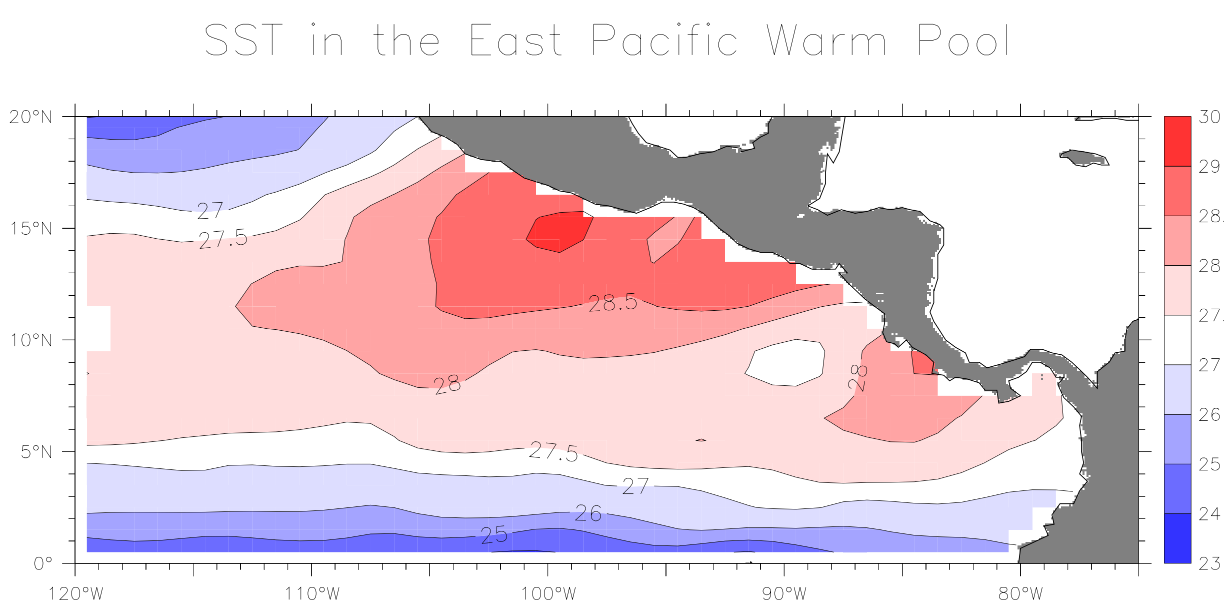
Mean three-dimensional circulation in the NE tropical Pacific

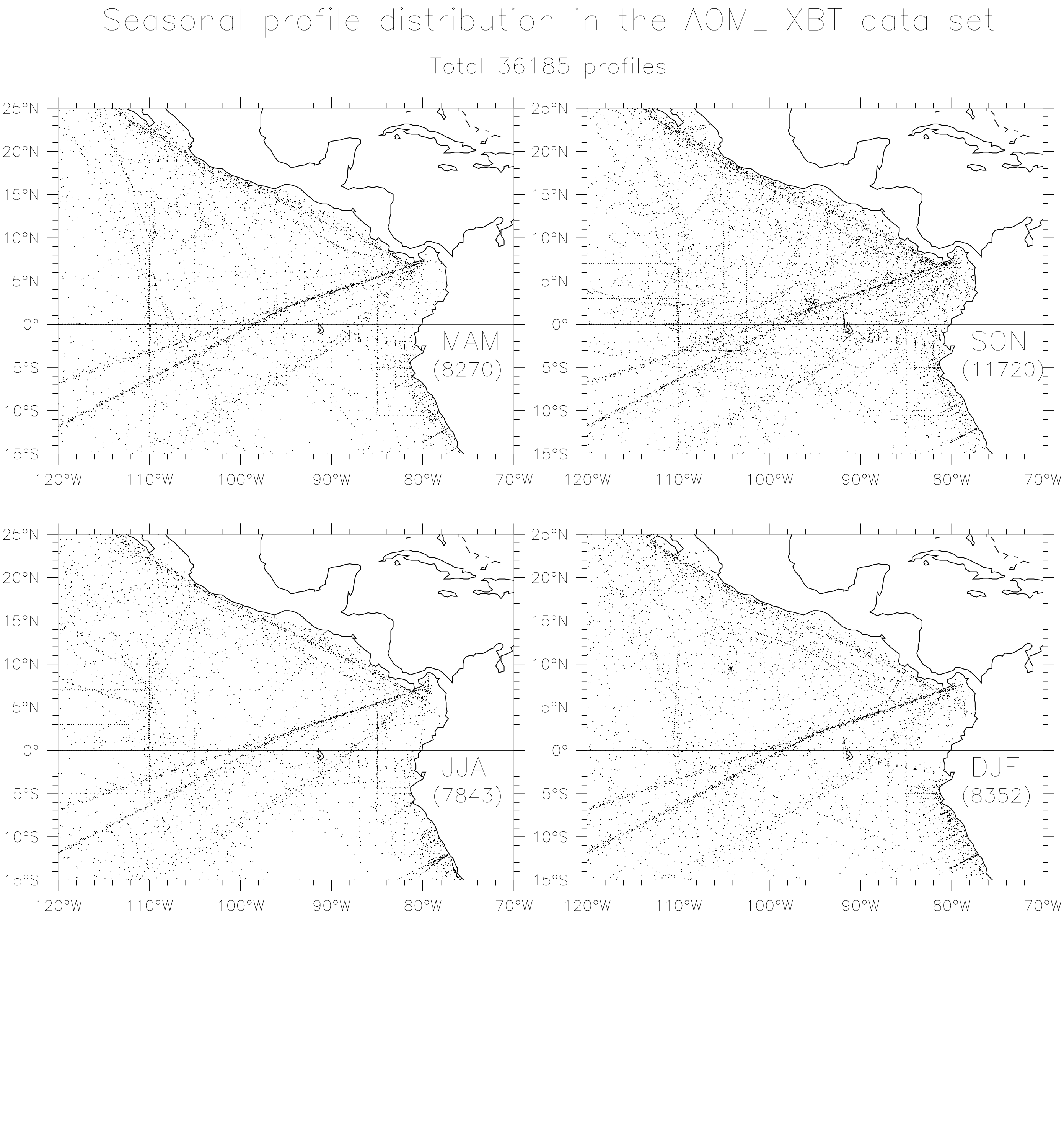
Kessler, 2002. JPO, 32, 2457-2471.

- Use XBT data and Quikscat winds to diagnose the mean circulation.

- Unlike the familiar central Pacific, winds in this region are dominated by easterly jets through three gaps in the mountains. These produce a pattern of curl that is quite different from that further west, and imprint on the circulation.

