THE SEASONAL HEAT BALANCE IN THE EASTERN TROPICAL PACIFIC

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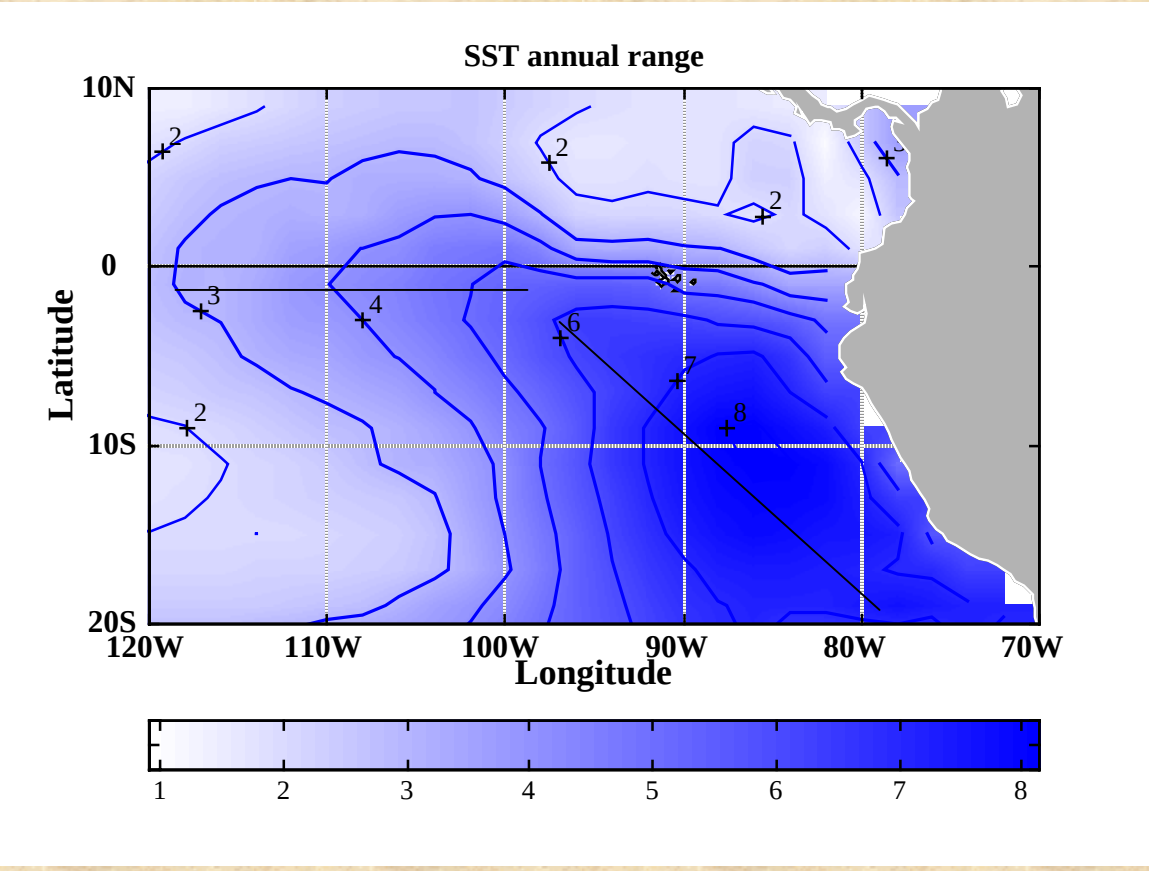
ESPOL-FIMCM

