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

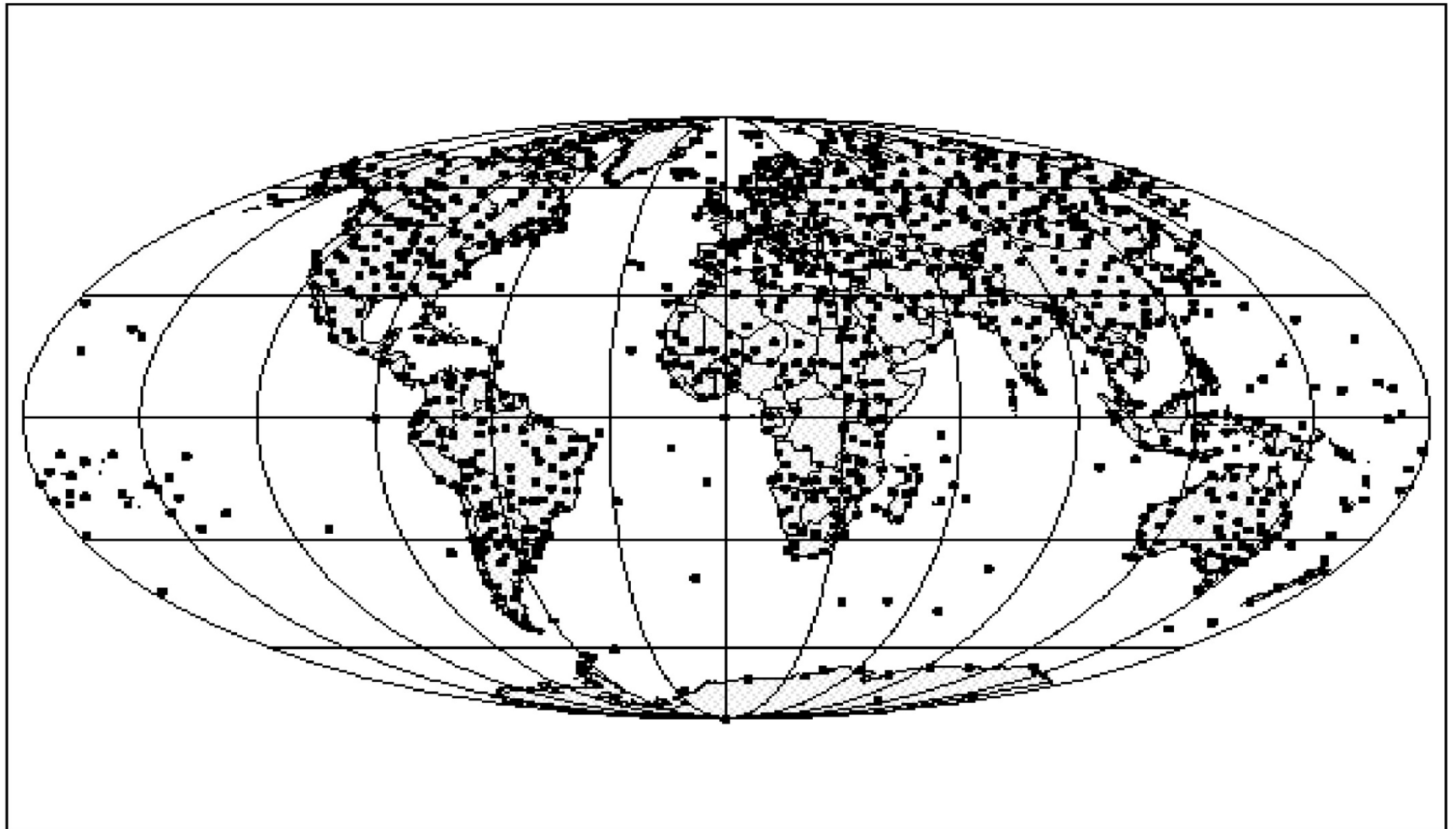   **-Ship Reports and Buoy Observations**

   -Aircraft Observations
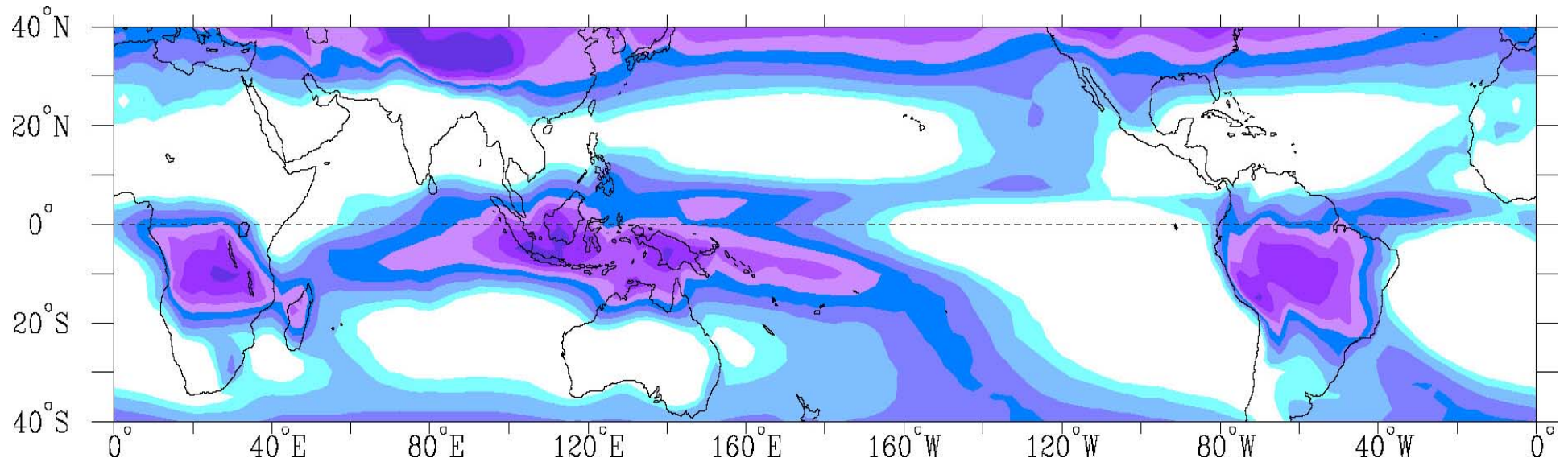
   -Satellite Observations

3. *Data Assimilation*

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

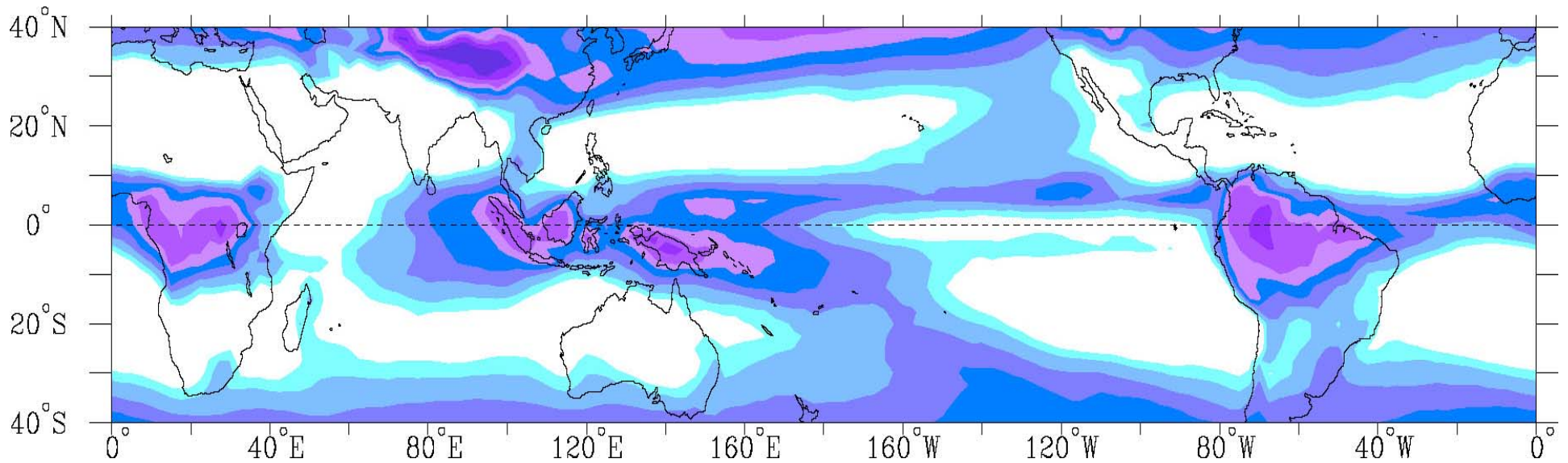**4. *Run General Circulation Model to Obtain next First Guess***

Radiosonde Network

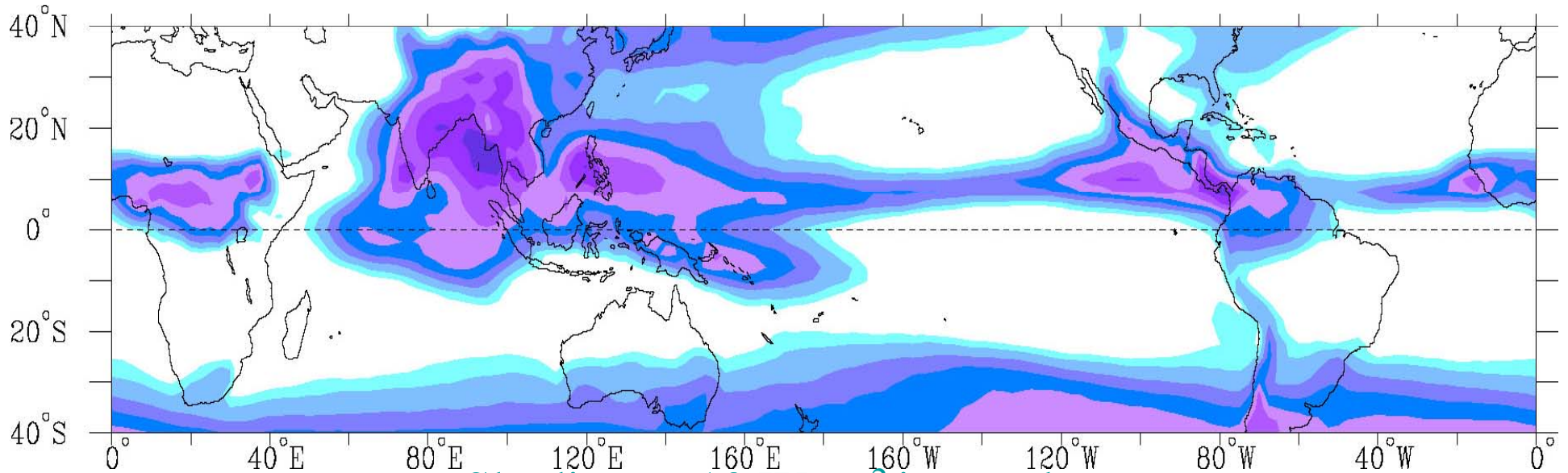# Mean January Outgoing Longwave Radiation (OLR), 1979-2001

Shading at 10 W m^{-2} intervals, starting at 260 W m^{-2}
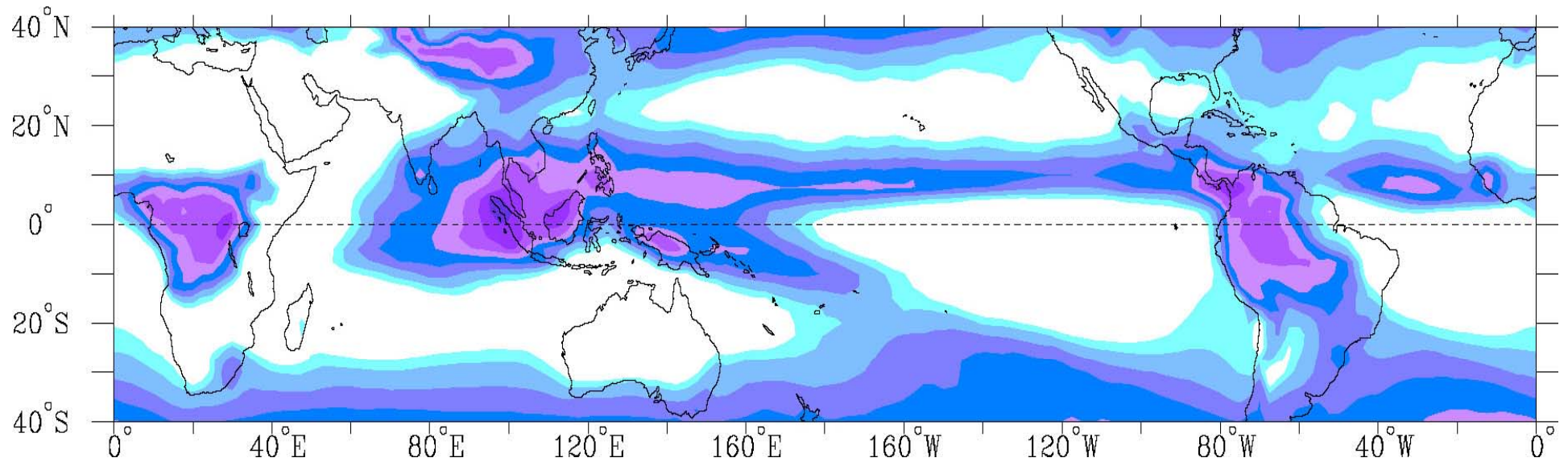
Mean April Outgoing Longwave Radiation,

1979-2001

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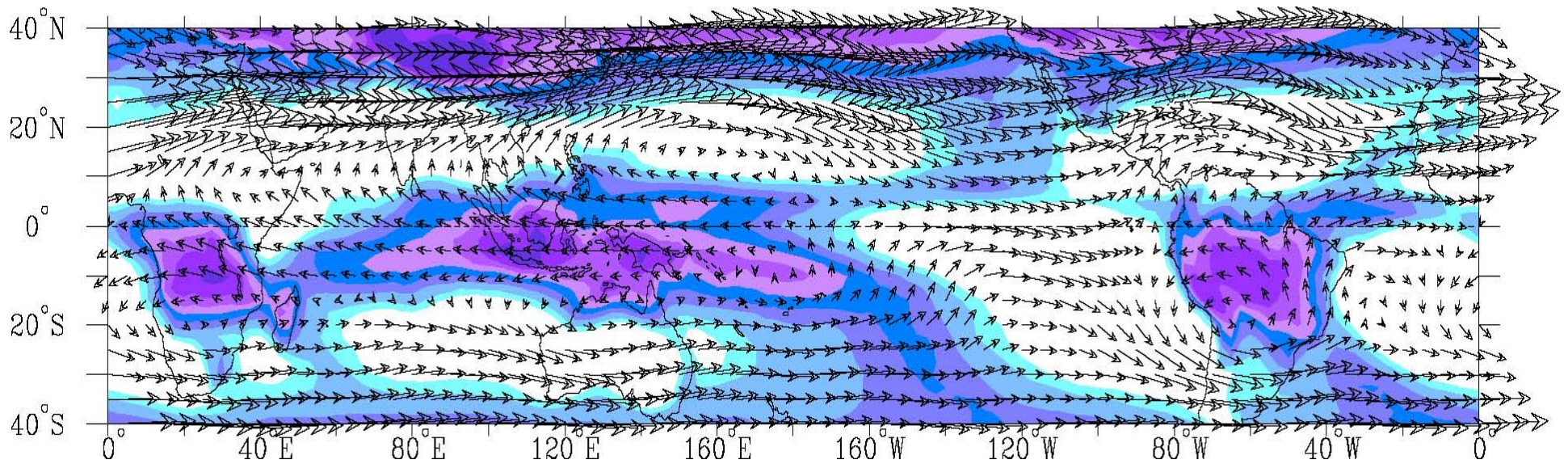starting at 260 W m^{-2}