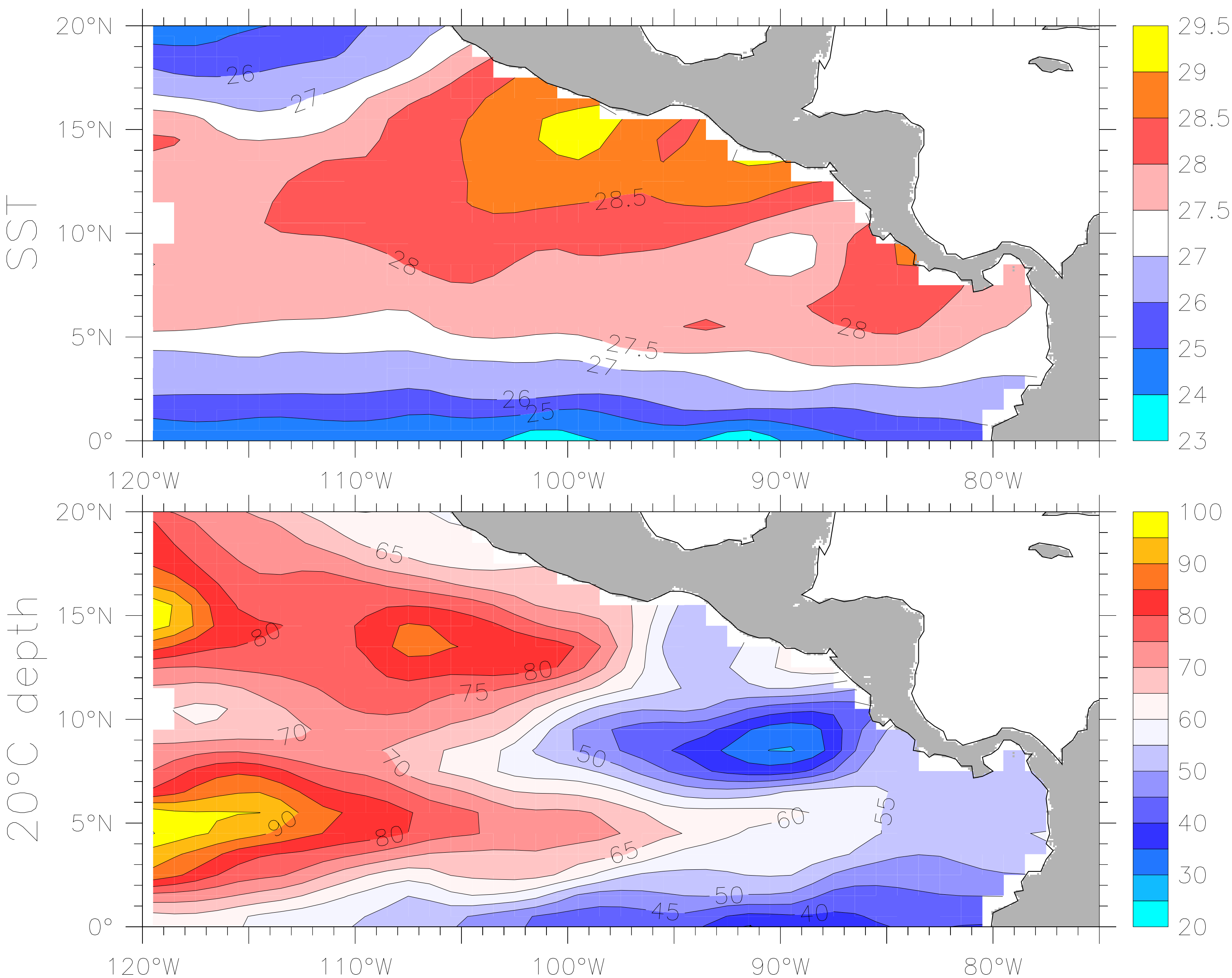
- The interconnections among the well-known zonal currents of the central Pacific are complicated and three-dimensional.

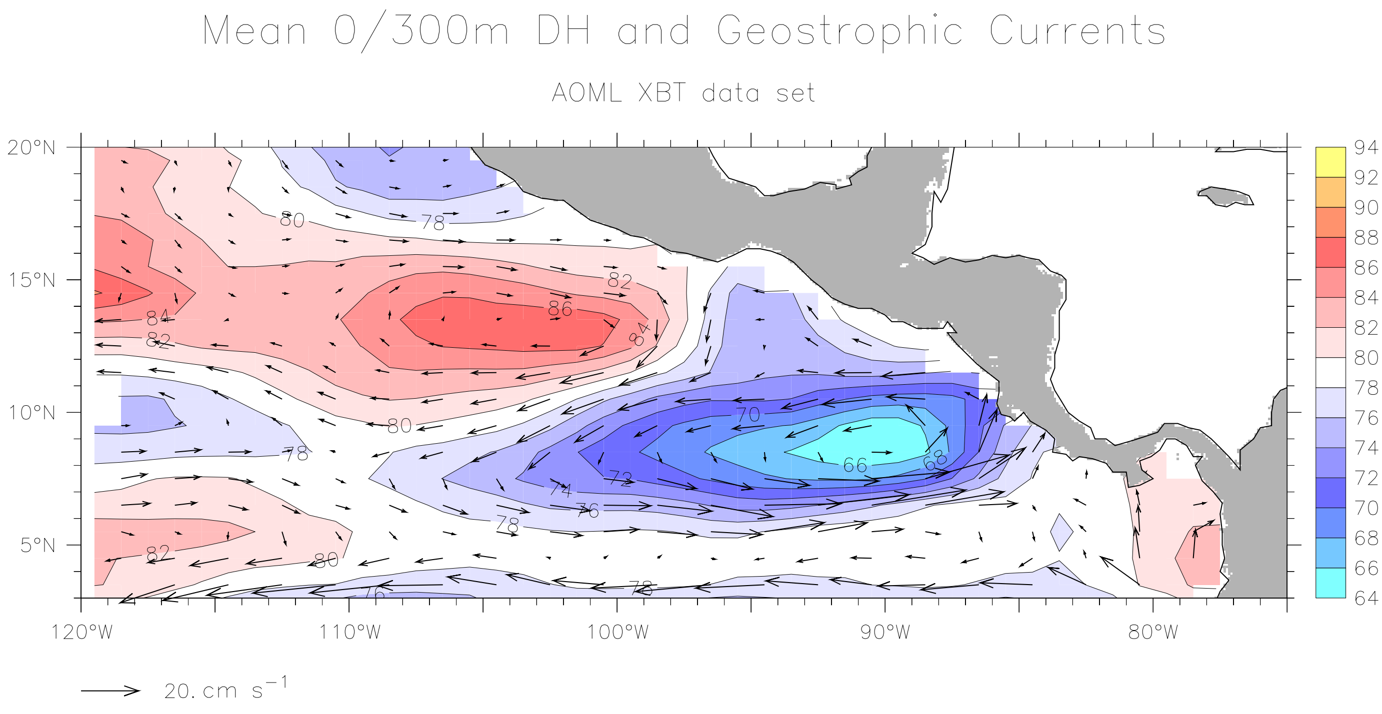



Seasonal profile distribution in the AOML XBT data set
Total 36185 profiles
MAM
(8270)
SON
(11720)
JJA
(7843)
DJF
(8352)
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
15°S
120°W
110°W
100°W
90°W
80°W
70°W

Mean SST and 20°C depth

AOML XBT data set




Mean 0/300m DH and Geostrophic Currents
AOML XBT data set
20°N
15°N
10°N
5°N
120°W
110°W
100°W
90°W
80°W
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
20. cm s^{-1}

Dynamics

Assume steady linear flow in Sverdrup balance:

$$\beta V = Curl(\tau)$$

Decomposing the meridional velocity into Ekman and geostrophic parts, and noting that $Curl(\tau/f) \equiv Curl(\tau)/f + \beta\tau^x/f^2$, allows rewriting the Sverdrup balance as

$$\frac{\beta}{f} V_g = Curl(\tau/f)$$

The geostrophic term on the left can be evaluated from the observed ocean data, and the term on the right from the observed winds.

