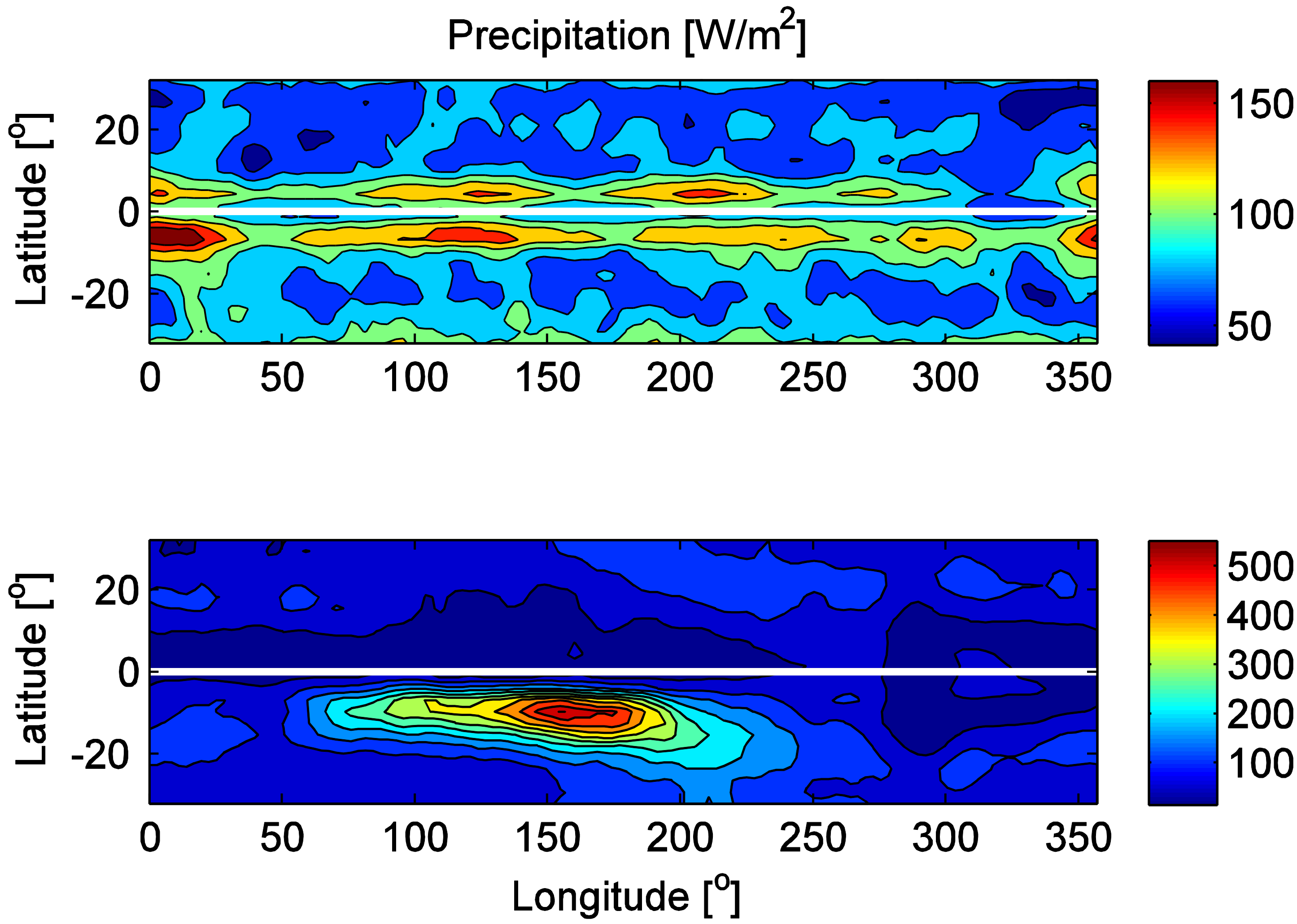


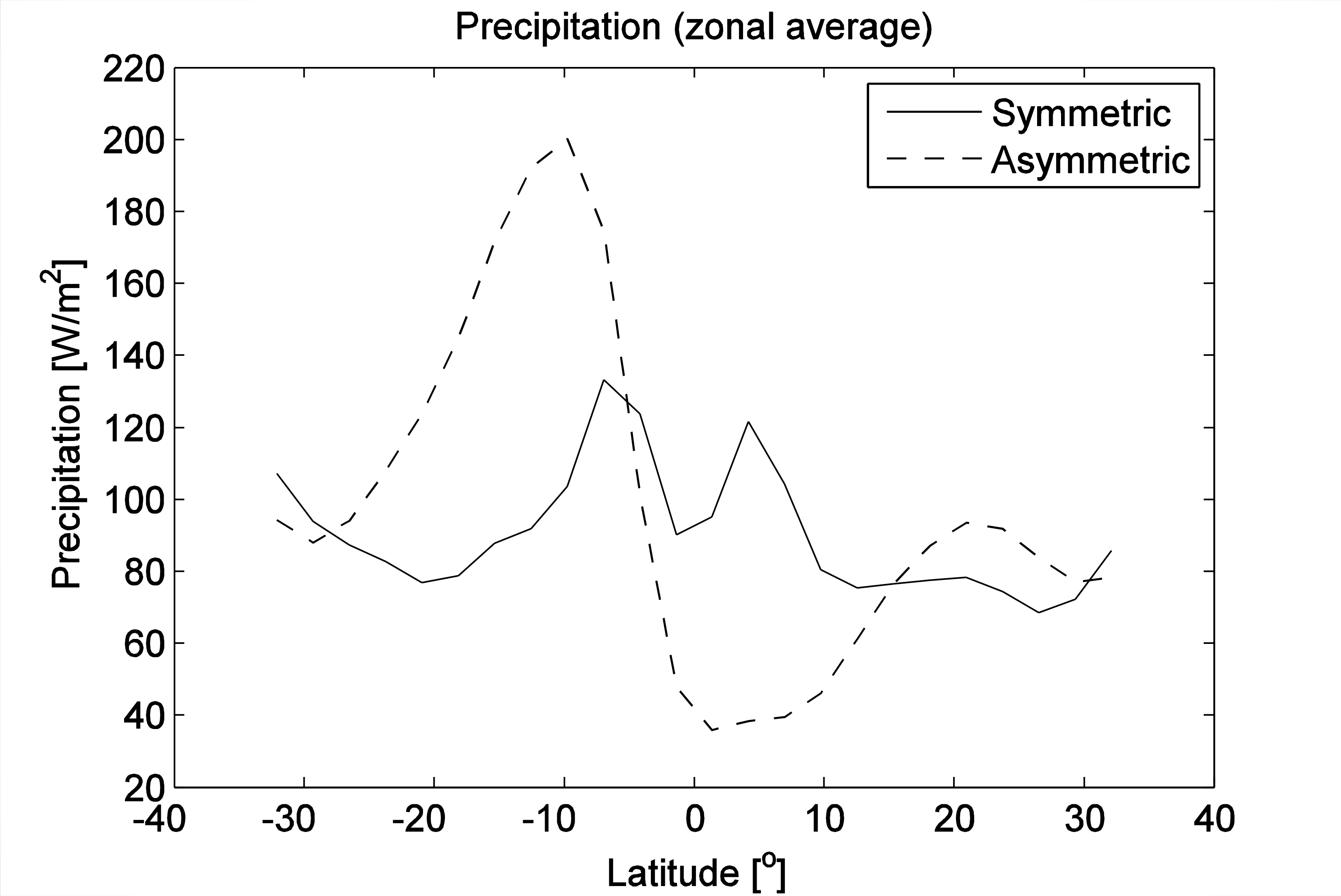
Average meridional velocity [m/s]
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
1
0
-1
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [°]
2
0
-2
-4



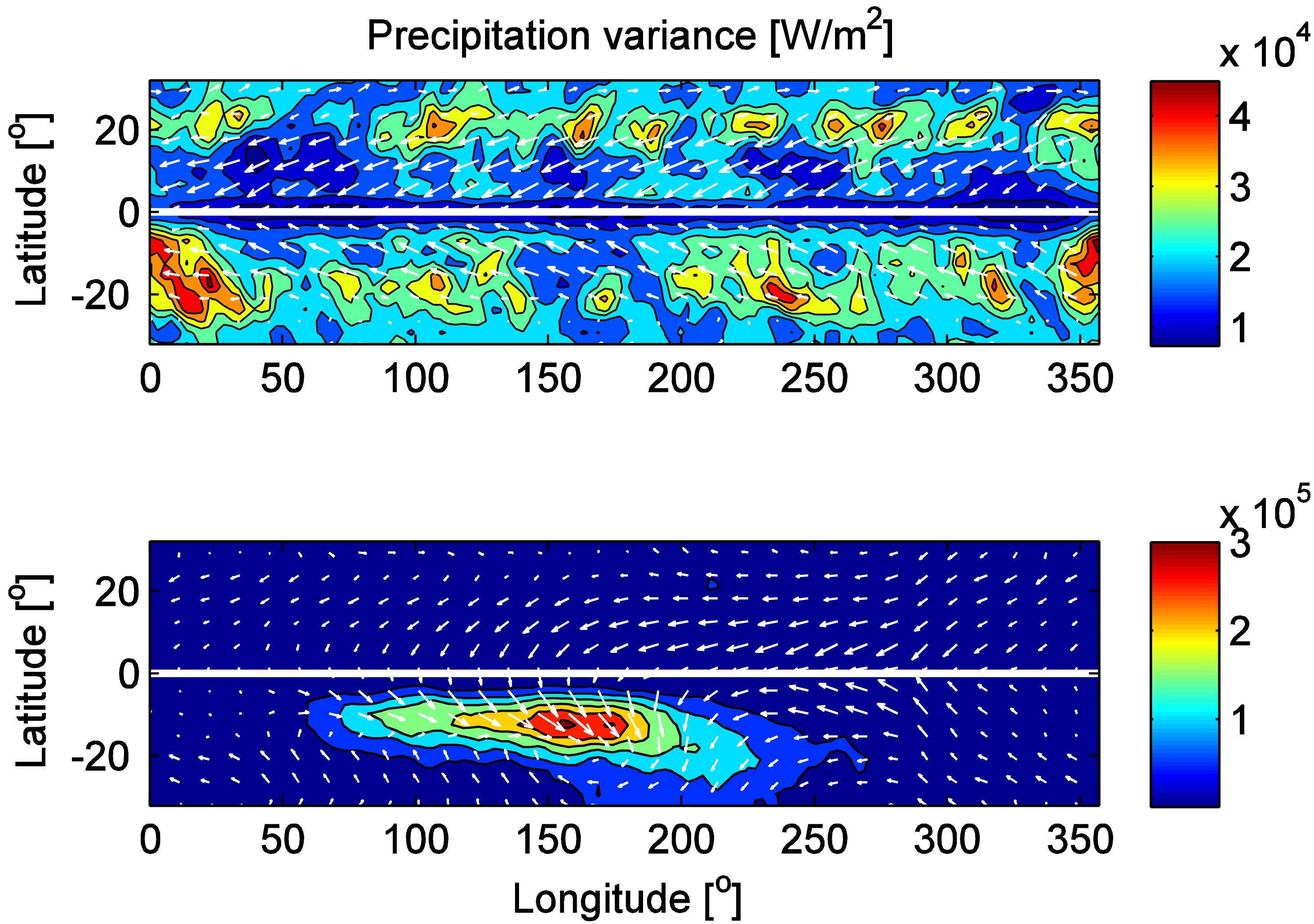
Meridional velocity (zonal average) [m/s]
Pressure [hPa]
100
300
500
700
850
970
-30
-20
-10
0
10
20
30
0.5
0
-0.5
-1
Pressure [hPa]
100
300
500
700
850
970
-30
-20
-10
0
10
20
30
2
0
-2
Latitude [o]