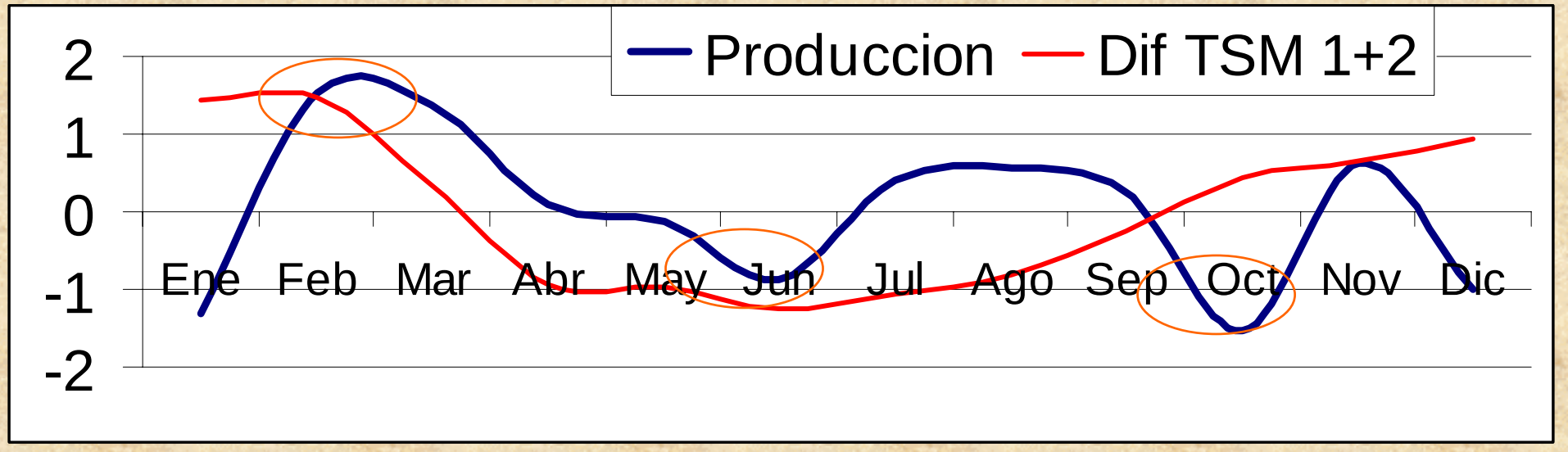
ECUADOR

motivation


SST annual range
10N
0
10S
20S
Latitude
120W
110W
100W
90W
80W
70W
Longitude
1
2
3
4
5
6
7
8