The stretching of water columns due to meridional motion

$$f\frac{\partial w}{\partial z} = \beta v_g$$

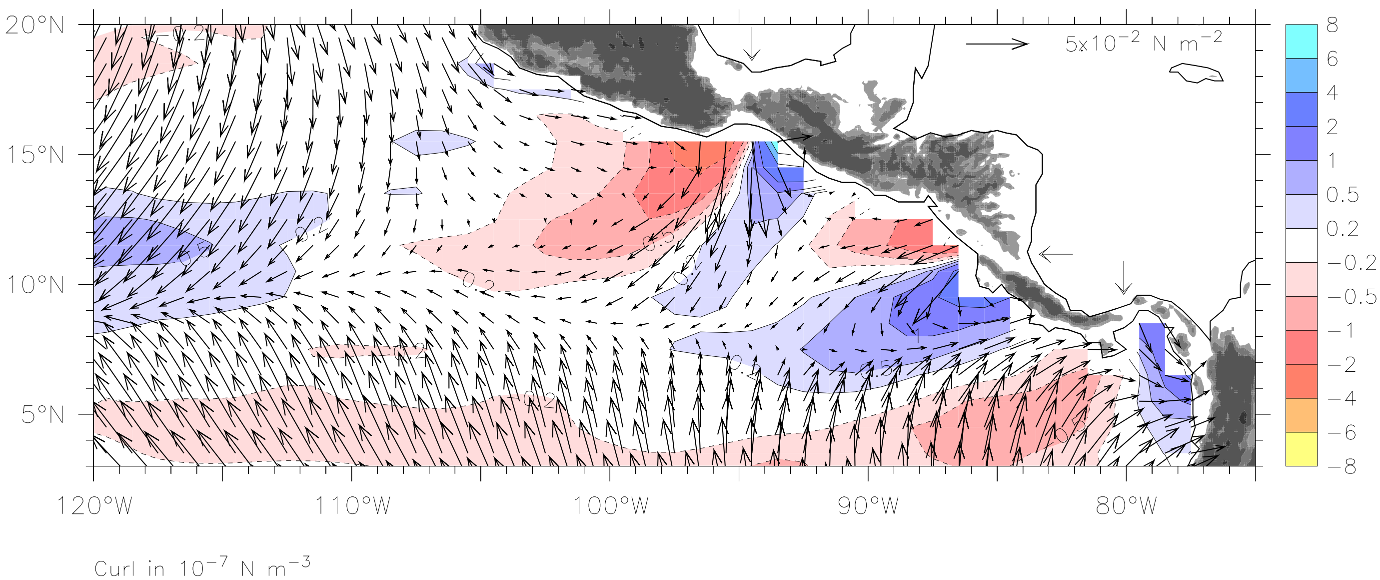
is balanced by the stretching due to Ekman pumping $w_E = Curl(\tau/f)$.

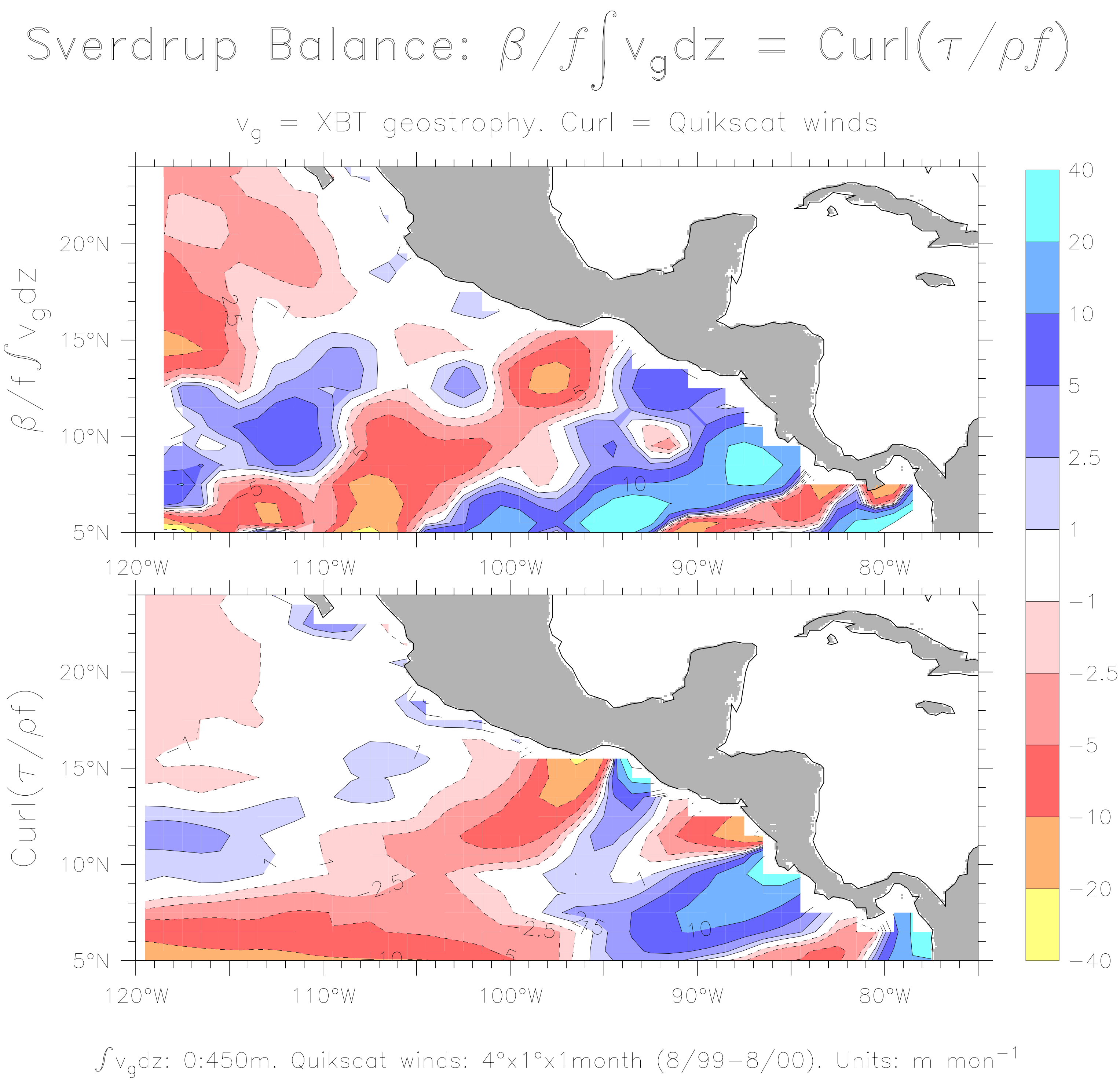
An indefinite integral, using the observed v_g from the XBT data, gives the vertical profile