Velocity magnitude [m/s]
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
5
4
3
2
1
8
6
4
2
Longitude [°]

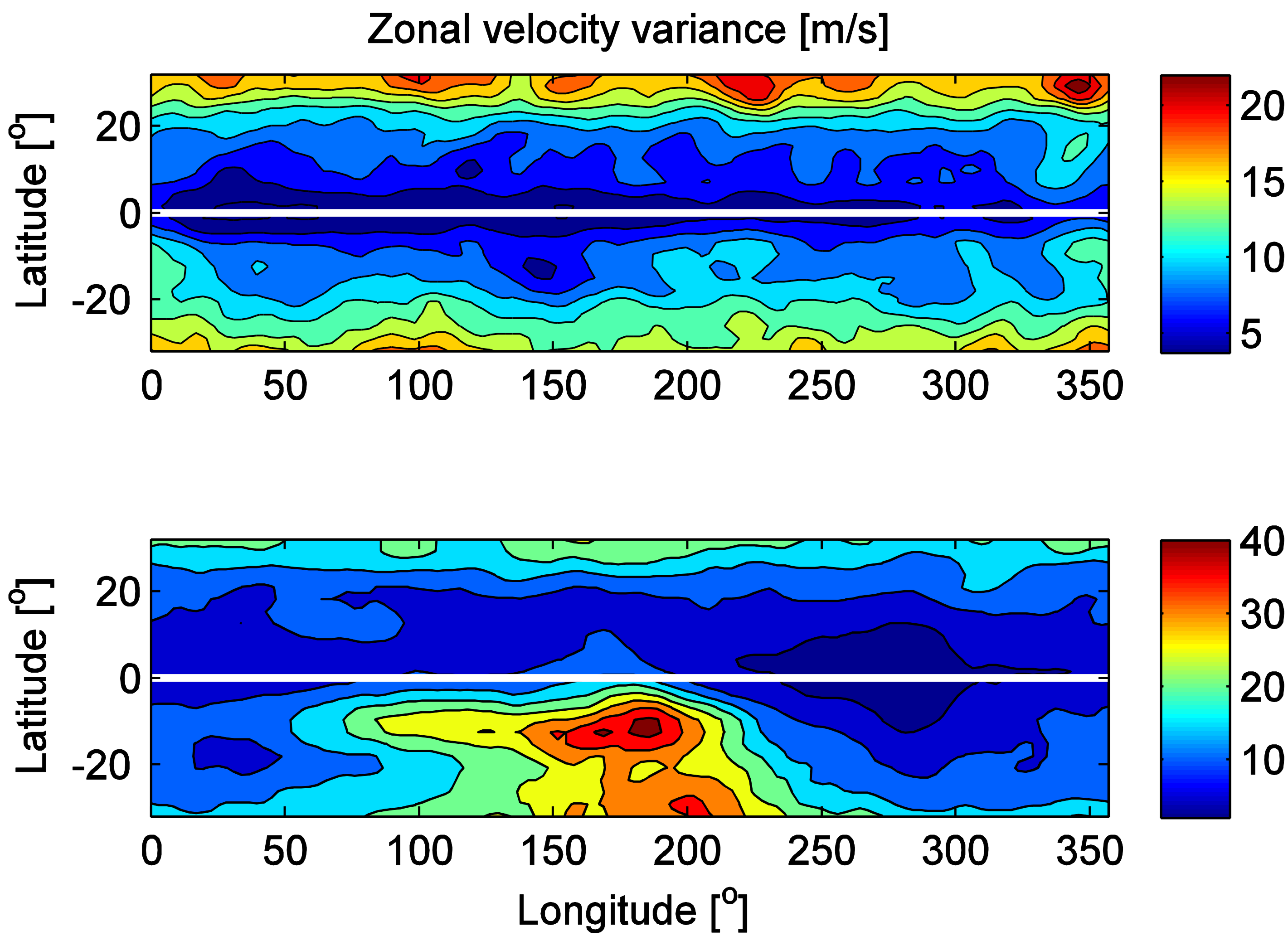

Precipitation [W/m2]
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
150
100
50
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [o]
500
400
300
200
100

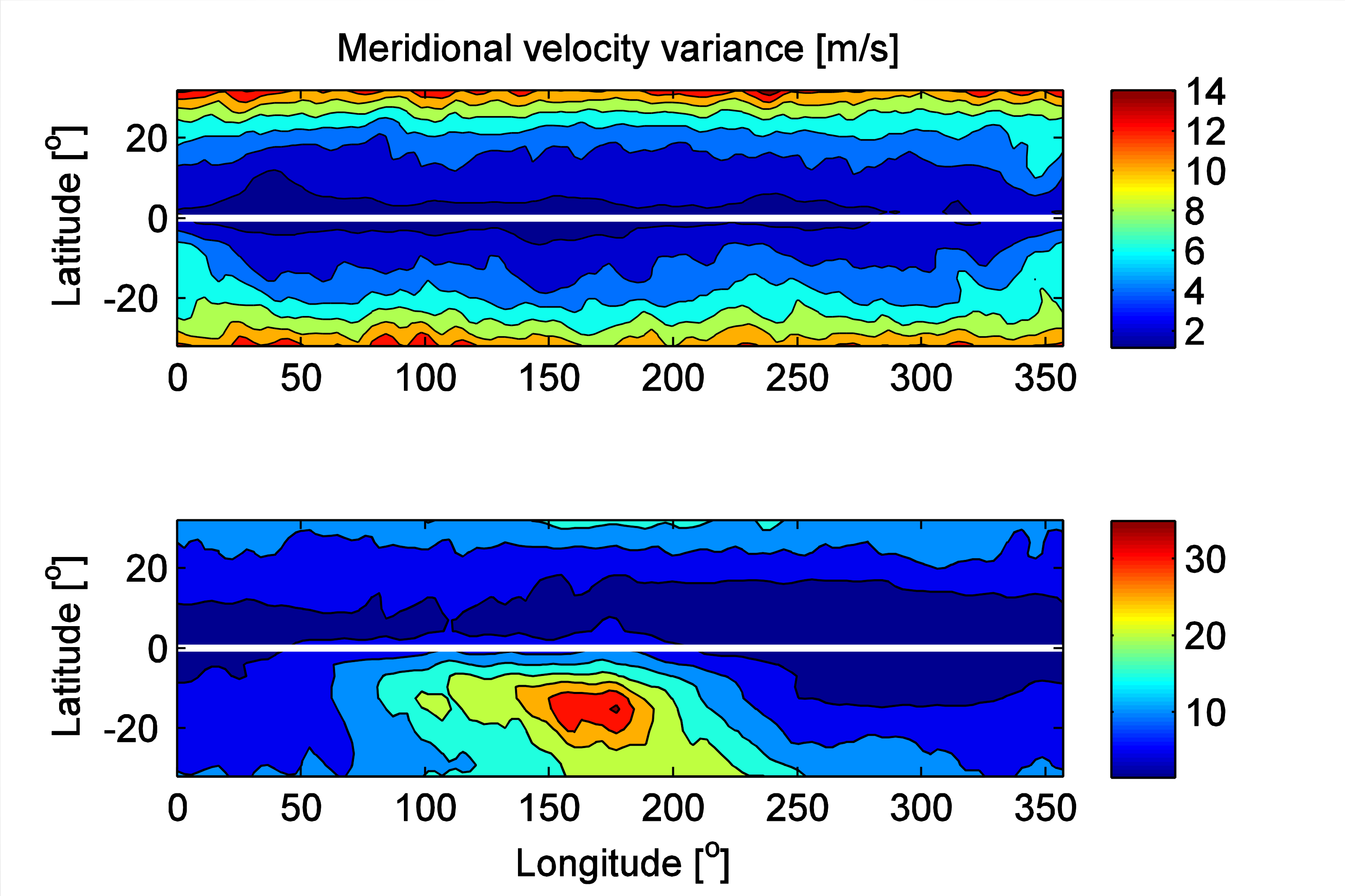


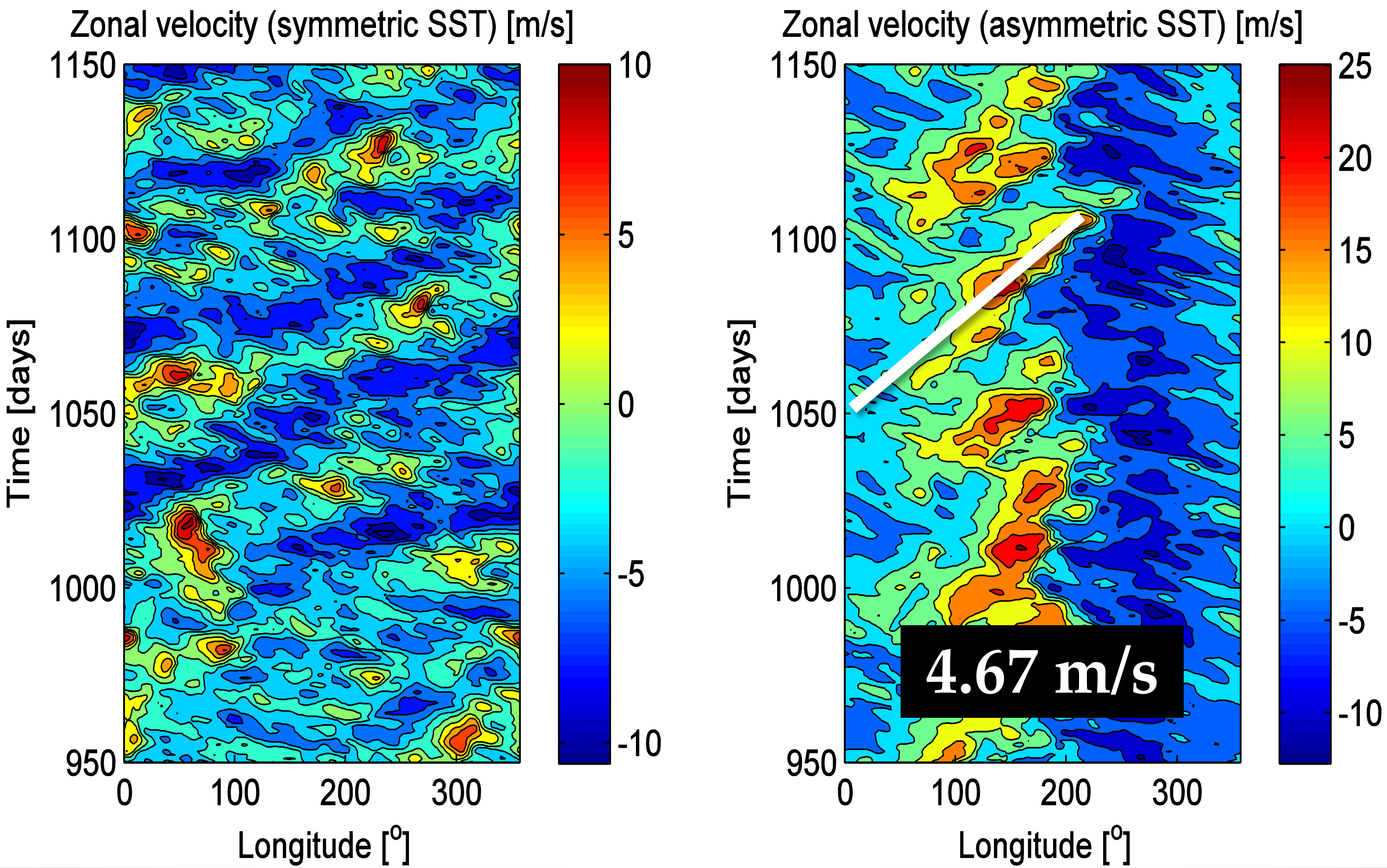
Precipitation (zonal average)
Symmetric
Asymmetric
Precipitation [W/m2]
Latitude [o]
220
200
180
160
140
120
100
80
60
40
20
-40
-30
-20
-10
0
10
20
30
40