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

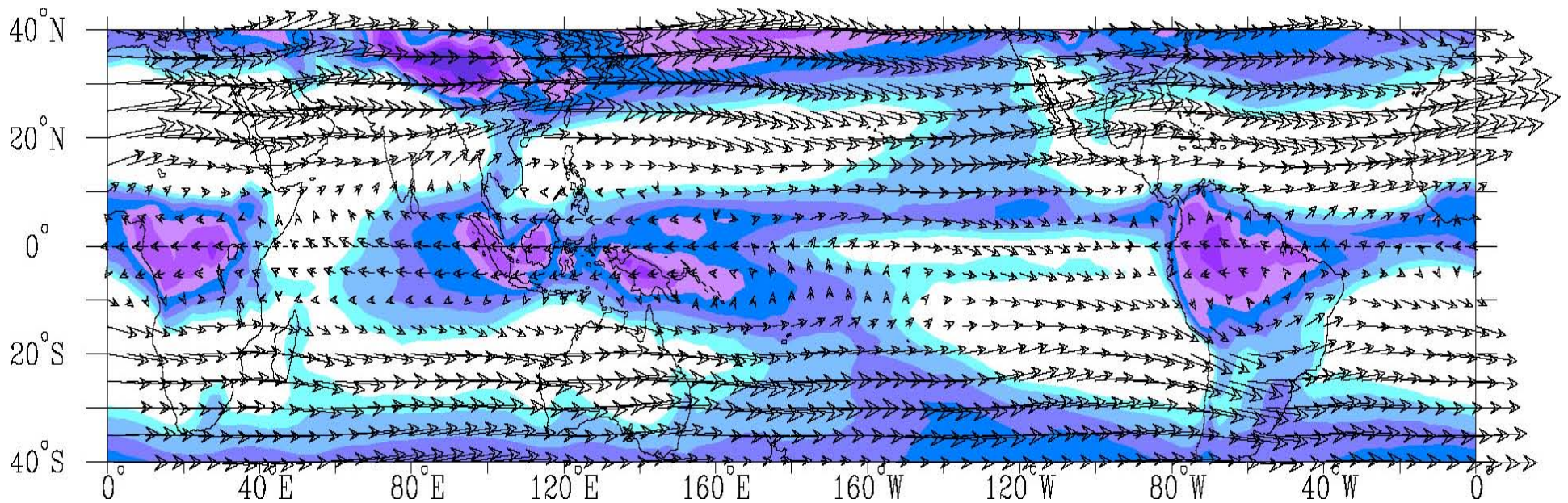Shading at 10 W m^{-2} intervals,
starting at 260 W m^{-2}

Mean January 200 hPa Total Wind,

Outgoing Longwave Radiation

1979-2001

Wind (vectors, largest around 70 m s^{-1})
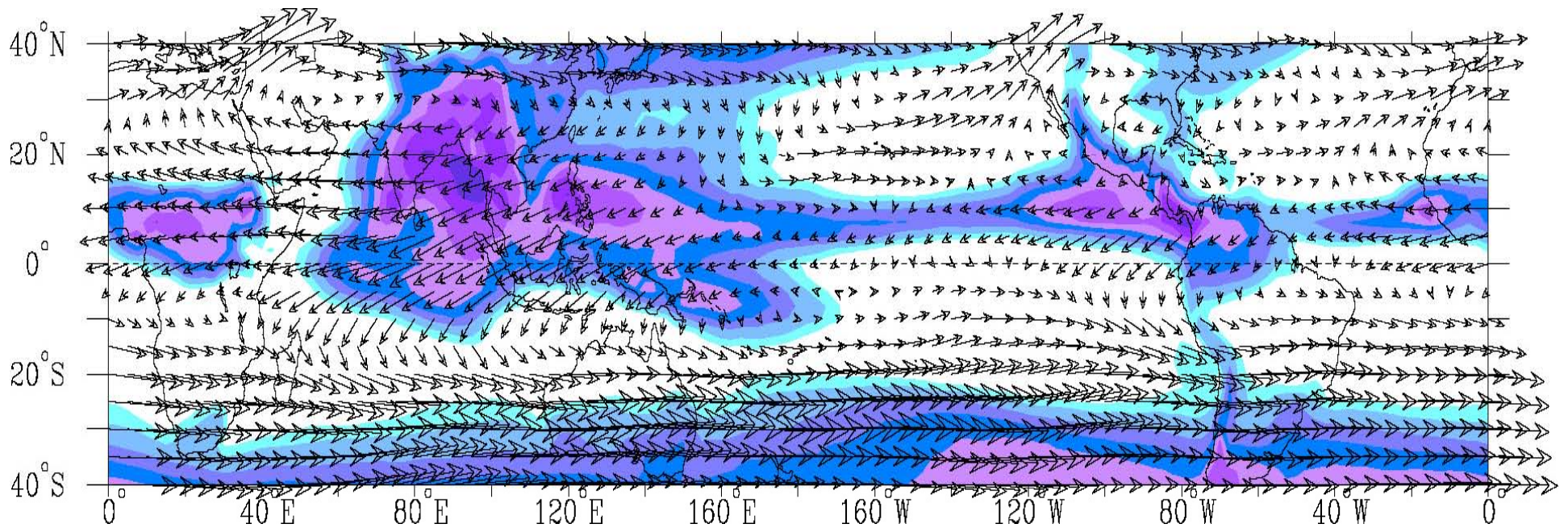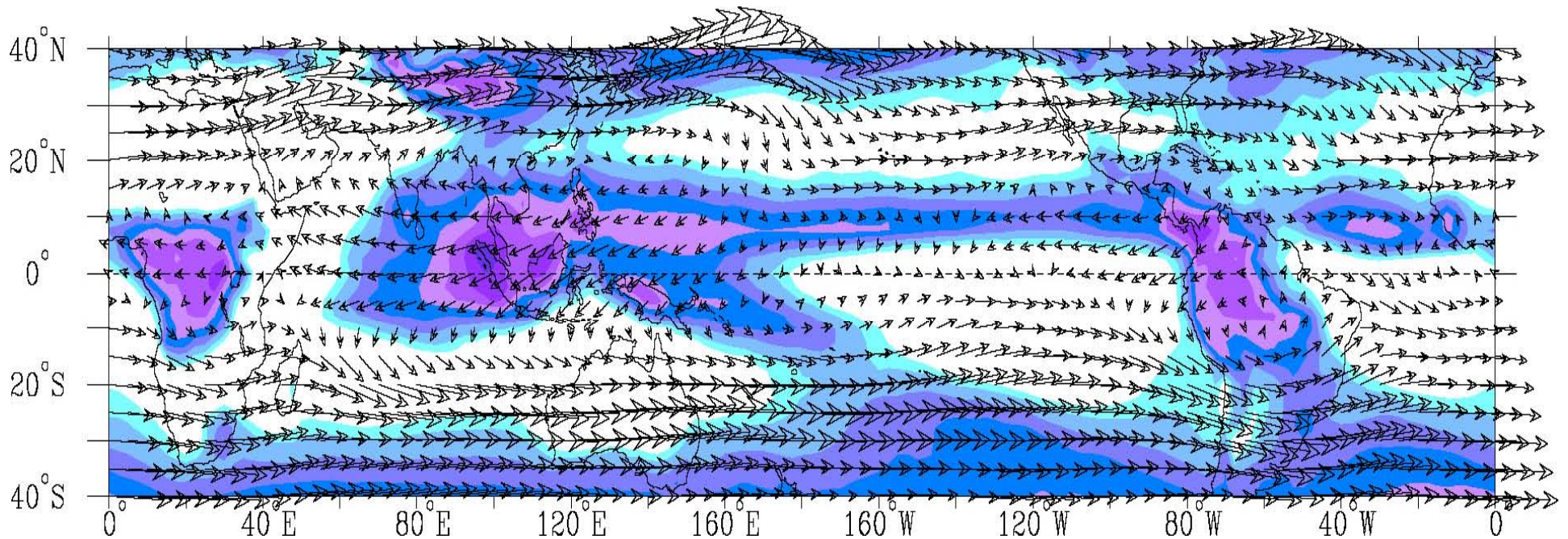
OLR (shading at 10 W s^{-2} intervals)

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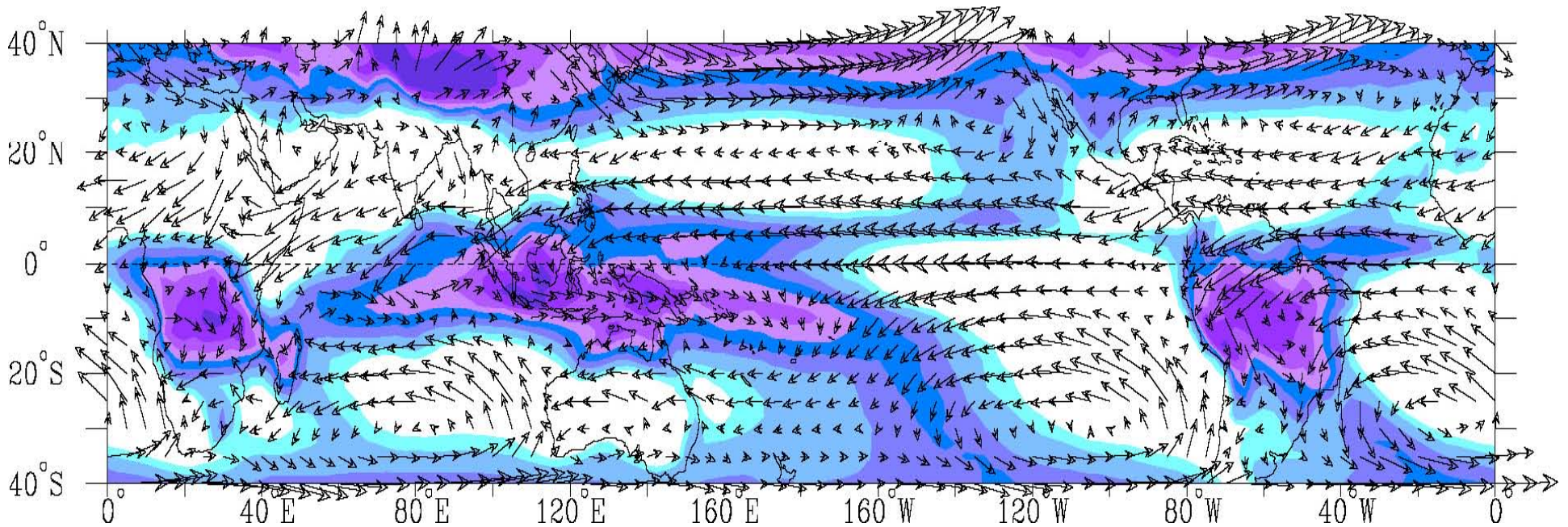
Mean July 200 hPa Total Wind,
Outgoing Longwave Radiation
1979-2001

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})
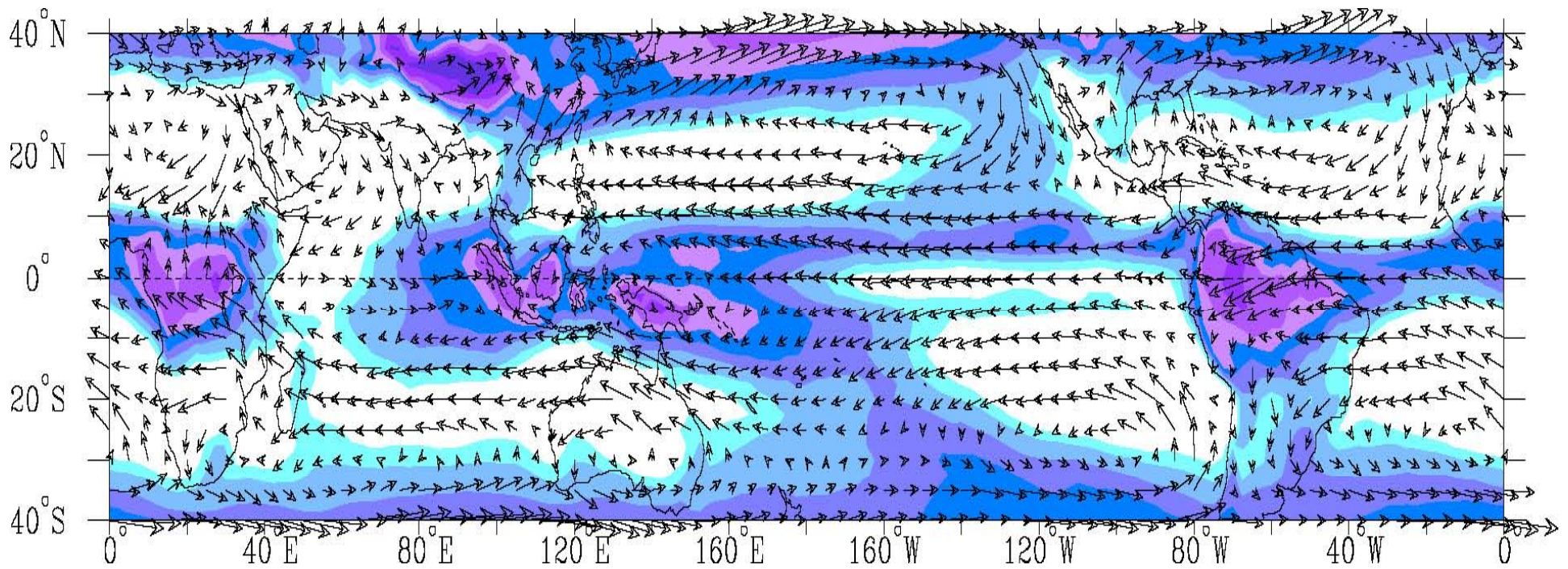
OLR (shading at 10 W s^{-2} intervals)
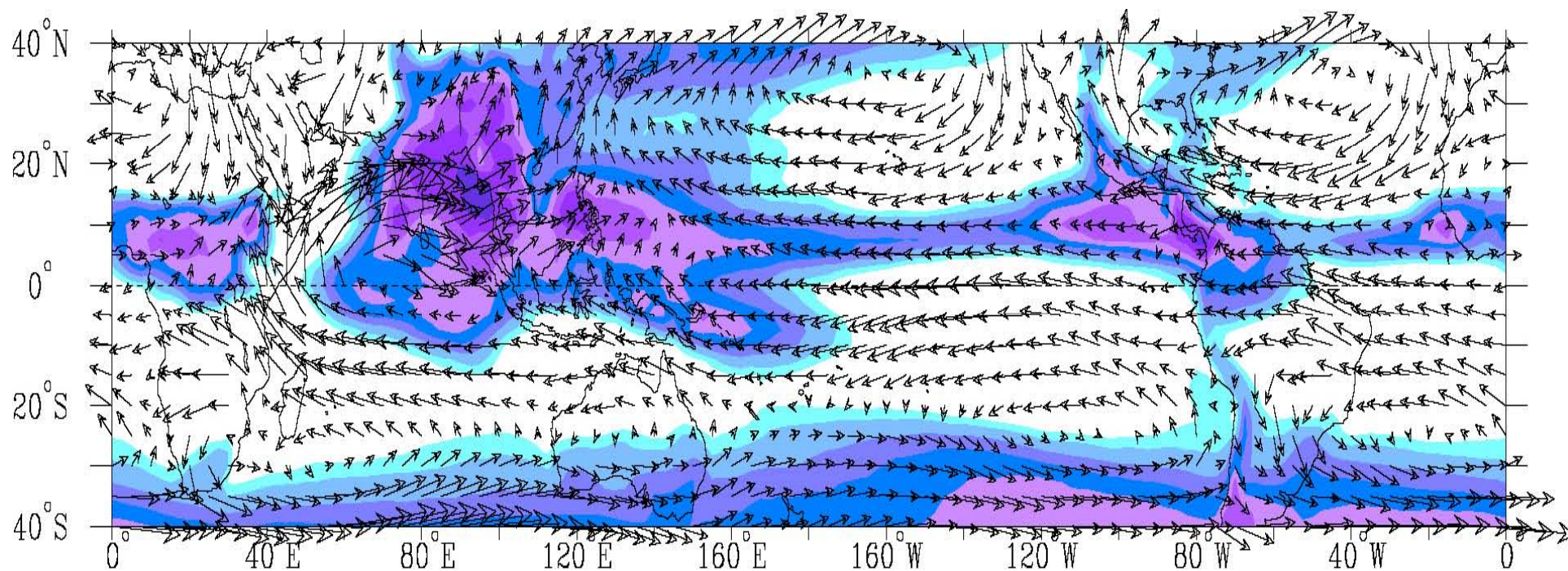
Mean January 850 hPa Total Wind,