$$w(z) = \frac{\beta}{f}\int_{-D}^{z} v_g dz$$

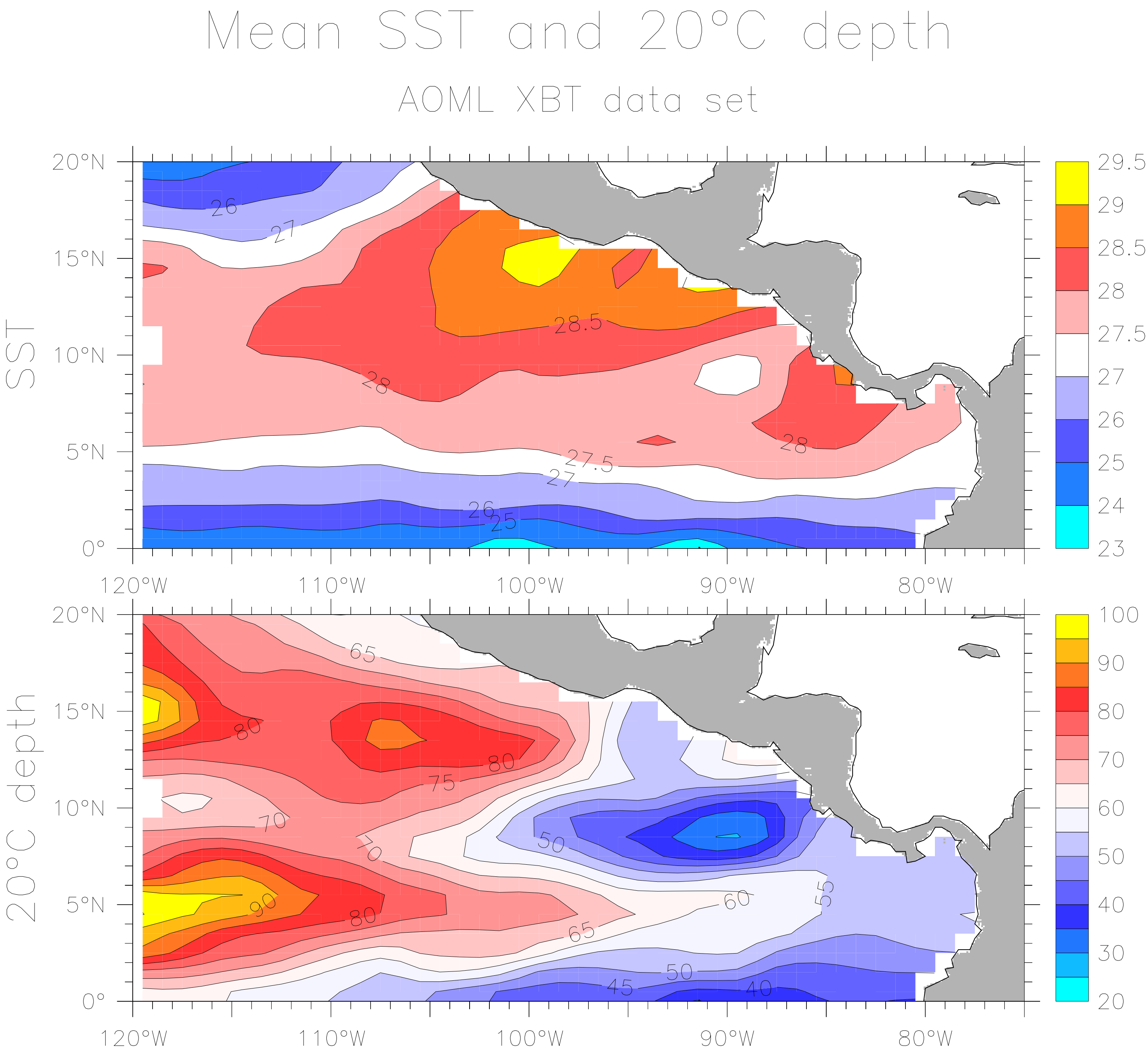
Mean Curl and Vector Wind Stress

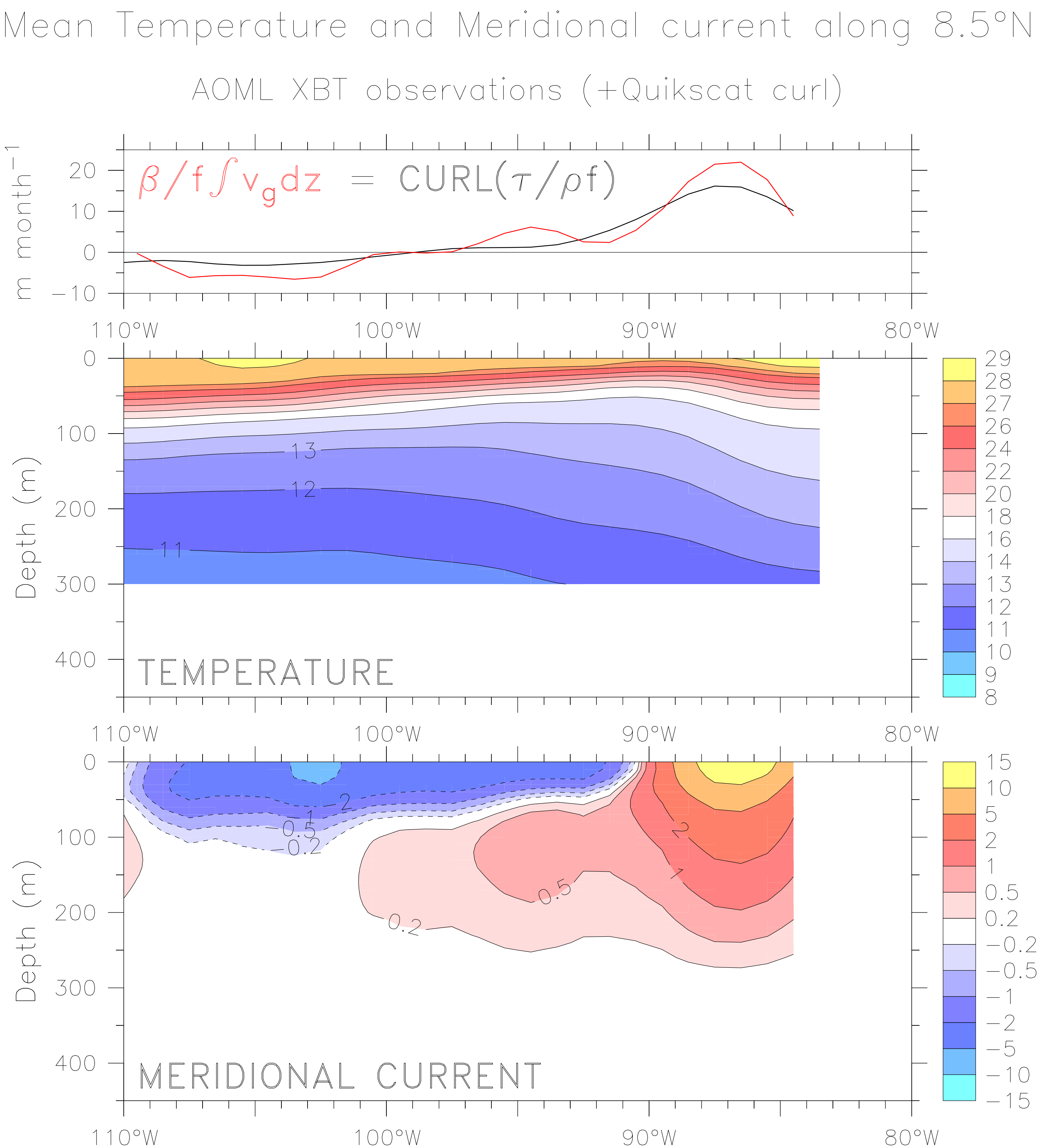
Quikscat winds (Aug 1999 – Aug 2000)