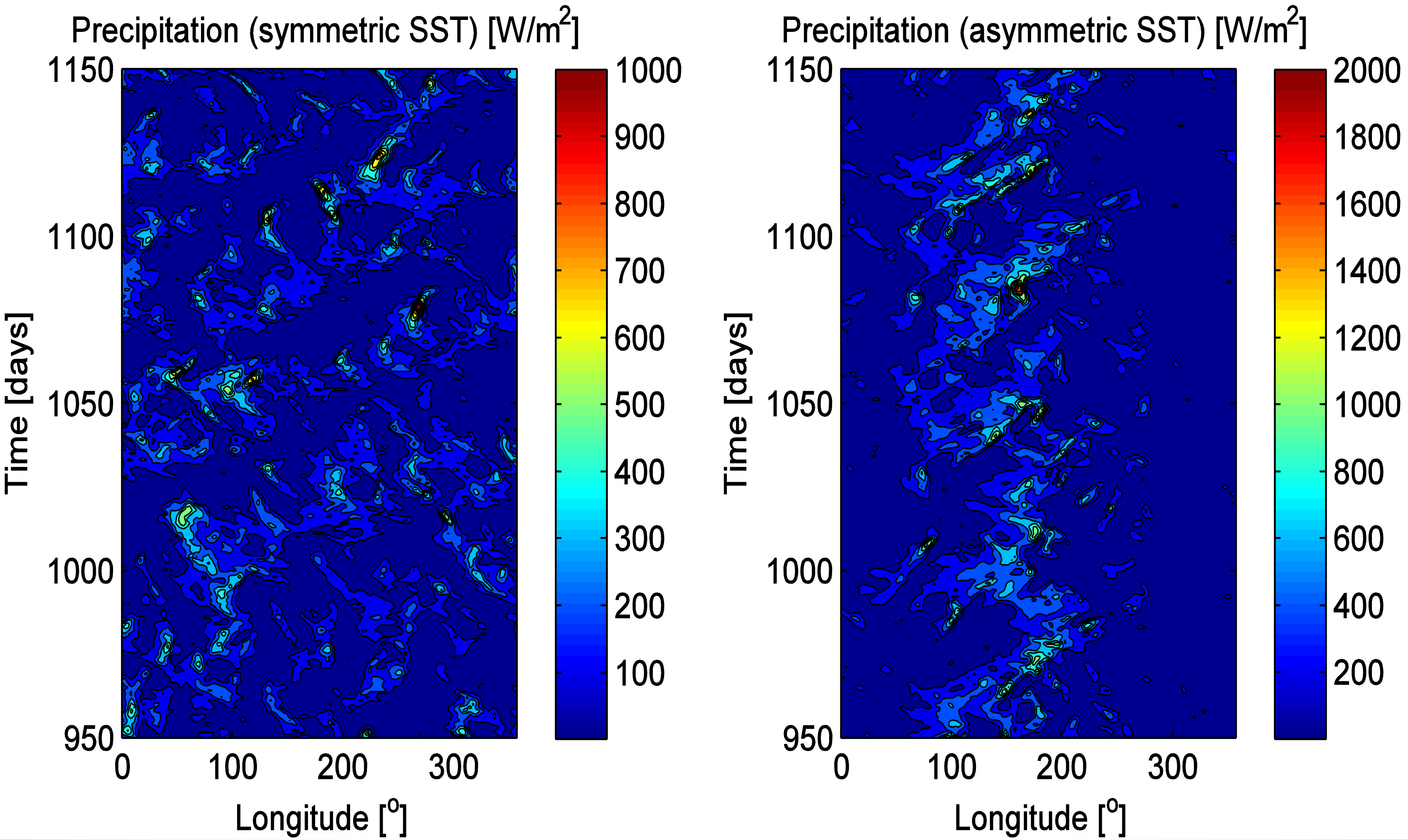


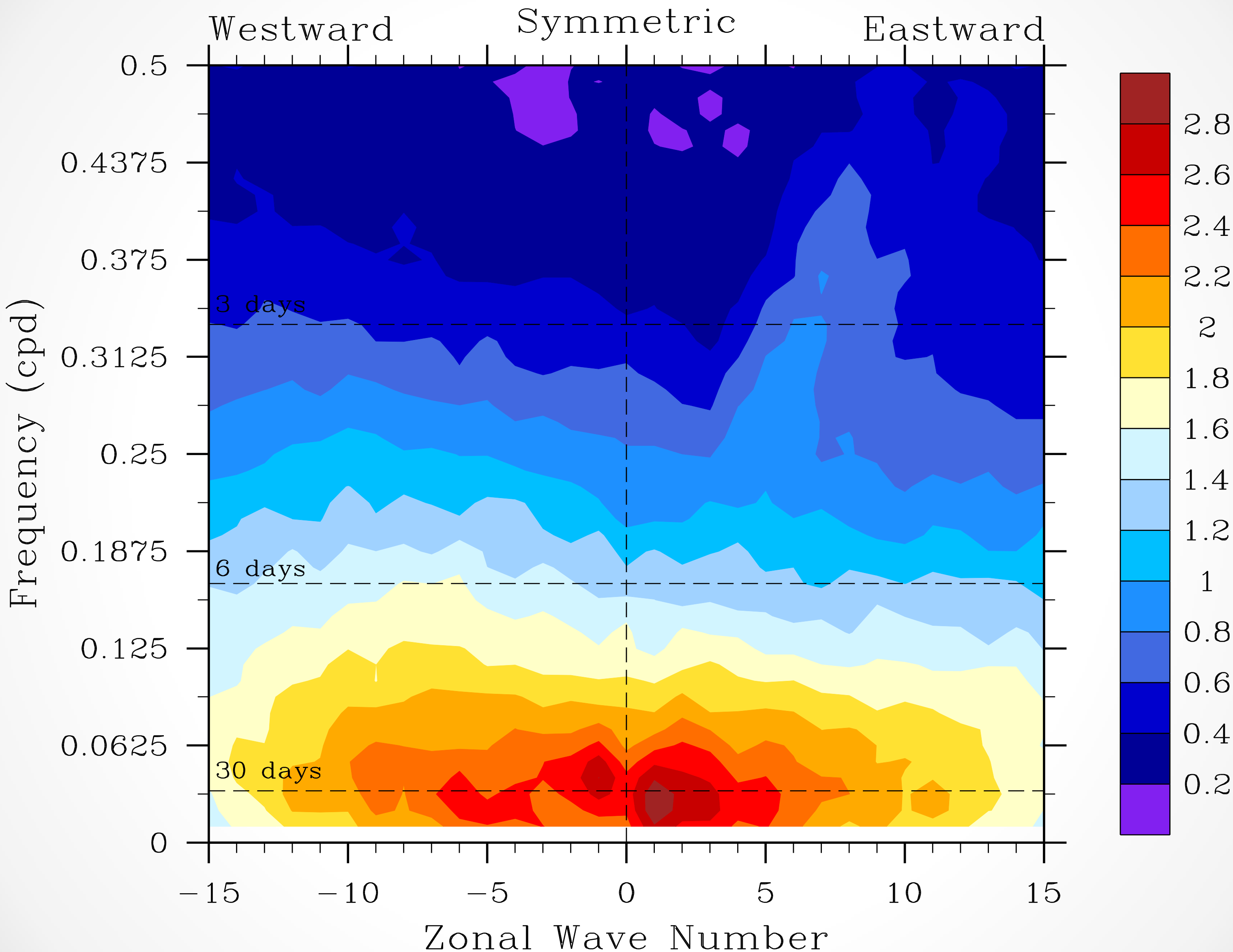
Precipitation variance [W/m^2]
Latitude [^{o}]
20
0
-20
0
50
100
150
200
250
300
350
x 10^4
4
3
2
1
Latitude [^{o}]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [^{o}]
x 10^5
3
2
1


Zonal velocity variance [m/s]
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
20
15
10
5
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [°]
40
30
20
10

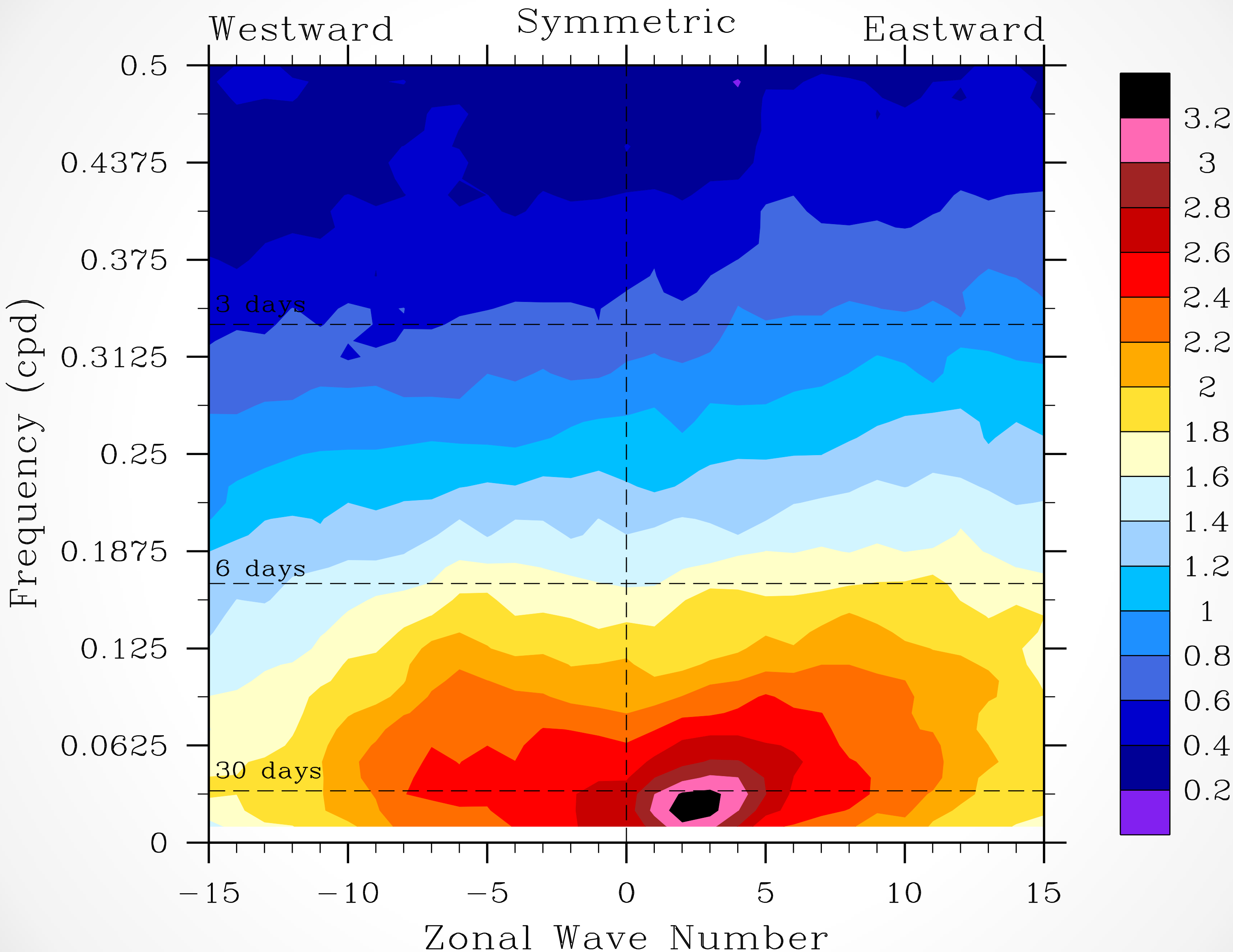

Meridional velocity variance [m/s]
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
14
12
10
8
6
4
2
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [°]
30
20
10