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

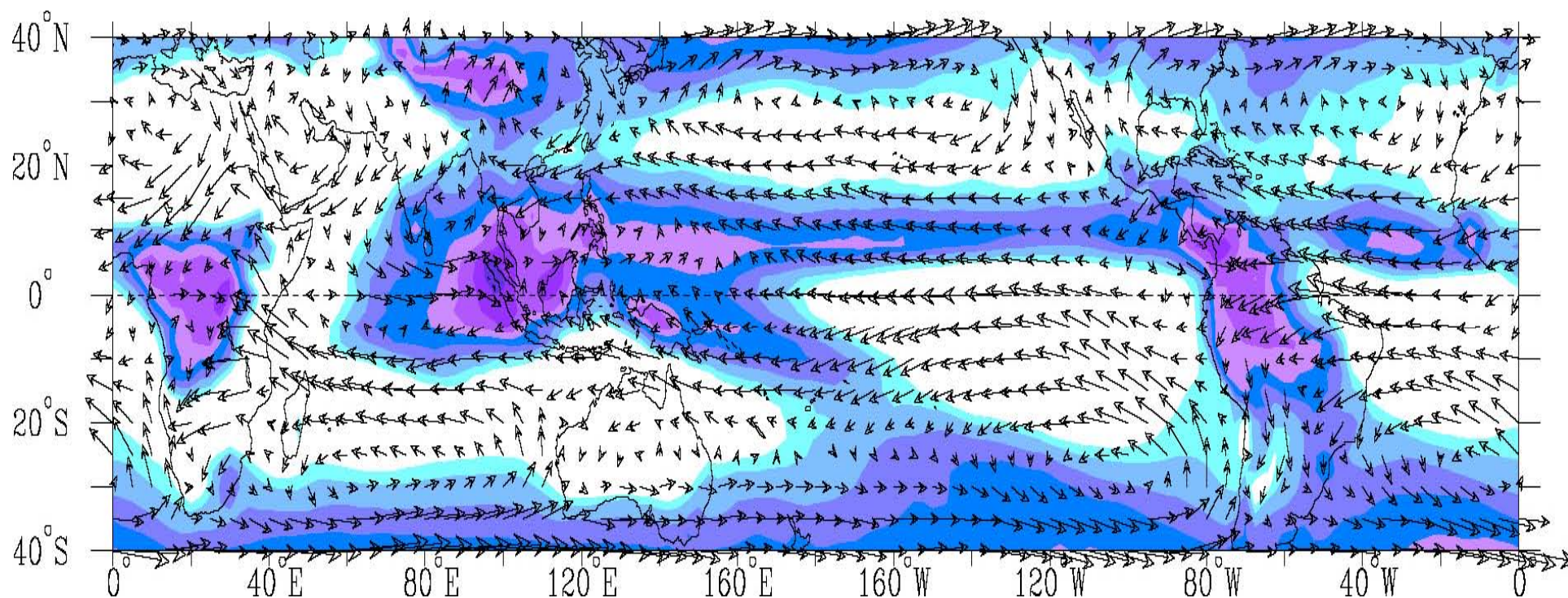Wind (vectors, largest around 10 m s^{-1})

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

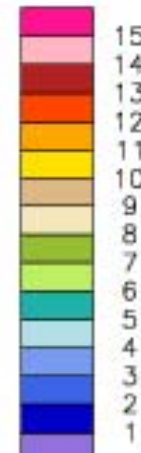# Mean July 850 hPa Total Wind,

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
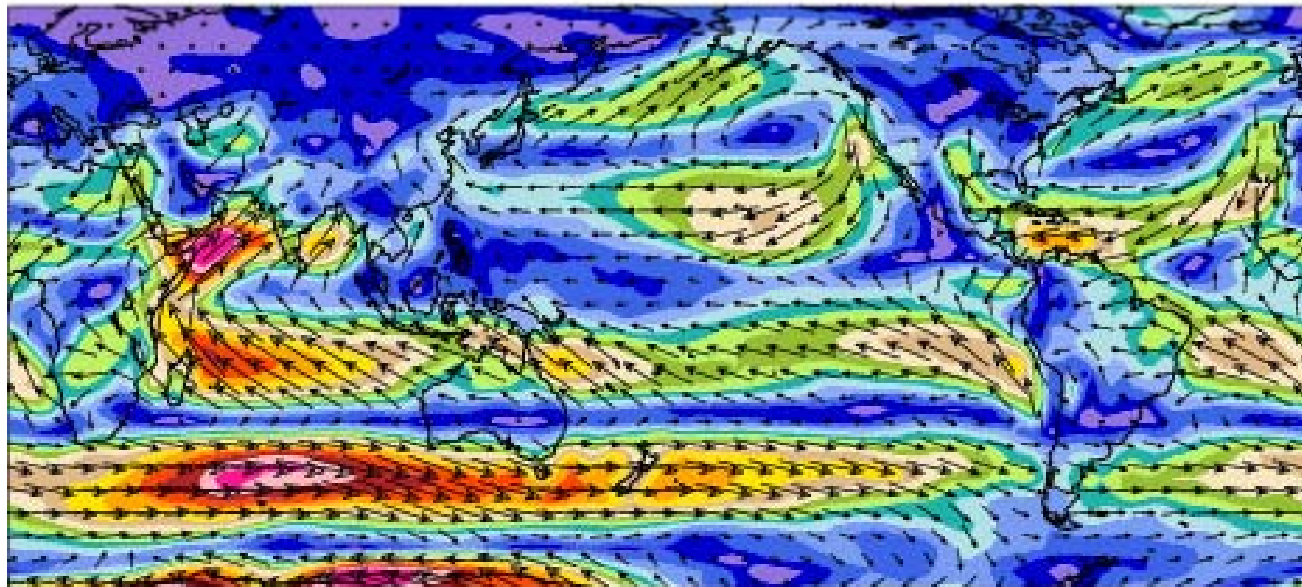
MIN =   0.03 MAX =   12.19

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
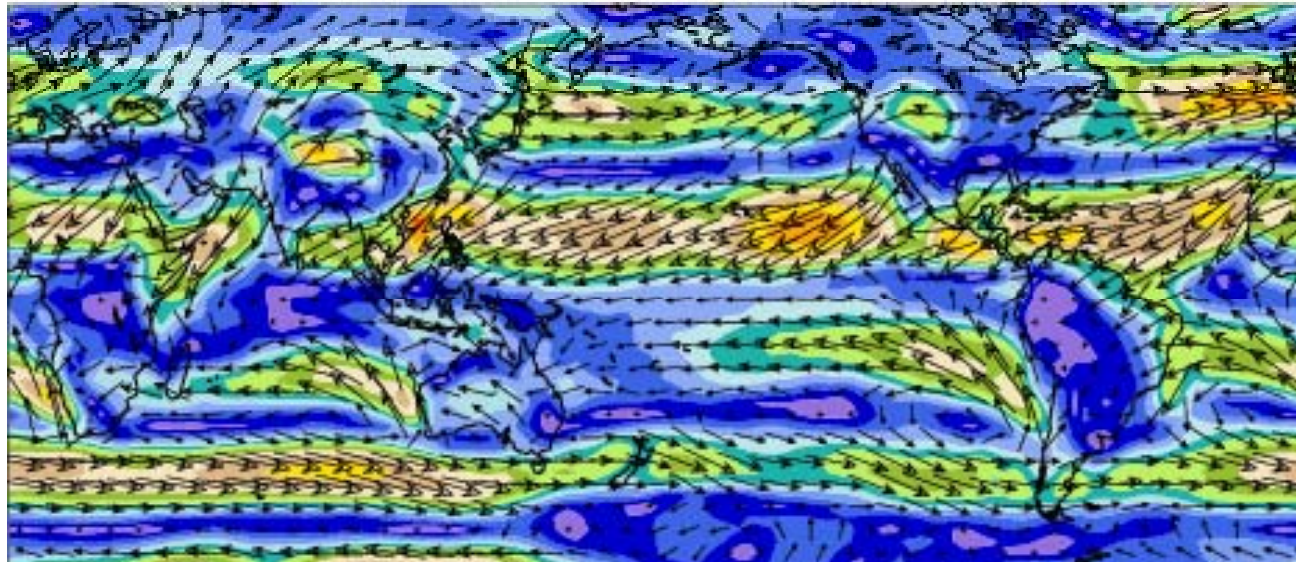
Near surface wind   mean=   5.32   m/s   JJA

MIN =   0.02 MAX =   17.32

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
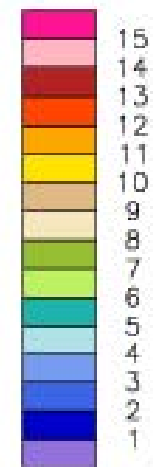
Vorticity

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

Divergence

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

Streamfunction

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

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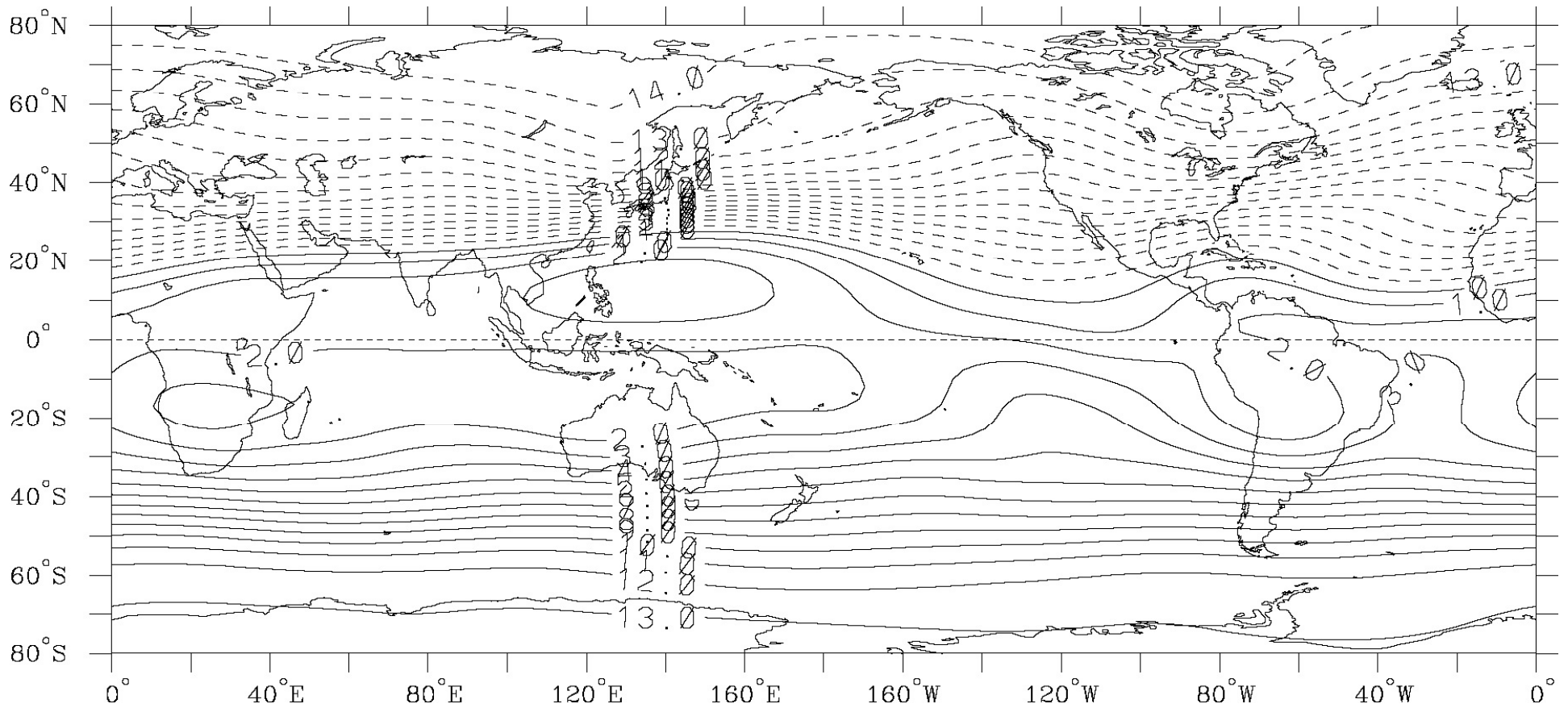
$$\nabla^2 \chi = D$$

Non-divergent (Rotational) Wind

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

Divergent Wind

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

Mean January 200 hPa Streamfunction

1979-2001

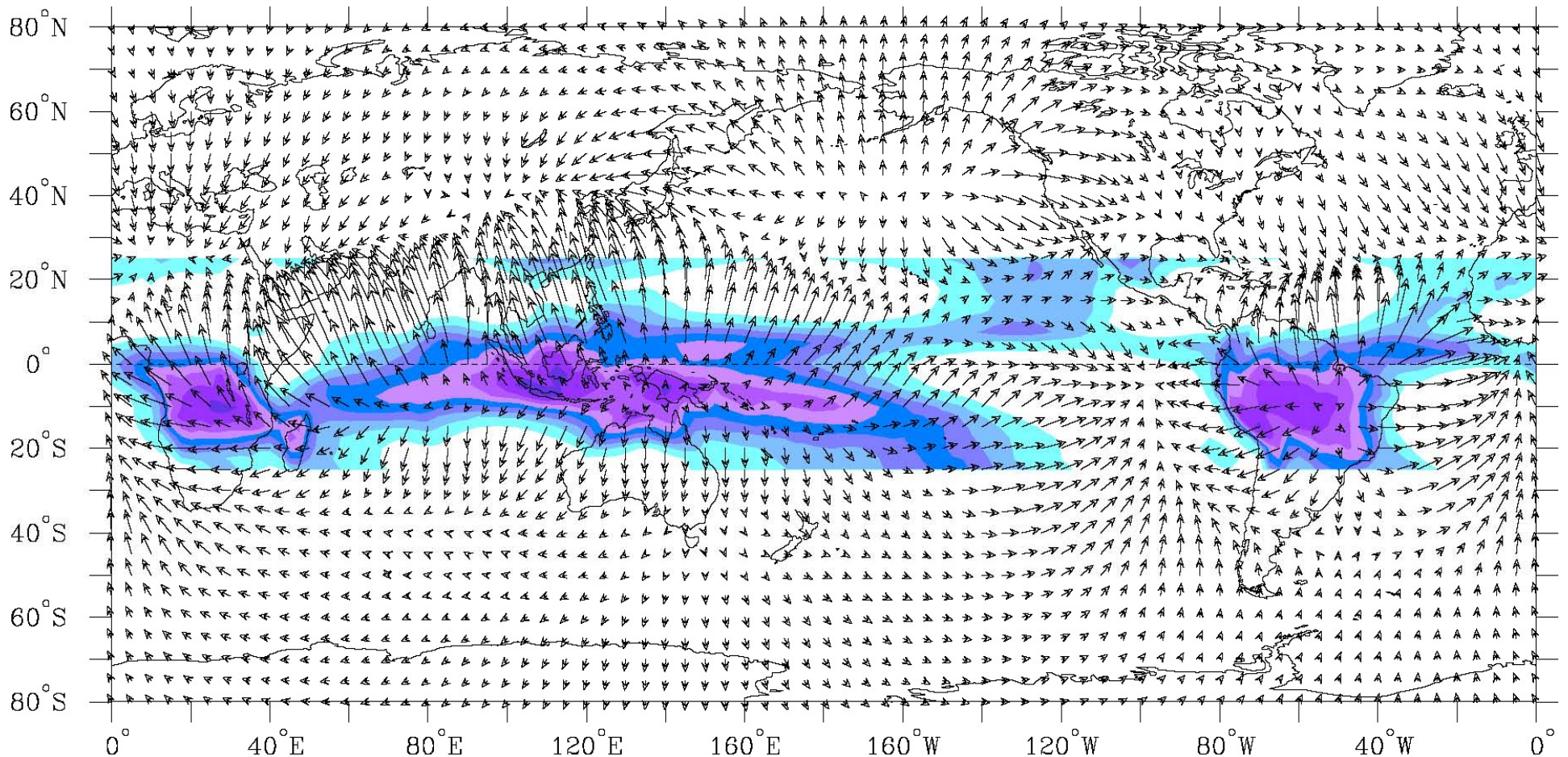Contour interval $1.0 \times 10^7 \text{ m}^2 \text{ s}^{-1}$

