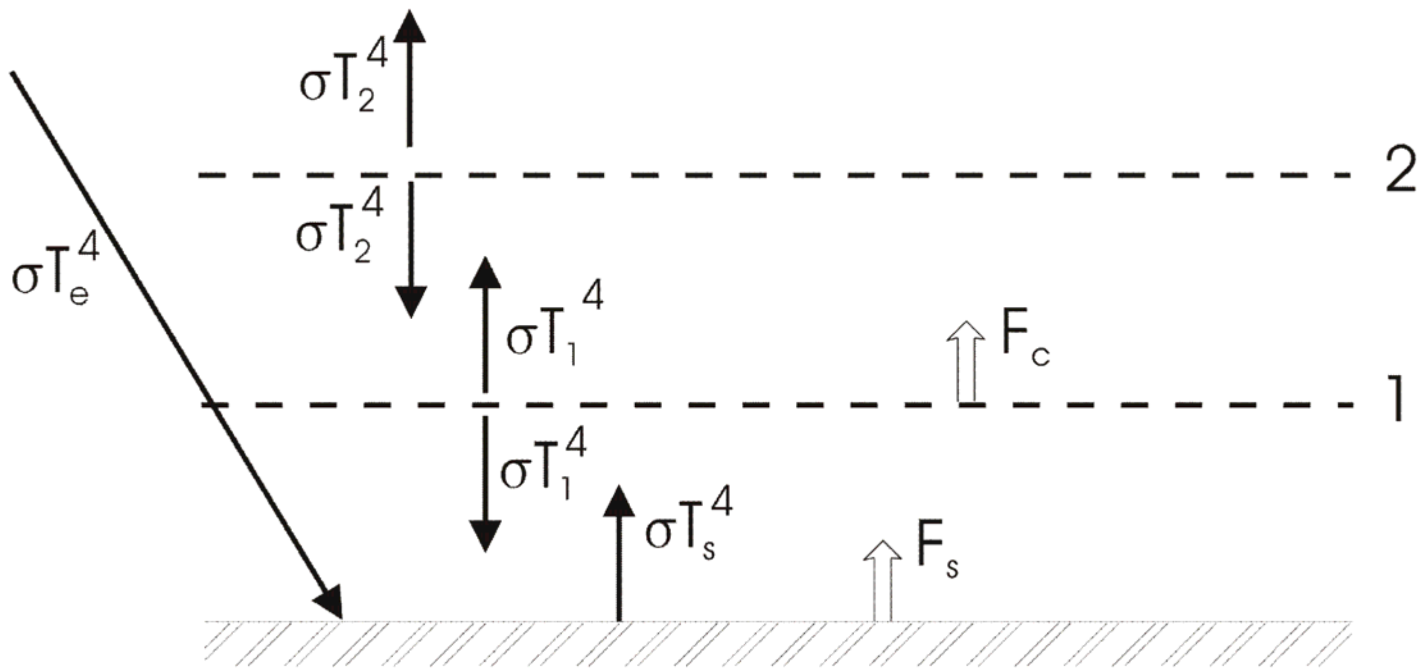
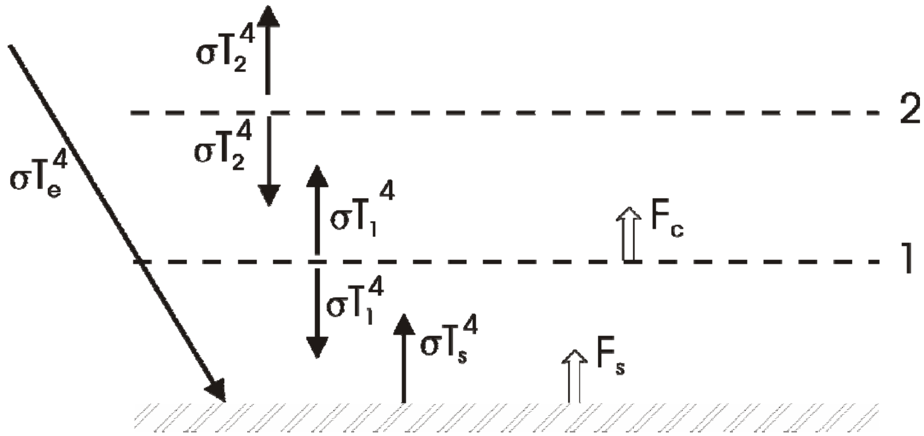
Simple Radiative-Convective Model



Enforce convective neutrality:

$$T_1 = T_2 + \Delta T,$$

$$T_s = T_2 + 2\Delta T$$



$$TOA: \quad T_2 = T_e \rightarrow T_1 = T_e + \Delta T, \quad T_s = T_e + 2\Delta T$$

$$Surface: \quad F_s + \sigma T_s^{\,4} = \sigma T_e^{\,4} + \sigma T_1^{\,4}$$

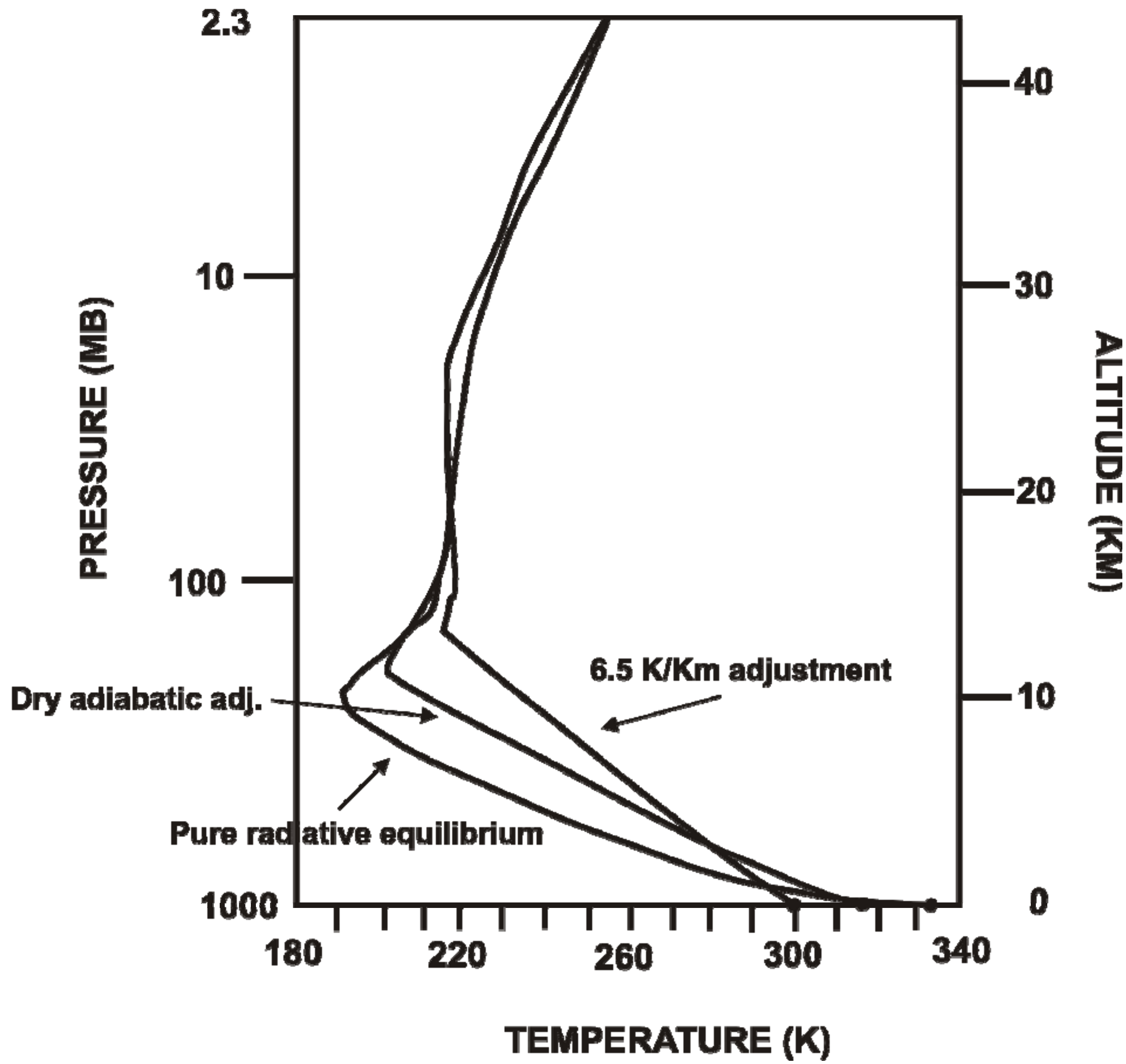
$$Layer\ 2: \quad 2\sigma T_e^{\,4} = \sigma T_1^{\,4} + F_c$$

$$Define \quad x \equiv \Delta T \big/ T_e,$$

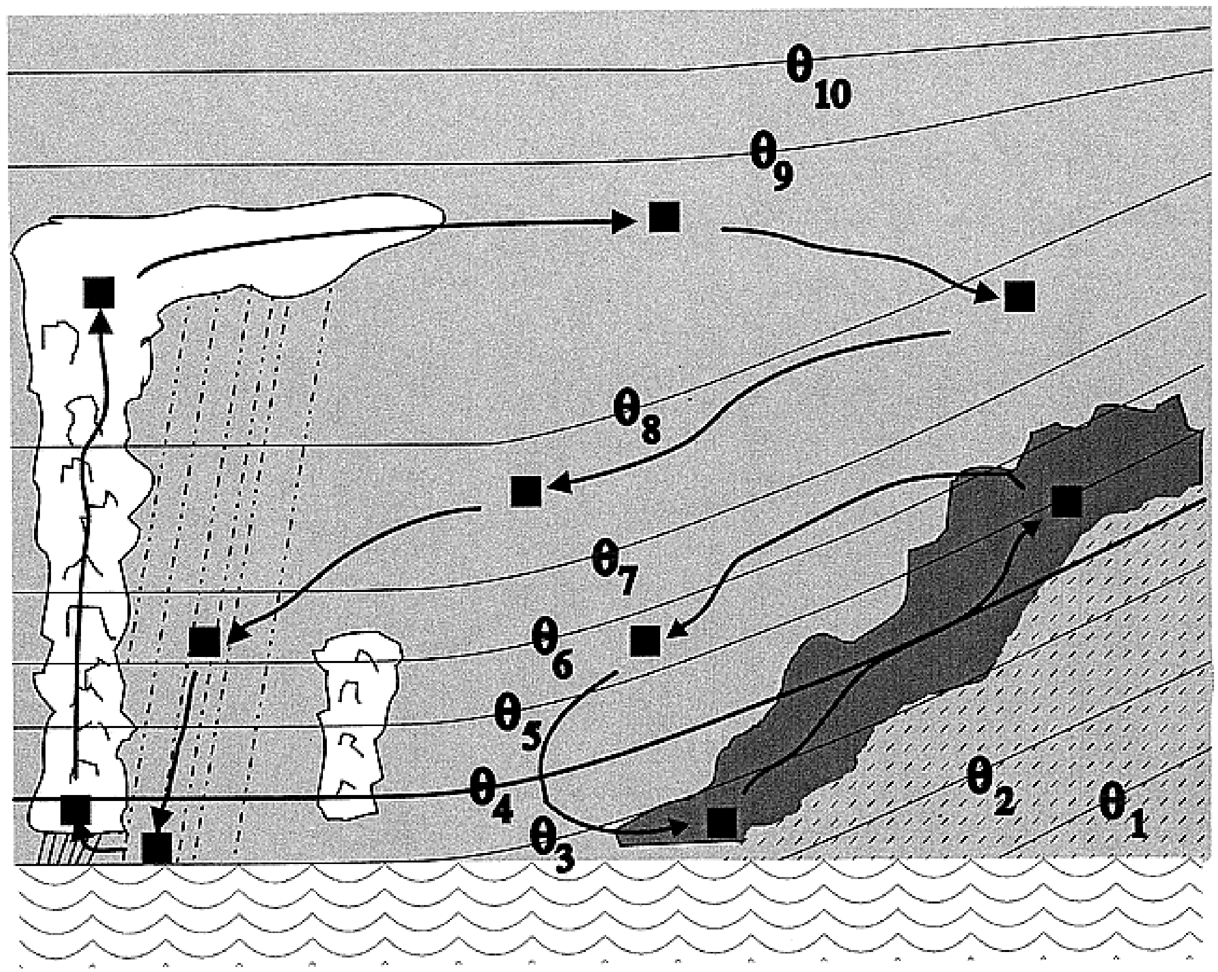
$$F_s = \sigma T_e^{\,4}\left[1 + (1+x)^4 - (1+2x)^4\right],$$

$$F_c = \sigma T_e^{\,4}\left[2 - (1+x)^4\right]$$

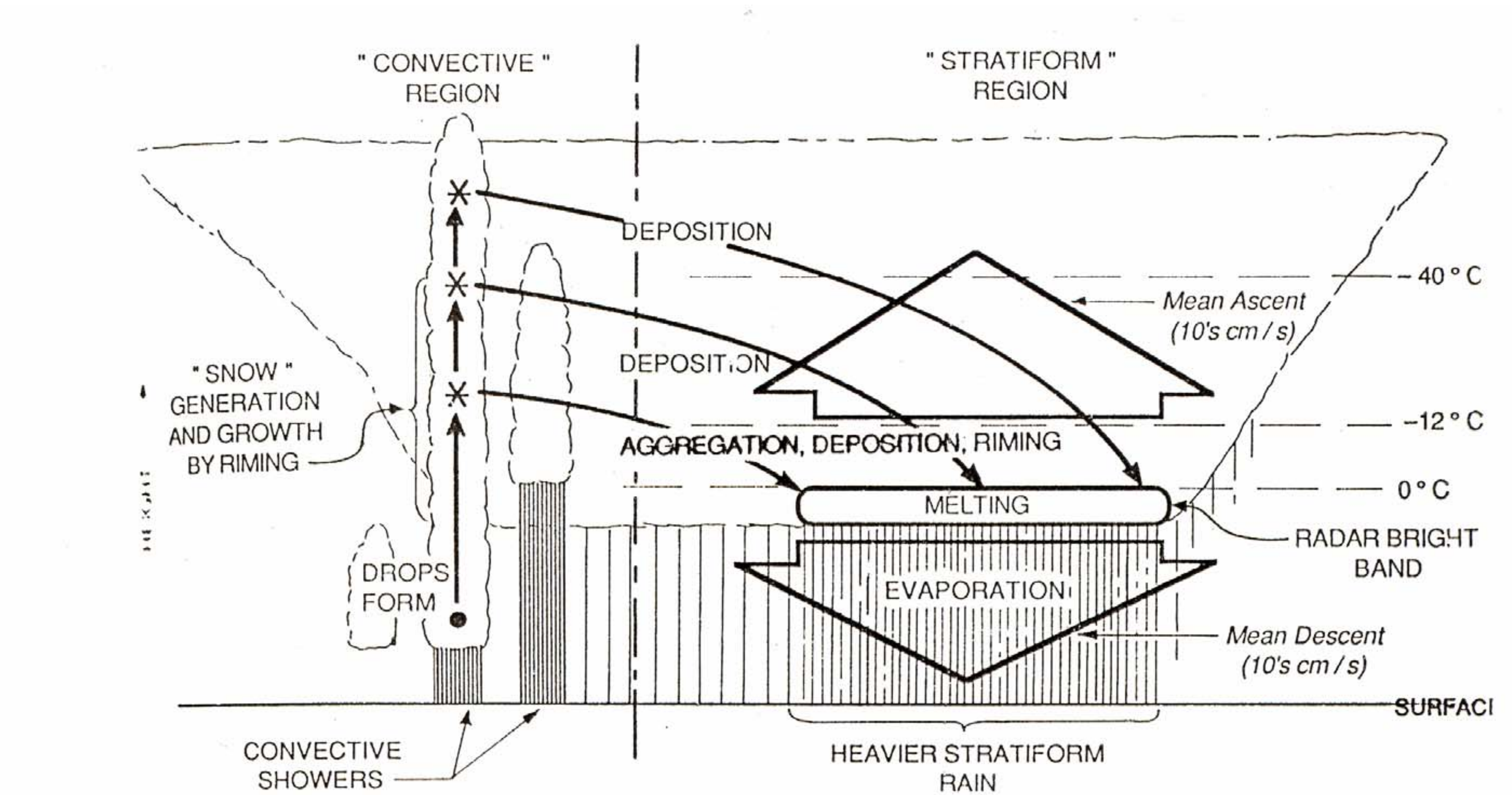
Manabe and Strickler 1964 calculation:

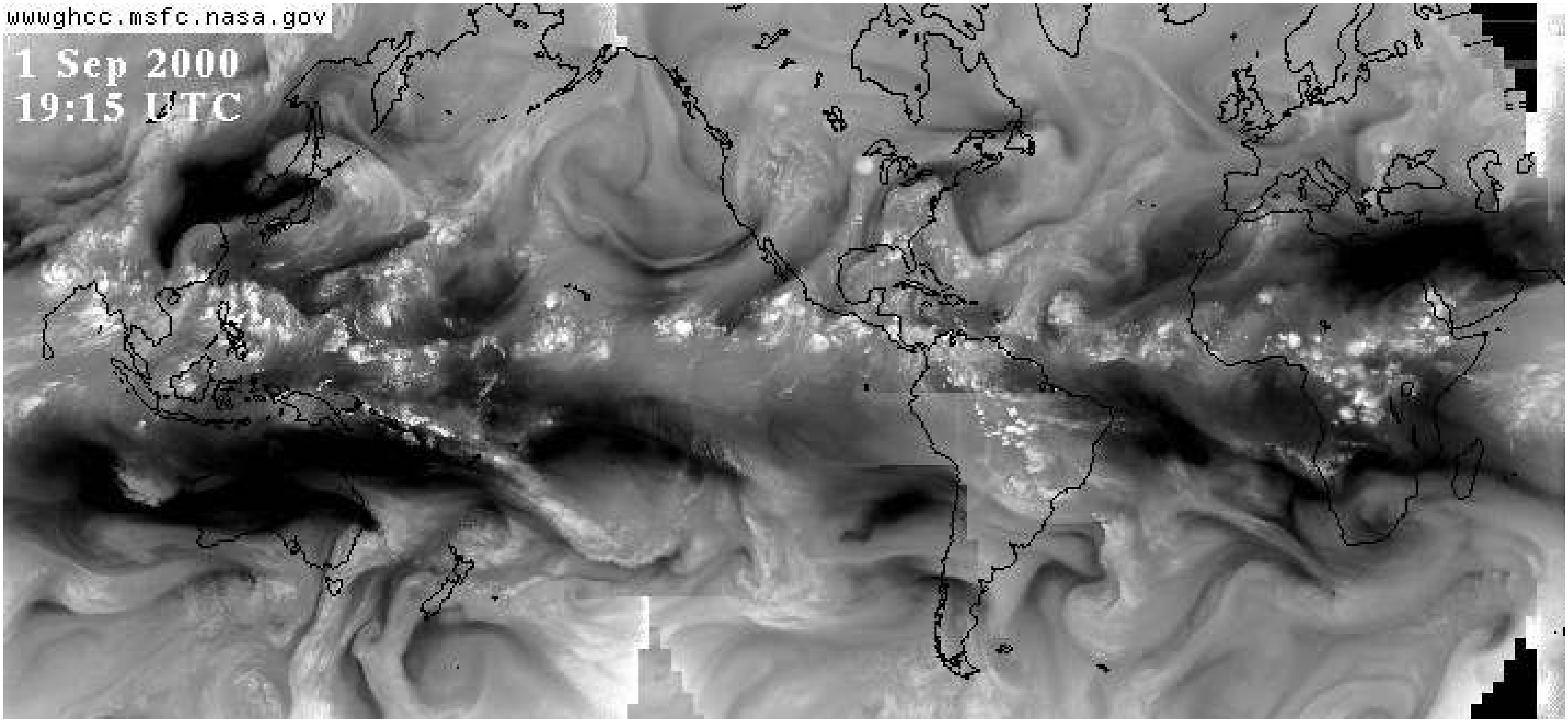


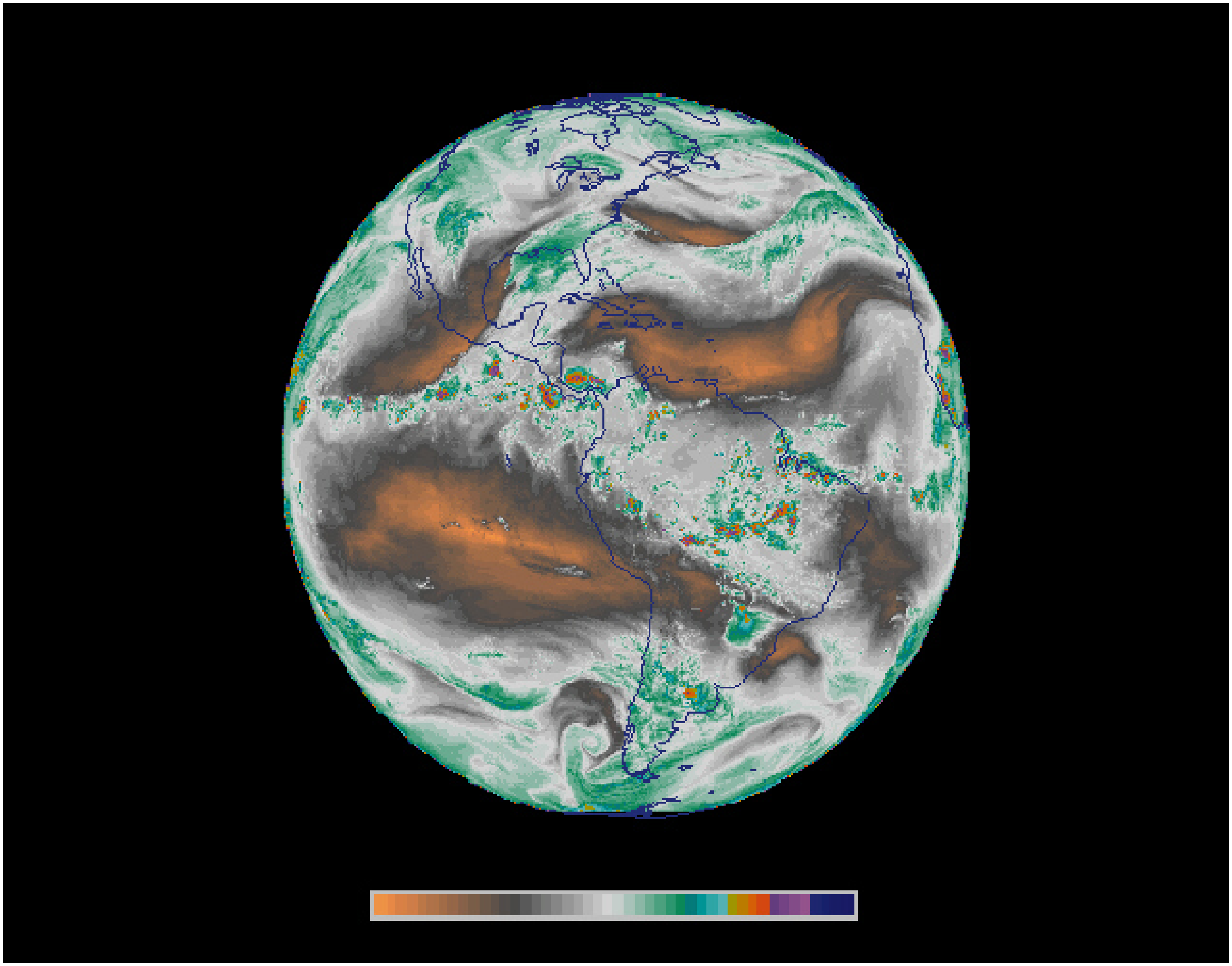
Flux of water by convection makes real problem complex



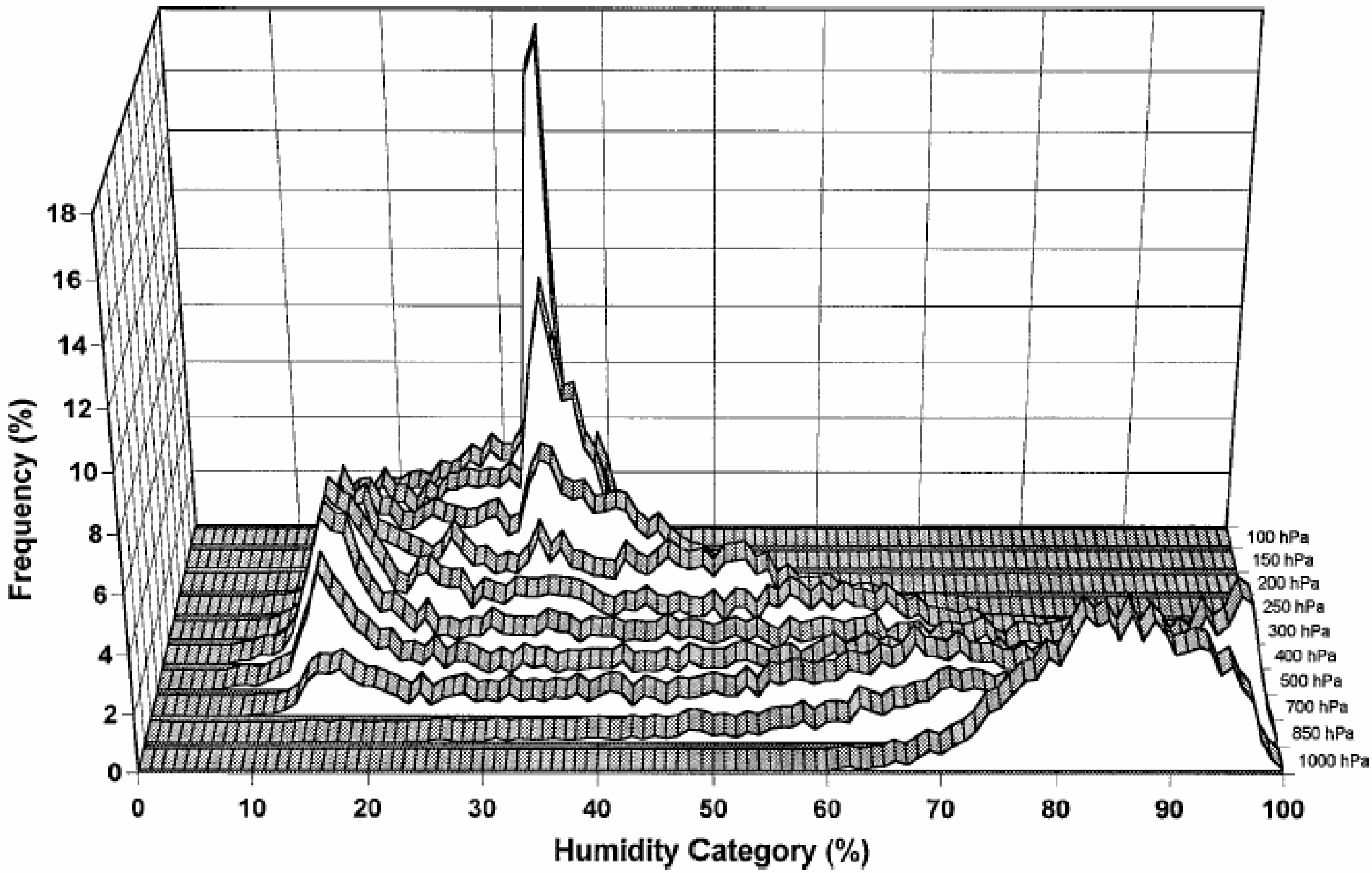
Microphysical processes operating in mesoscale convective systems. From Houze (1989).




wwwghcc.msfc.nasa.gov
1 Sep 2000
19:15 UTC



Frequency histogram of rawindsonde relative humidities from 1600 ascents at the tropical Pacific islands of Yap, Koror, Ponape and Majuro, January-May, 1994-95. Spencer and Braswell, *Bull. Amer. Meteor. Soc.,* 1997.



The Three-Dimensional Circulation

Steady Flow:

$$\nabla \bullet \left[F_{rad}\hat{k} + F_{conv}\hat{k} + \rho \mathbf{V}E \right] = 0,$$

where

$$E \equiv c_p T + gz + L_v q + \frac{1}{2}|\,\mathbf{V}\,|^2$$

Integrate from surface to top of atmosphere:

$$\nabla \bullet \overline{\rho \mathbf{V}E} + F_{rad_{TOA}} - \left(F_{rad} + F_{conv} \right)_{surface} = 0$$

What causes lateral enthalpy transport by atmosphere?

1: Large-scale, quasi-steady overturning motion in the Tropics,

2: Eddies with horizontal dimensions of ~ 3000 km in middle and high latitudes

Observed Characteristics of the Time Mean Tropical Atmosphere

- Monthly and seasonal means
- Zonal means

Objective Analysis

Provides "Best Guess" as to the State of the Atmosphere

1. *Start with "First Guess" Analysis*

2. *Ingest Data*

-Radiosondes

-Surface Observations

-Ship Reports and Buoy Observations

-Aircraft Observations

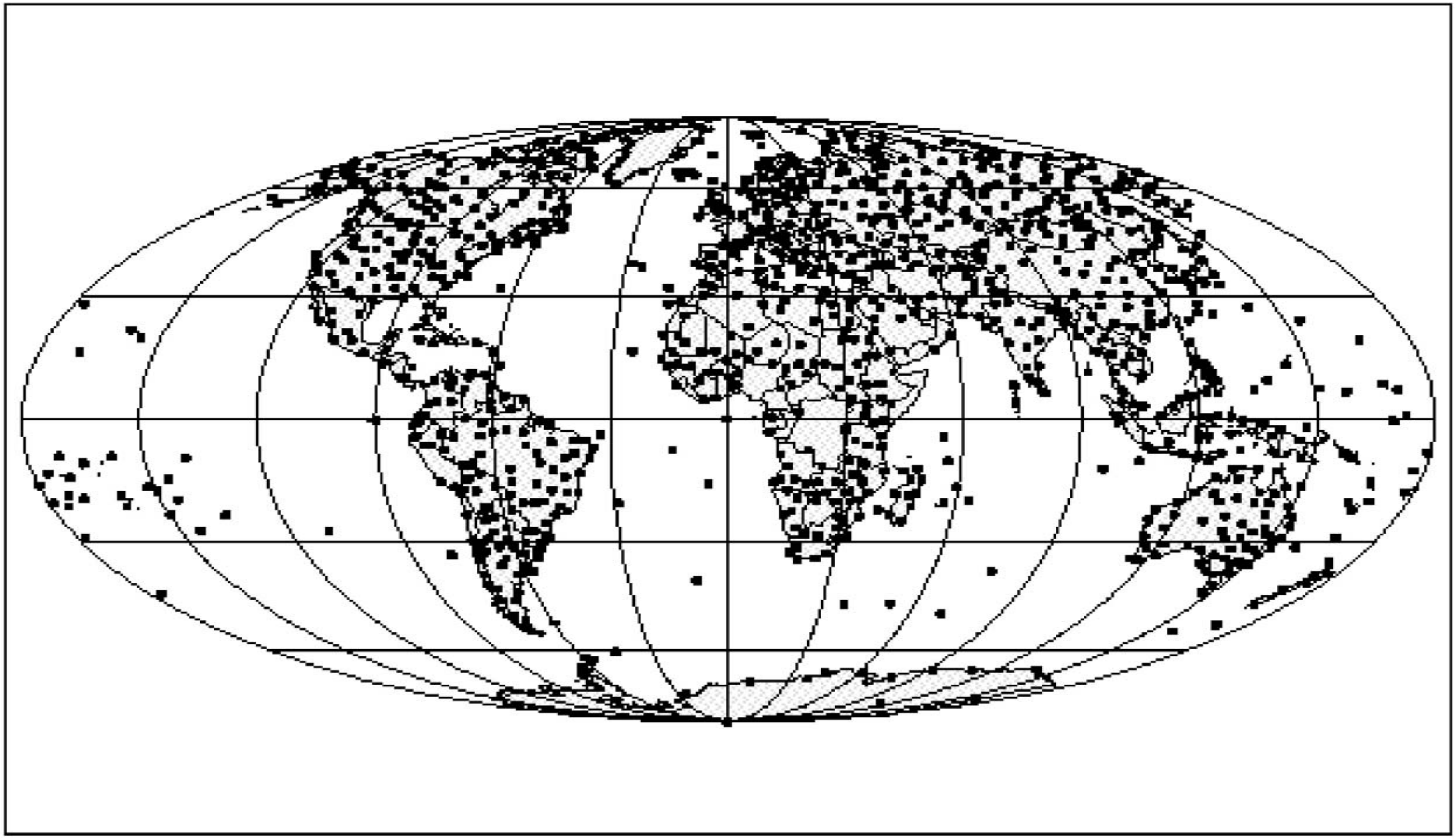
-Satellite Observations

3. *Data Assimilation*

-Blend data to produce an "initialized" (balanced) analysis (or not....)

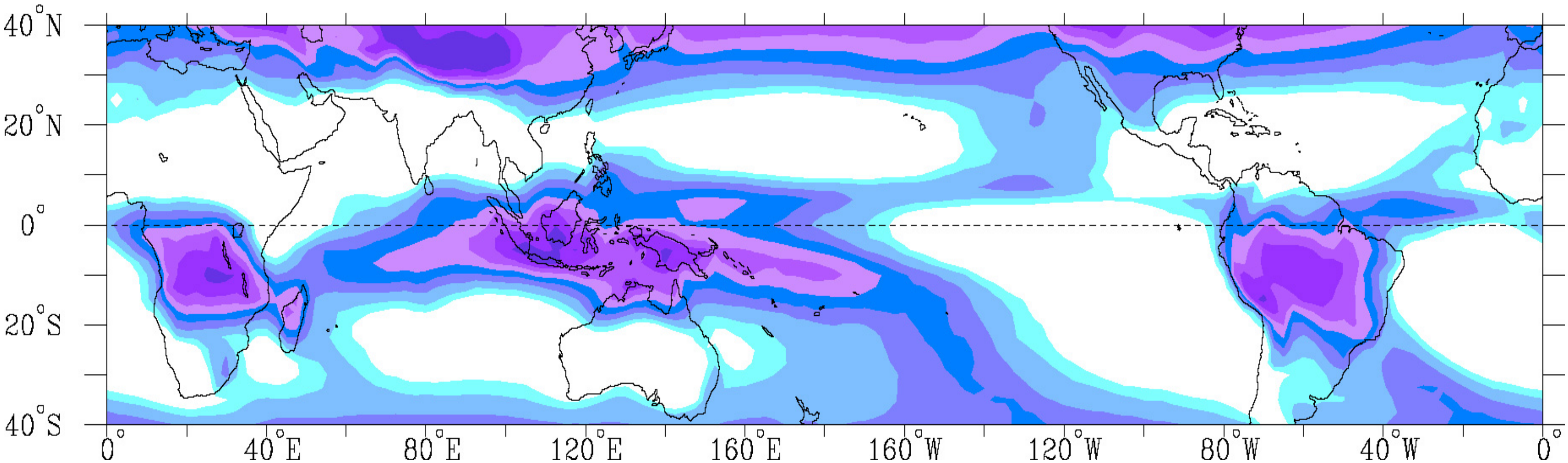
4. *Run General Circulation Model to Obtain next First Guess*

Radiosonde Network



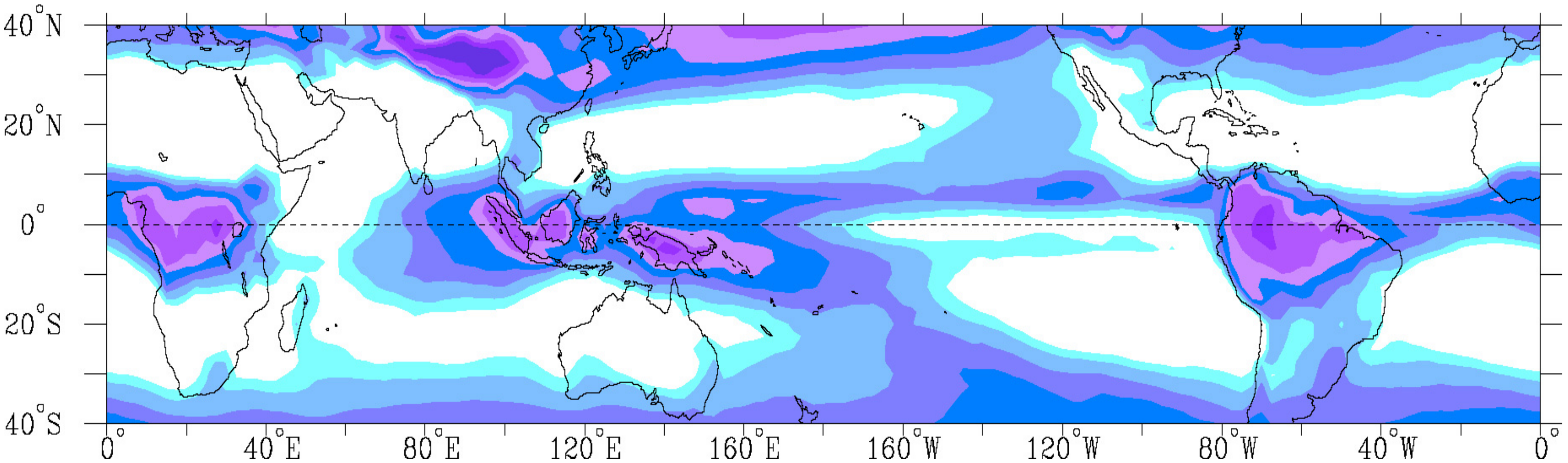
Mean January Outgoing Longwave Radiation (OLR),

1979-2001



Shading at 10 W m^{-2} intervals,
starting at 260 W m^{-2}

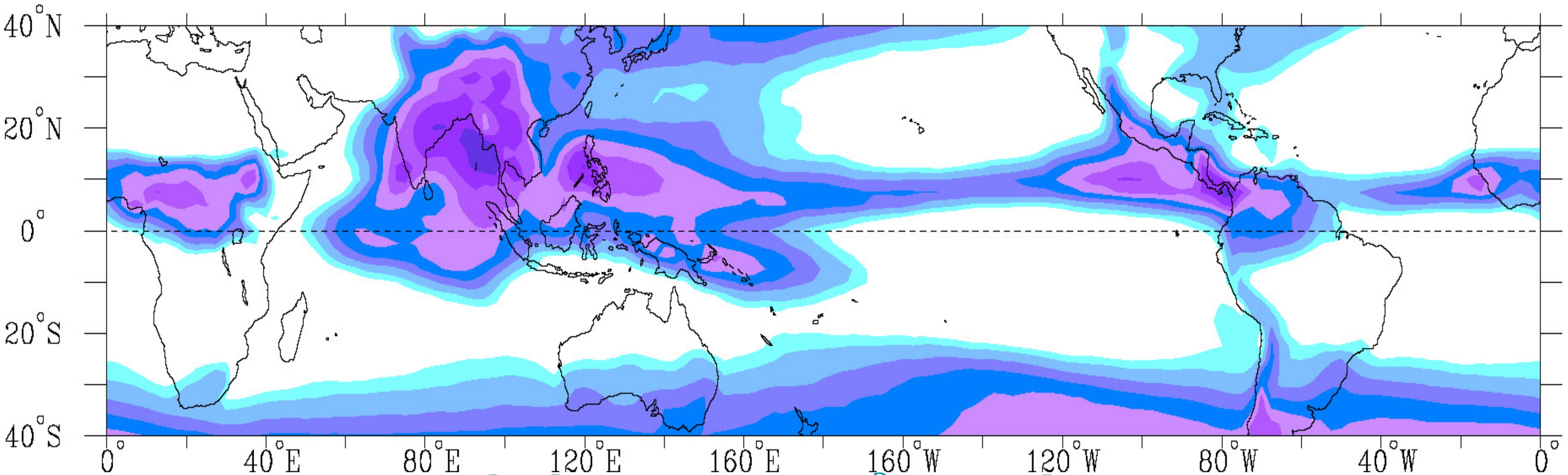
Mean April Outgoing Longwave Radiation, 1979-2001