Zonal velocity (symmetric SST) [m/s]
Zonal velocity (asymmetric SST) [m/s]
Time [days]
Longitude [°]
1150
1100
1050
1000
950
0
100
200
300
10
5
0
-5
-10
25
20
15
4.67 m/s


Precipitation (symmetric SST) [W/m2]
1150
1100
1050
1000
950
Time [days]
0
100
200
300
Longitude [o]
1000
900
800
700
600
500
400
300
200
100
Precipitation (asymmetric SST) [W/m2]
2000
1800
1600
1400
1200
1000
800
600
400
200

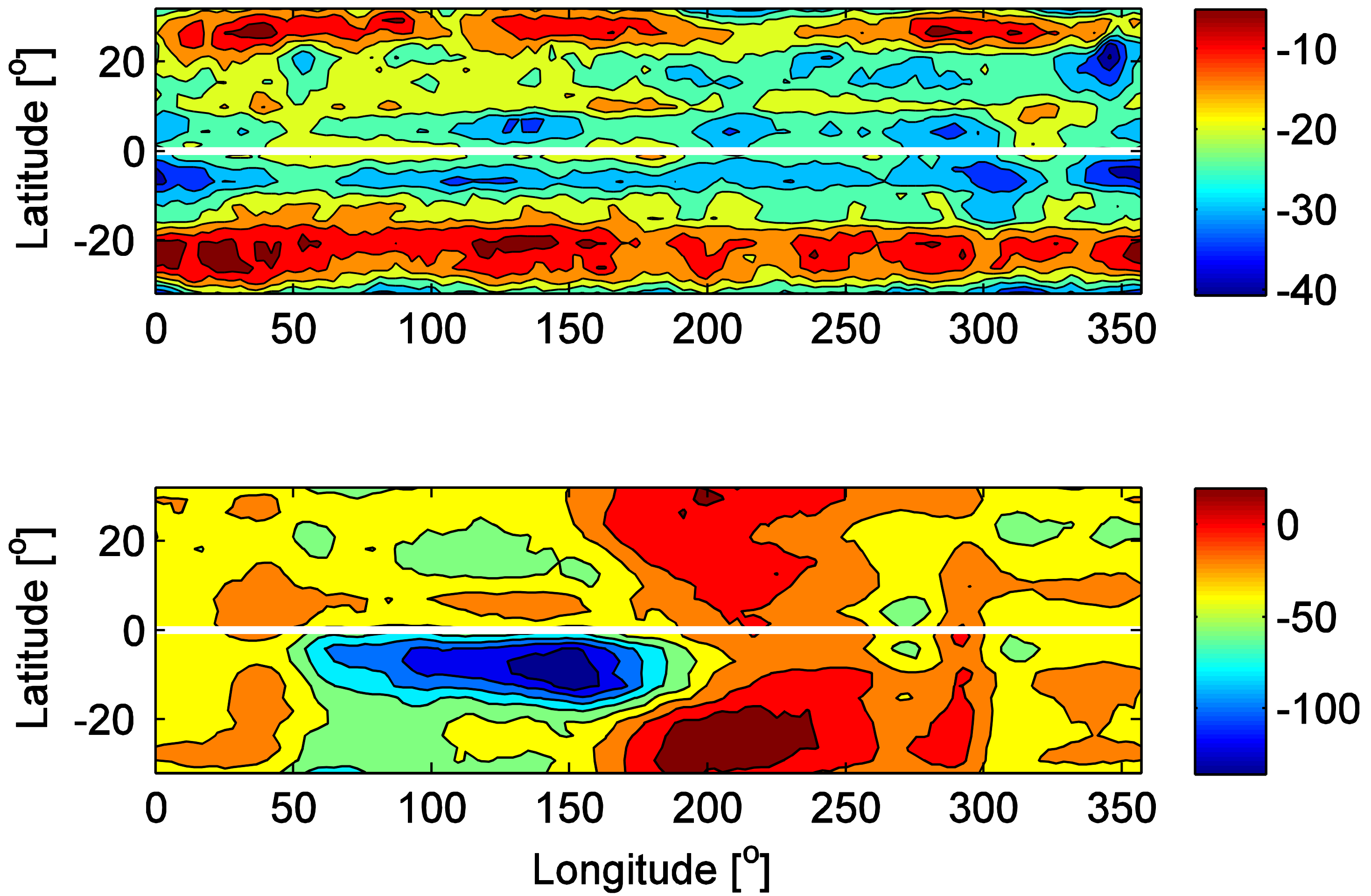


Westward
Symmetric
Eastward
0.5
0.4375
0.375
0.3125
0.25
0.1875
0.125
0.0625
0
Frequency (cpd)
3 days
6 days
30 days
−15
−10
−5
0
5
10
15
Zonal Wave Number
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2

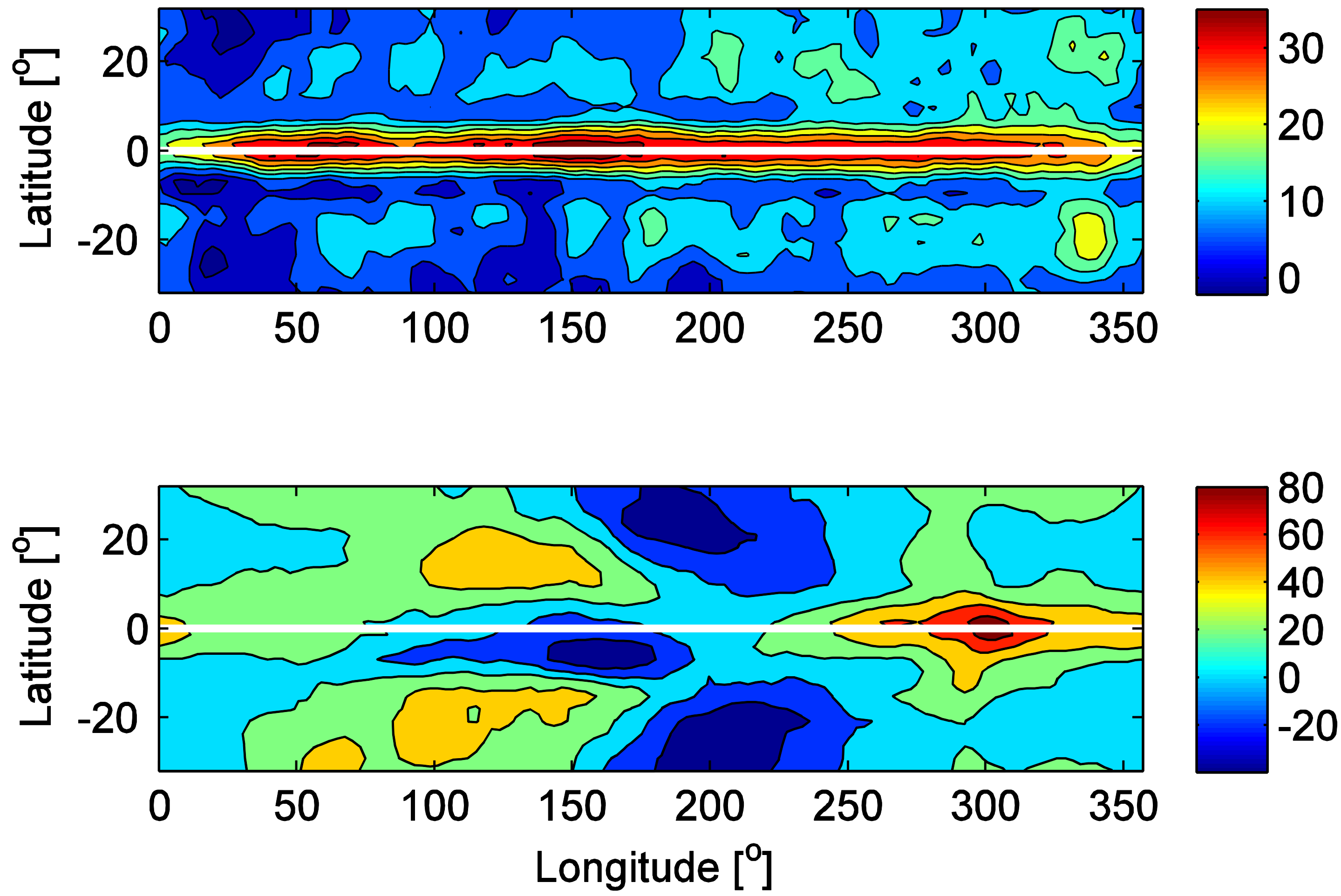


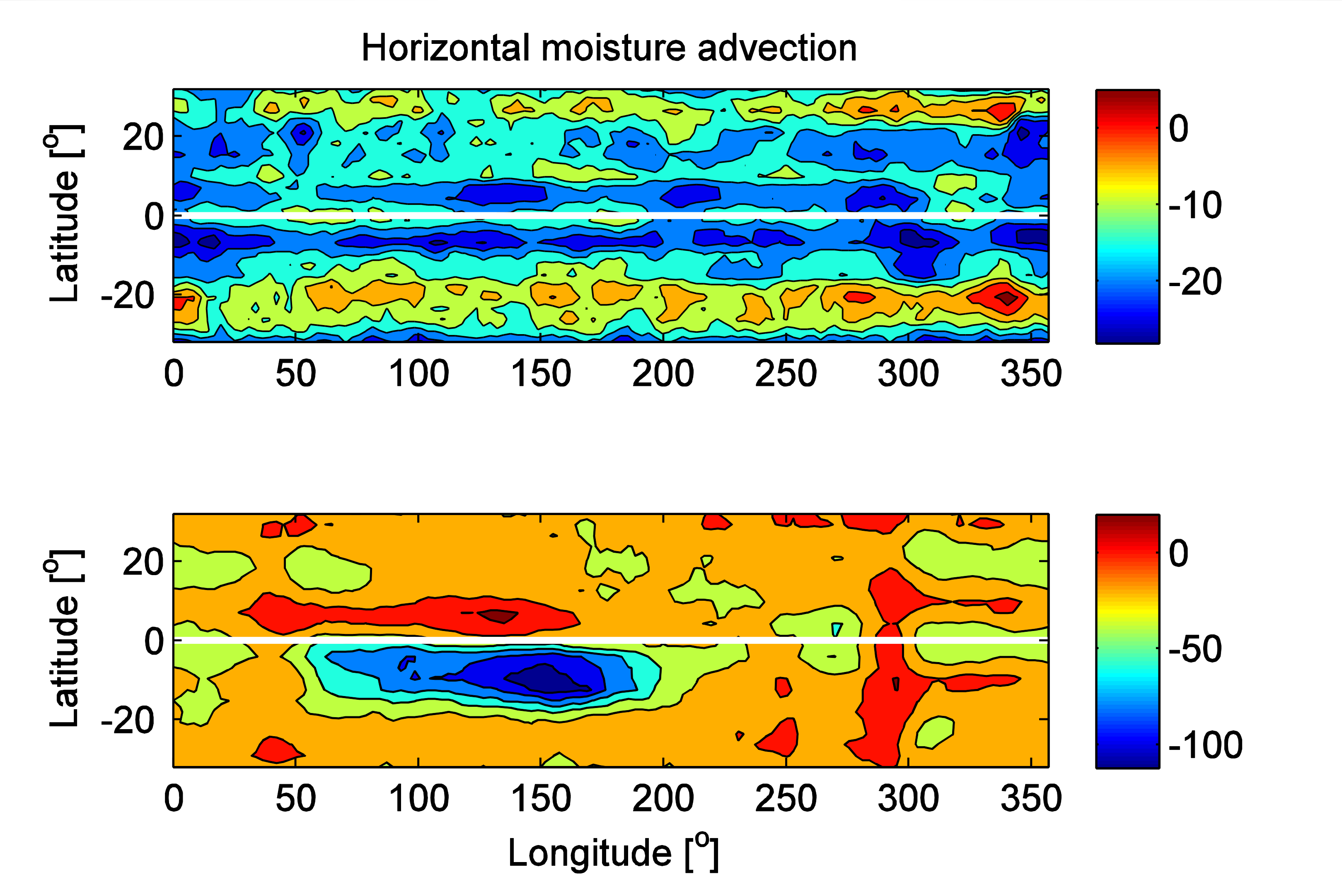
Westward
Symmetric
Eastward
Frequency (cpd)
0.5
0.4375
0.375
0.3125
0.25
0.1875
0.125
0.0625
0
3 days
6 days
30 days
−15
−10
−5
0
5
10
15
Zonal Wave Number
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2