Mean January 200 hPa Velocity Potential

and Divergent Wind

1979-2001
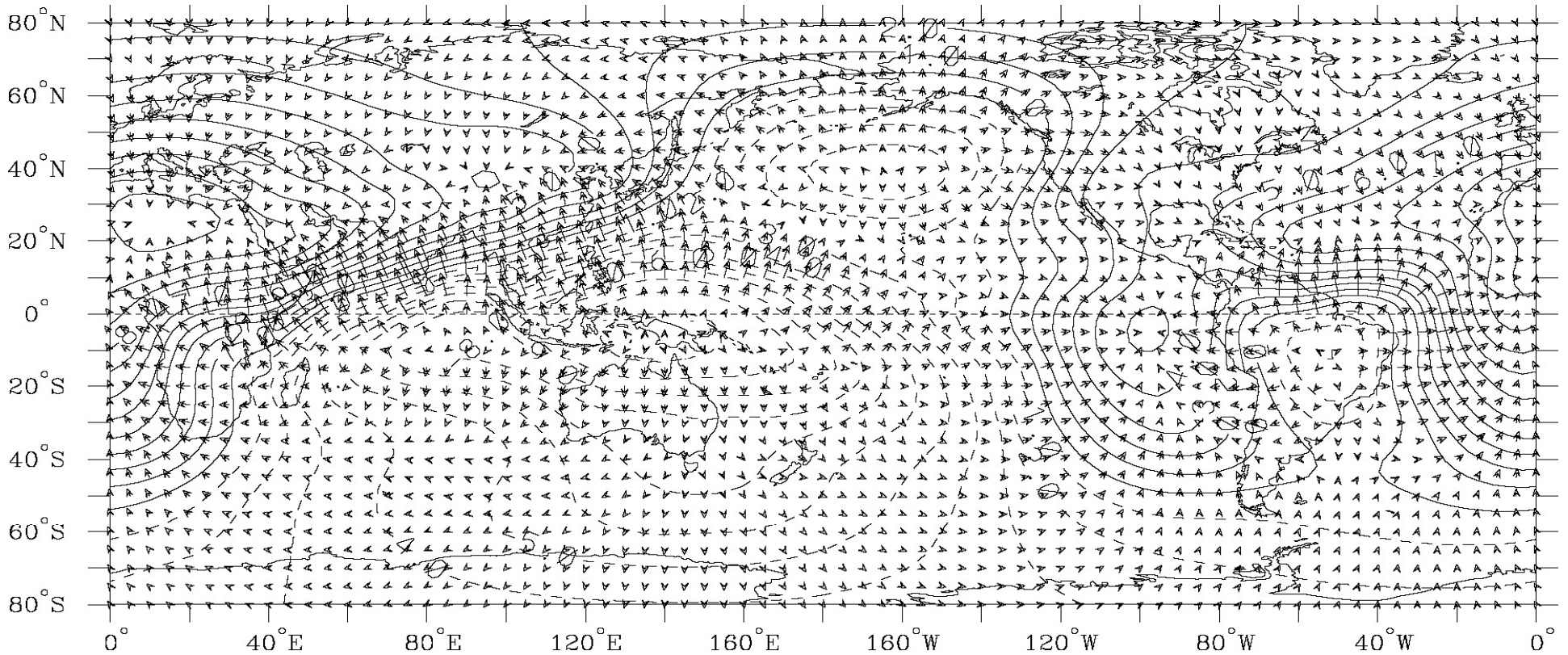
Contour interval 1.0 X 10^6 m^2 s^{-1}

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

Mean January 200 hPa Divergent Wind,

Outgoing Longwave Radiation

1979-2001

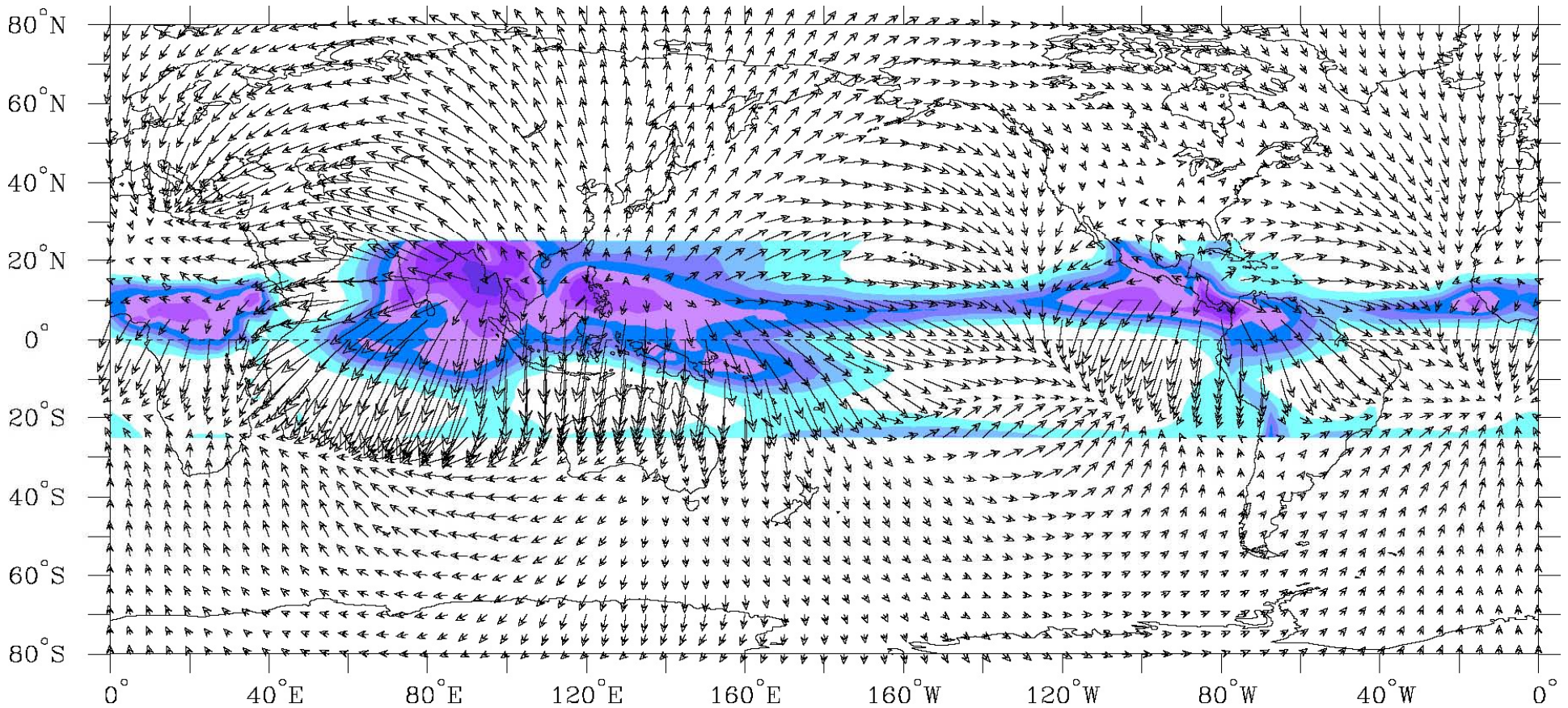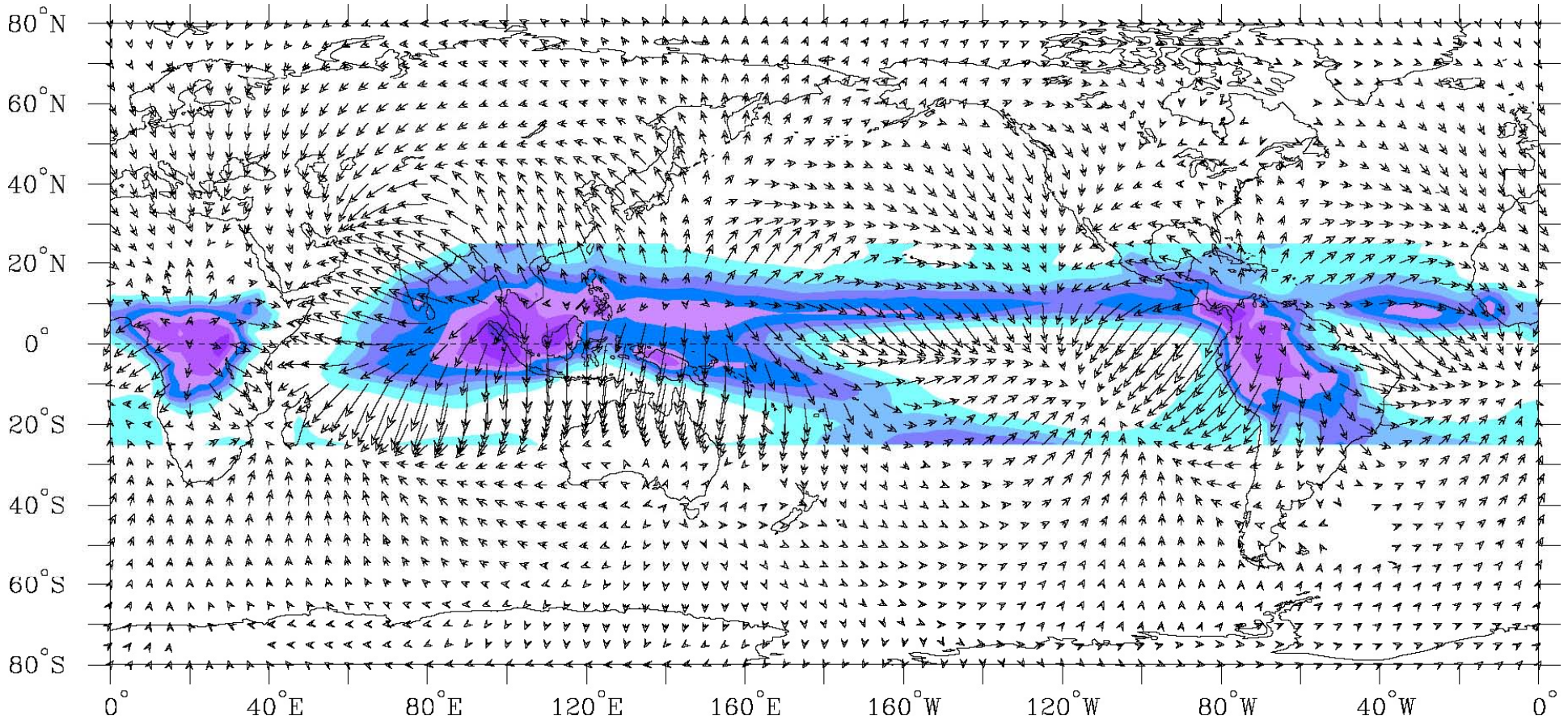Div. Wind (vectors, largest around 15 m s^{-1})

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

Mean April 200 hPa Divergent Wind,

Outgoing Longwave Radiation
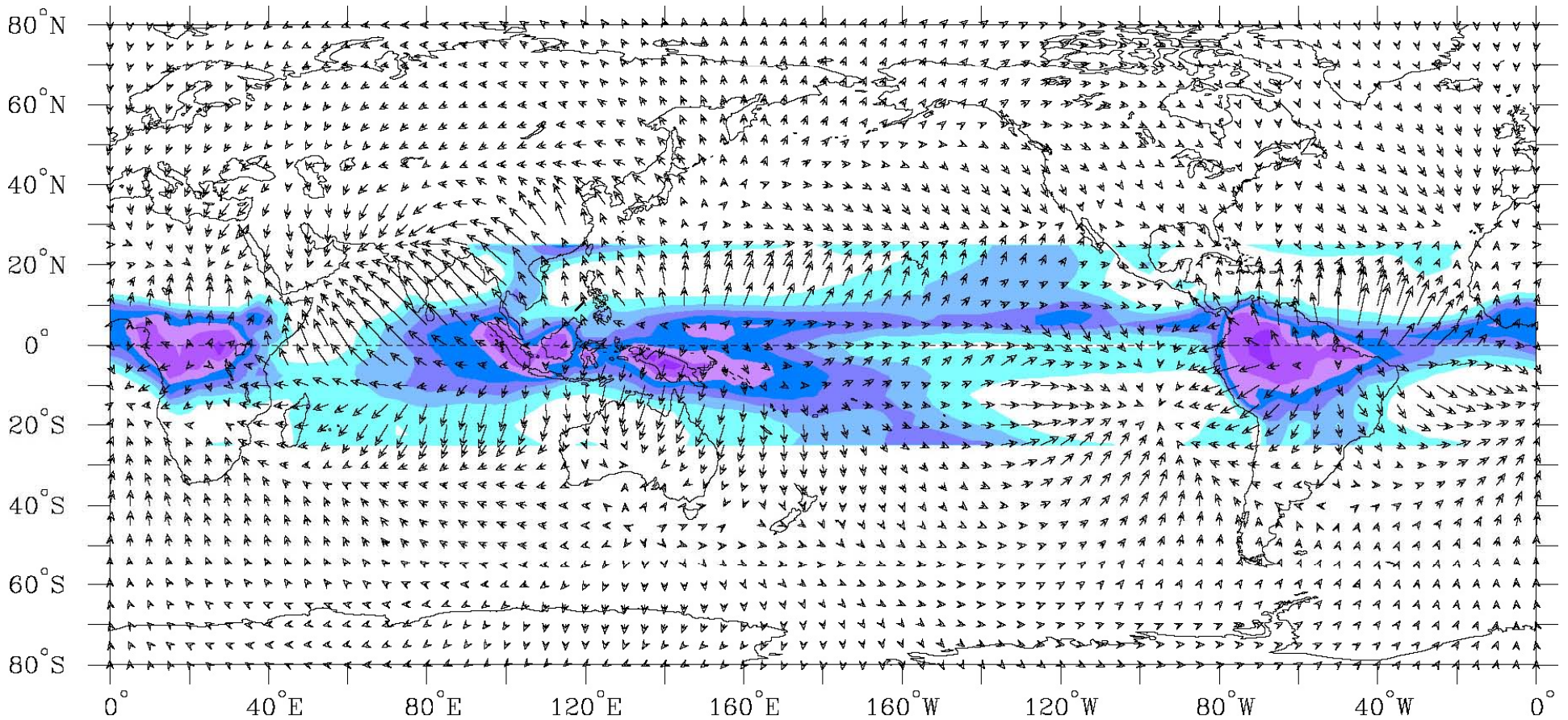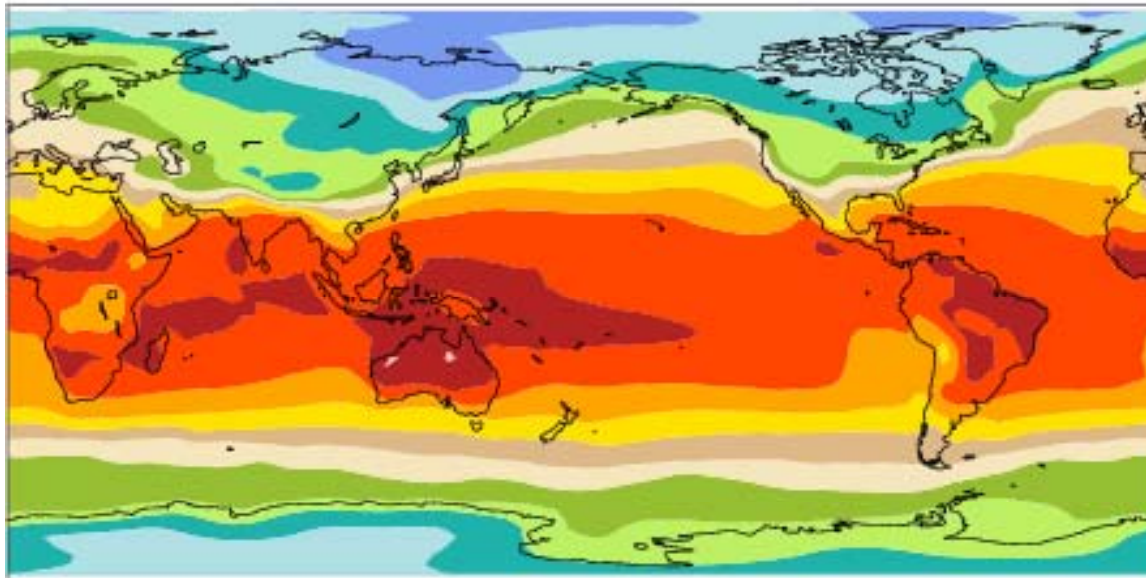
1979-2001