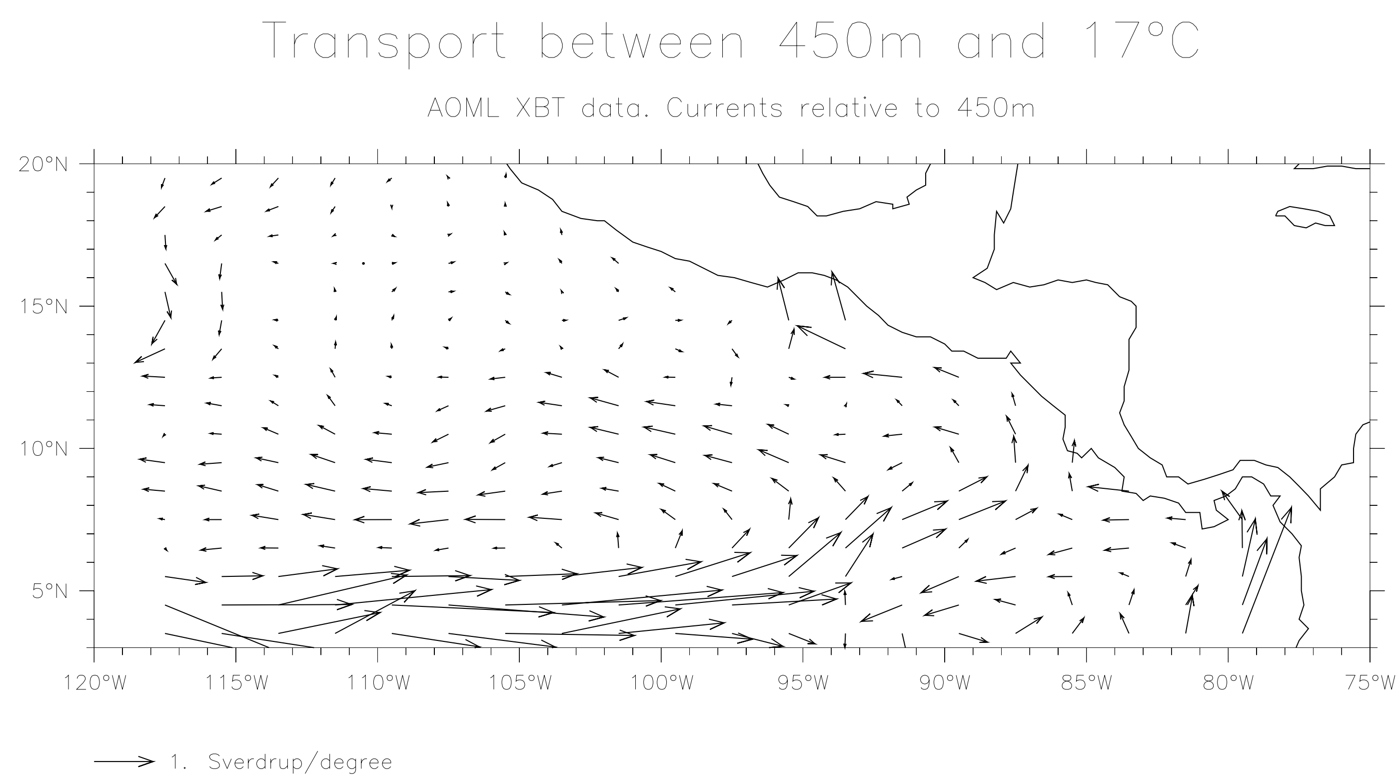


Sverdrup Balance: $\beta/f\int v_g dz = Curl(\tau/\rho f)$
v_g = XBT geostrophy. Curl = Quikscat winds
$\beta/f\int v_g dz$
$Curl(\tau/\rho f)$
20°N
15°N
10°N
5°N
120°W
110°W
100°W
90°W
80°W
40
20
10
5
2.5
1
−1
−2.5
−5
−10
−20
−40
$\int v_g dz$: 0:450m. Quikscat winds: 4°x1°x1month (8/99−8/00). Units: m mon^{-1}


Mean SST and 20°C depth
AOML XBT data set
SST
20°C depth
20°N
15°N
10°N
5°N
0°
120°W
110°W
100°W
90°W
80°W
29.5
29
28.5
28
27.5
27
26
25
24
23
100
90
80
70
60
50
40
30
20



Mean Temperature and Meridional current along 8.5°N
AOML XBT observations (+Quikscat curl)
$\beta/f\int v_g dz = CURL(\tau/\rho f)$
m month^{-1}
20
10
0
−10
110°W
100°W
90°W
80°W
Depth (m)
TEMPERATURE
0
100
200
300
400
13
12
11
29
28
27
26
24
22
20
18
16
14
13
12
11
10
9
8
MERIDIONAL CURRENT
2
1
0.5
0.2
2
1
0.5
0.2
15
10
5
2
1
0.5
0.2
−0.2
−0.5
−1
−2
−5
−10
−15


Transport between 450m and 17°C
AOML XBT data. Currents relative to 450m
20°N
15°N
10°N
5°N
120°W
115°W
110°W
105°W
100°W
95°W
90°W
85°W
80°W
75°W
1. Sverdrup/degree

Conclude:

1. The Sverdrup Balance explains important features of the mean circulation in the NE tropical Pacific.

2. Positive curl due to the Papagayo wind jet forces upwelling amounting to about 3+ Sv through 17°C.

   Consequences of this upwelling include:

   - A relatively cool region (SST about 1°C cooler than surrounding areas) is due to the upwelling.
   - Stretching of the water column forces the northern Tsuchiya Jet to turn poleward and upwell.

3. Downwelling curl SW of Tehuantepec produces a dip in the 10°N thermocline ridge and weakens the NECC near 110°W.

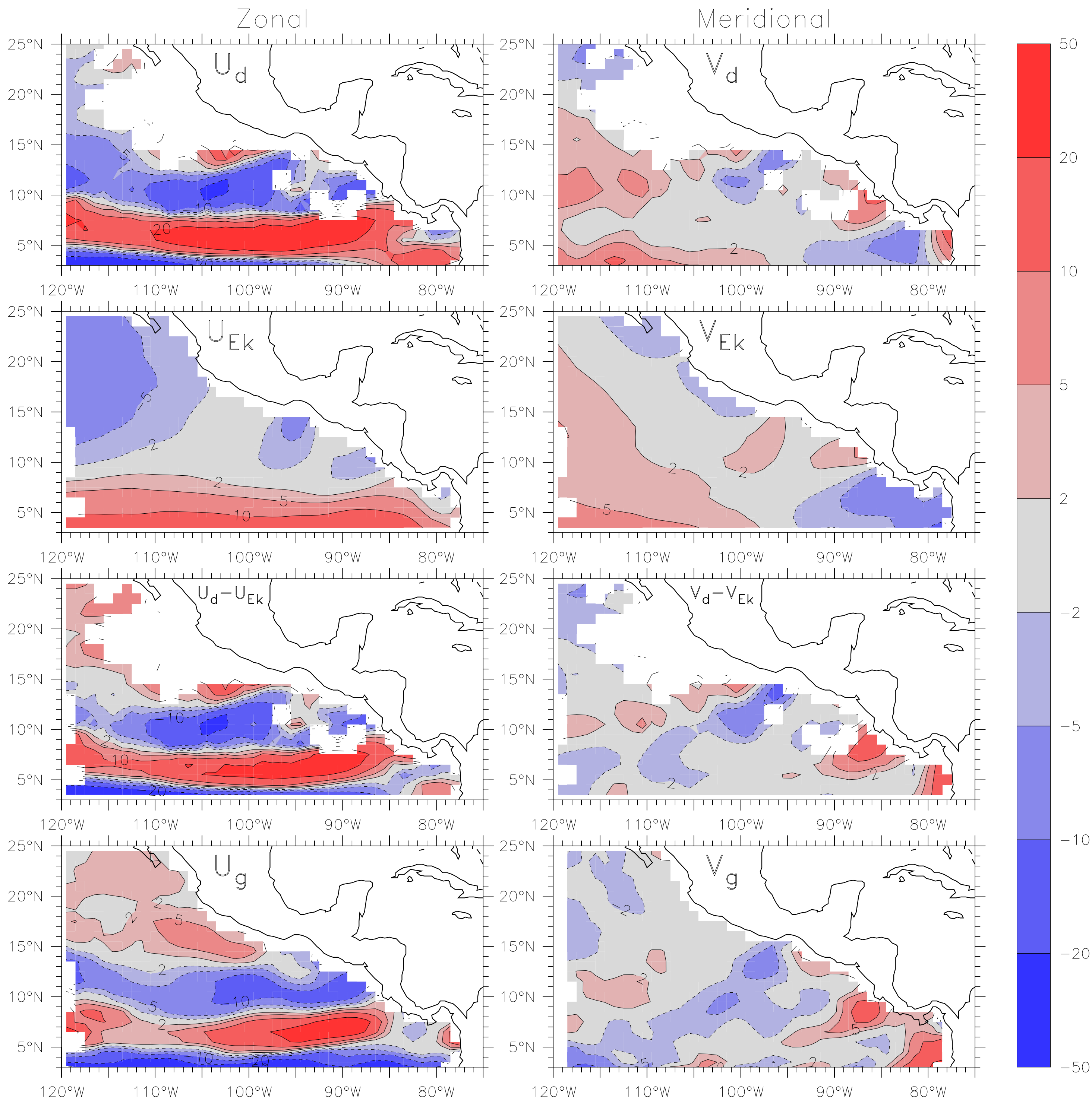
4. The imprint of the unusual wind system of the NE tropical Pacific on the ocean may turn out to be an aspect of the path by which intermediate-depth water, flowing into the Pacific from the south, is brought to the surface and into the northern hemisphere.