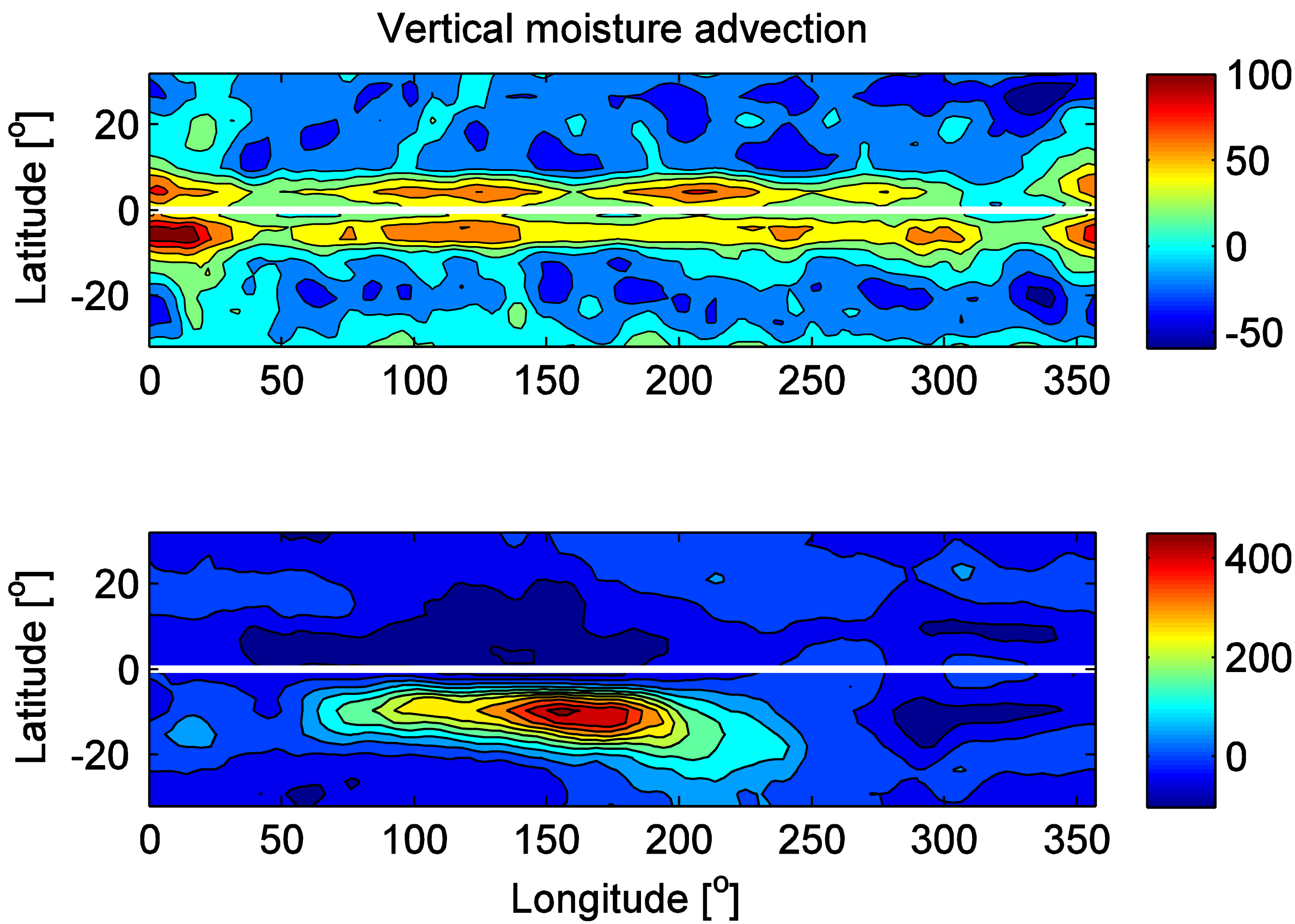
MSE horizontal advection



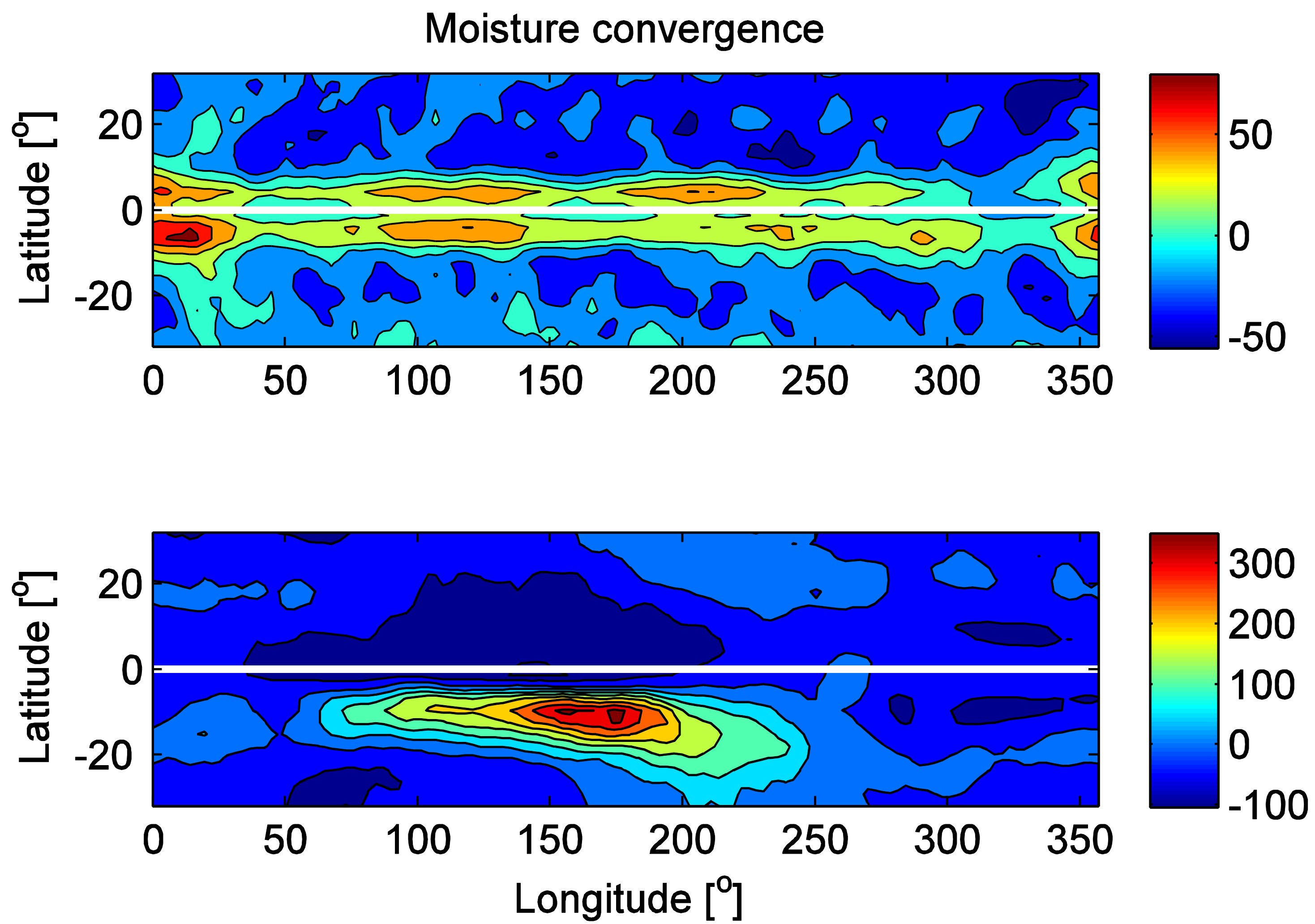
MSE vertical advection




Horizontal moisture advection
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
0
-10
-20
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [°]
0
-50
-100



Vertical moisture advection
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
100
50
0
-50
Latitude [°]
20
0
-20
0
50
100
150
200
250
300
350
400
200
0
Longitude [°]


Moisture convergence
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
50
0
-50
Latitude [o]
20
0
-20
0
50
100
150
200
250
300
350
Longitude [o]
300
200
100
0
-100

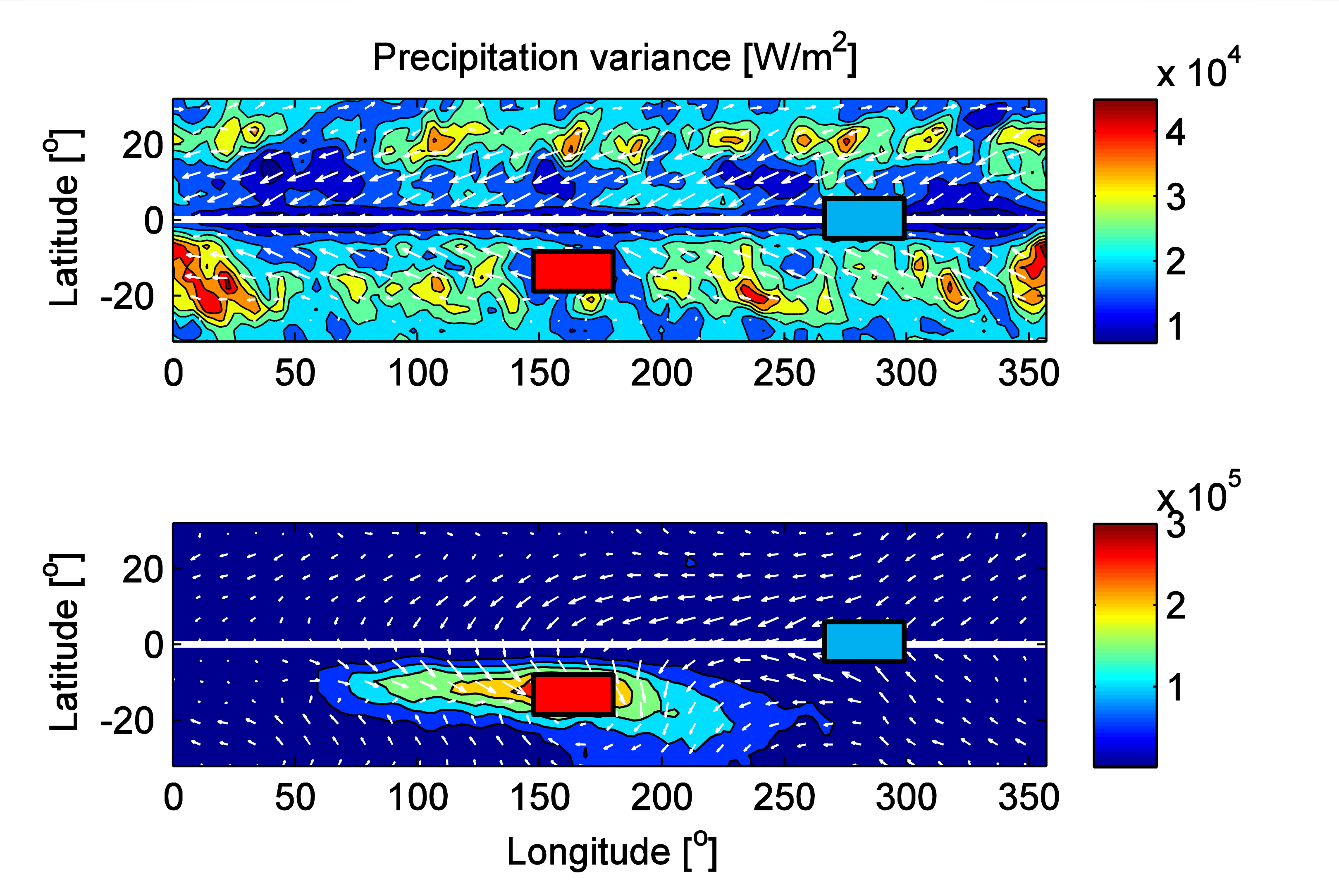
NGMS

- Raymond and Fuchs (2009)