motivation

Shrimp production (1985-2000 seasonal cycle



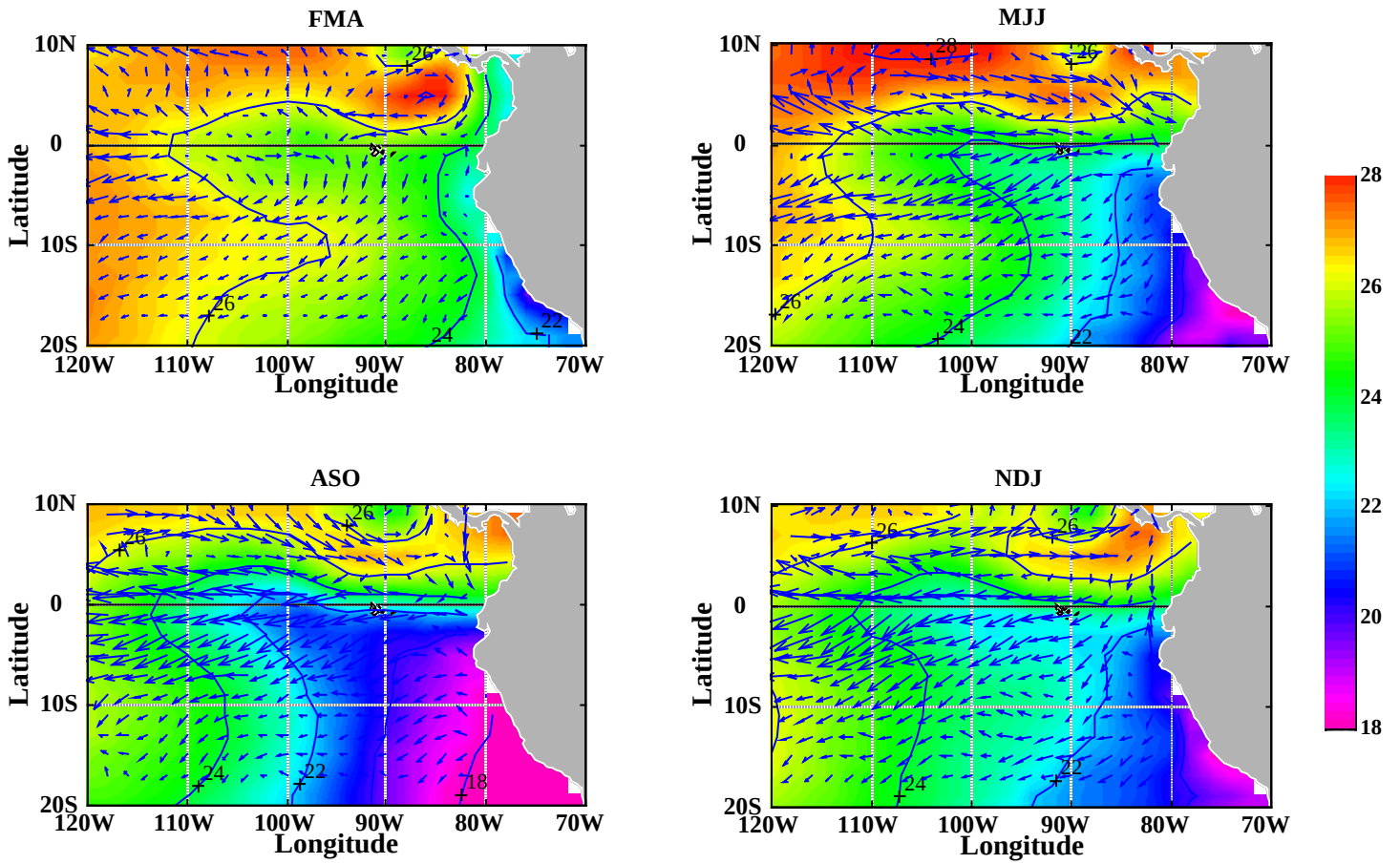
main objective

To analyze the seasonal variability of sea surface temperature (SST) in the eastern tropical Pacific (ETP) and how it responds to different forcing mechanisms such as wind stress and surface heat fluxes.

How was the analysis done?

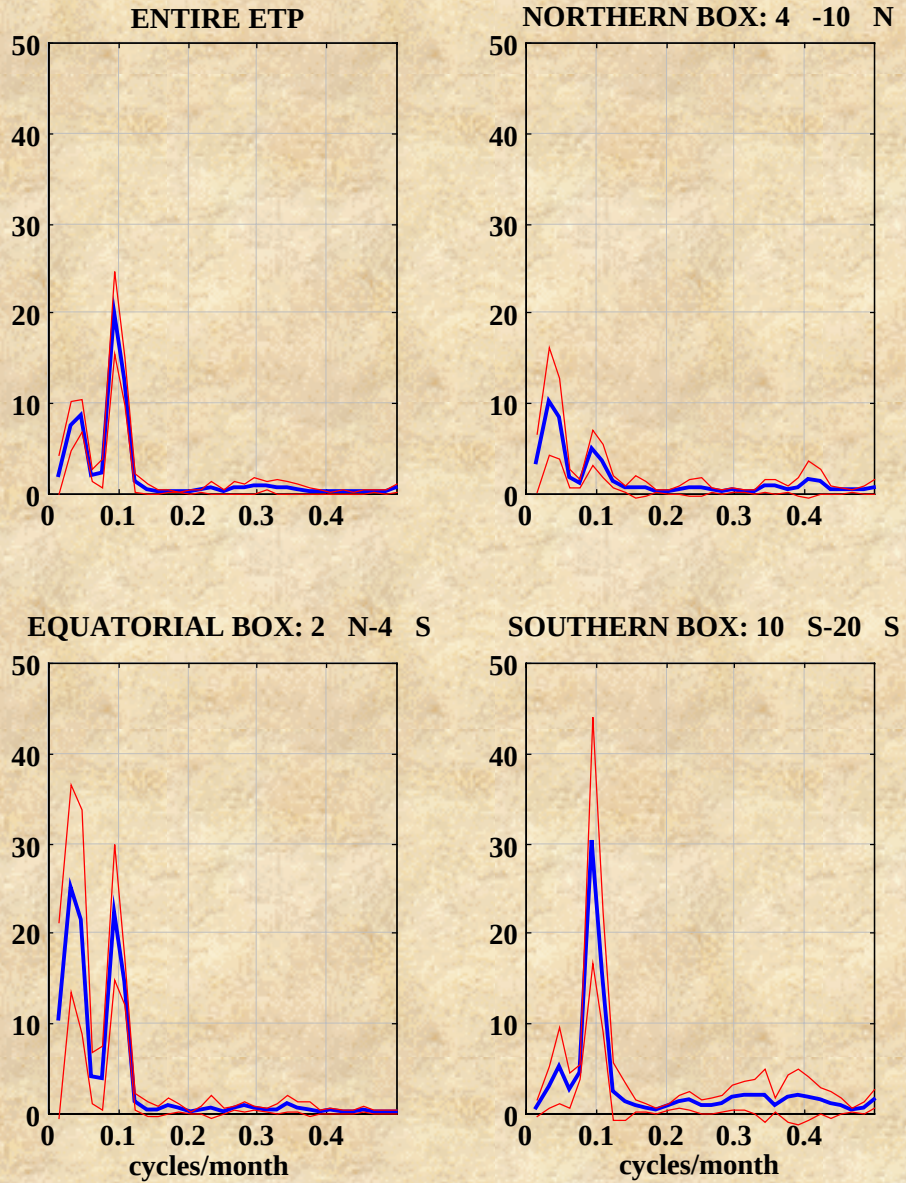
- The thermal and surface current fields analysis
- The model
- The heat balance terms
- The zonal differences
- Summary and Conclusions
- future research