All figures from this talk are available at:

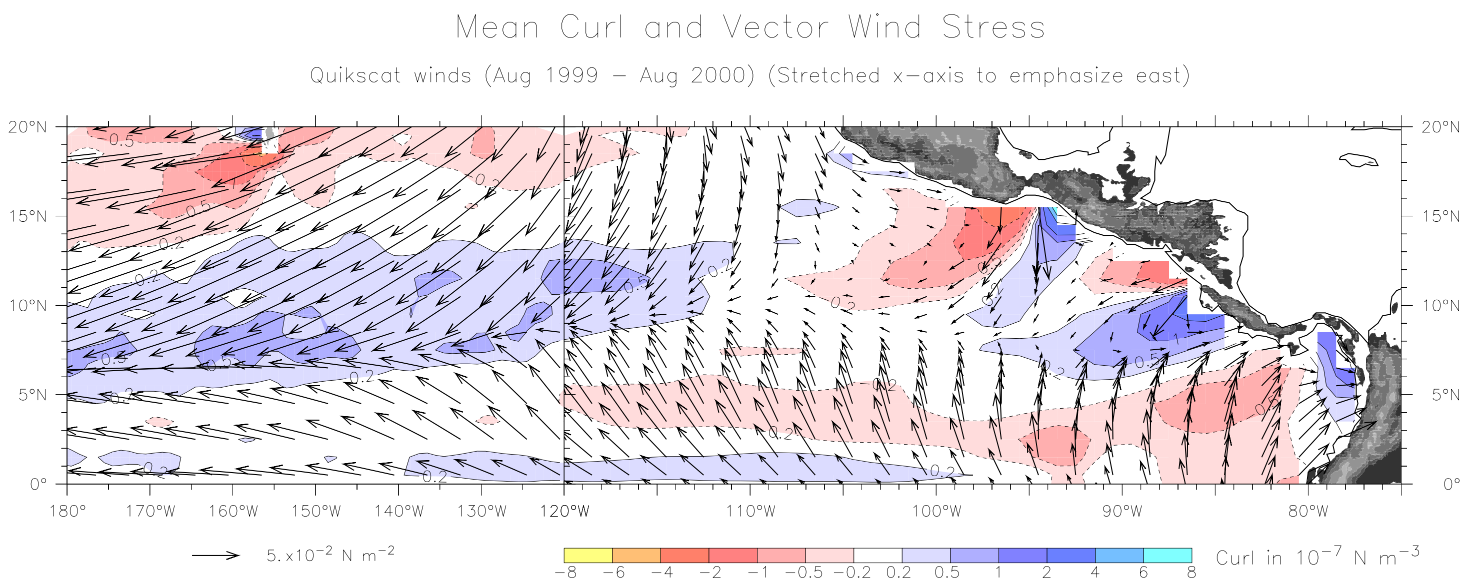
http://www.pmel.noaa.gov/~kessler/ ➜ Latest talk

Extra slides .....

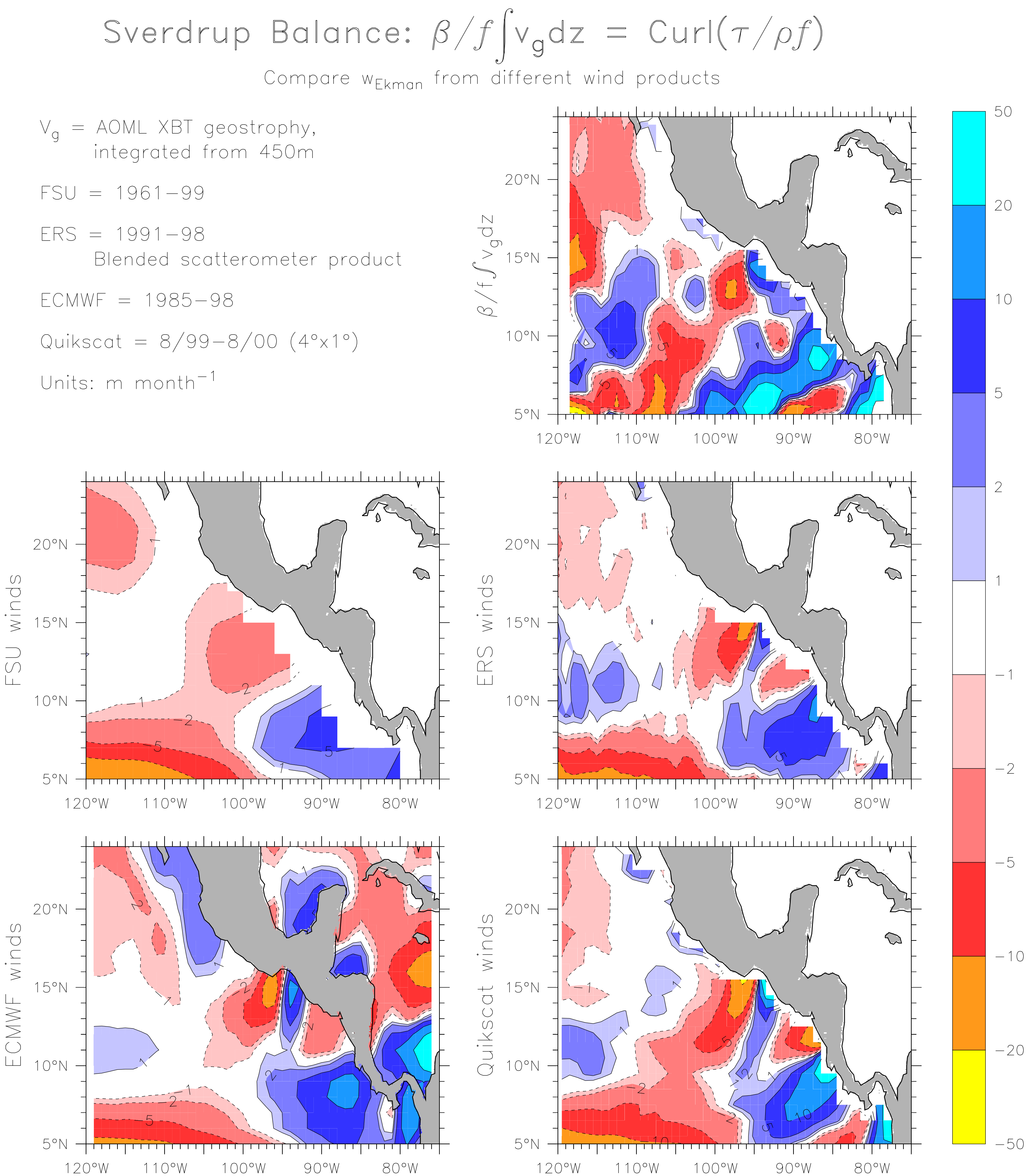
Geostrophic, Drifter and Ekman surface currents