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)

2-meter Air Temp   mean= 285.69   K

DJF

Min = 235.22 Max = 305.52

	310
	305
	300
	295
	290
	285
	280
	275
	270
	260
	250
	240
	230
	220
	210
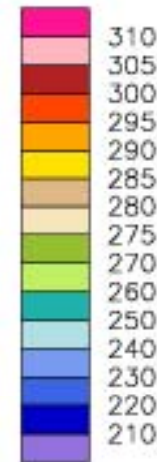
2-meter Air Temp   mean= 288.87   K

JJA

Min = 209.01 Max = 310.25

	310
	305
	300
	295
	290
	285
	280
	275
	270
	260
	250
	240
	230
	220
	210
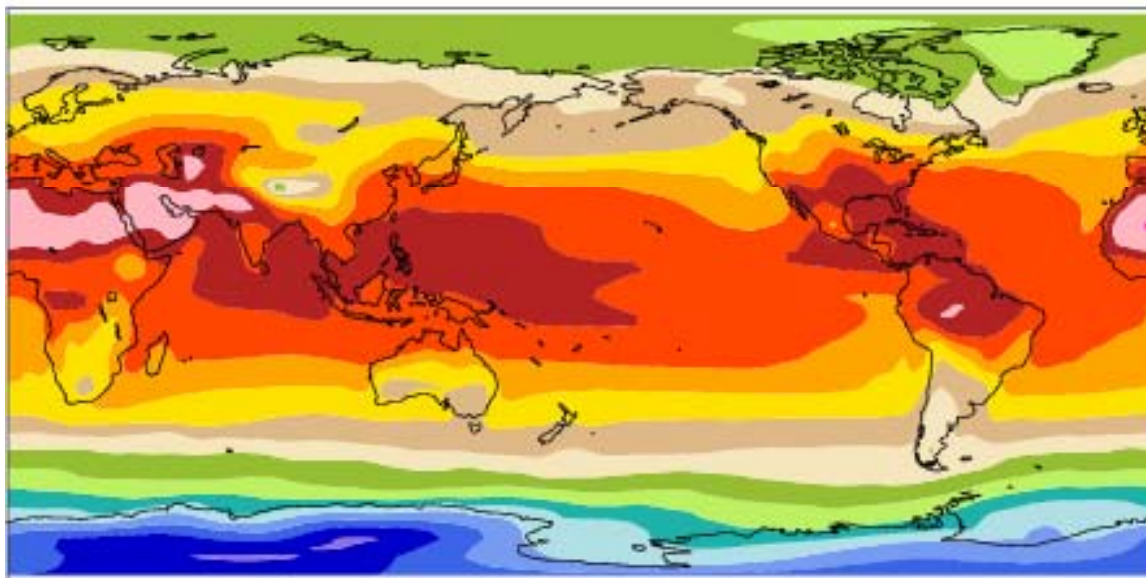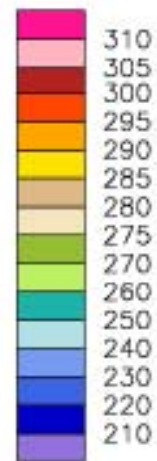
Annual Mean Precipitation

Tropical Rainfall Measuring Mission (TRMM)

Six – Year TRMM Climatology
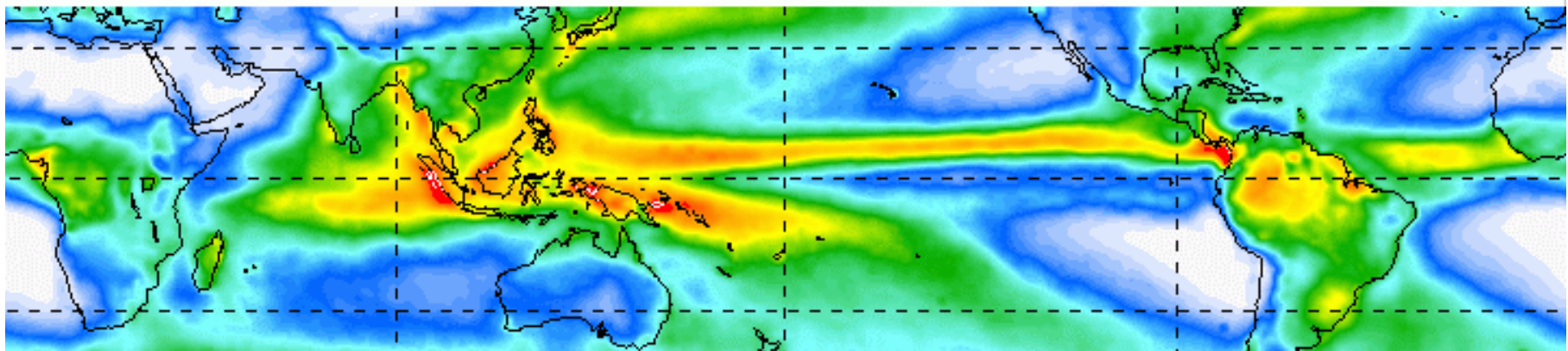
TRMM Merged Precip Annual Climo (mm/d)

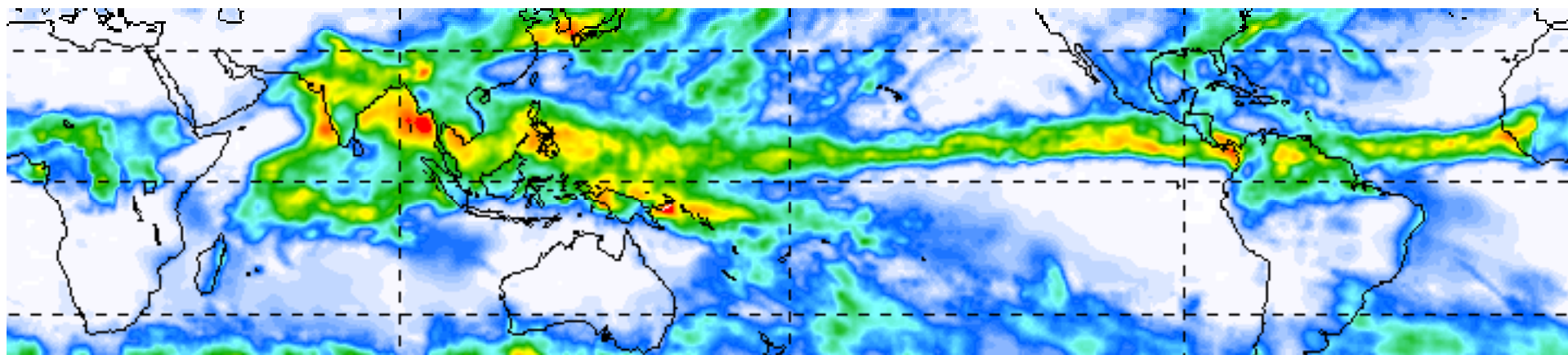0 2 4 6 8 10+

January 1998 – December 2003
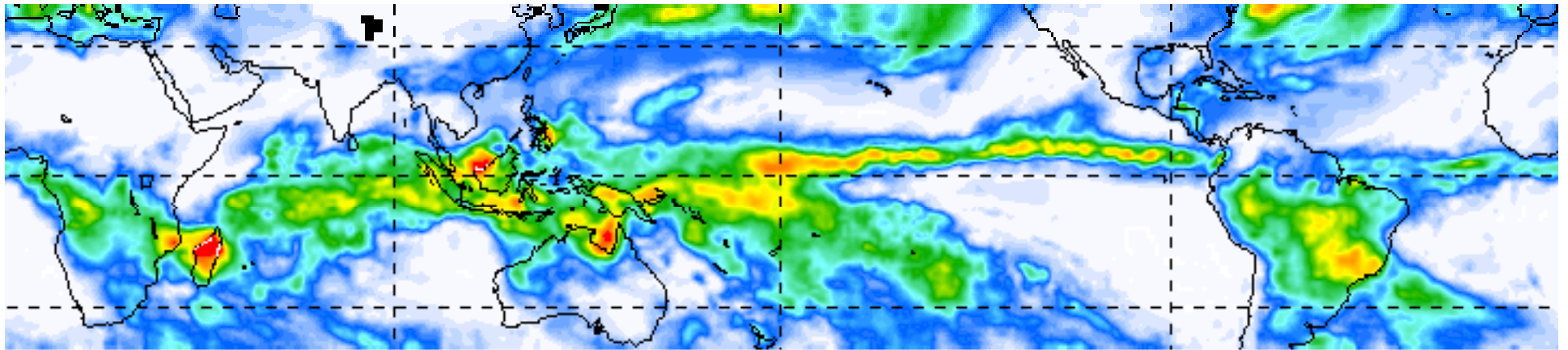
TRMM Merged Precip Jan 2003   (mm/d)   0   4   8   12   16   20+
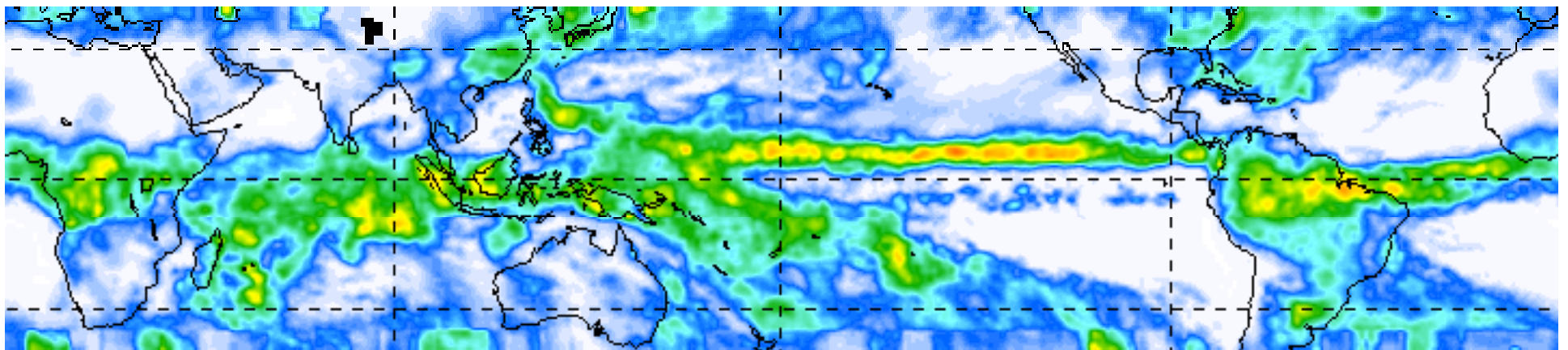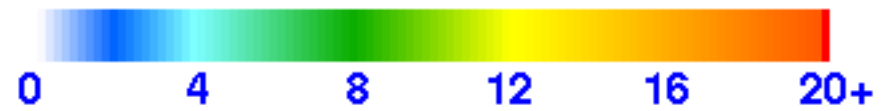
TRMM Merged Precip Apr 2003   (mm/d)   0   4   8   12   16   20+
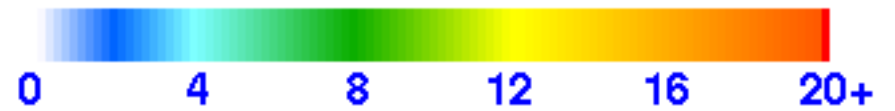
TRMM Merged Precip Jul 2003   (mm/d)   0   4   8   12   16   20+
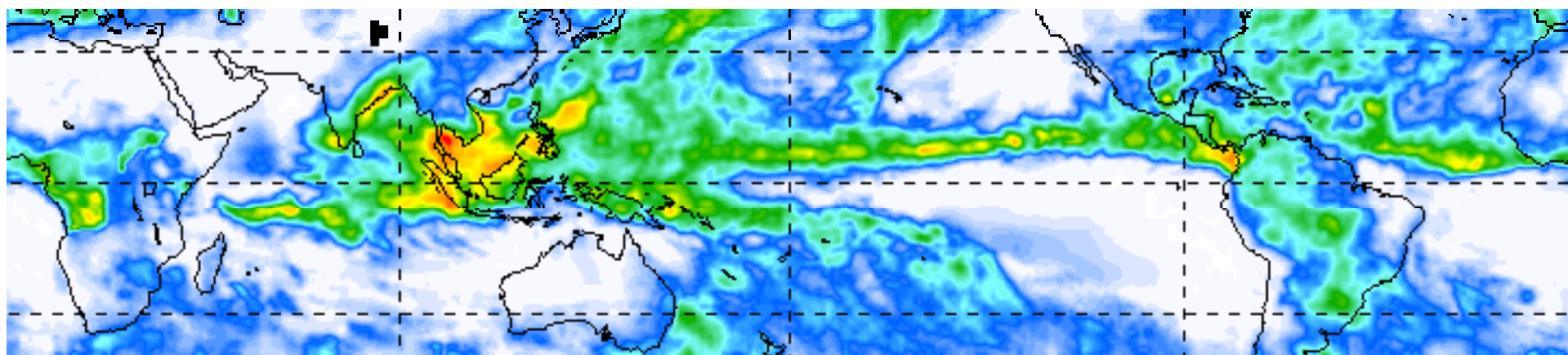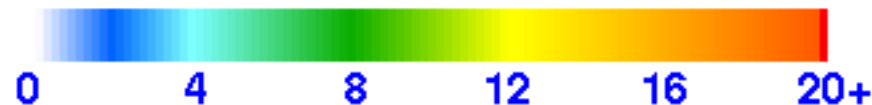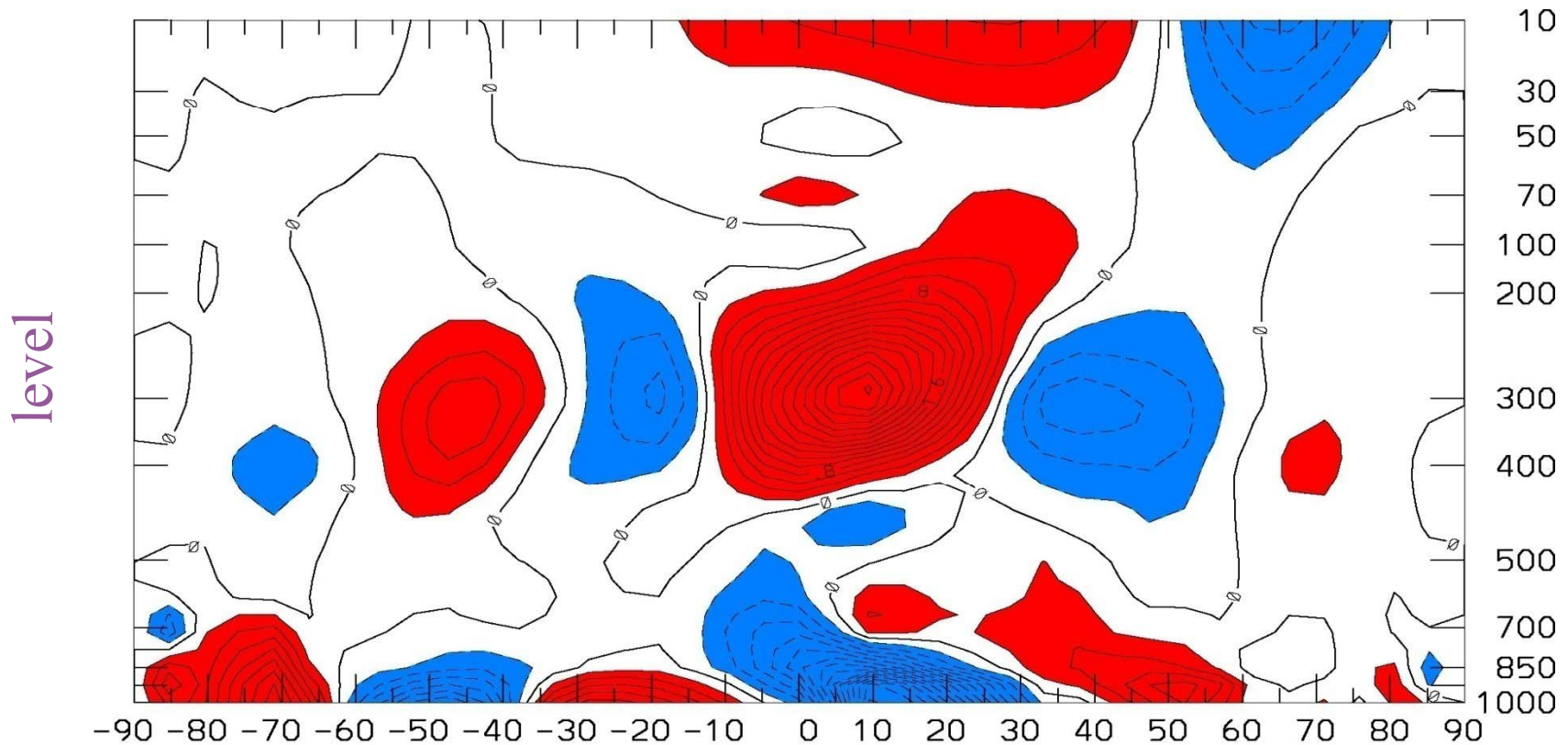
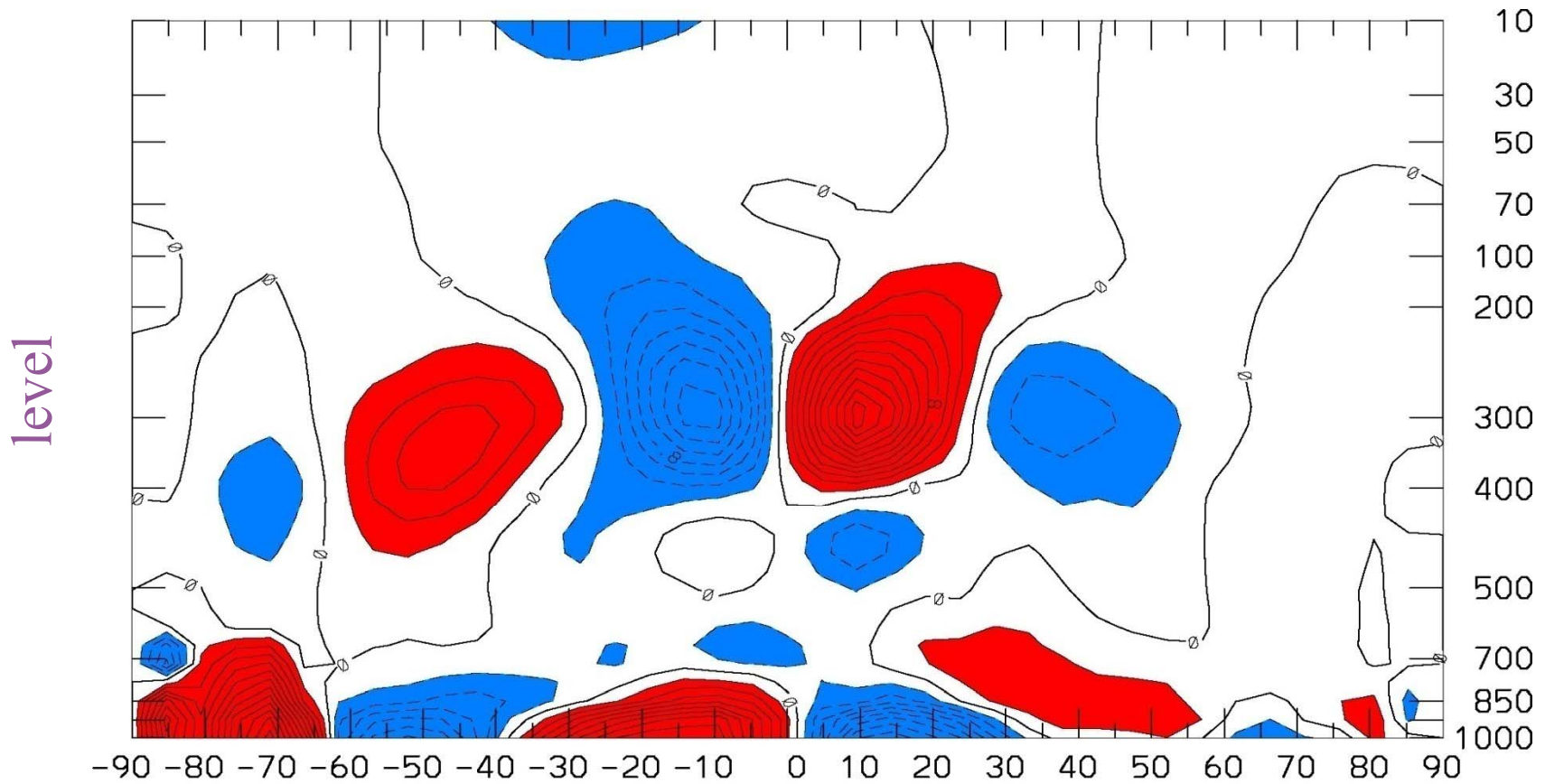TRMM Merged Precip Oct 2003   (mm/d)   0   4   8   12   16   20+
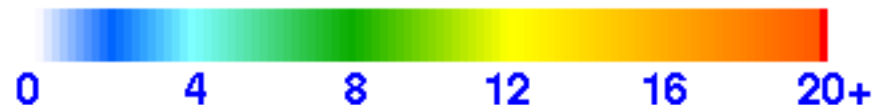
January Zonal Mean Meridional Wind 1979-1993 from ECMWF