$$NGMS < 0 \Rightarrow Moisture\ mode$$

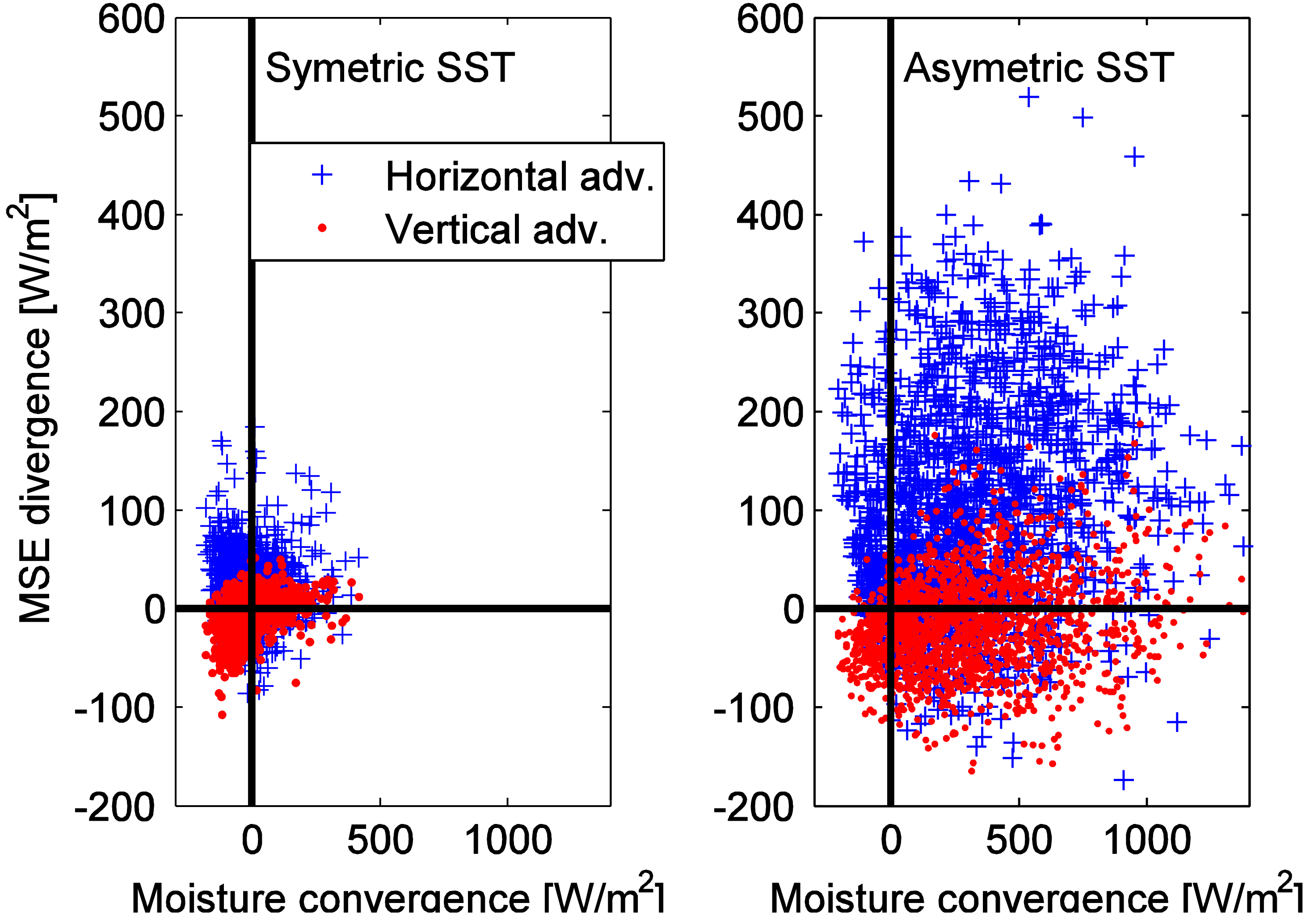
$$NGMS = \frac{Moist\ static\ energy\ advection}{Moisture\ advection}$$

$$NGMS = \frac{\begin{array}{c}Vertically\ integrated\ divergence\ of\ some\ intensive\\ quantity\ conserved\ in\ mosit\ adiabatic\ processes\end{array}}{\begin{array}{c}Measure\ of\ strength\ of\ moist\\ convection\ per\ unit\ area\end{array}}$$



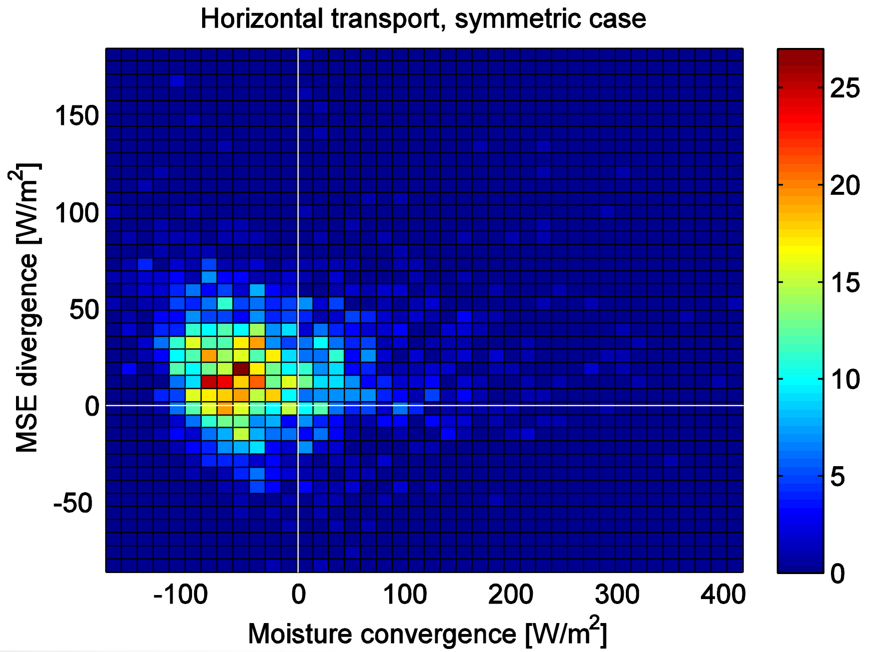
Warm patch

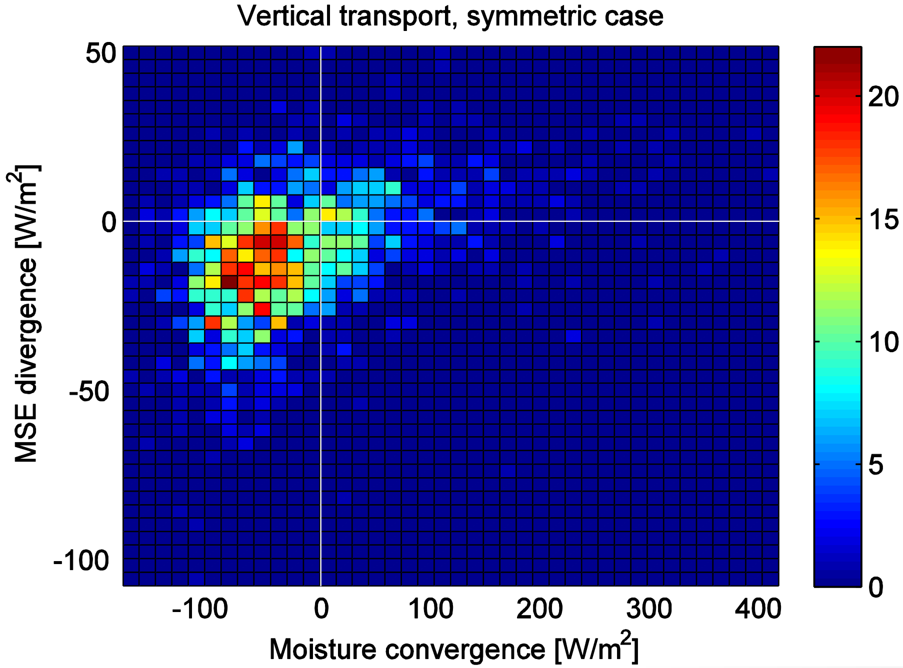
Cold patch



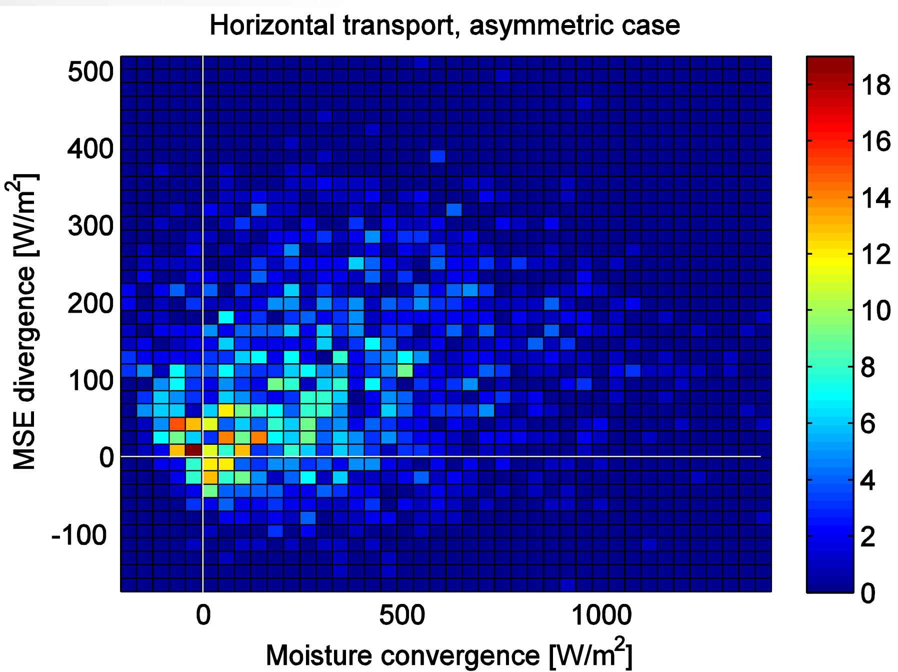
Symetric SST
Asymetric SST
Horizontal adv.
Vertical adv.
MSE divergence [W/m2]
Moisture convergence [W/m2]
600
500
400
300
200
100
0
-100
-200
0
500
1000