Shading at 10 W m^{-2} intervals, starting at 260 W m^{-2}

Mean July Outgoing Longwave Radiation,

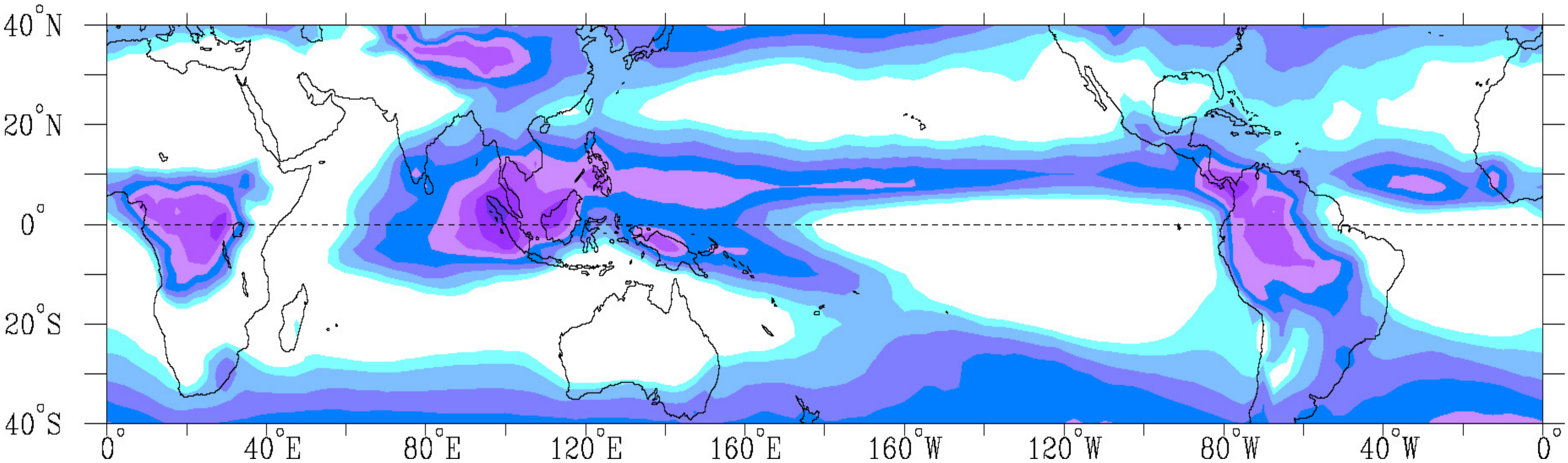
1979-2001



Shading at 10 W m^{-2} intervals,
starting at 260 W m^{-2}

Mean October Outgoing Longwave Radiation,

1979-2001

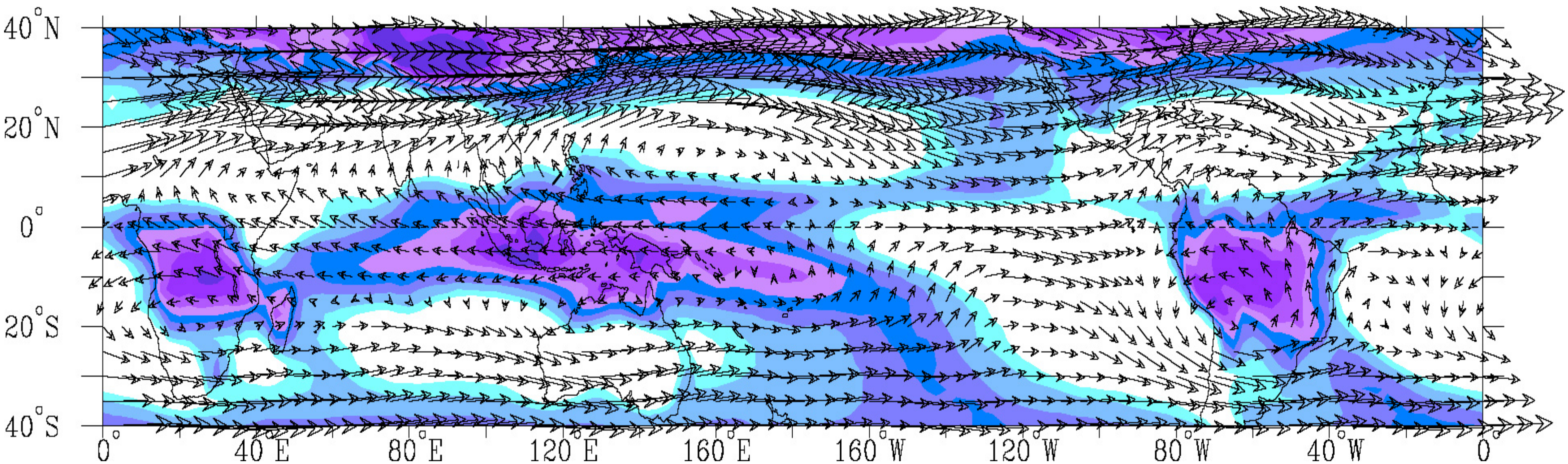


Shading at 10 W m^{-2} intervals,
starting at 260 W m^{-2}

Mean January 200 hPa Total Wind,

Outgoing Longwave Radiation

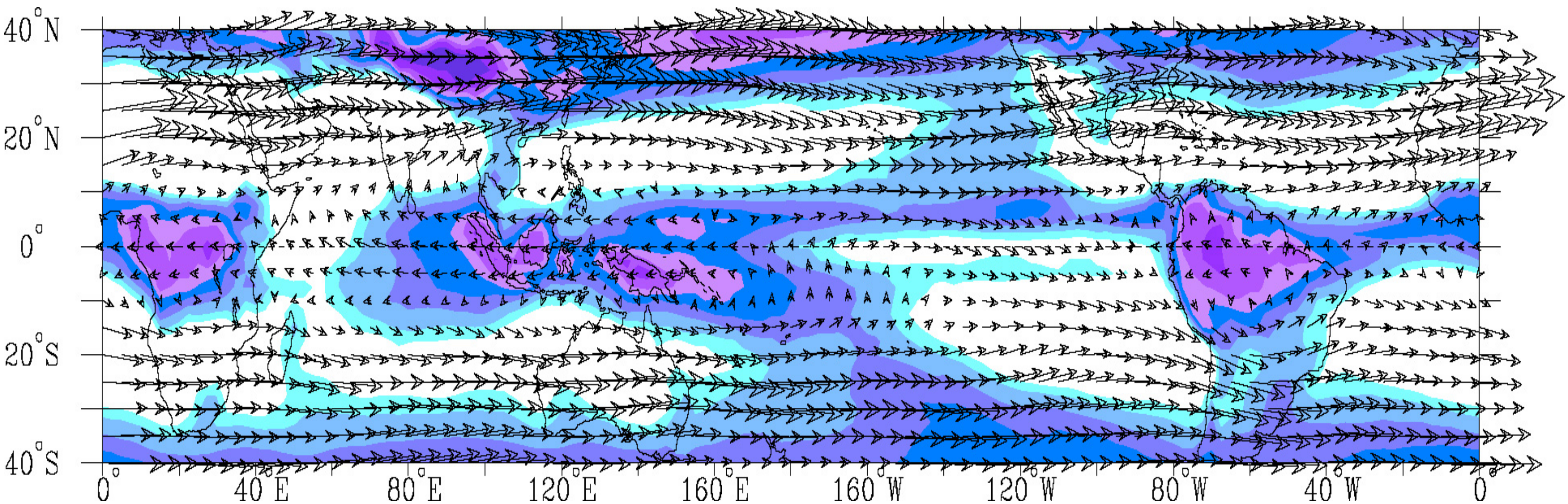
1979-2001



Wind (vectors, largest around 70 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

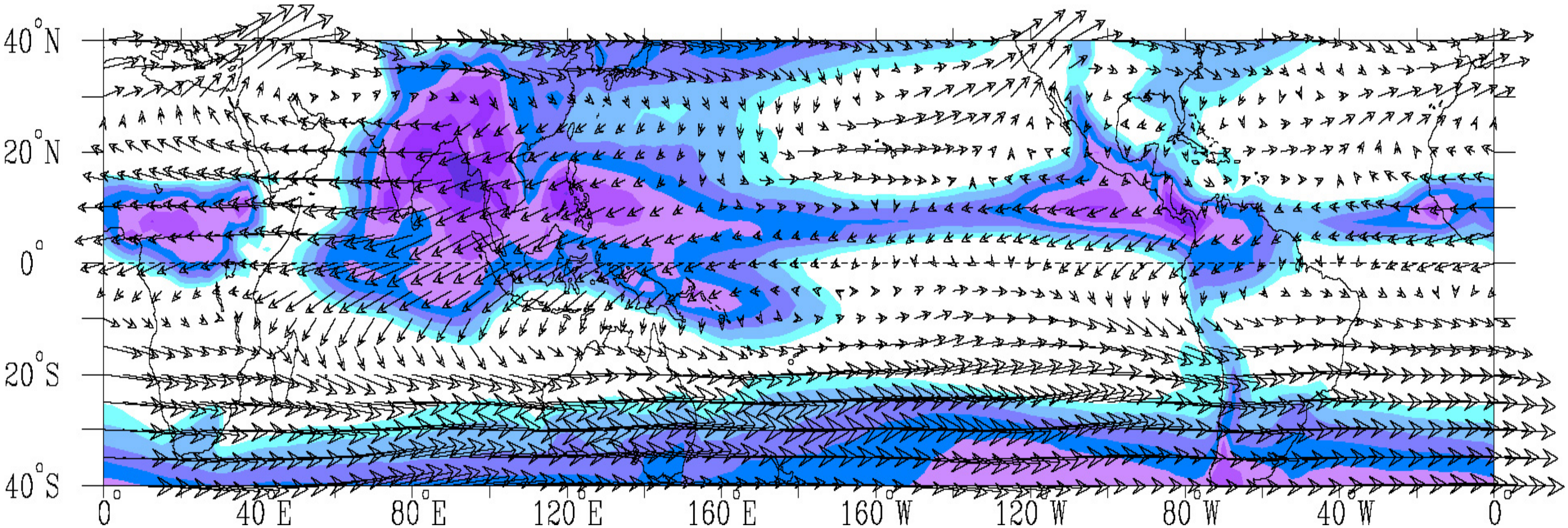
Mean April 200 hPa Total Wind, Outgoing Longwave Radiation 1979-2001



Wind (vectors, largest around 70 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean July 200 hPa Total Wind, Outgoing Longwave Radiation 1979-2001



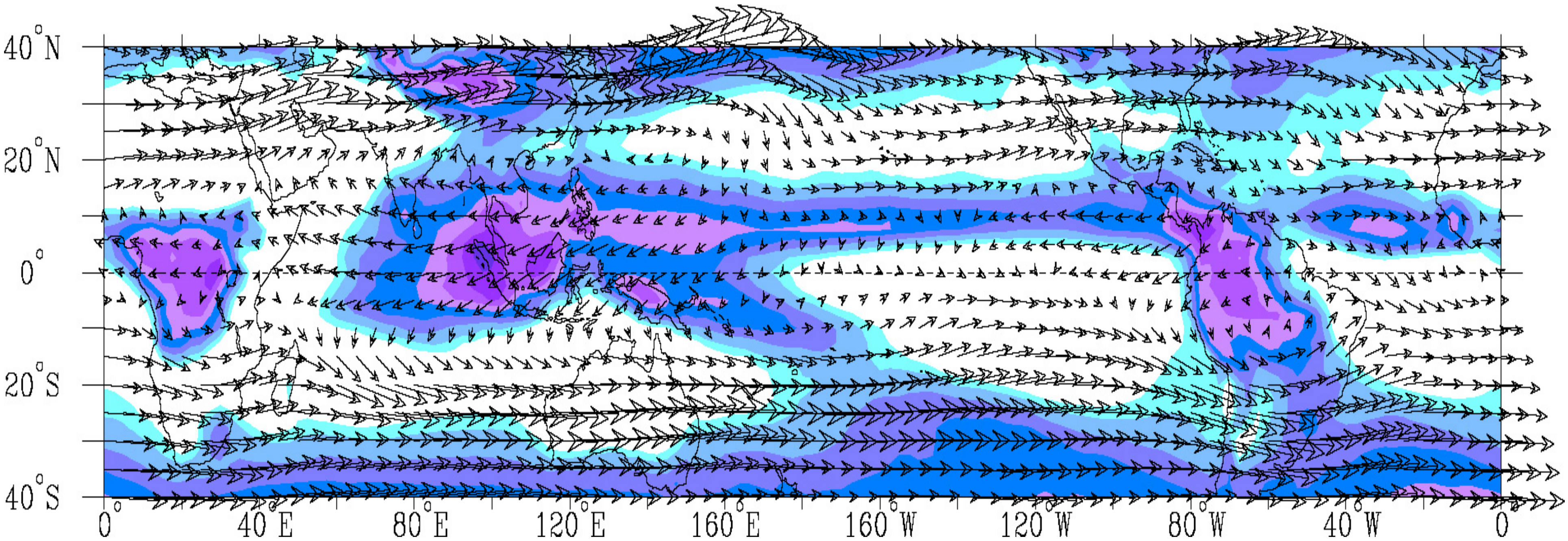
Wind (vectors, largest around 70 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean October 200 hPa Total Wind,

Outgoing Longwave Radiation

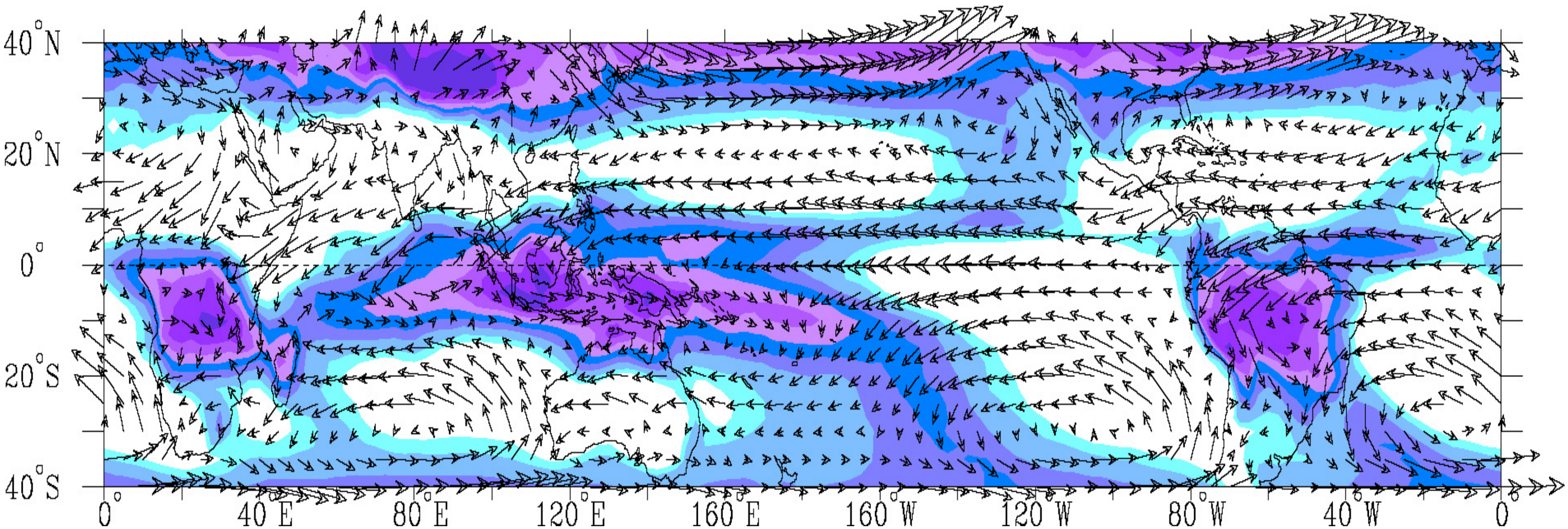
1979-2001



Wind (vectors, largest around 70 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean January 850 hPa Total Wind, Outgoing Longwave Radiation 1979-2001



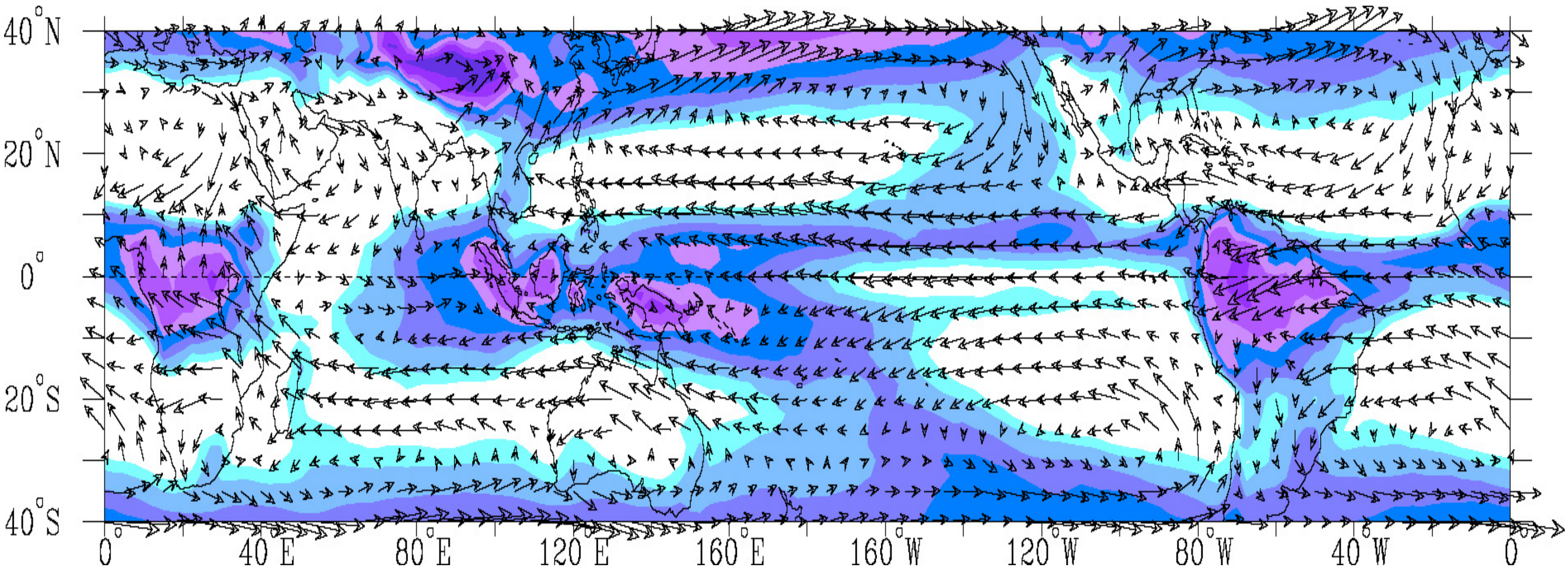
Wind (vectors, largest around 10 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean April 850 hPa Total Wind,