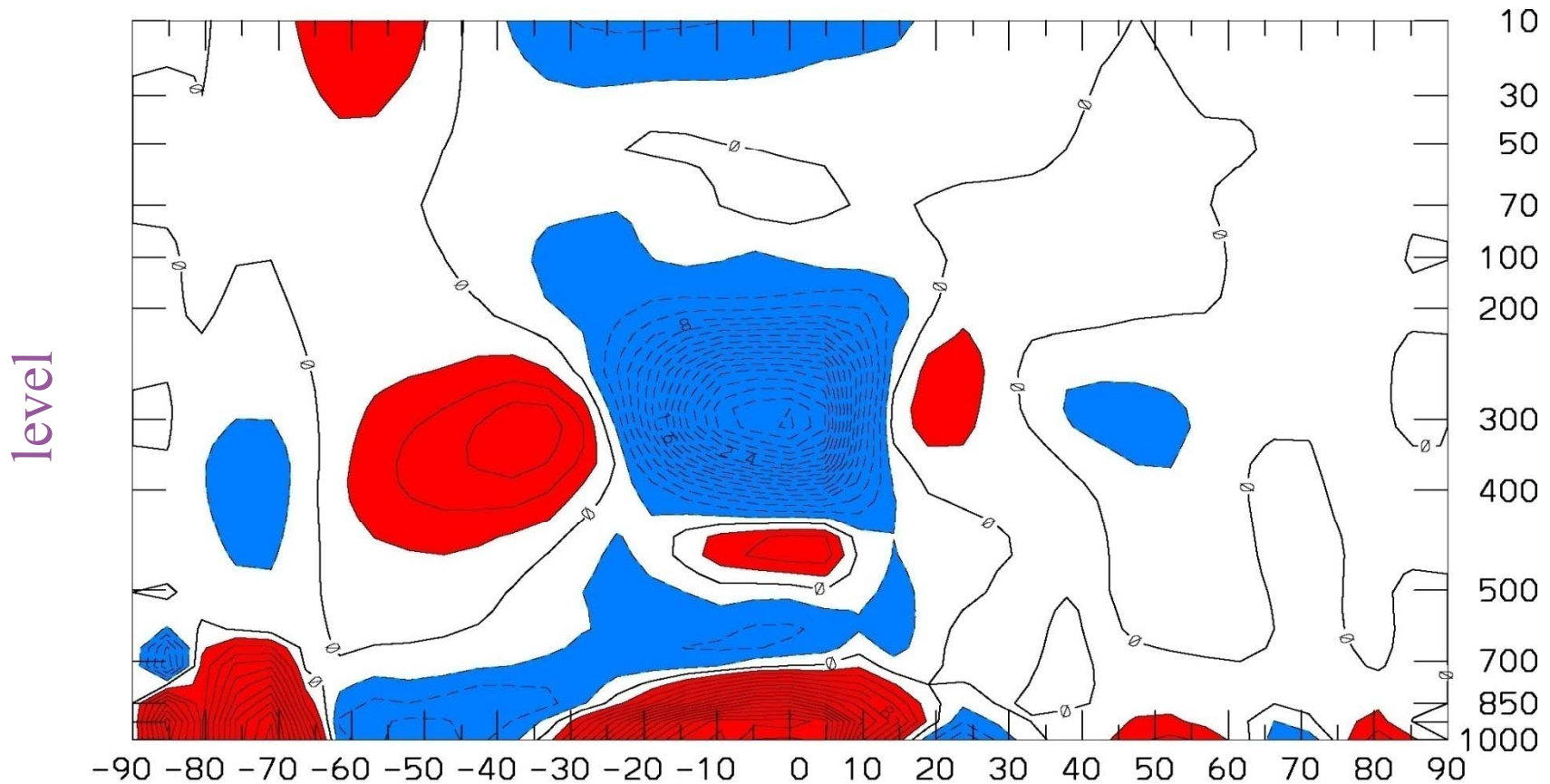Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

April Zonal Mean Meridional Wind   1979-1993 from ECMWF

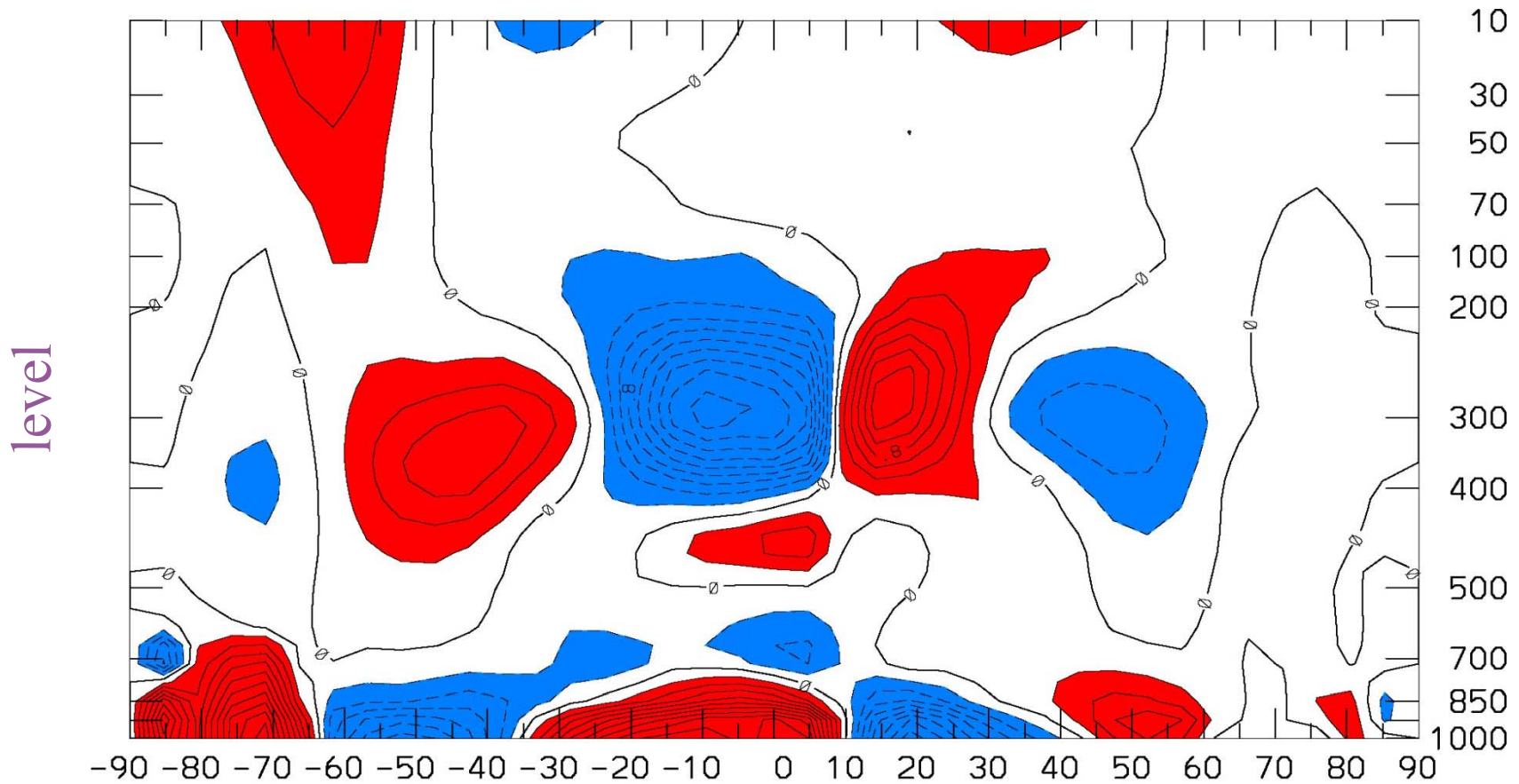Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

July Zonal Mean Meridional Wind   1979-1993 from ECMWF

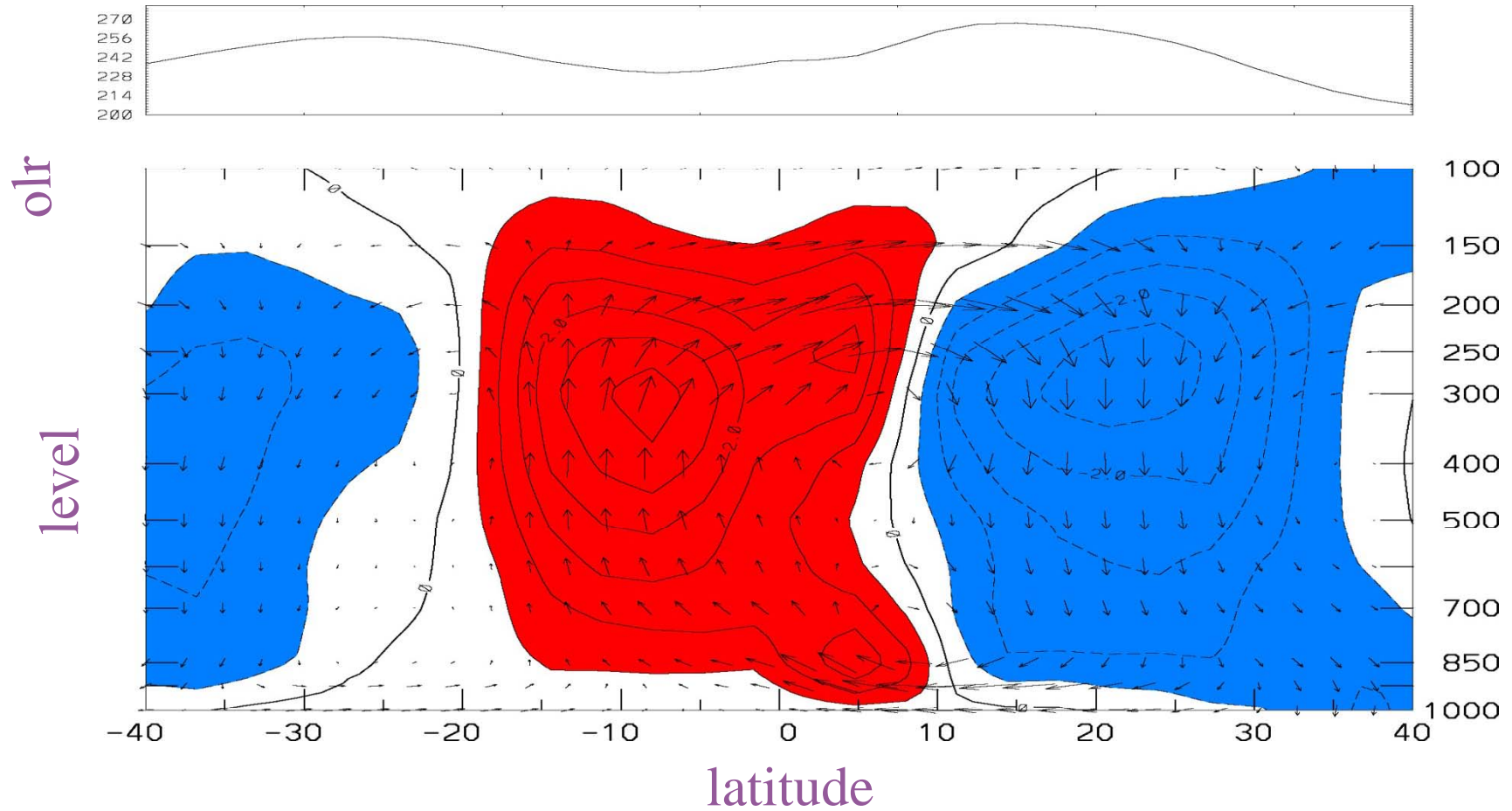Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