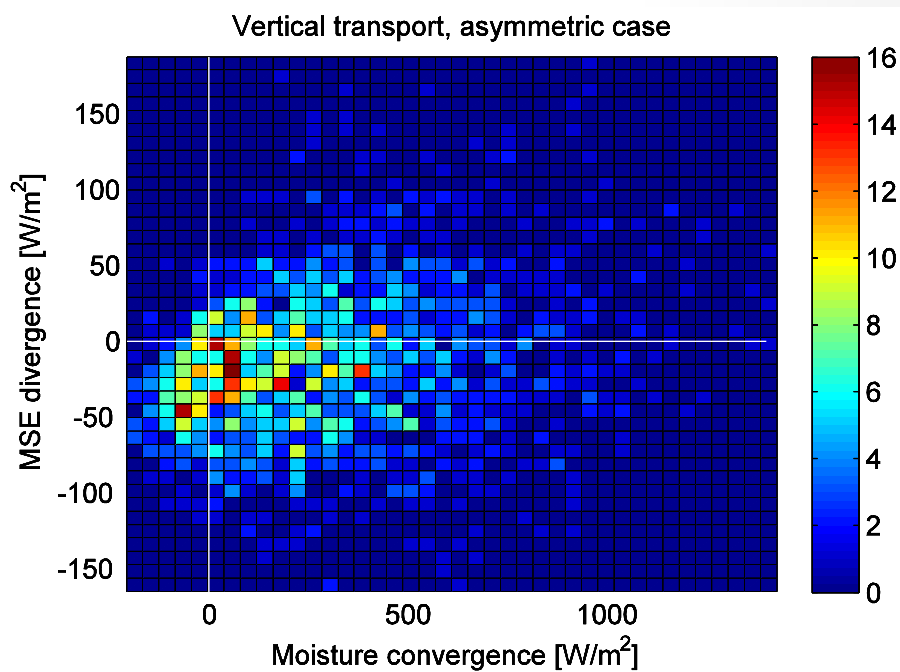
Warm patch

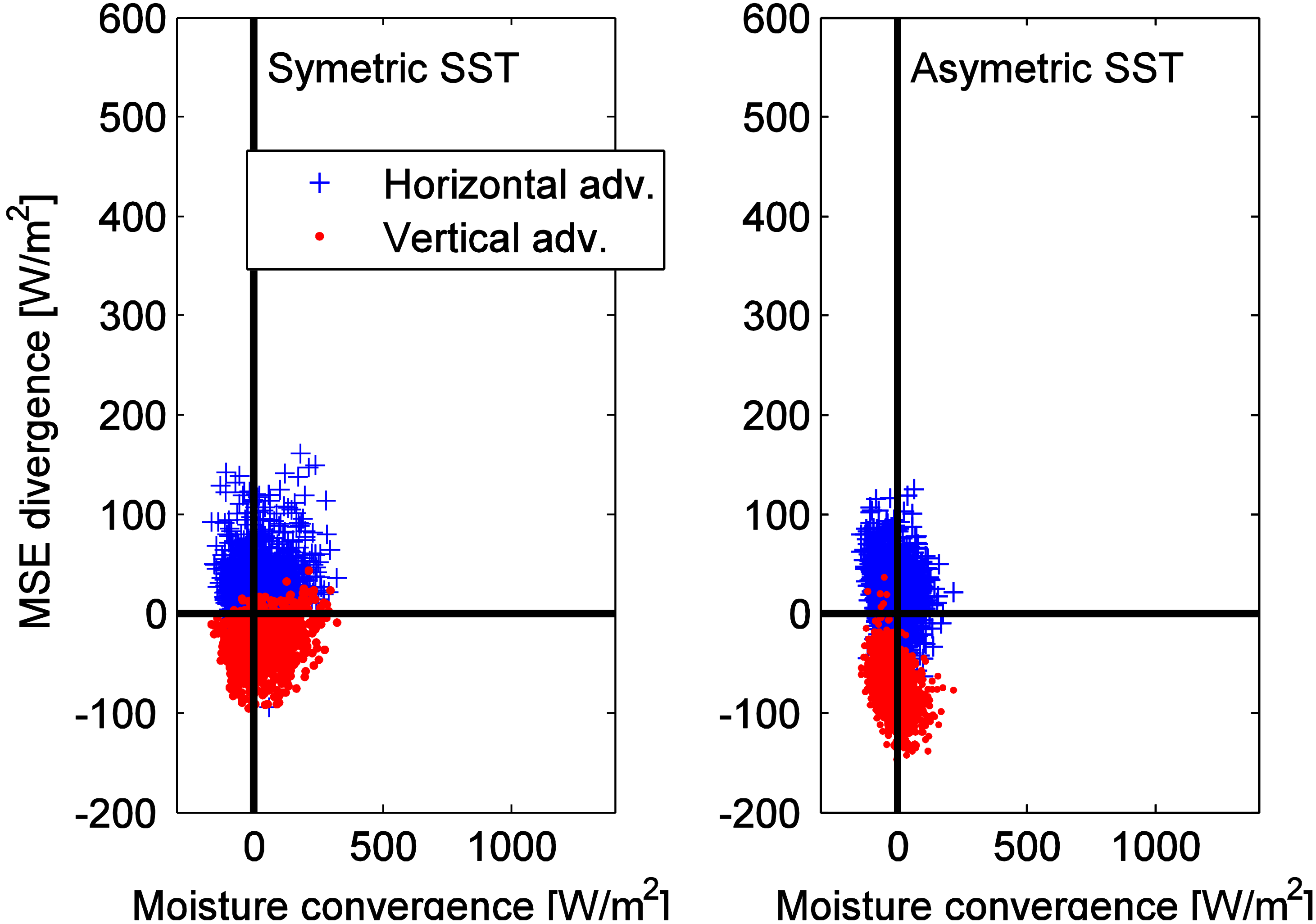

Horizontal transport, symmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
150
100
50
0
-50
-100
0
100
200
300
400
25
20
15
10
5
0


Vertical transport, symmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
50
0
-50
-100
-100
0
100
200
300
400
20
15
10
5
0

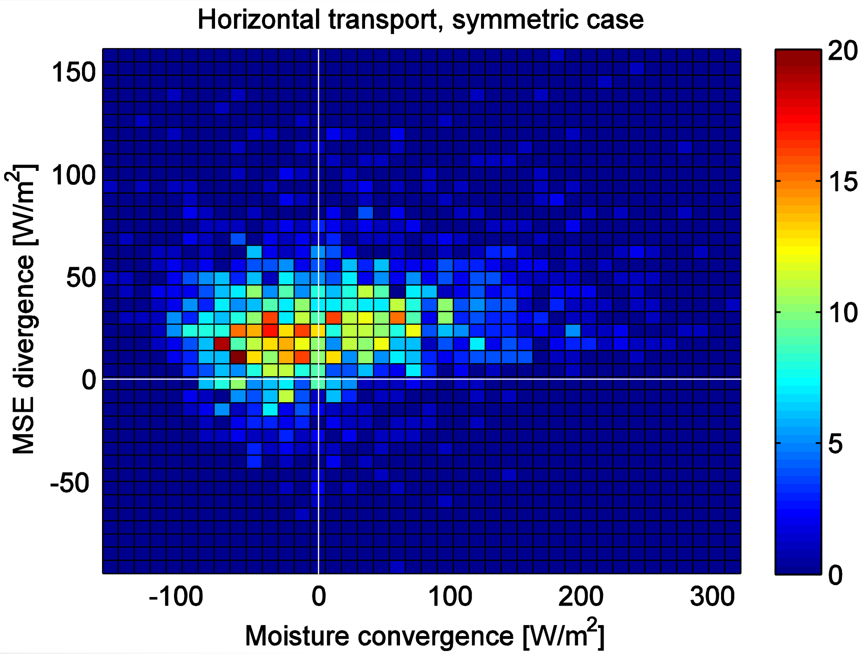
Warm patch

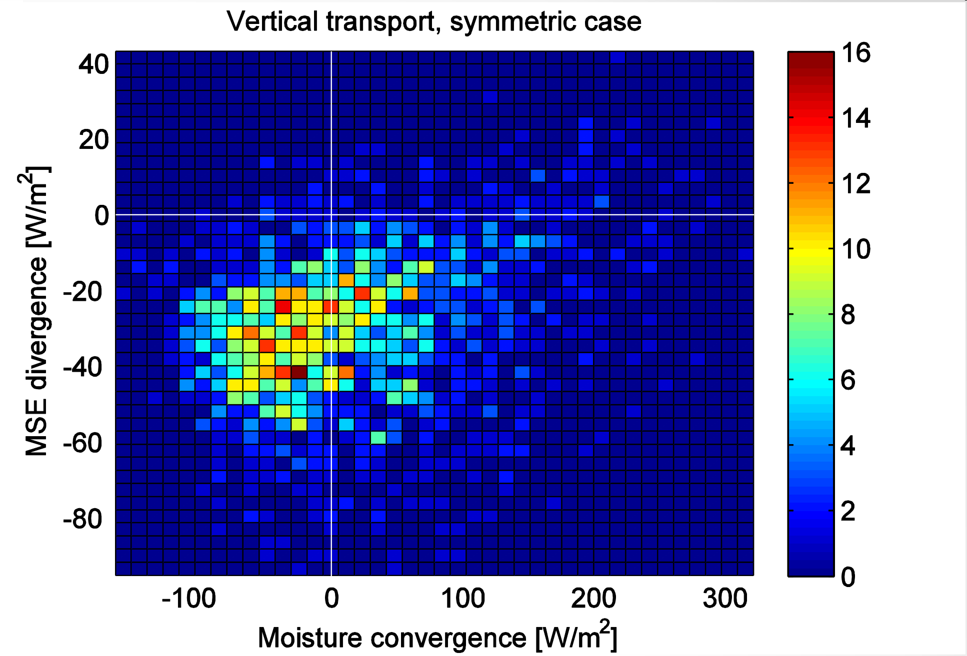

Horizontal transport, asymmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
500
400
300
200
100
0
-100
0
500
1000
18
16
14
12
10
8
6
4
2
0


Vertical transport, asymmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
150
100
50
0
-50
-100
-150
0
500
1000
16
14
12
10
8
6
4
2
0

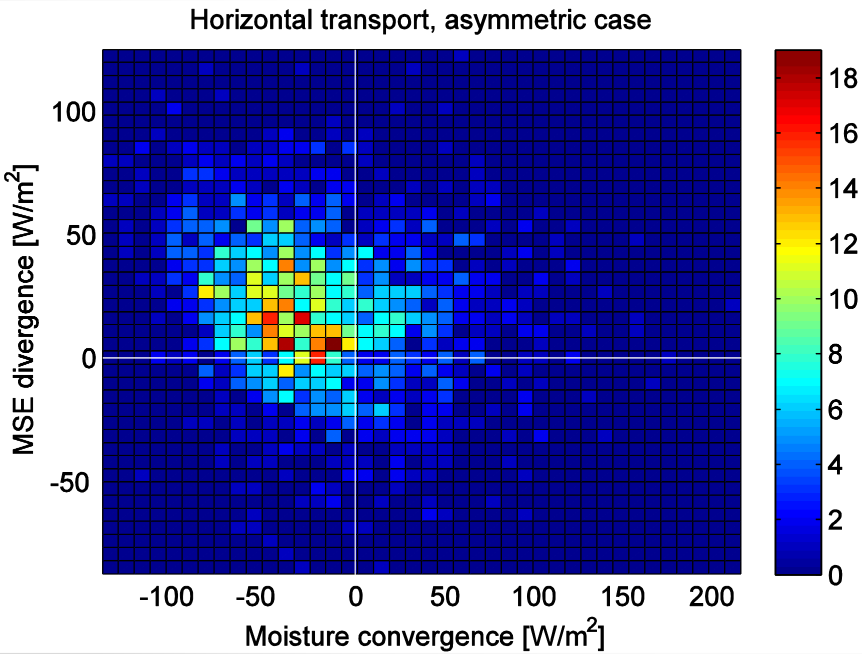

Symetric SST
Asymetric SST
Horizontal adv.
Vertical adv.
MSE divergence [W/m2]
Moisture convergence [W/m2]
600
500
400
300
200
100
0
-100
-200
0
500
1000