The thermal and surface current field



The thermal field

SPECTRUM OF THE 0-30M AVERAGE TEMPERATURE IN THE ETP



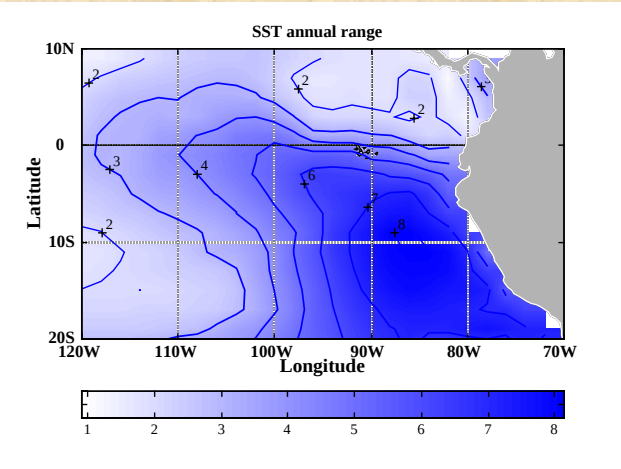
The model

- Data:
  - Temperature field from XBT's processed at NOAA/AOML (Donoso et al., 1994)
  - Velocity field (climatology) from the Pacific drifters (as in Bauer et al., 1998)
  - Da Silva unconstrained surface fluxes (Da Silva et al., 1994)
  - Horizontally varying latteral diffusivity coefficient (Zhurba and Oh, 2003)
  - Average vertical diffusivity coefficient (2.6×10^{-4} $m^2 s^{-1}$)
- Data coverage: 1979 -1993

The model

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{1}{\rho c_p}\left[\nabla_H k_{xy}(\nabla T) + \frac{\partial\left(k_z(z)\frac{\partial T}{\partial z}\right)}{\partial z} + Q_{net}\right]$$

2°x2° grid
Layer 30m deep
10°N-20°S, 120°W to the coast
Seasons center on March, June, September, and December



The model

- Error propagation has been computed for all terms

$$S_Z^2 = S_X^2 + S_Y^2 \pm 2S_{XY}$$

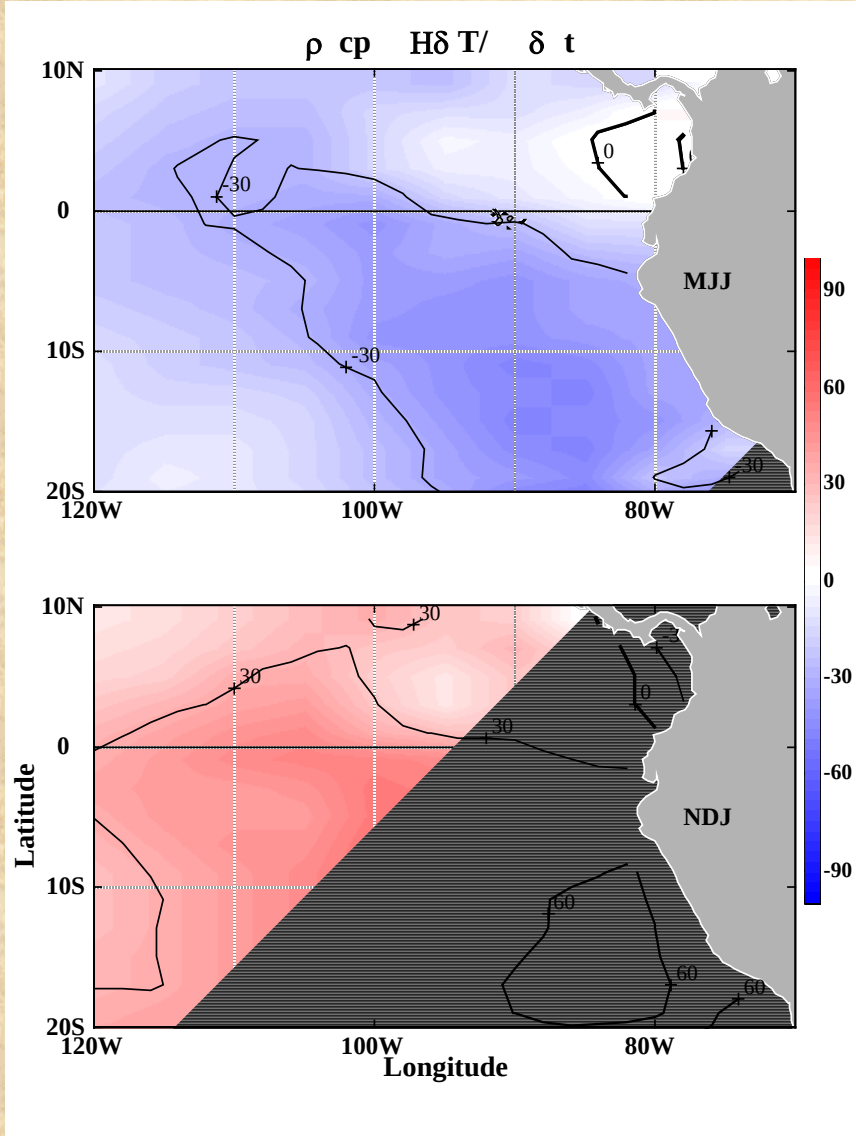
$$\frac{S_Z^2}{(\bar{Z})^2} = \frac{S_X^2}{(\bar{X})^2} + \frac{S_Y^2}{(\bar{Y})^2} \pm 2\frac{S_{XY}}{\bar{X}\bar{Y}}$$