Outgoing Longwave Radiation

1979-2001



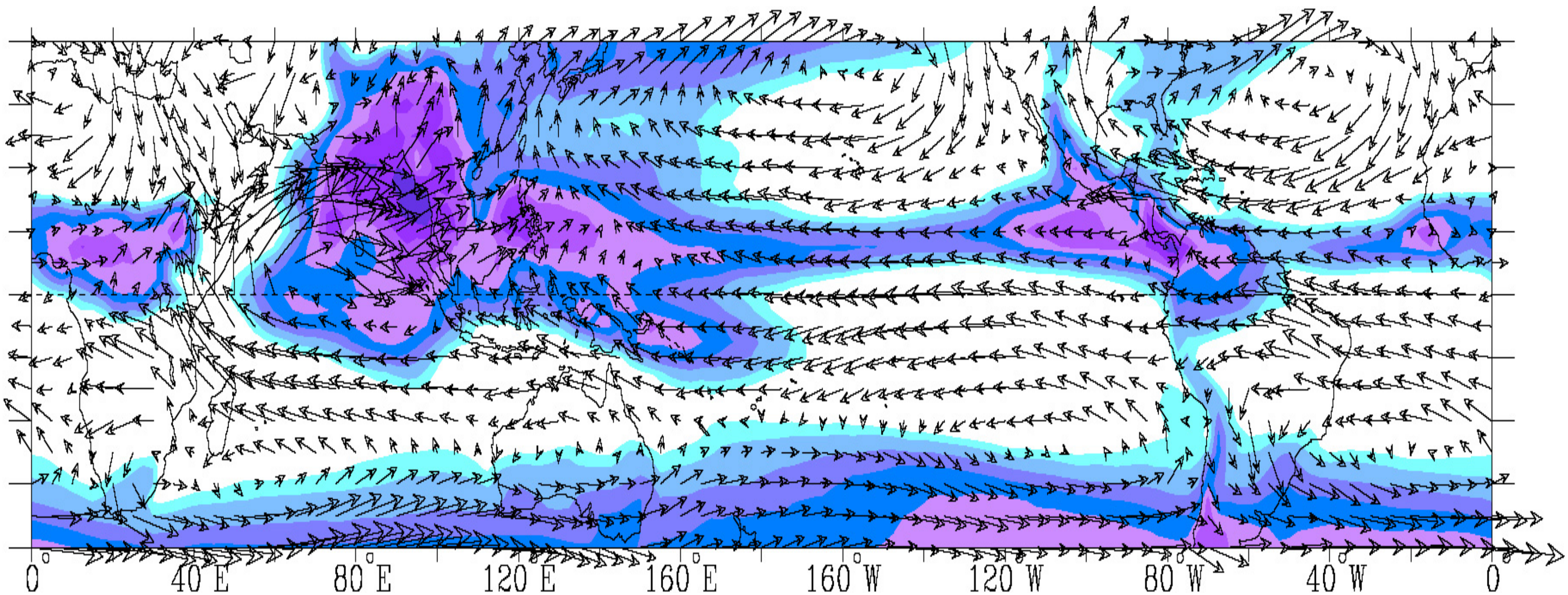
Wind (vectors, largest around 10 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean July 850 hPa Total Wind,

Outgoing Longwave Radiation

1979-2001



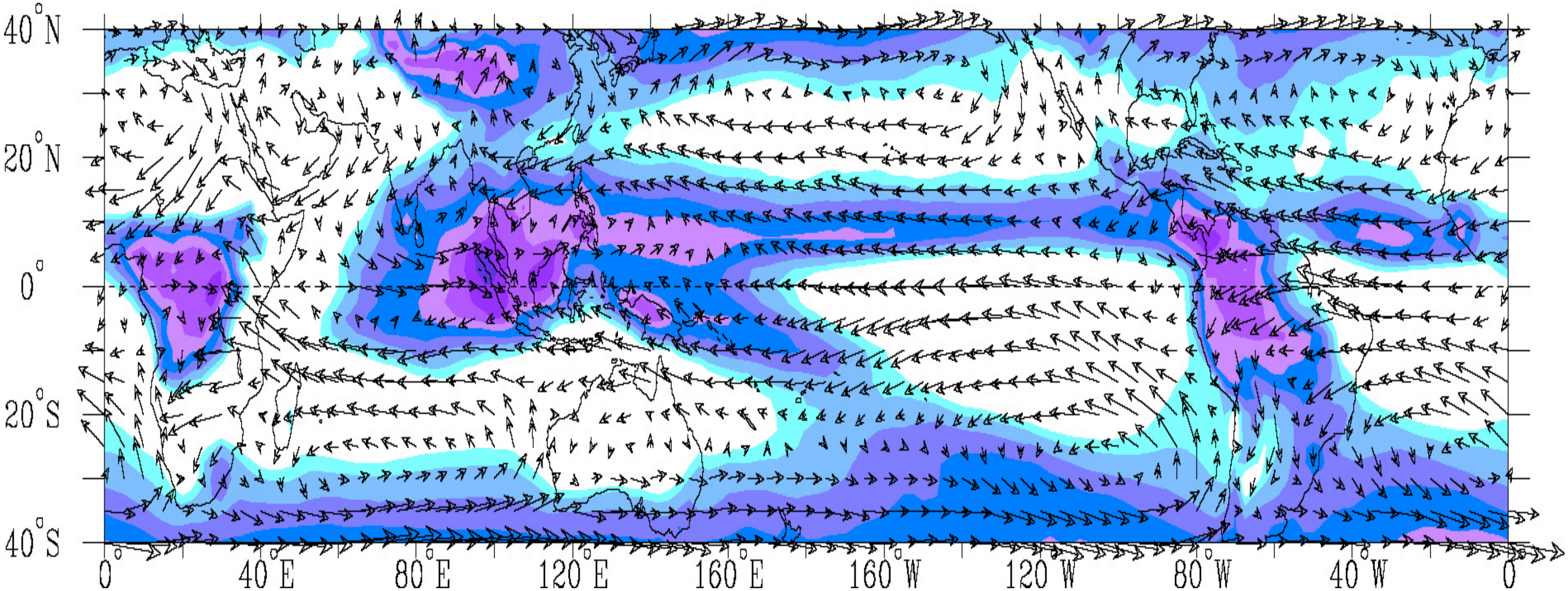
Wind (vectors, largest around 10 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean October 850 hPa Total Wind,

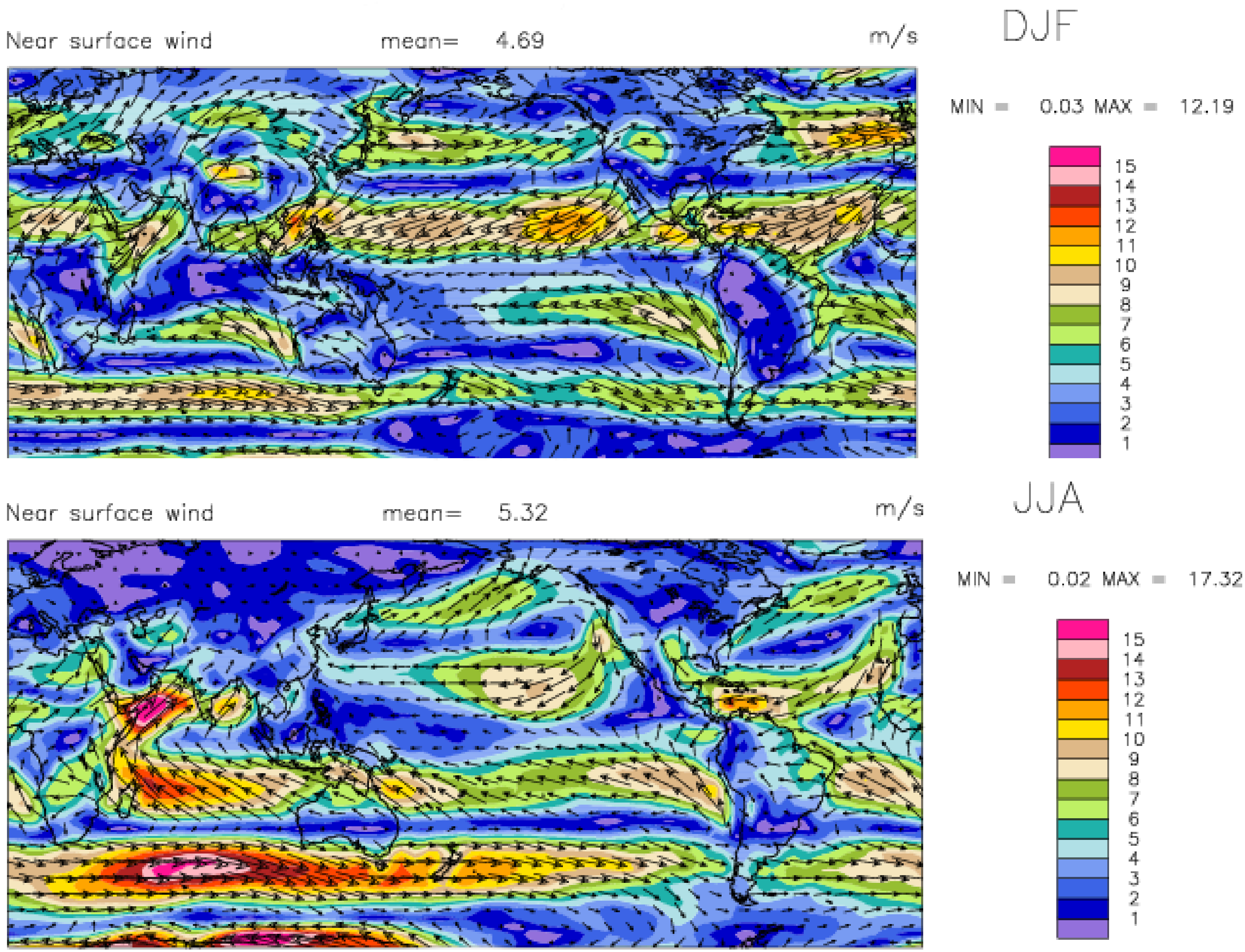
Outgoing Longwave Radiation

1979-2001



Wind (vectors, largest around 10 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)


Near surface wind
mean= 4.69
m/s
DJF
MIN = 0.03 MAX = 12.19
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Near surface wind
mean= 5.32
m/s
JJA
MIN = 0.02 MAX = 17.32
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

Vorticity

$$\zeta = \nabla \times \vec{V} = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Divergence

$$D = \nabla \bullet \vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Streamfunction

$$\nabla^2 \psi = \zeta$$

Velocity Potential

$$\nabla^2 \chi = D$$

Non-divergent (Rotational) Wind

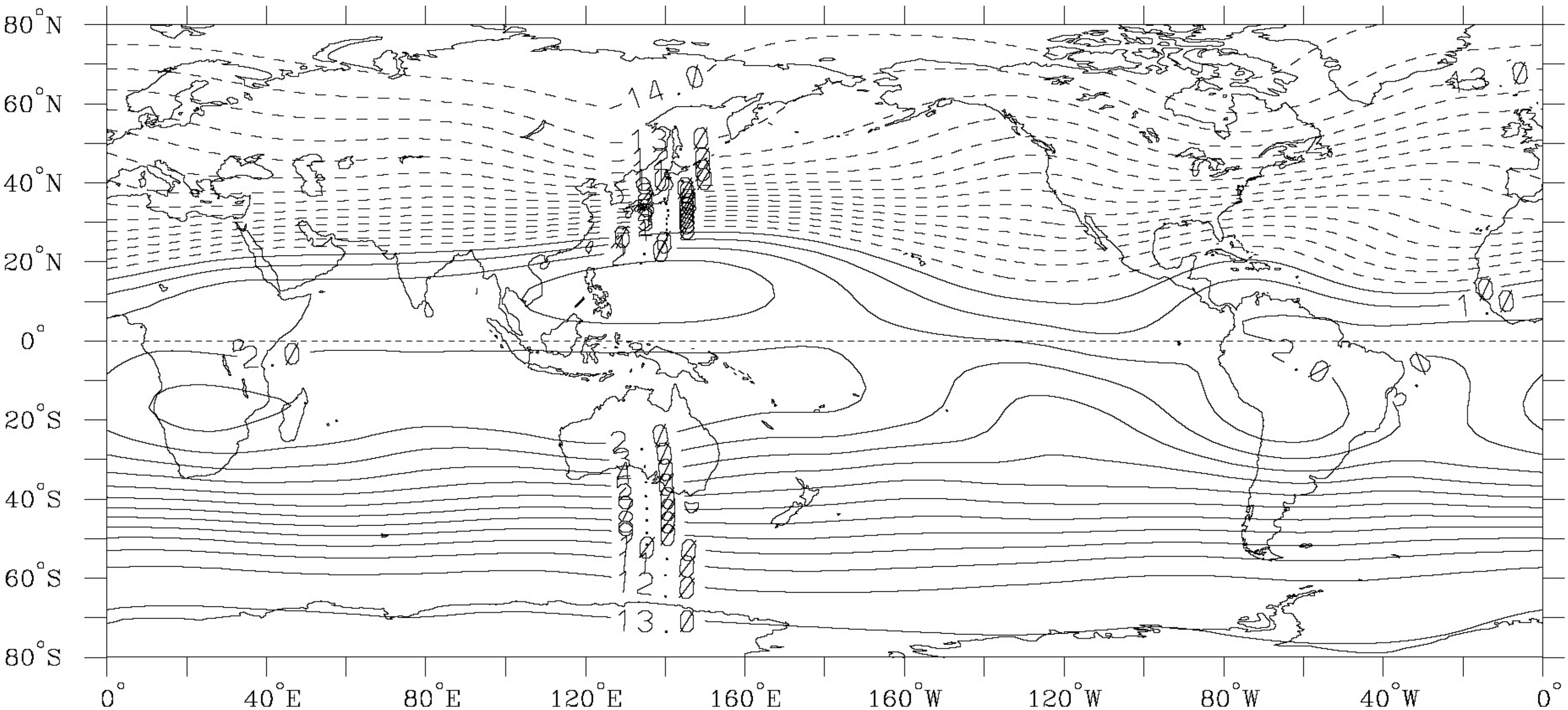
$$u_{\psi} = -\frac{\partial \psi}{\partial y} \qquad v_{\psi} = \frac{\partial \psi}{\partial x}$$

Divergent Wind

$$u_{\chi} = \frac{\partial \chi}{\partial x} \qquad v_{\chi} = \frac{\partial \chi}{\partial y}$$