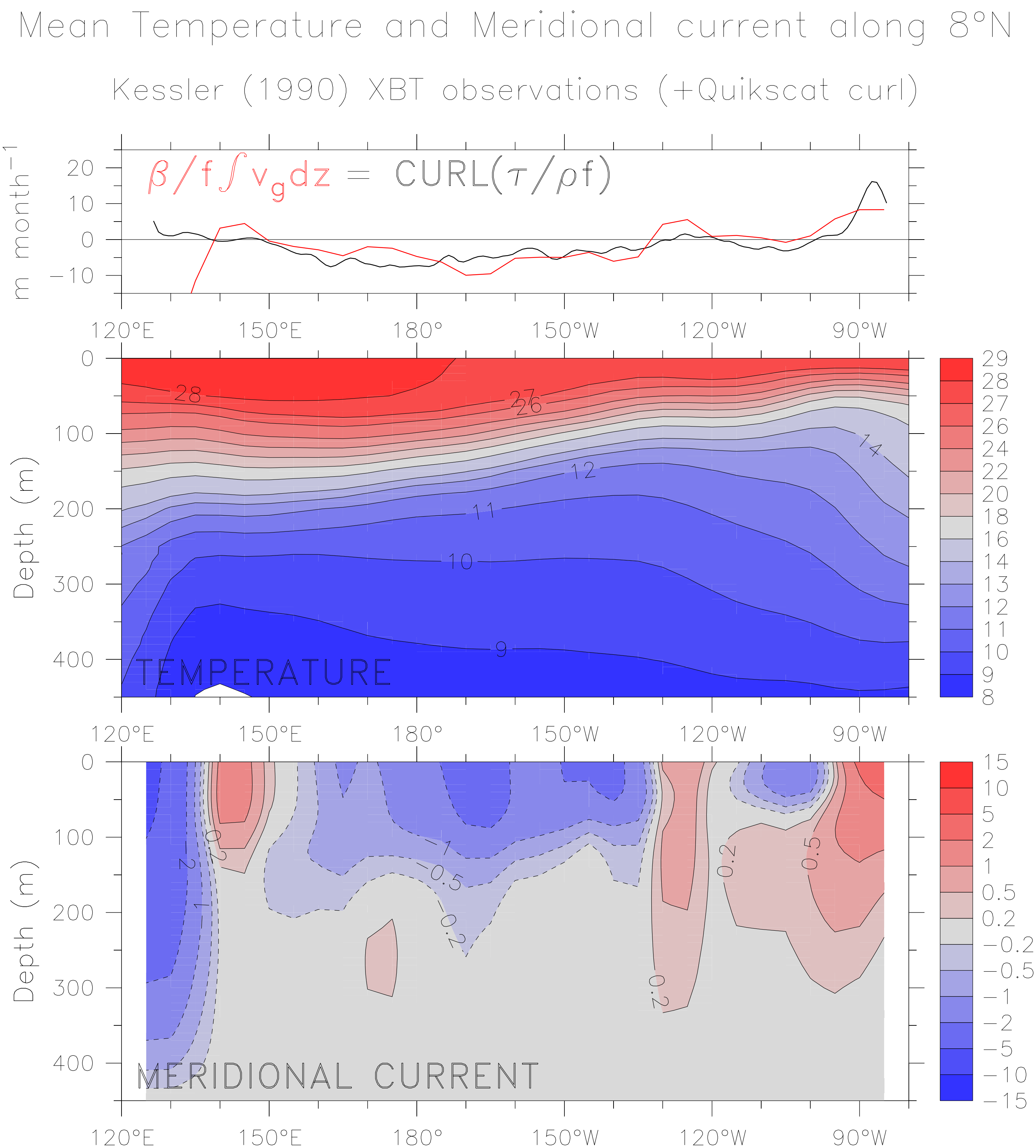
Ekman currents assume H_E = Ralph&Niiler H_*. Quikscat winds



Mean Curl and Vector Wind Stress
Quikscat winds (Aug 1999 – Aug 2000) (Stretched x–axis to emphasize east)
20°N
15°N
10°N
5°N
0°
180°
170°W
160°W
150°W
140°W
130°W
120°W
110°W
100°W
90°W
80°W
5.x10⁻² N m⁻²
Curl in 10⁻⁷ N m⁻³
–8 –6 –4 –2 –1 –0.5 –0.2 0.2 0.5 1 2 4 6 8