October Zonal Mean Meridional Wind   1979-1993 from ECMWF
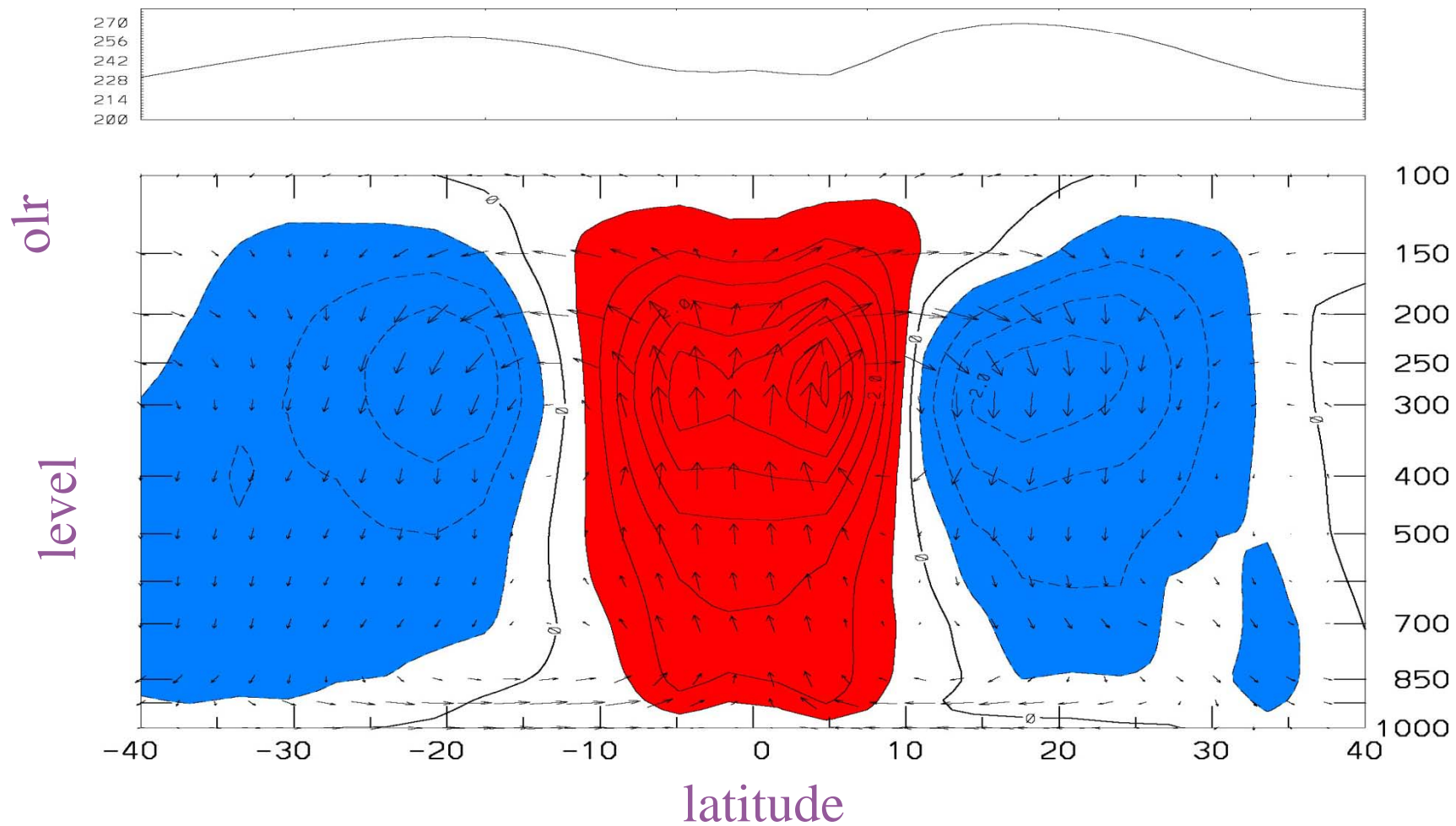

Contour interval .2 m s^{-1}

Shading Red Positive (Southerly)

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

Contour interval 1 mm s^{-1}
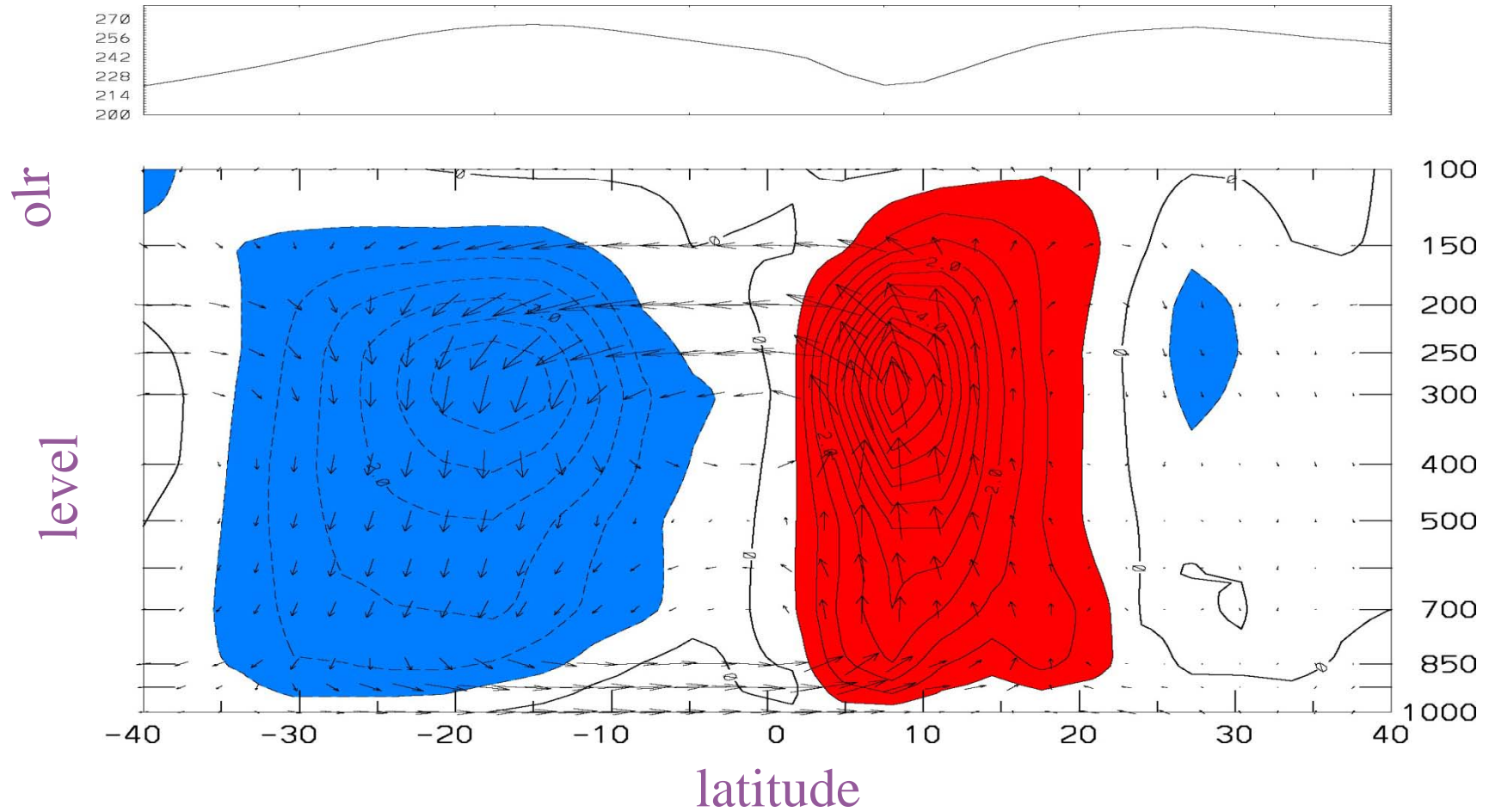
Shading Red Positive (Upward)

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

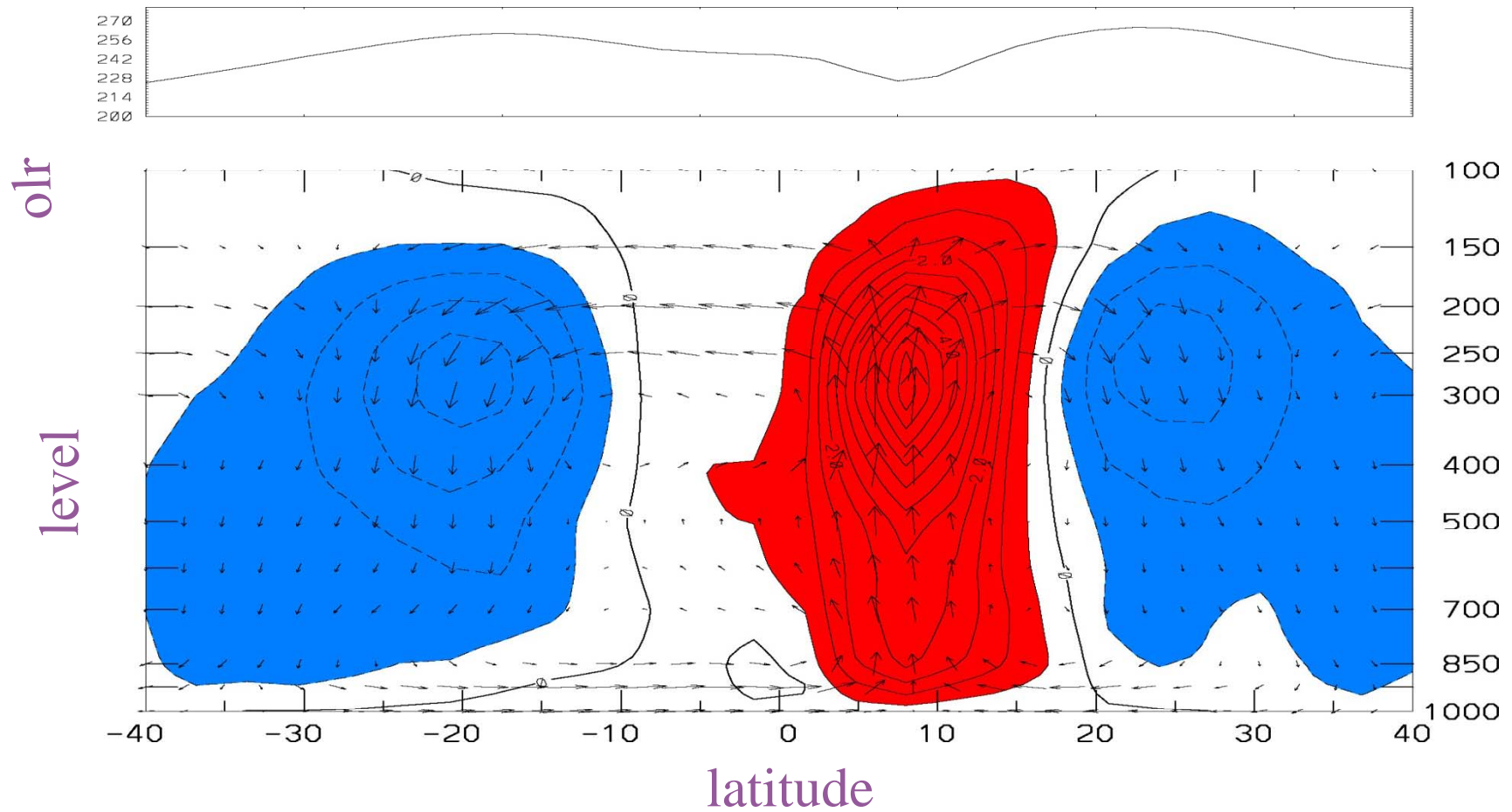Contour interval 1 mm s^{-1}

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)

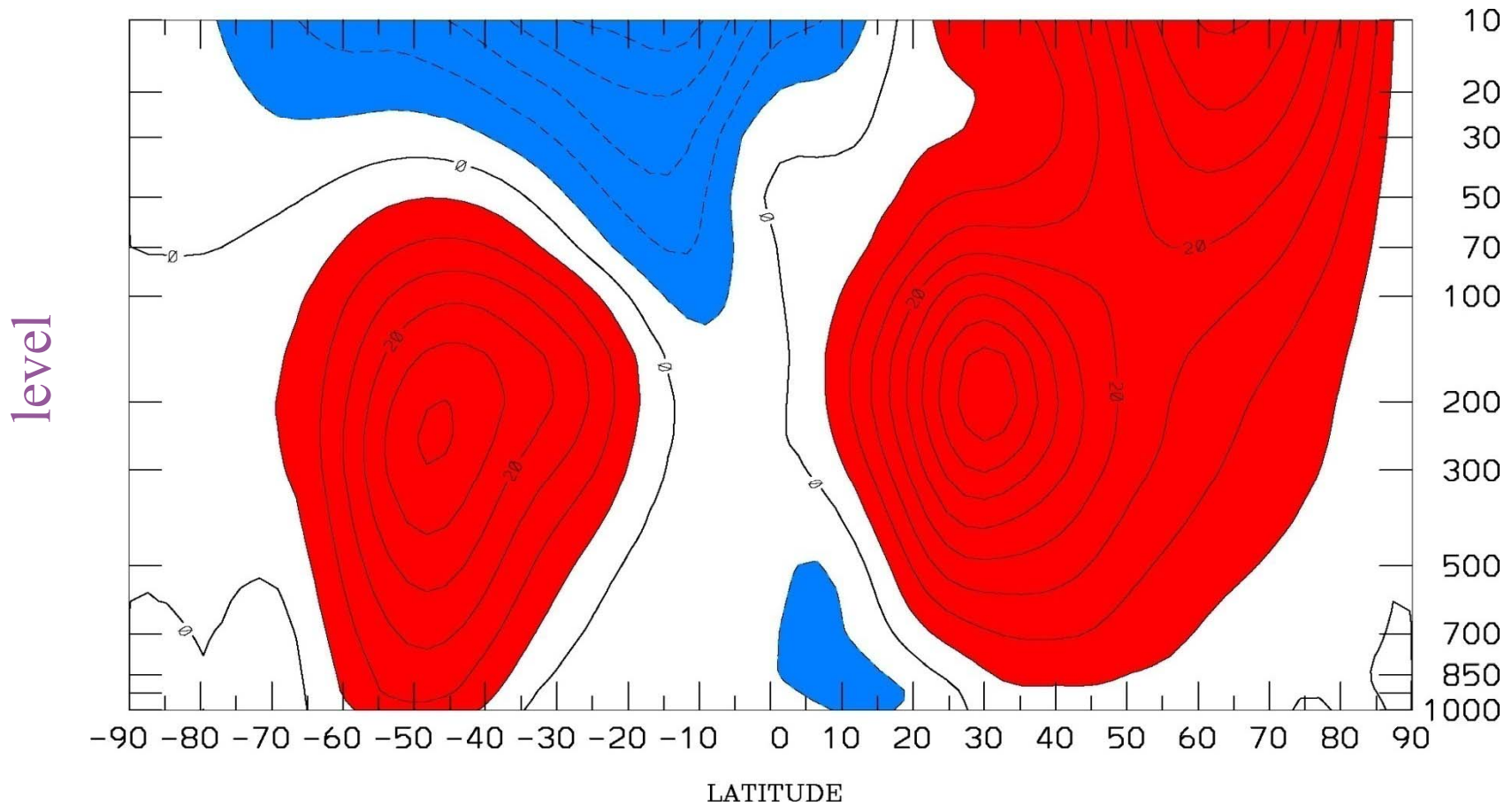# October Zonal Mean OLR, Vertical and Meridional Wind, 1979-1993 from ECMWF