Mean January 200 hPa Streamfunction

1979-2001

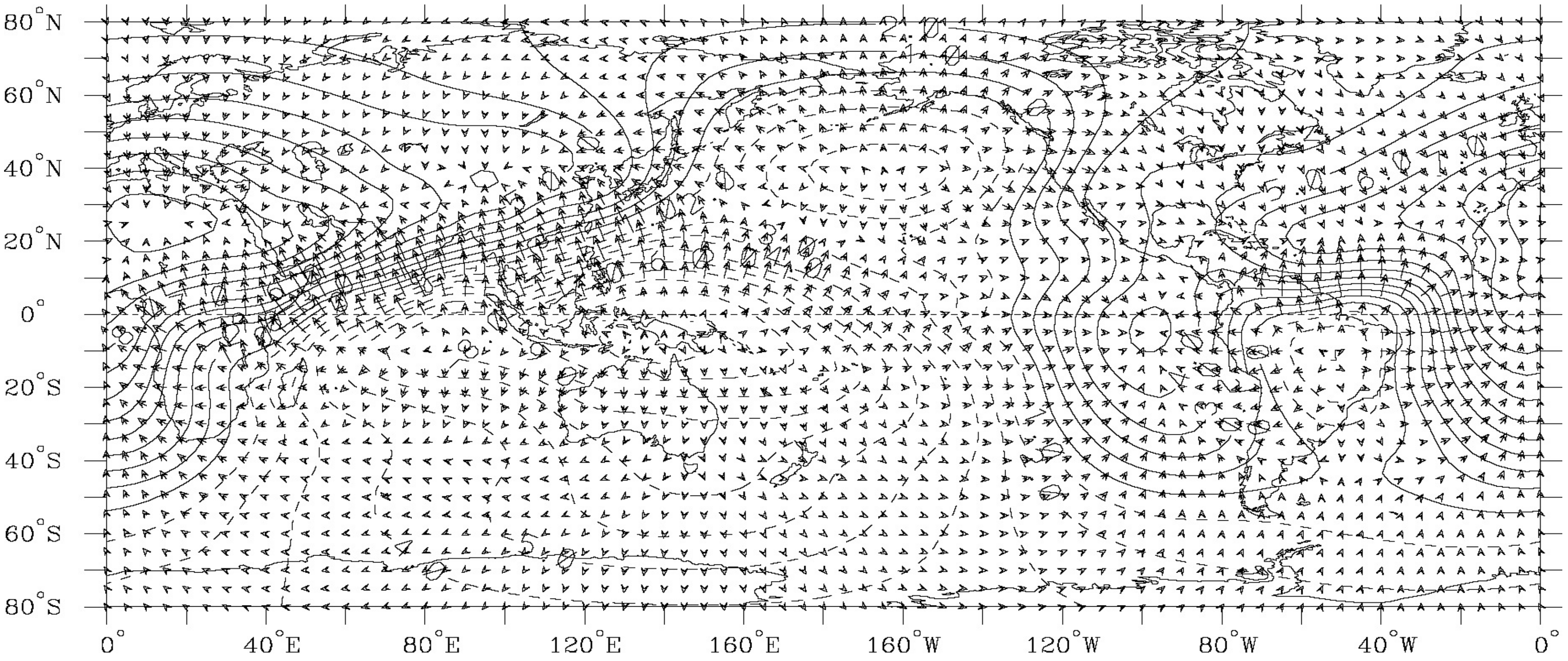


Contour interval 1.0 X 10^7 m^2 s^{-1}

Mean January 200 hPa Velocity Potential

and Divergent Wind

1979-2001



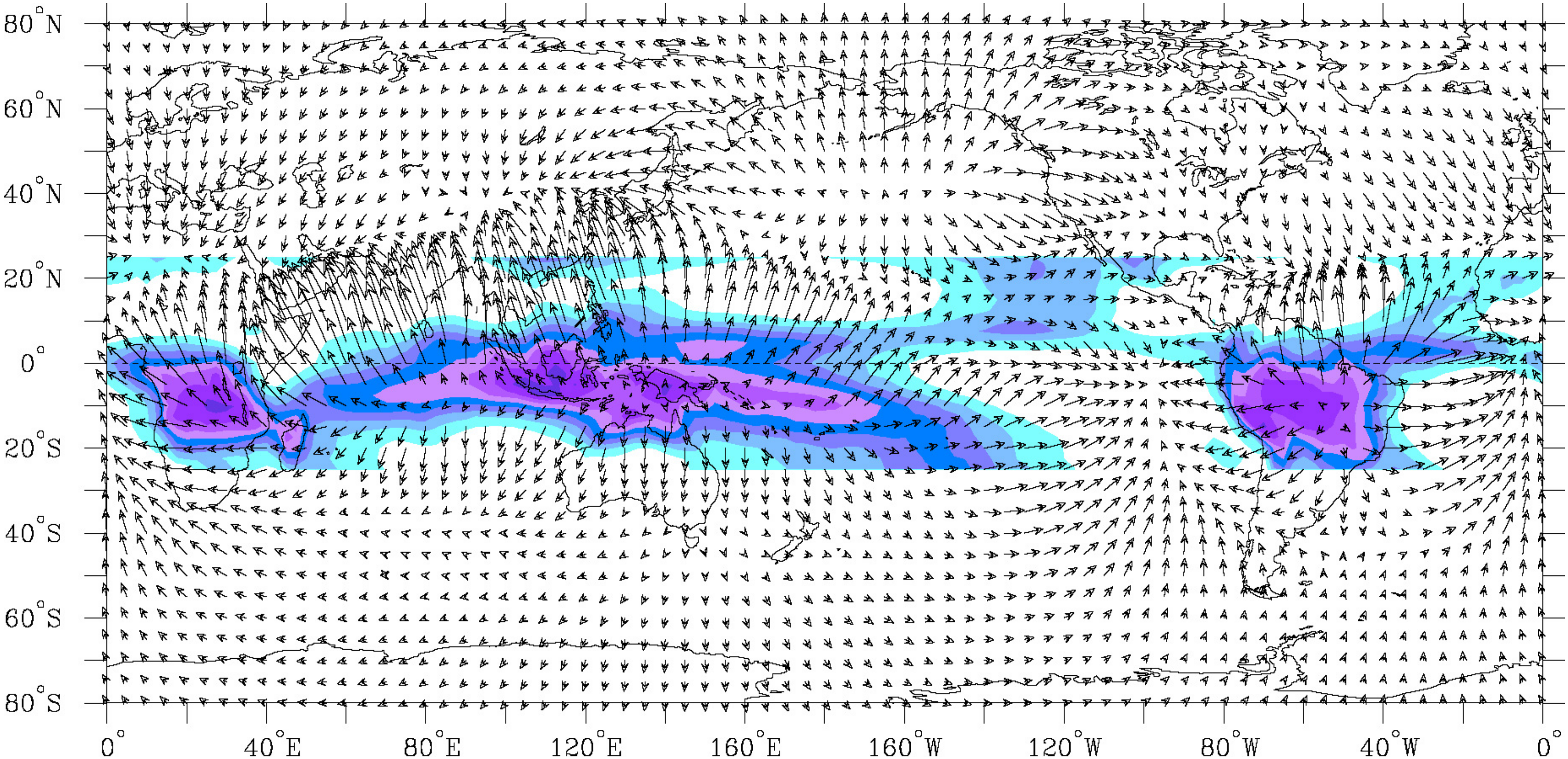
Contour interval 1.0 X 10^6 m^2 s^{-1}

Largest vector is about 5 m s^{-1}

Mean January 200 hPa Divergent Wind,

Outgoing Longwave Radiation

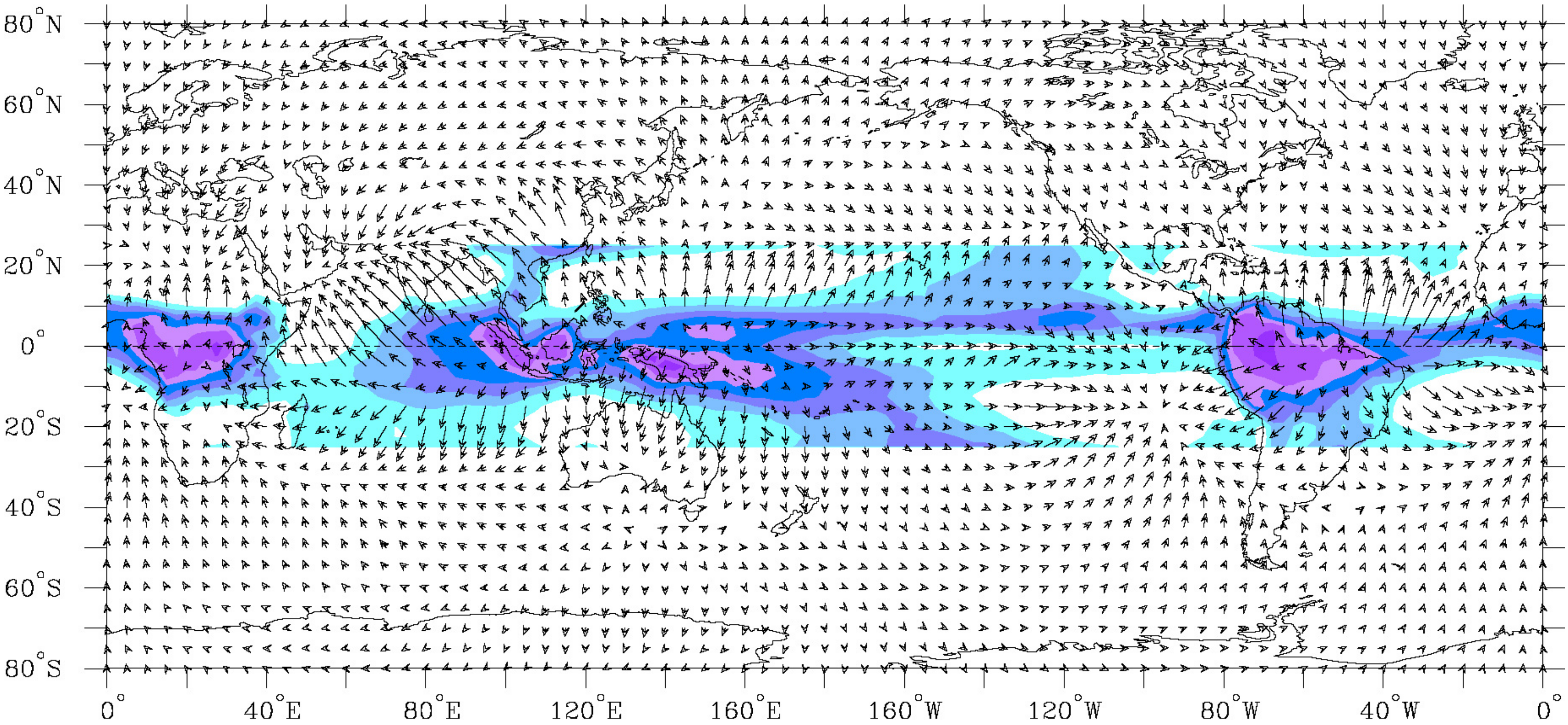
1979-2001



Div. Wind (vectors, largest around 15 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean April 200 hPa Divergent Wind, Outgoing Longwave Radiation 1979-2001



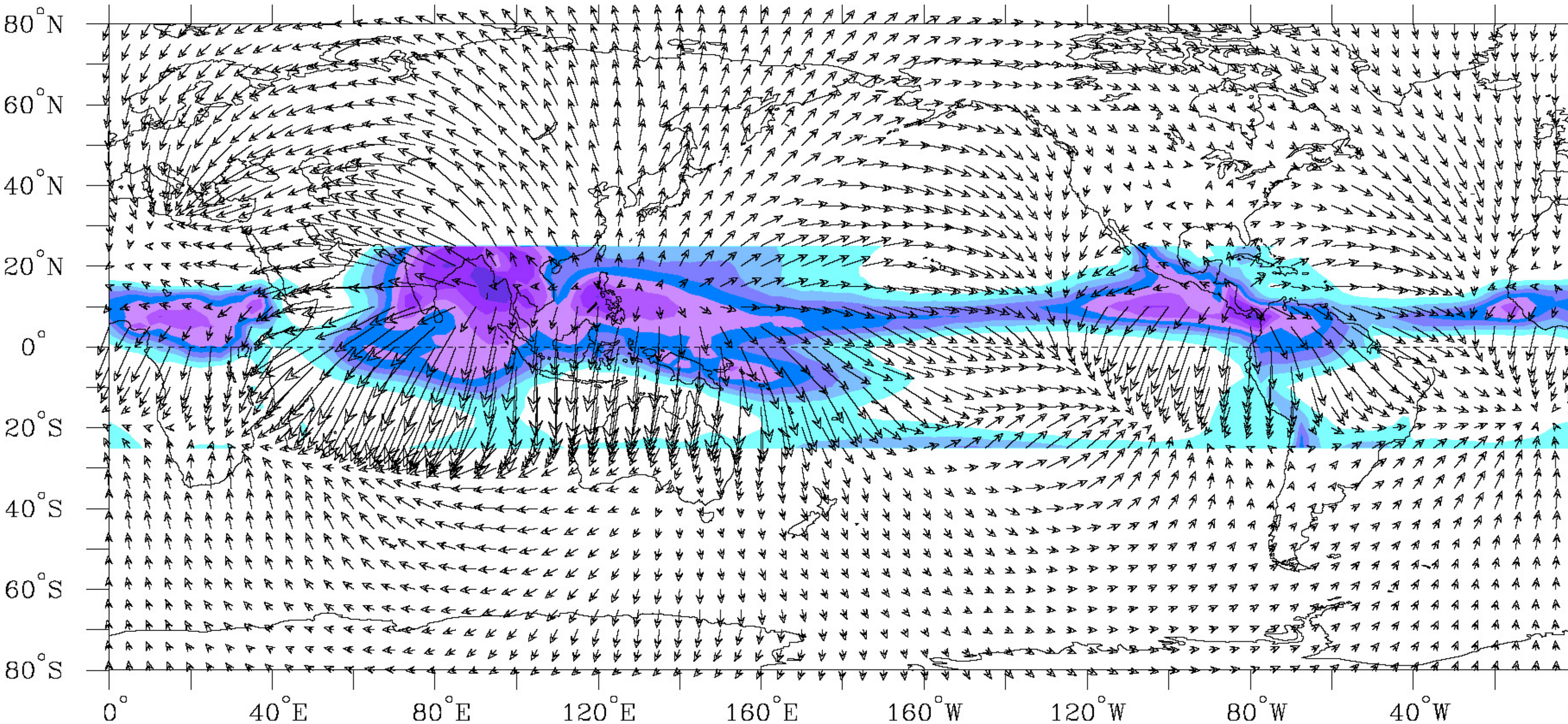
Div. Wind (vectors, largest around 15 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

Mean July 200 hPa Divergent Wind,

Outgoing Longwave Radiation

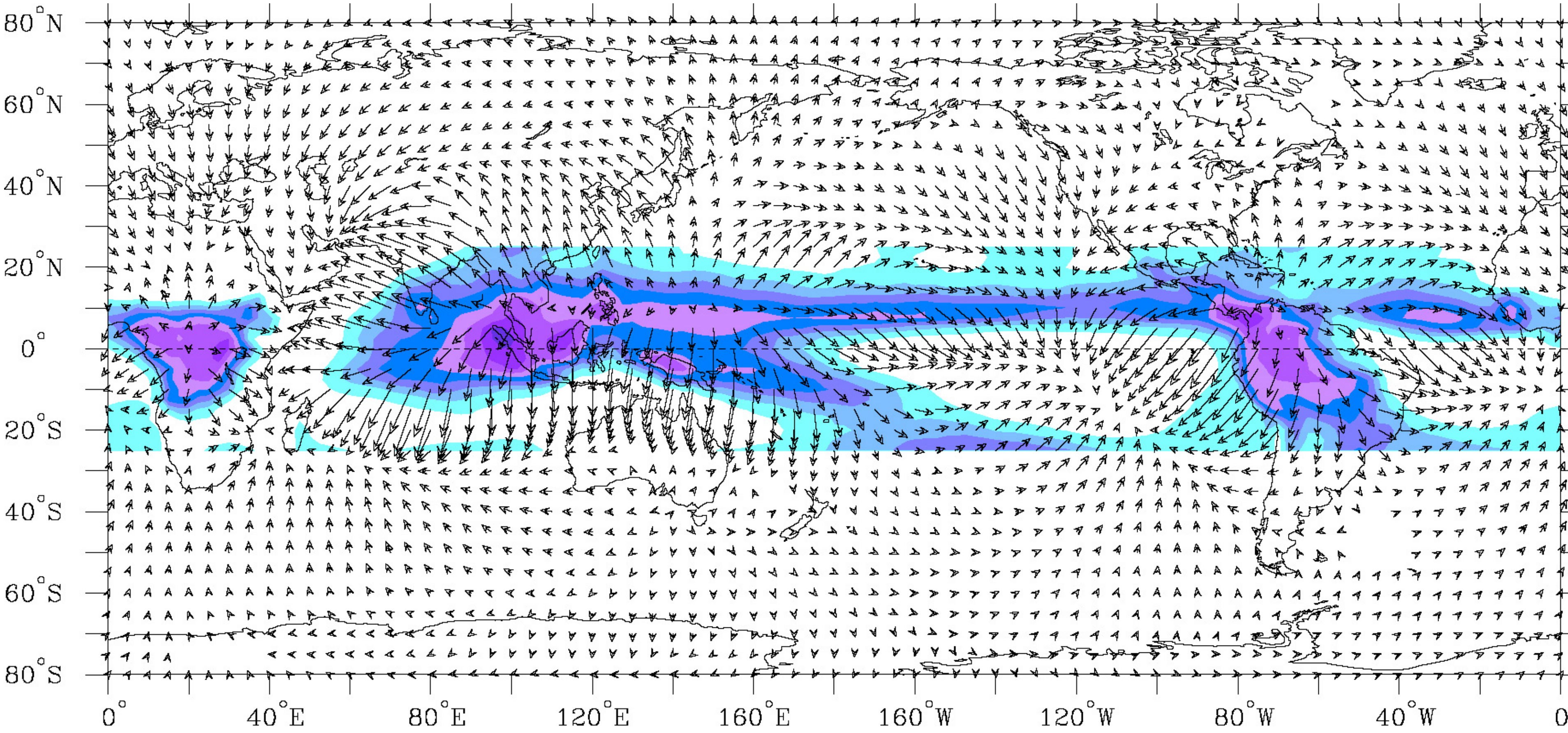
1979-2001



Div. Wind (vectors, largest around 15 m s^{-1})

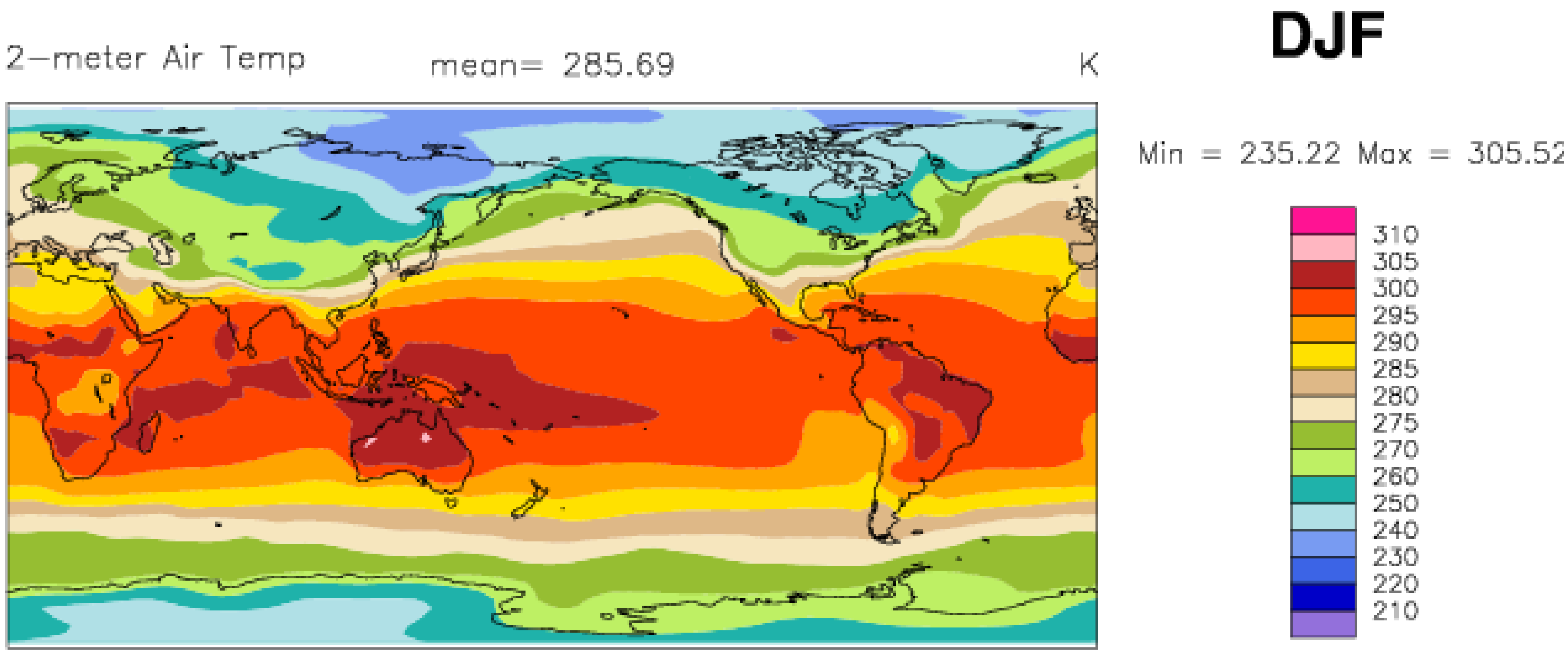
OLR (shading at 10 W s^{-2} intervals)

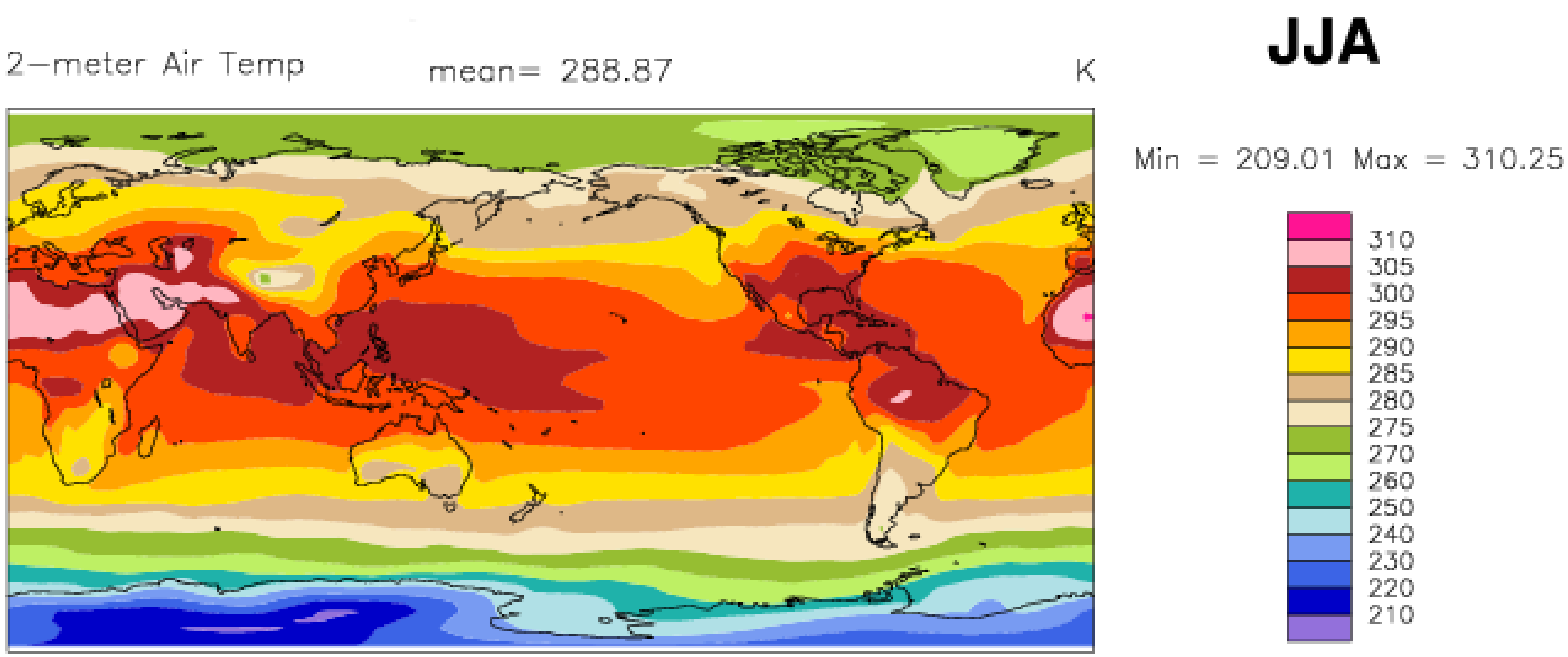
Mean October 200 hPa Divergent Wind, Outgoing Longwave Radiation 1979-2001