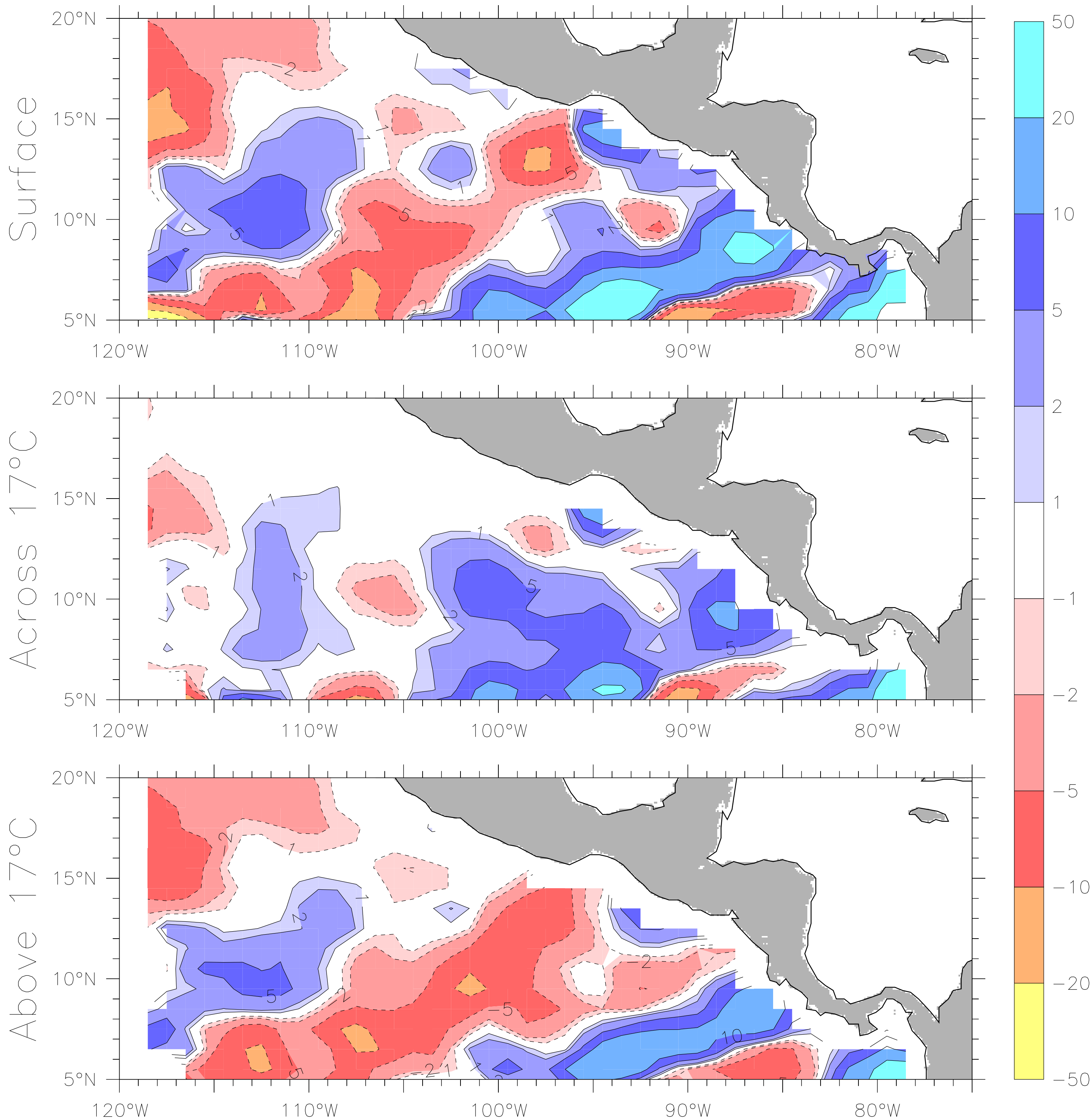


Sverdrup Balance: $\beta/f\int v_g dz = \mathrm{Curl}(\tau/\rho f)$
Compare w_{Ekman} from different wind products
V_g = AOML XBT geostrophy, integrated from 450m
FSU = 1961–99
ERS = 1991–98
Blended scatterometer product
ECMWF = 1985–98
Quikscat = 8/99–8/00 (4°x1°)
Units: m $month^{-1}$
$\beta/f\int v_g dz$
FSU winds
ERS winds
ECMWF winds
Quikscat winds
5°N
10°N
15°N
20°N
120°W
110°W
100°W
90°W
80°W
50
20
10
5
2
1
−1
−2
−5
−10
−20
−50

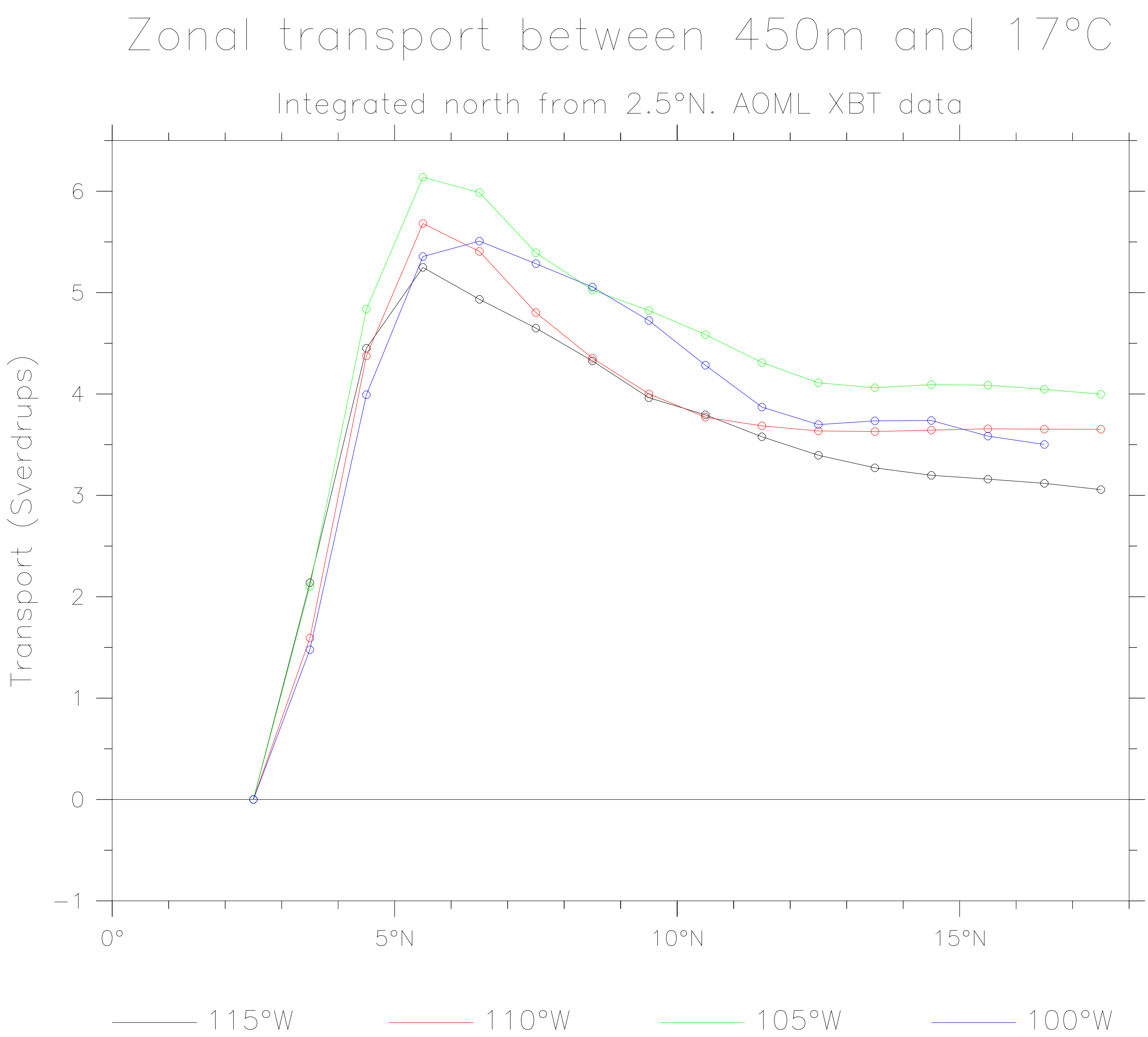


Mean Temperature and Meridional current along 8°N
Kessler (1990) XBT observations (+Quikscat curl)
$\beta/f\int v_g dz$ = CURL($\tau/\rho f$)
m month^{-1}
20
10
0
−10
120°E
150°E
180°
150°W
120°W
90°W
Depth (m)
0
100
200
300
400
TEMPERATURE
28
27
26
14
12
11
10
9
29
24
22
20
18
16
13
8
MERIDIONAL CURRENT
0.2
−2
−1
−0.5
−0.2
0.5
15
10
5
2
1
−5
−10
−15

Vertical velocity ($w=\beta/f\int v_g dz$) at z=0 and across Z17



Velocity across Z17 is $w-(uh_x+vh_y)$. Units m month^{-1}



Zonal transport between 450m and 17°C
Integrated north from 2.5°N. AOML XBT data
Transport (Sverdrups)
6
5
4
3
2
1
0
−1
0°
5°N
10°N
15°N
115°W
110°W
105°W
100°W