Contour interval 1 mm s^{-1}

Shading Red Positive (Upward)

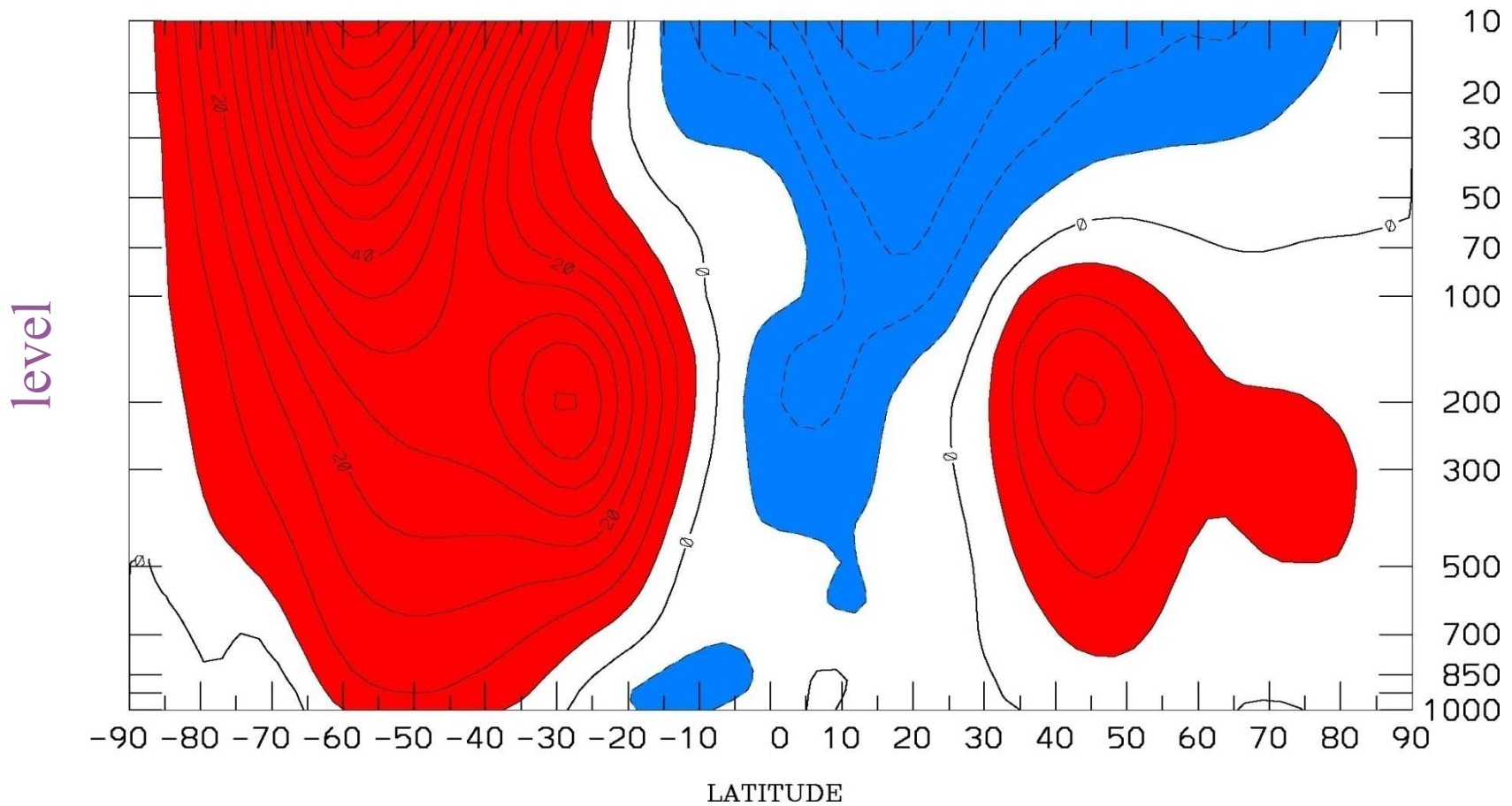# January Zonal Mean Zonal Wind

1979-2001 from NCEP

Contour interval 5 m s^{-1}
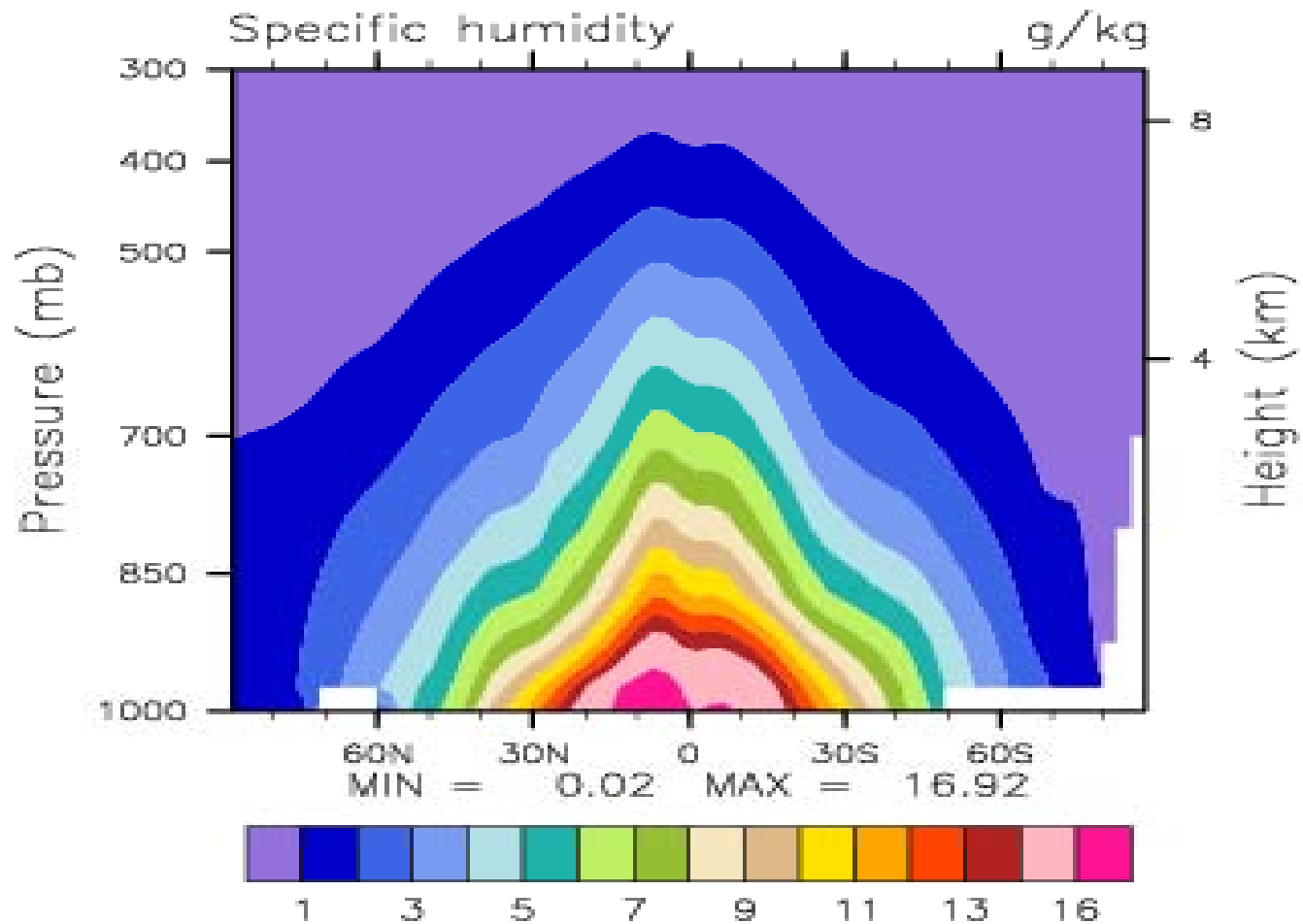
Shading Red Positive (Westerly)
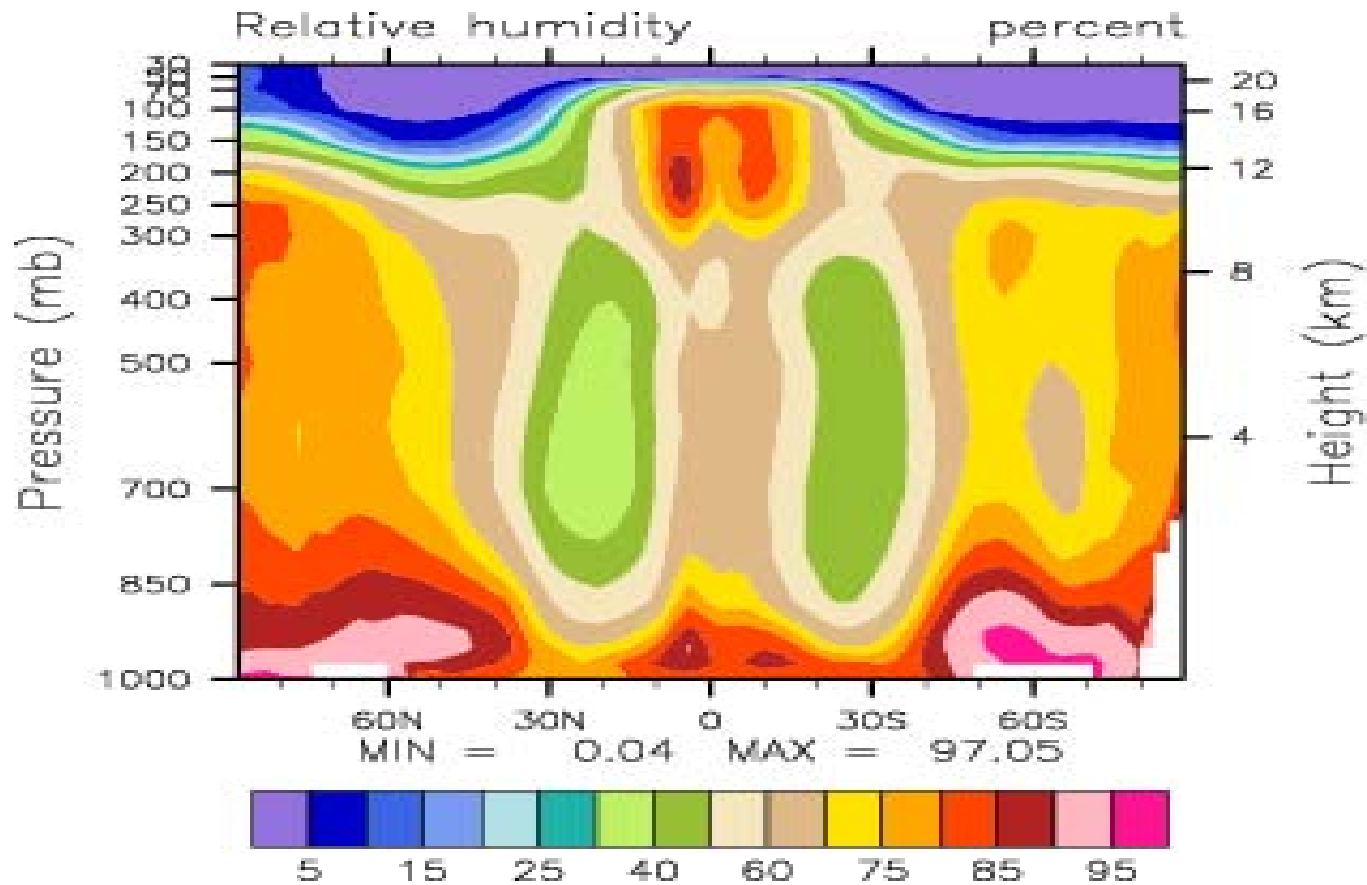
July Zonal Mean Zonal Wind

1979-2001 from NCEP
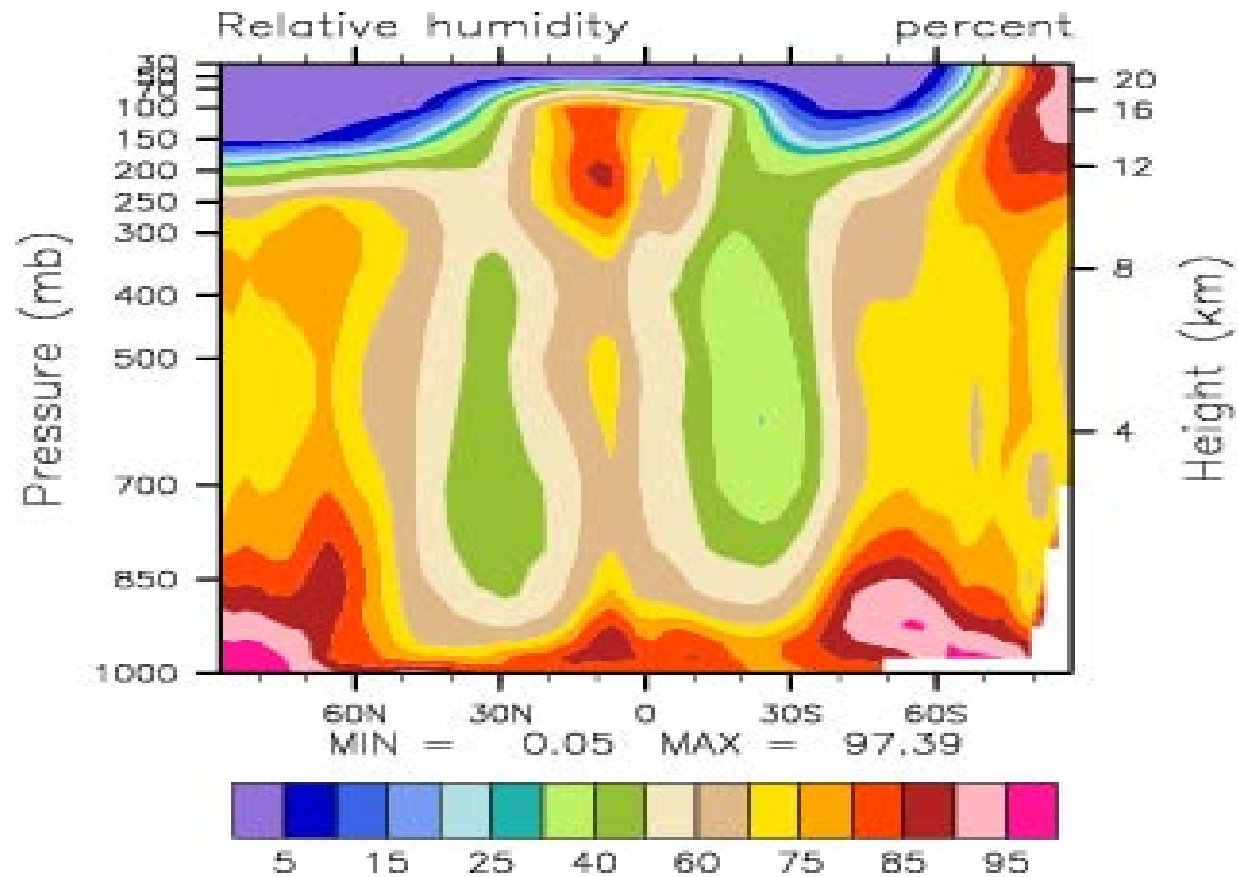

Contour interval 5 m s⁻¹

Shading Red Positive (Westerly)

Annual Mean

December, January, February

June, July, August

Relative humidity — percent

MIN = 0.05 MAX = 97.39

12.811 Tropical Meteorology

Spring 2011