Div. Wind (vectors, largest around 15 m s^{-1})

OLR (shading at 10 W s^{-2} intervals)

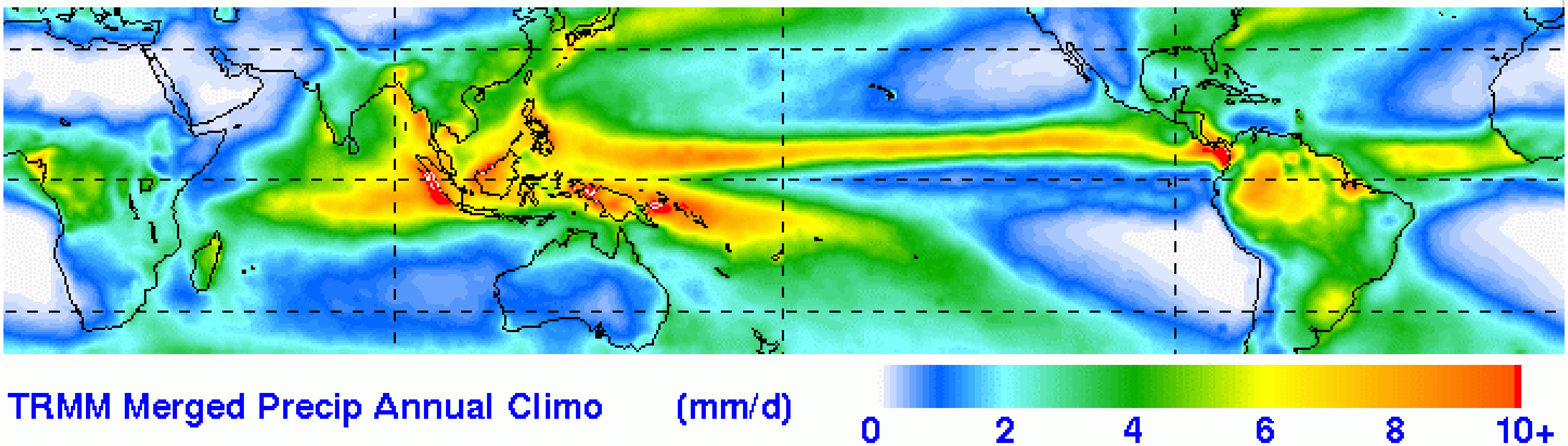

DJF
2–meter Air Temp
mean= 285.69
K
Min = 235.22 Max = 305.52
310
305
300
295
290
285
280
275
270
260
250
240
230
220
210


JJA
2–meter Air Temp
mean= 288.87
K
Min = 209.01 Max = 310.25
310
305
300
295
290
285
280
275
270
260
250
240
230
220
210

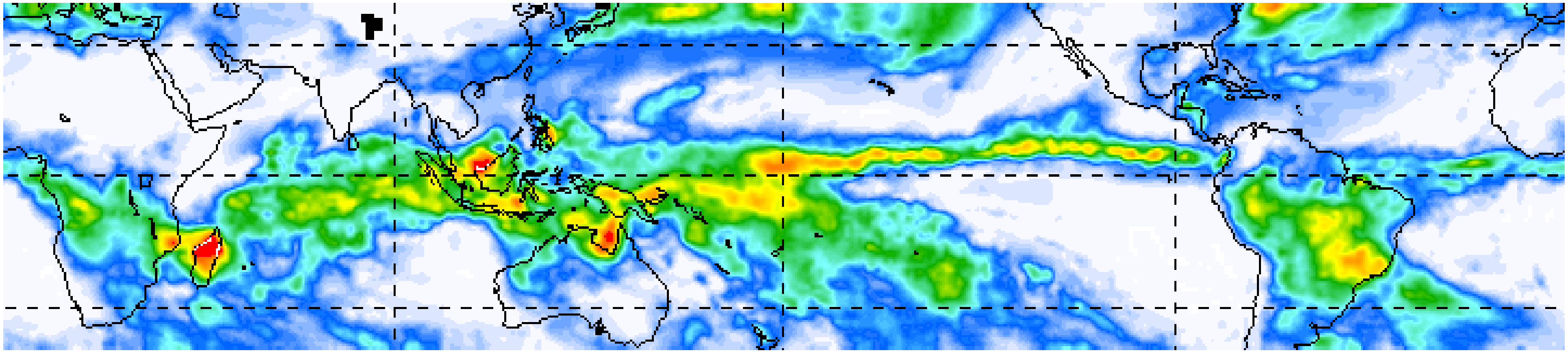
Annual Mean Precipitation

Tropical Rainfall Measuring Mission (TRMM)

Six – Year TRMM Climatology

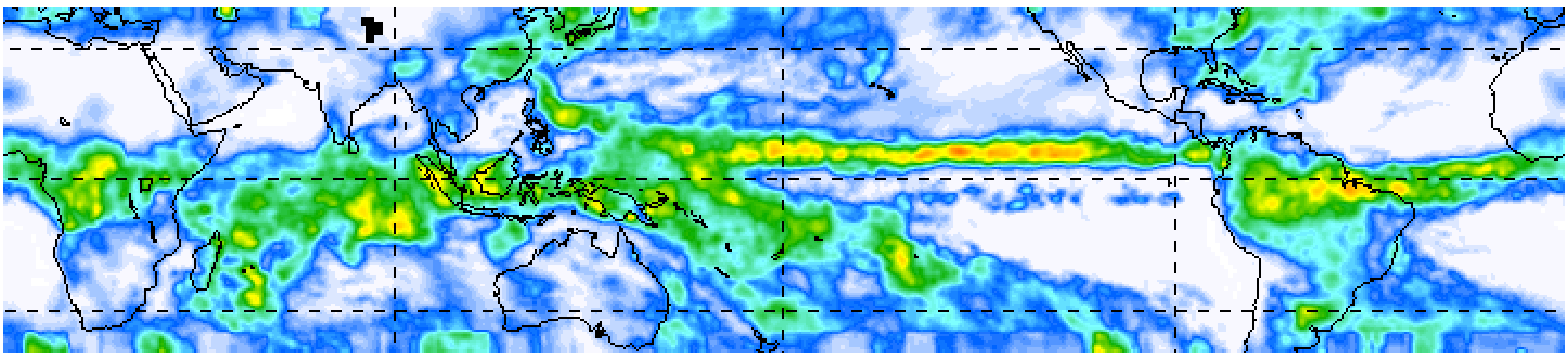


January 1998 – December 2003



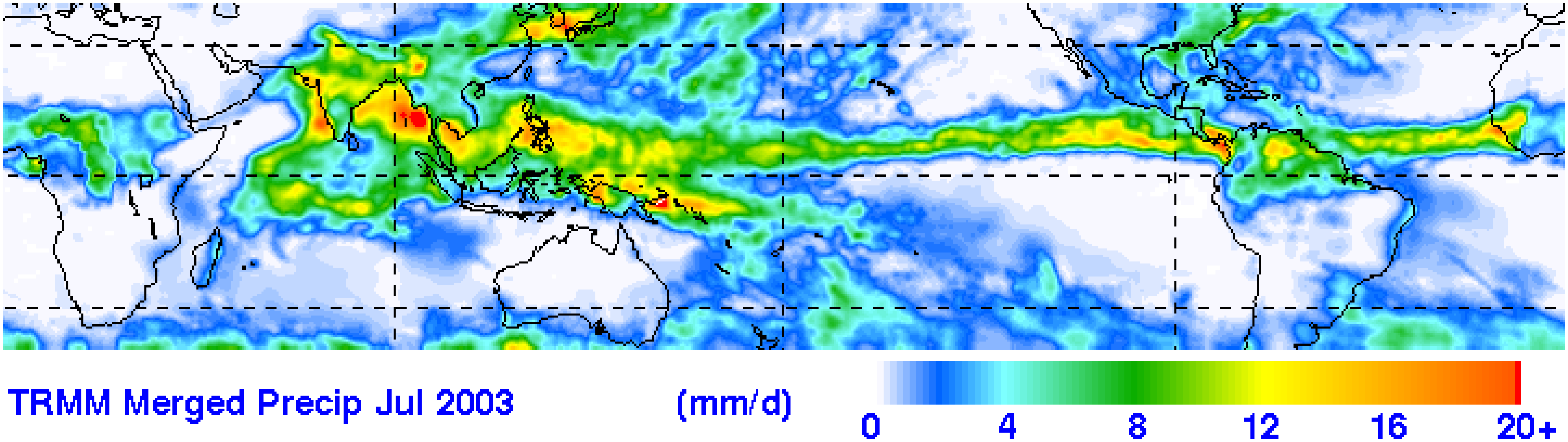
TRMM Merged Precip Jan 2003 (mm/d)

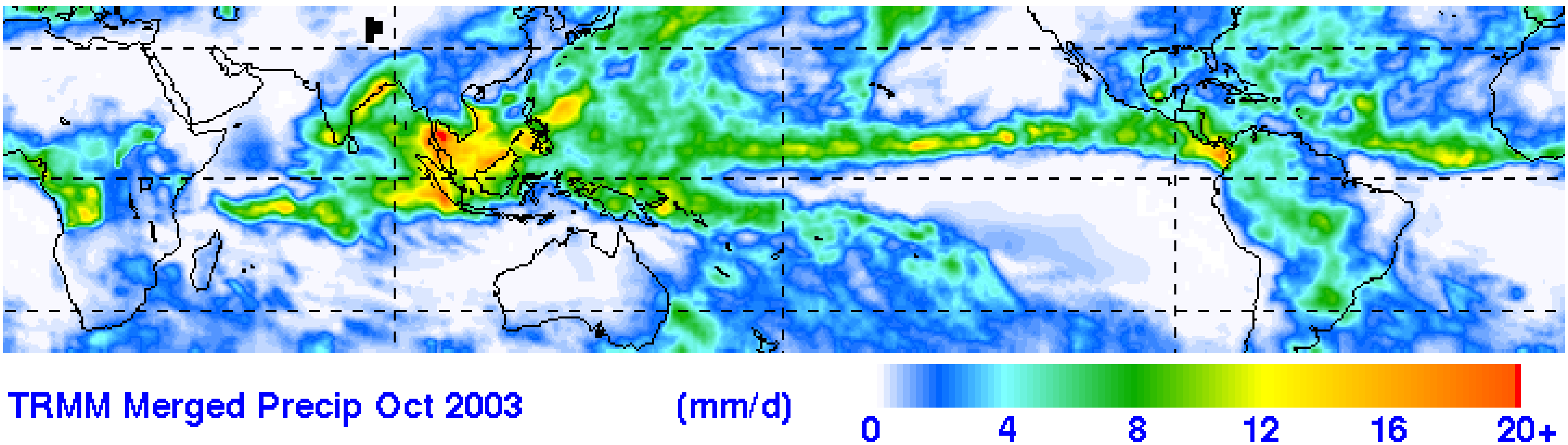
0 4 8 12 16 20+



TRMM Merged Precip Apr 2003 (mm/d)

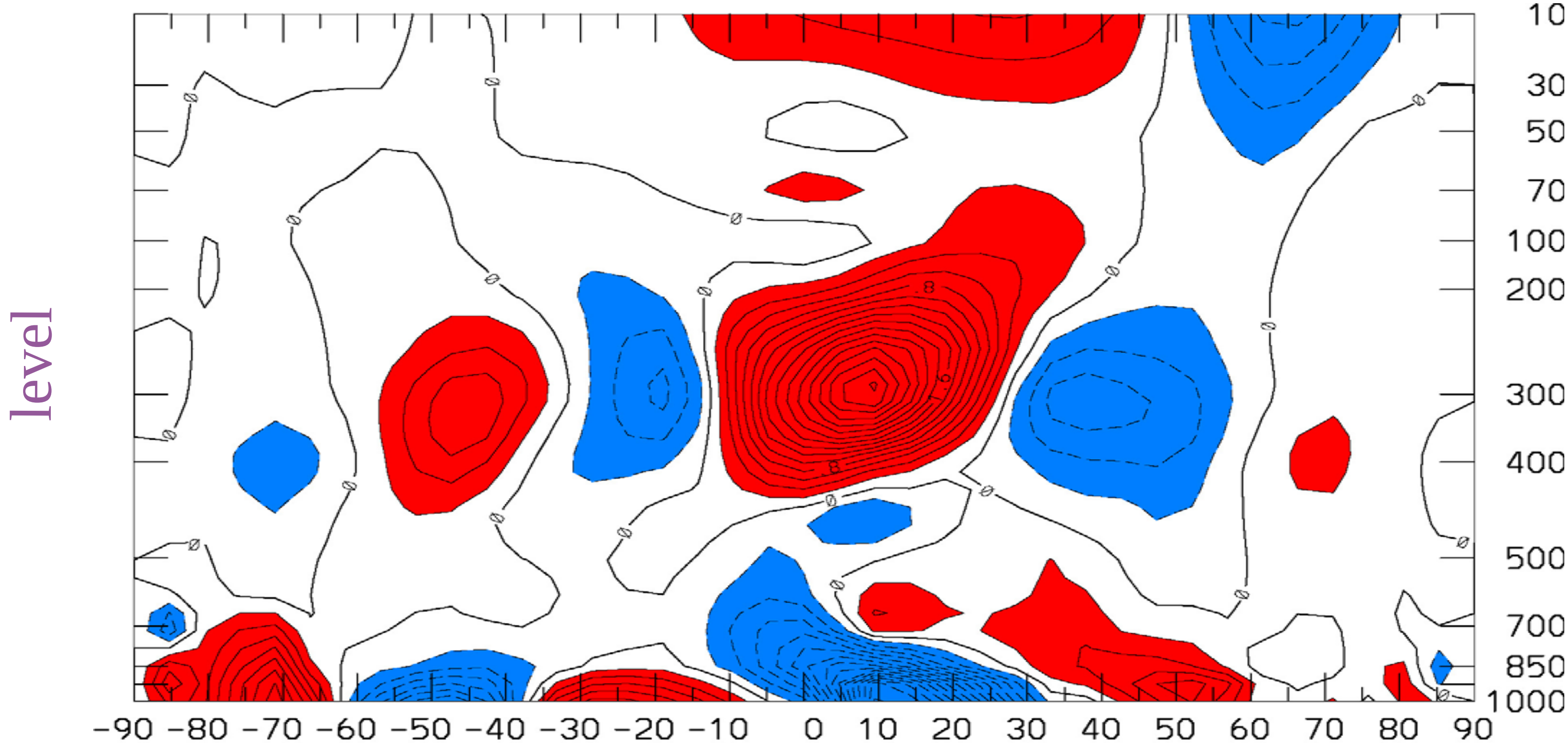
0 4 8 12 16 20+


TRMM Merged Precip Jul 2003
(mm/d)
0
4
8
12
16
20+


TRMM Merged Precip Oct 2003
(mm/d)
0
4
8
12
16
20+

The Zonally Symmetric Circulation

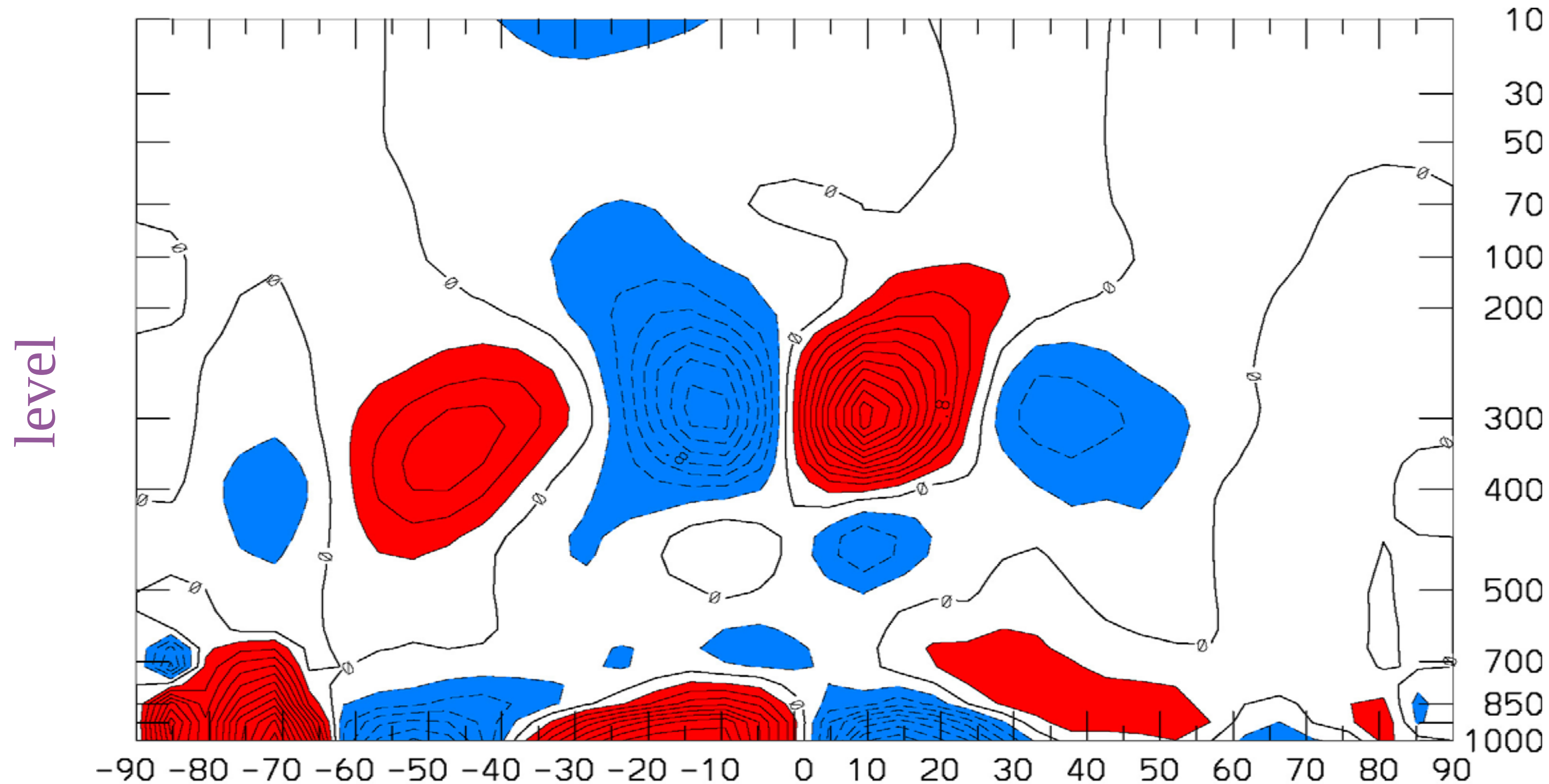
January Zonal Mean Meridional Wind 1979-1993 from ECMWF



Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

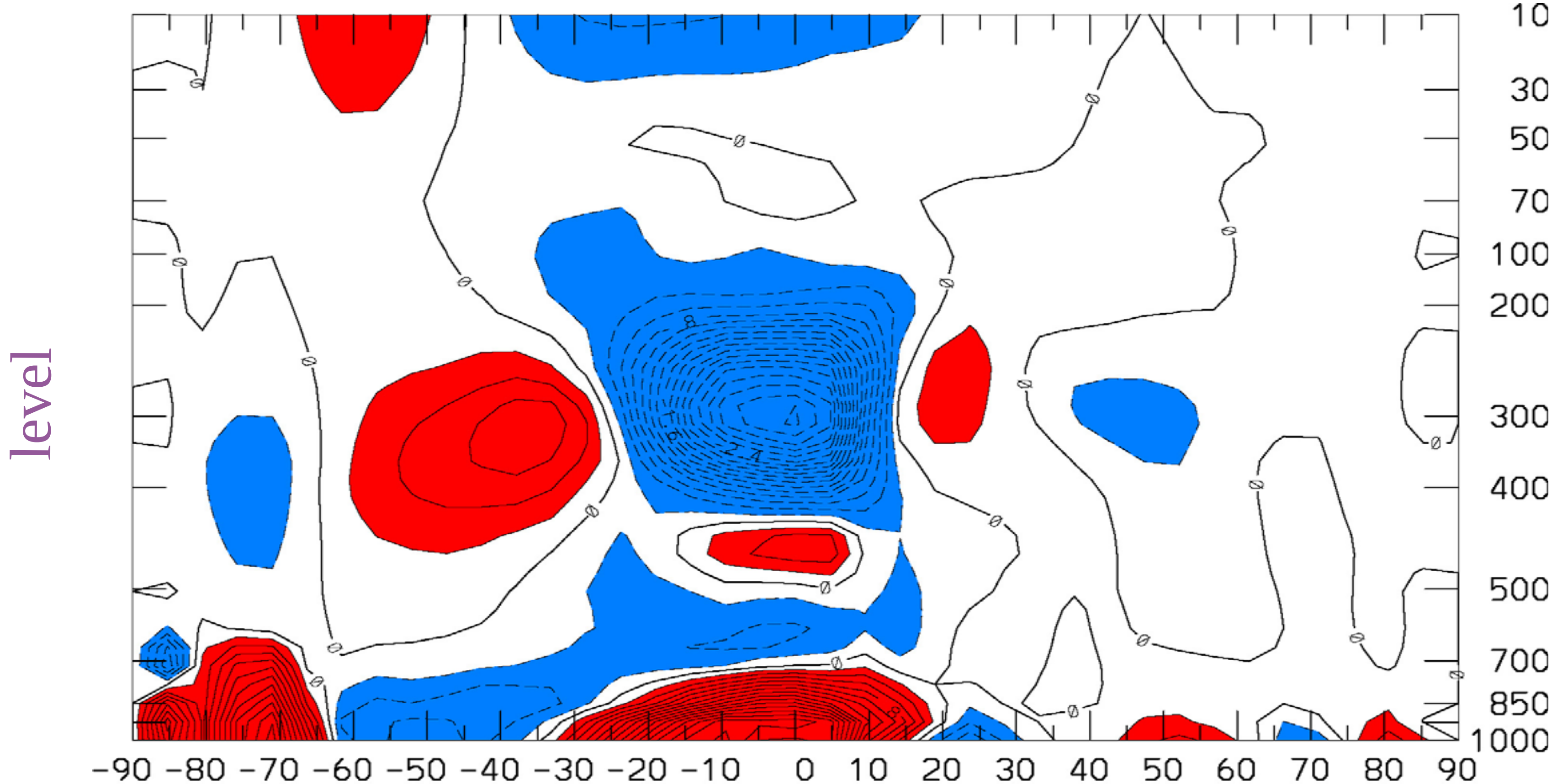
April Zonal Mean Meridional Wind 1979-1993 from ECMWF



Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

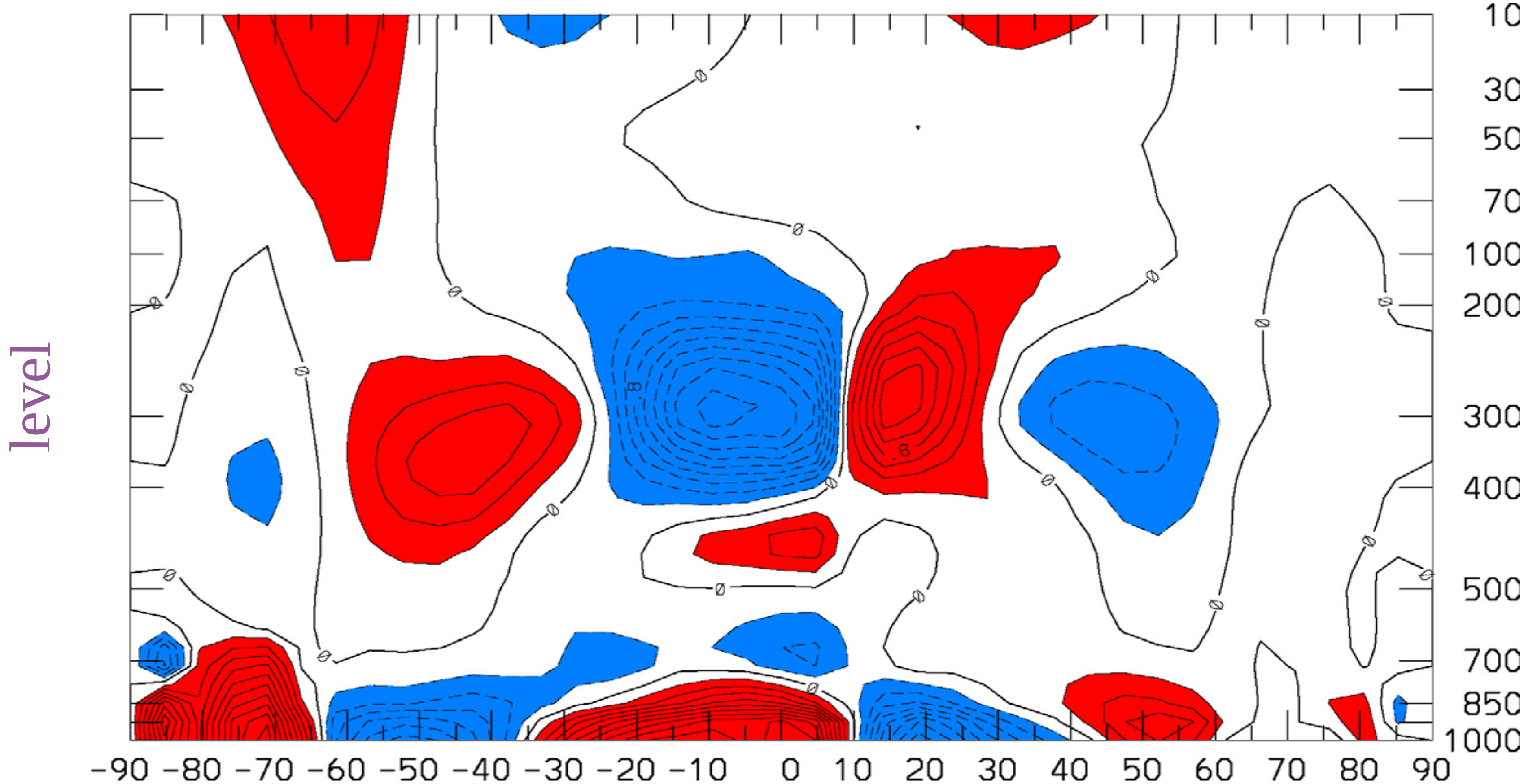
July Zonal Mean Meridional Wind 1979-1993 from ECMWF



Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

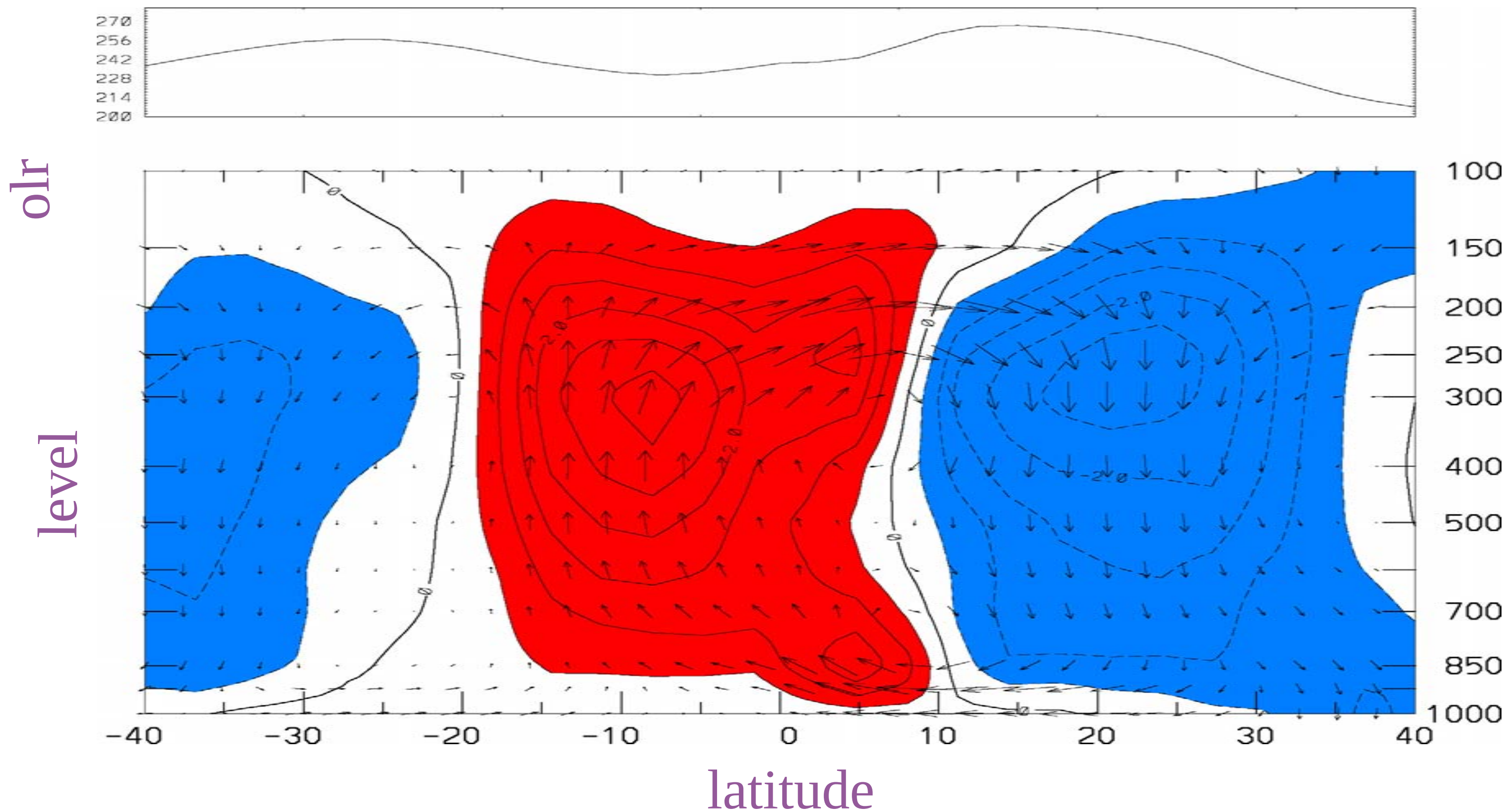
October Zonal Mean Meridional Wind 1979-1993 from ECMWF



Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

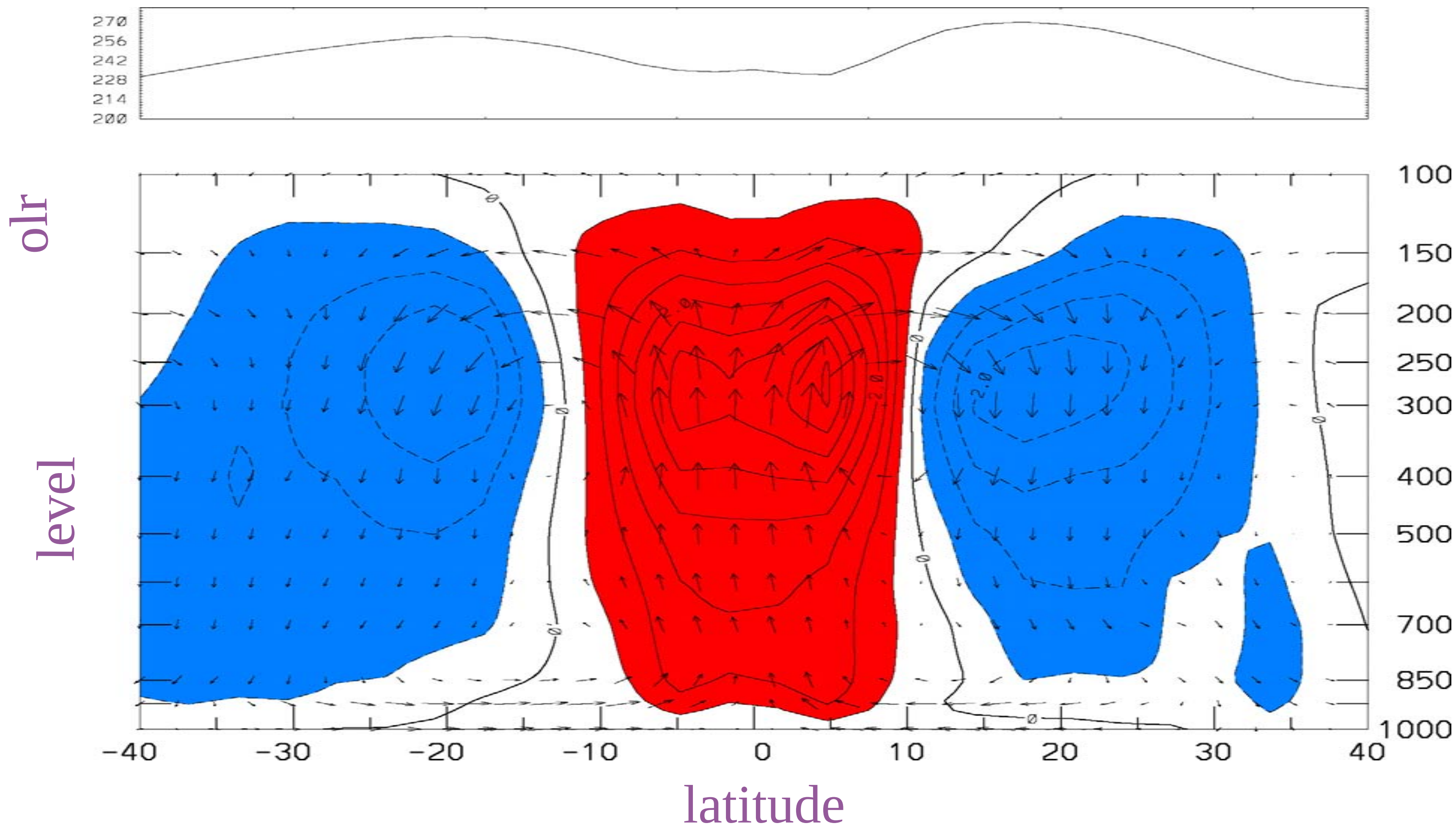
January Zonal Mean OLR, Vertical and Meridional Wind, 1979-1993 from ECMWF



Contour interval 1 mm s^{-1}

Shading Red Positive (Upward)

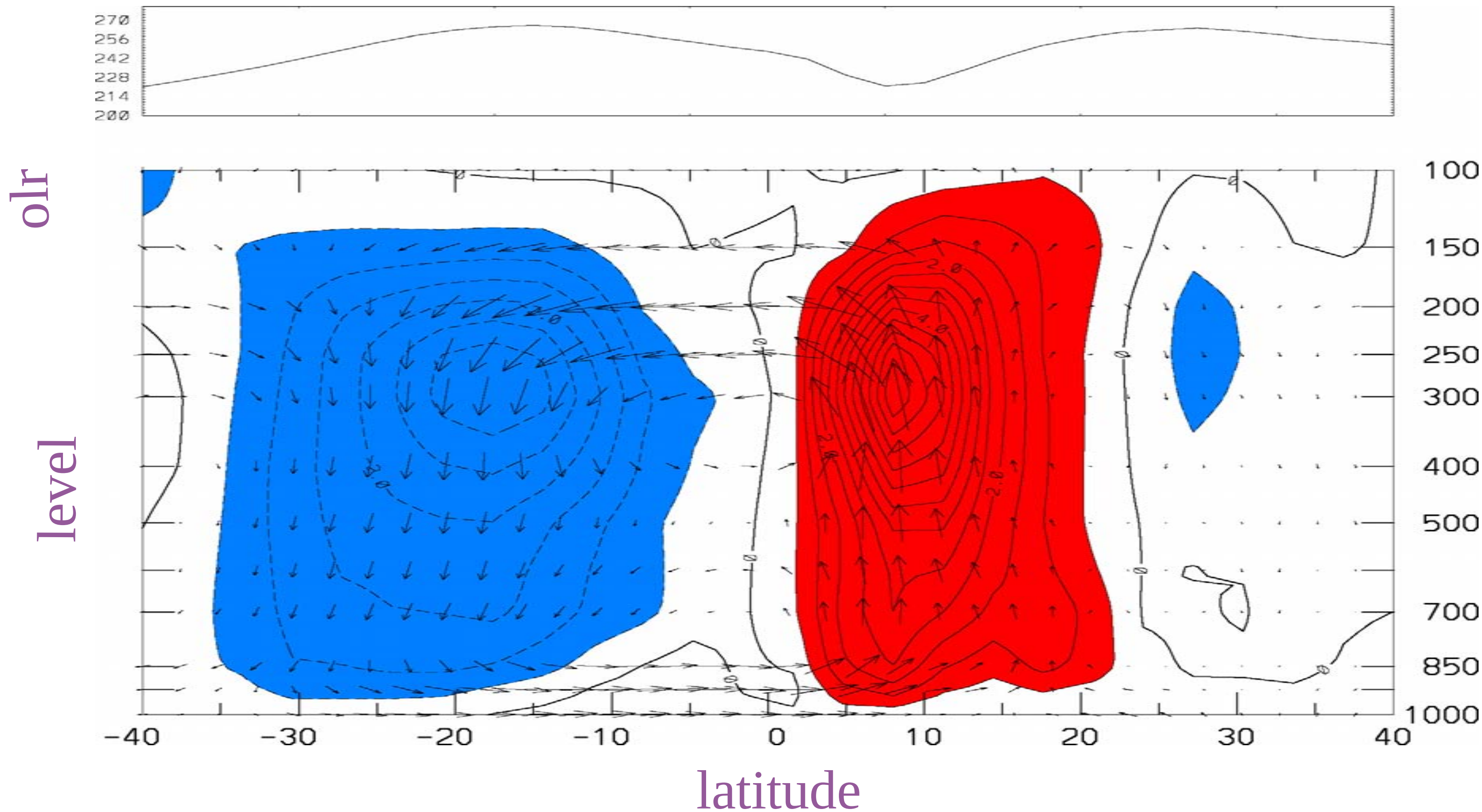
April Zonal Mean OLR, Vertical and Meridional Wind, 1979-1993 from ECMWF



Contour interval 1 mm s^{-1}

Shading Red Positive (Upward)