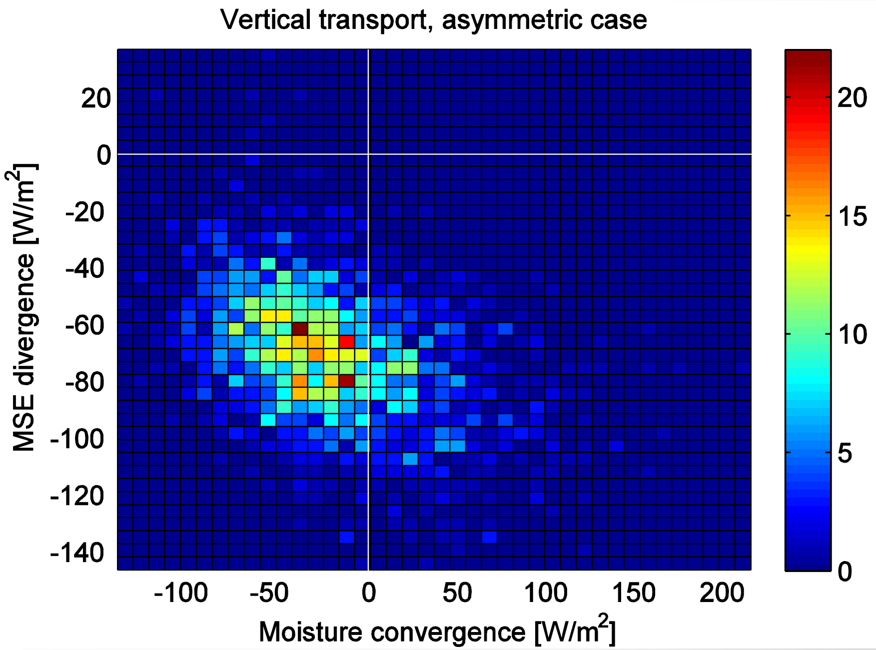
Cold patch

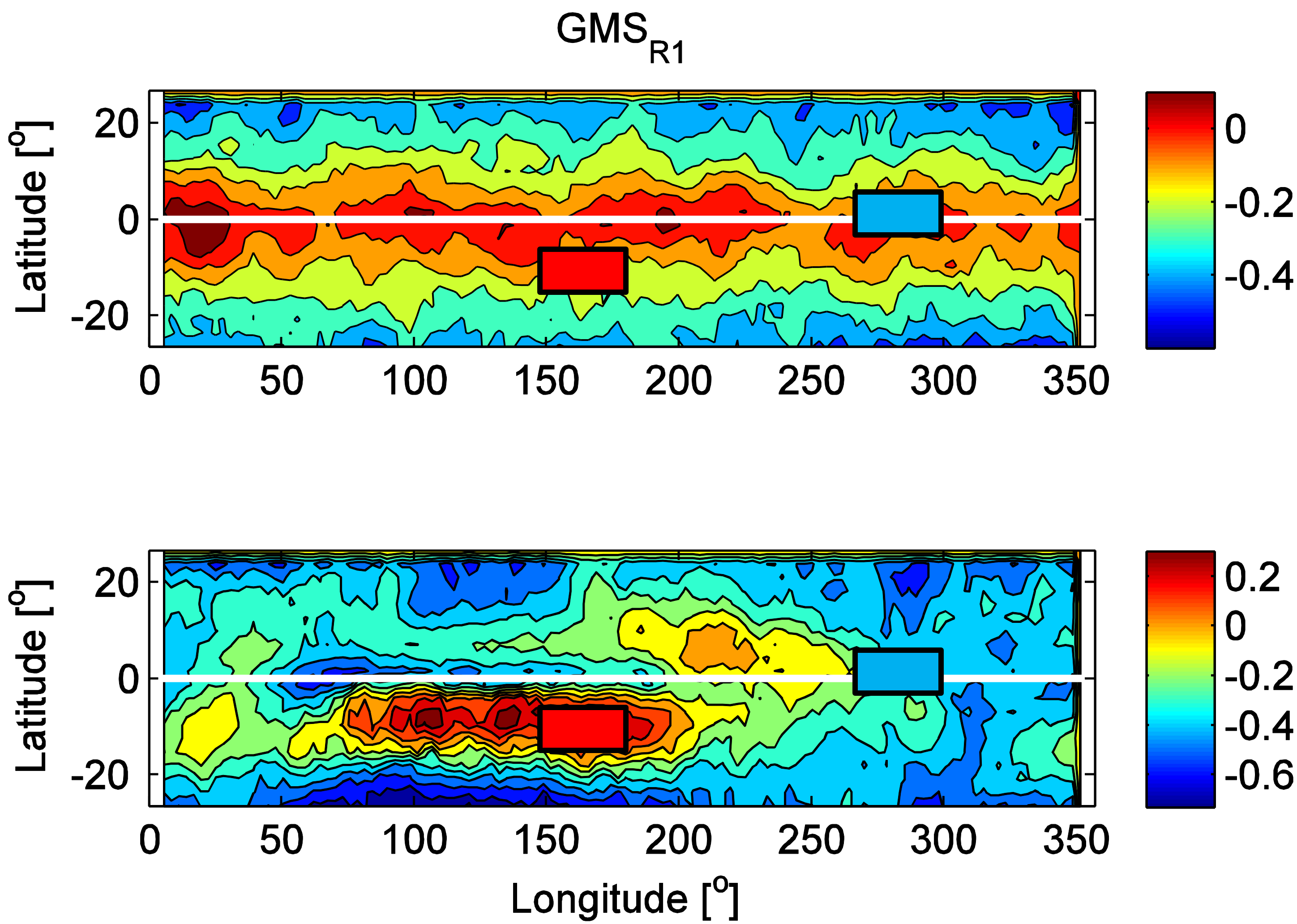

Horizontal transport, symmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
150
100
50
0
-50
-100
0
100
200
300
20
15
10
5
0


Vertical transport, symmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
40
20
0
-20
-40
-60
-80
-100
0
100
200
300
16
14
12
10
8
6
4
2
0

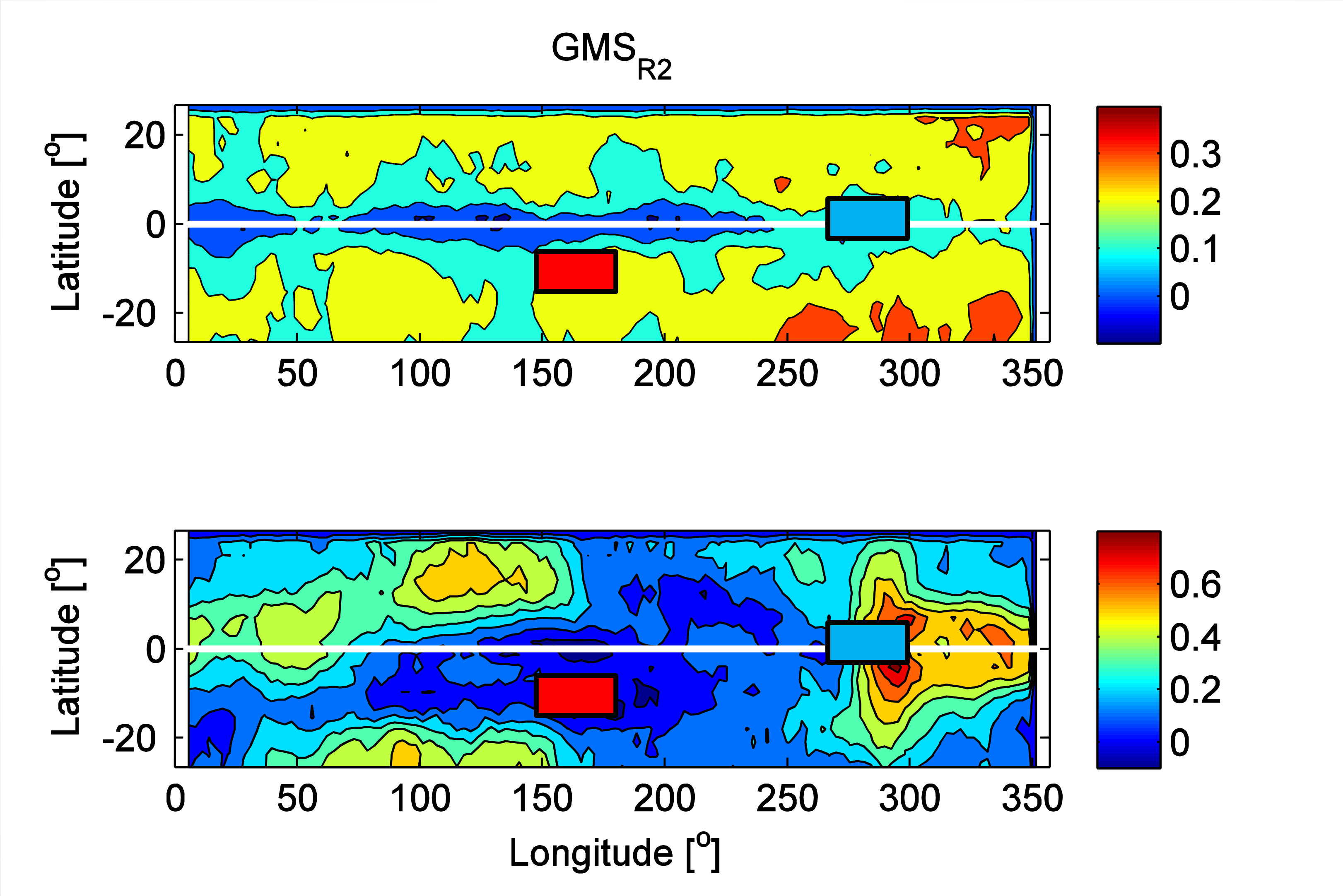
Cold patch


Horizontal transport, asymmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
100
50
0
-50
-100
-50
0
50
100
150
200
18
16
14
12
10
8
6
4
2
0


Vertical transport, asymmetric case
MSE divergence [W/m^2]
Moisture convergence [W/m^2]
20
0
-20
-40
-60
-80
-100
-120
-140
-100
-50
0
50
100
150
200
20
15
10
5
0



Warm patch Cold patch



Warm patch Cold patch

Conclusion(s)

- Area of low to negative NGMS in the warm patch
- Confirmation of the variability resembling a moisture mode

References

- Kiranmayi, L, and Maloney, E, 2010, Effects of SST Distribution and Radiative Feedbacks on the Simulation of Intraseasonal Variability in an Aquaplanet GCM, Journ. Meteo. Soc. Of Japan
- Raymond, D, and Fuchs, Z, 2009, Moisture Moede and the Madden-Julian Oscillation, DOI: 10.1175/2008JCLI2739.1
- Maloney, E, Sobel, A, and Hannah, W, 2010, Intraseasonal Variability in a Acquaplanet general Circulation model, Jou. of Advances in Modeling Earth Systems