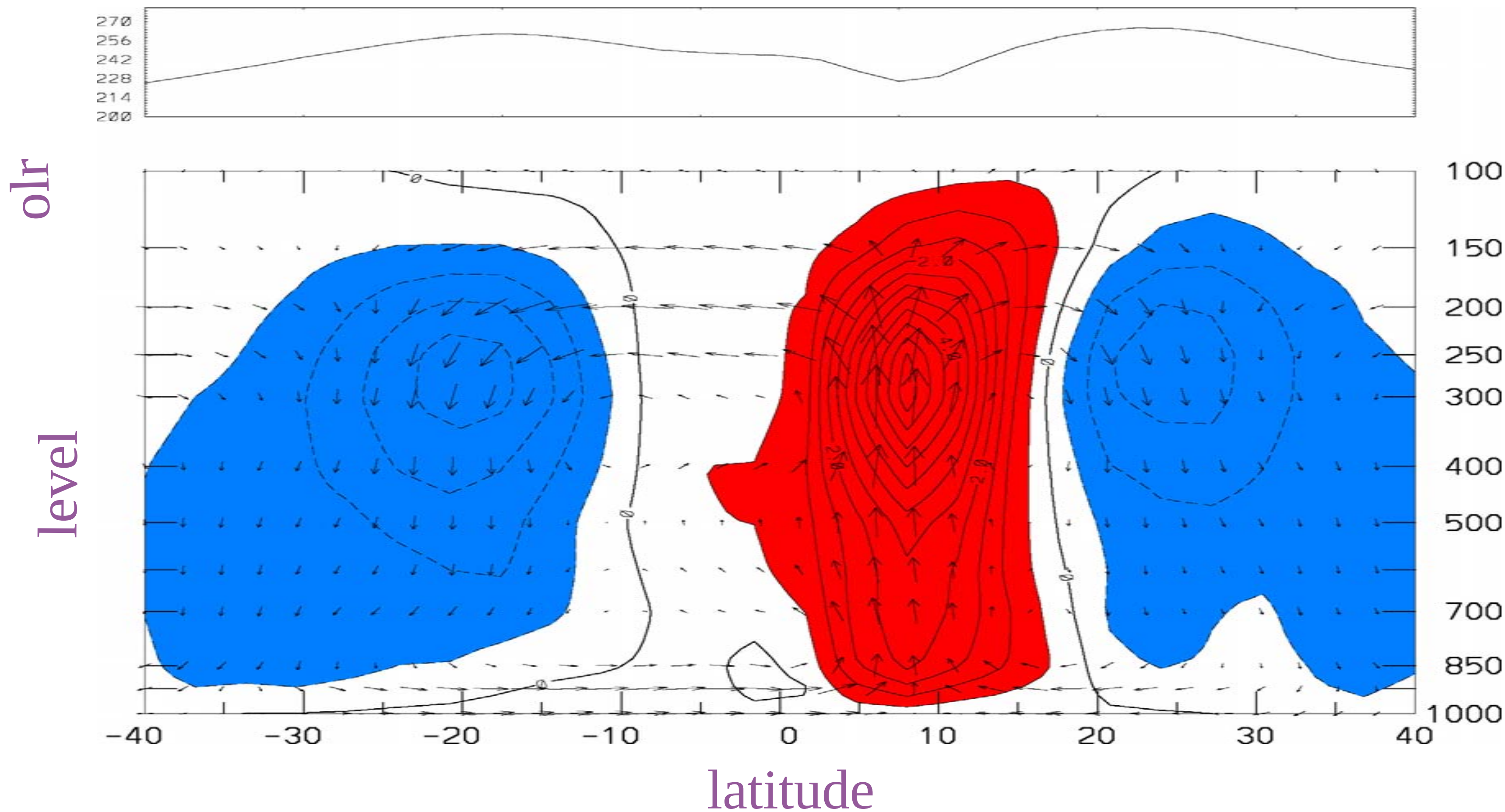
July Zonal Mean OLR, Vertical and Meridional Wind, 1979-1993 from ECMWF



Contour interval 1 mm s^{-1}

Shading Red Positive (Upward)

October Zonal Mean OLR, Vertical and Meridional Wind, 1979-1993 from ECMWF

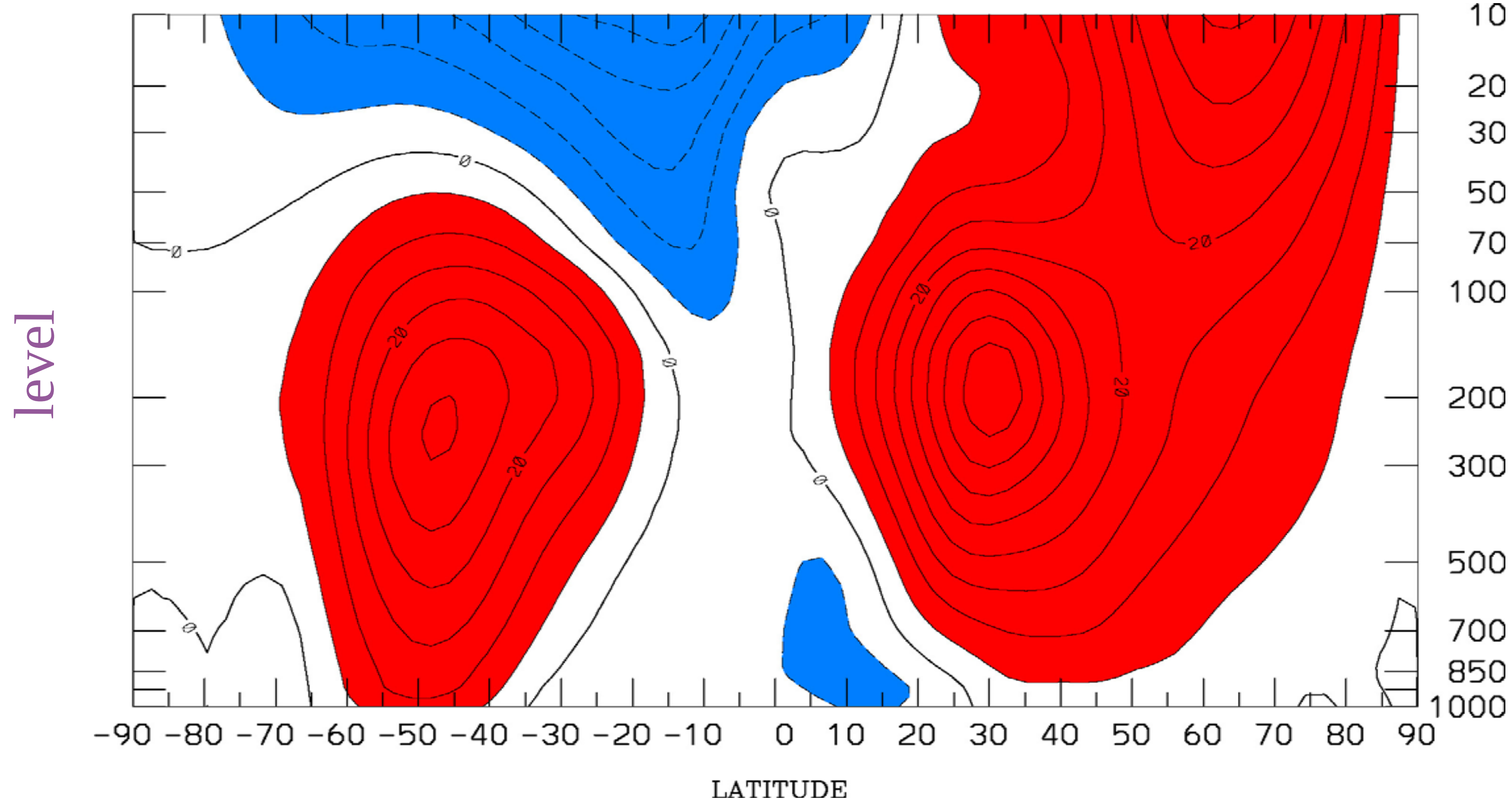


Contour interval 1 mm s^{-1}

Shading Red Positive (Upward)

January Zonal Mean Zonal Wind

1979-2001 from NCEP

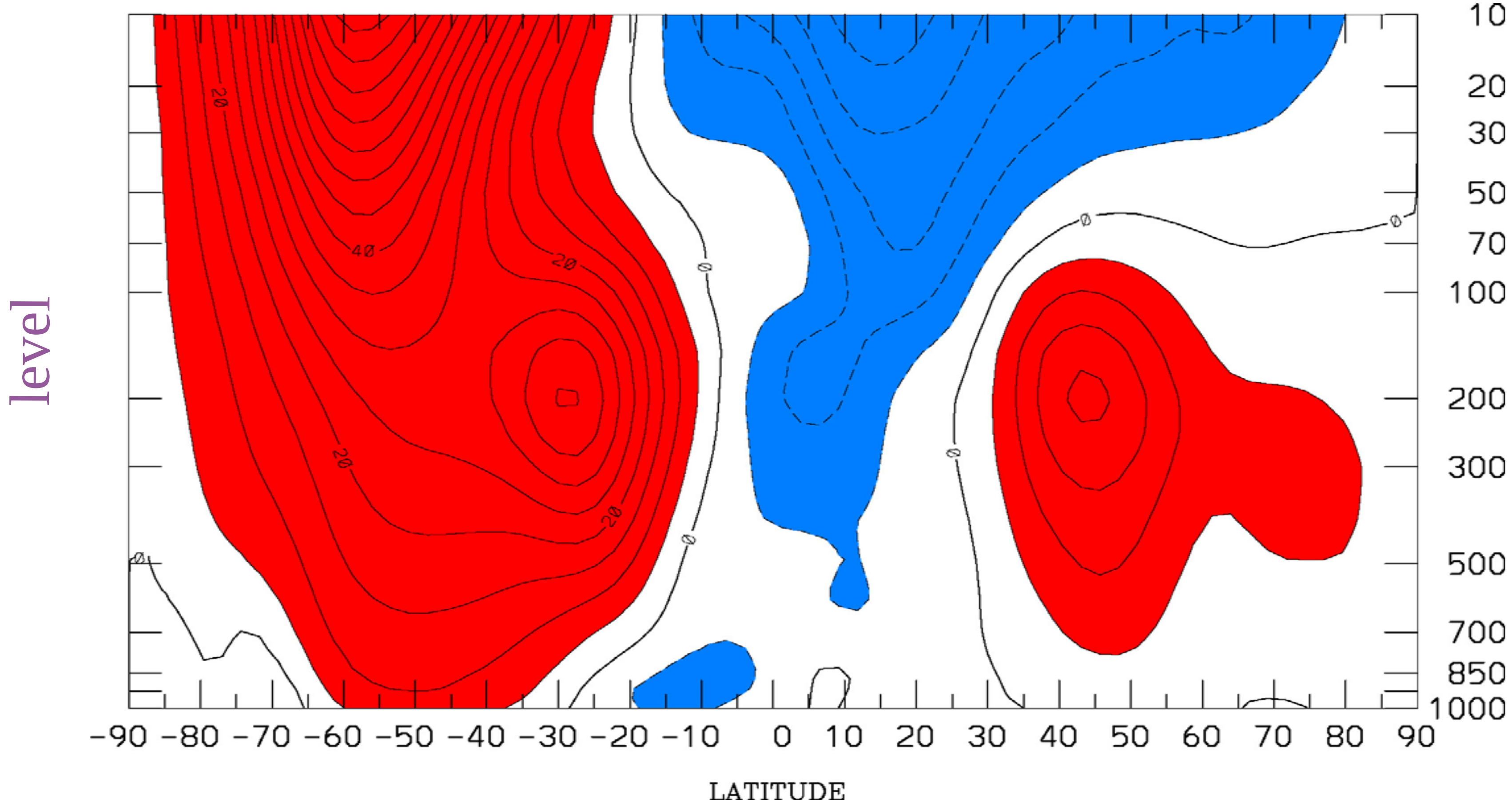


Contour interval 5 m s^{-1}

Shading Red Positive (Westerly)

July Zonal Mean Zonal Wind

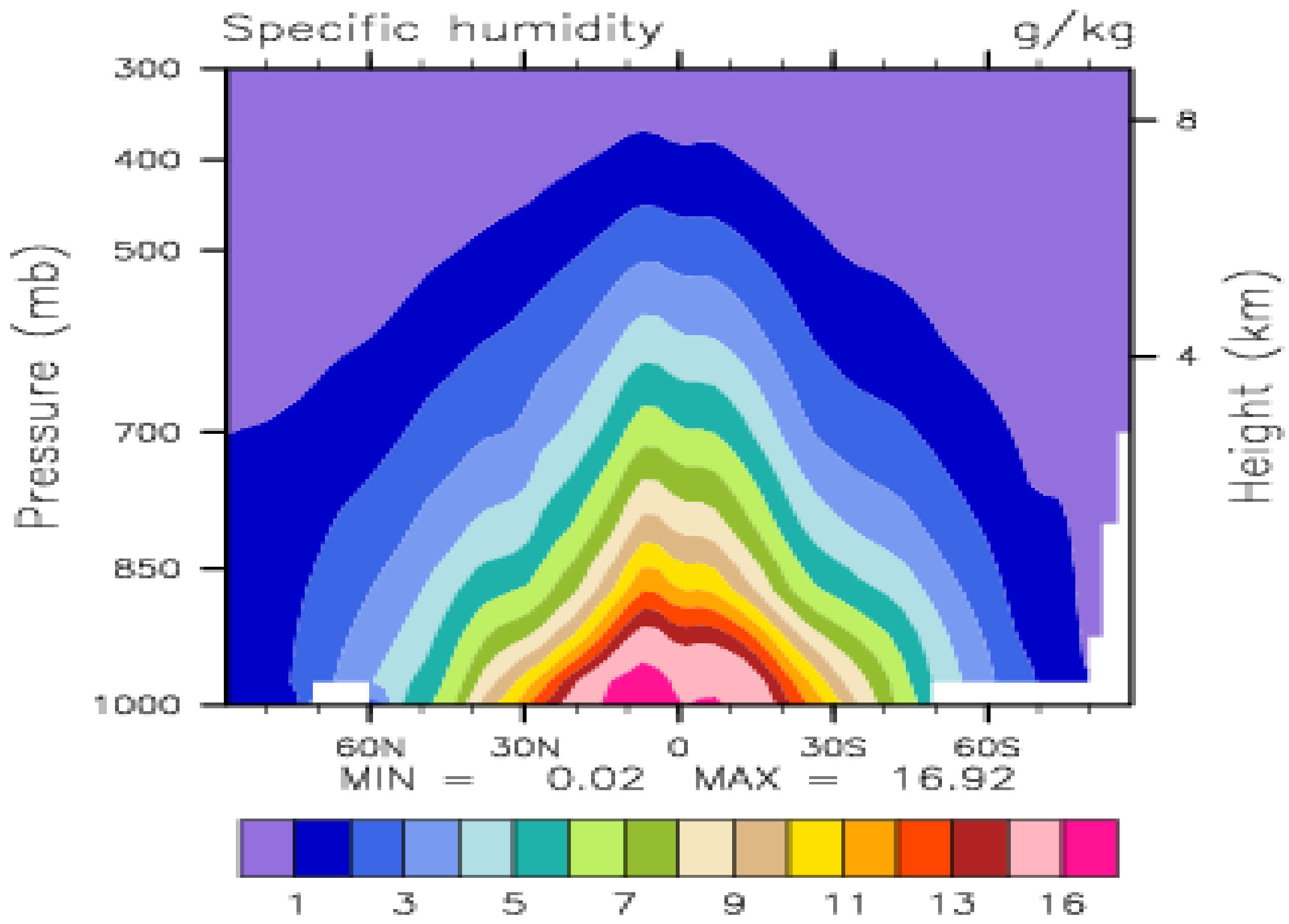
1979-2001 from NCEP



Contour interval 5 m s^{-1}

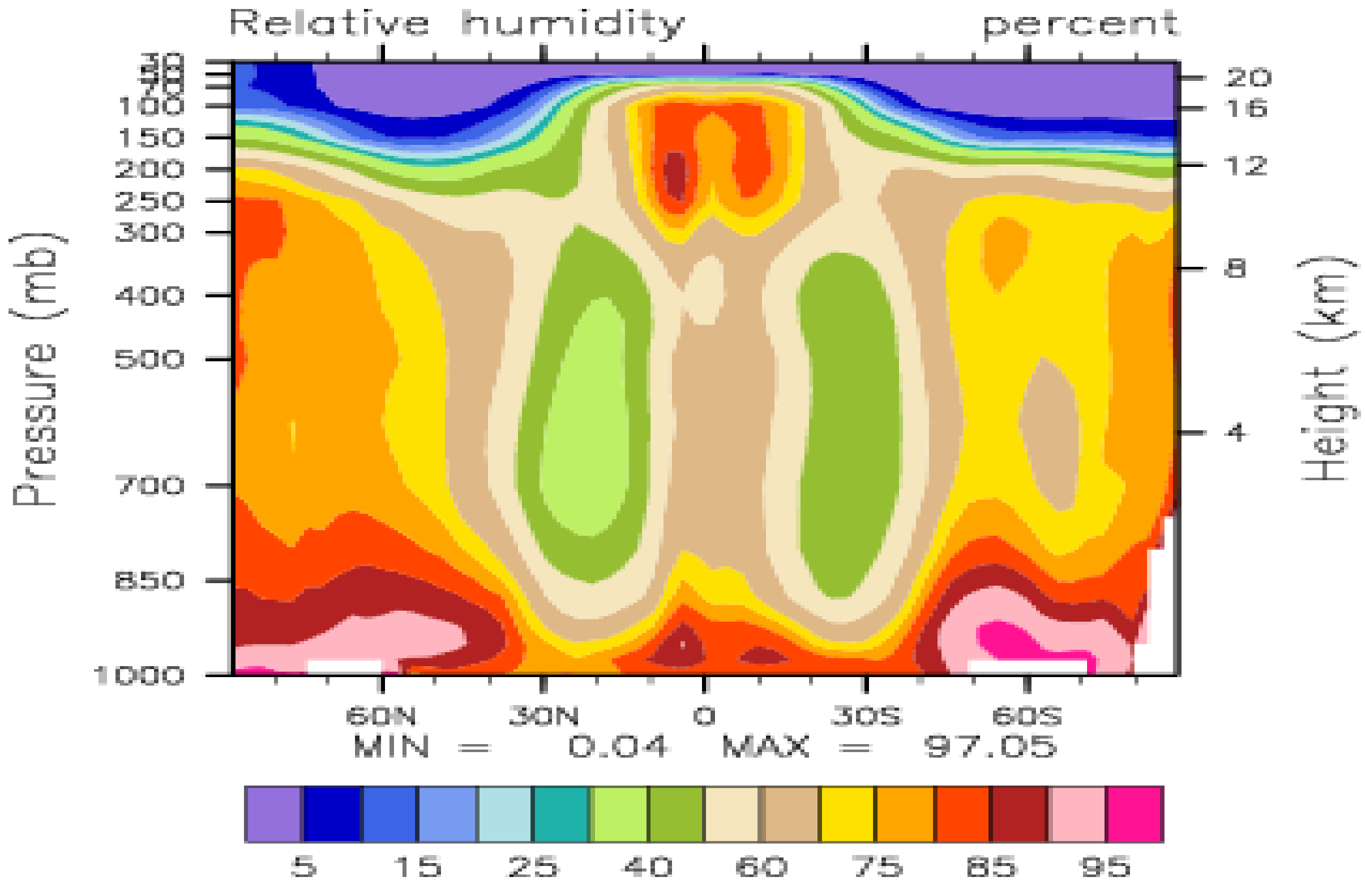
Shading Red Positive (Westerly)

Annual Mean



Specific humidity
g/kg
300
400
500
700
850
1000
Pressure (mb)
8
4
Height (km)
60N
30N
0
30S
60S
MIN = 0.02 MAX = 16.92
1
3
5
7
9
11
13
16

December, January, February



June, July, August