Error (coefficient) = (maximum -minimum)/6

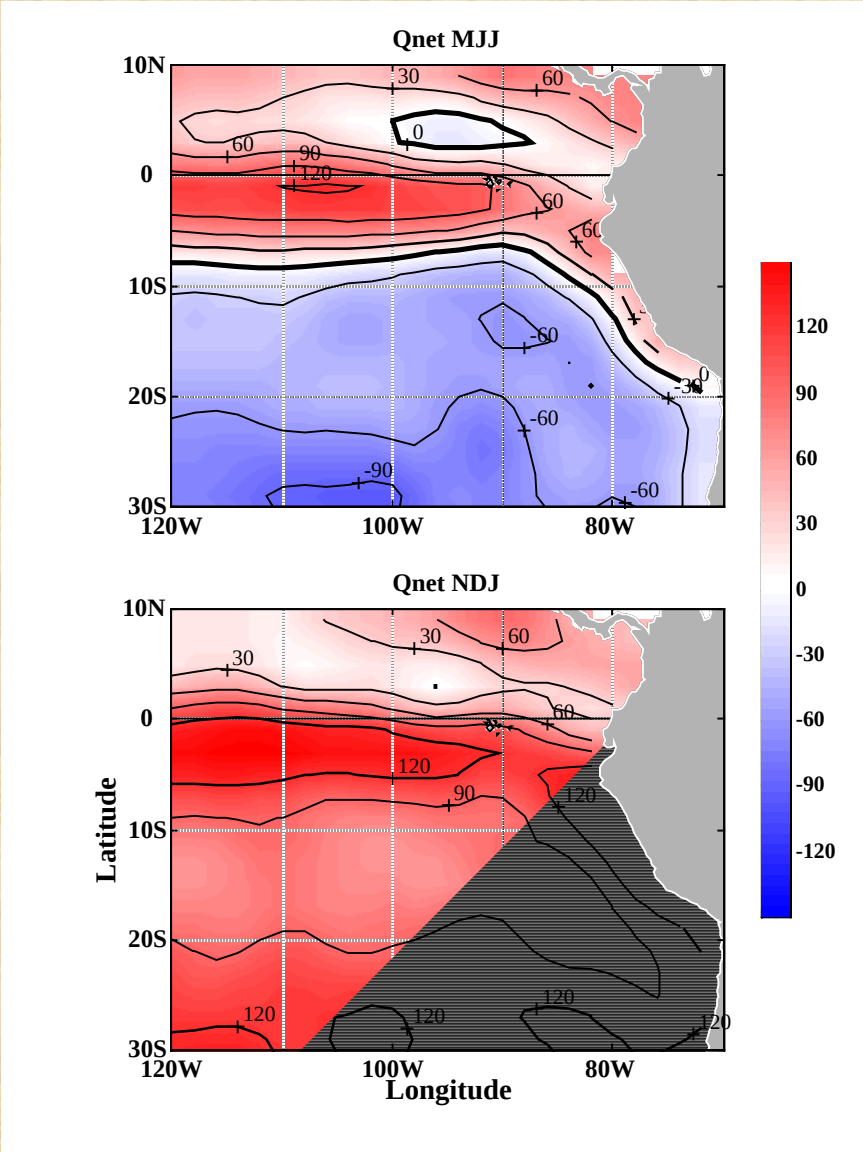
$$SEM = \sigma = \frac{S_Z}{\sqrt{n*}}$$

σ total = σ1 +σ2+σ3+…

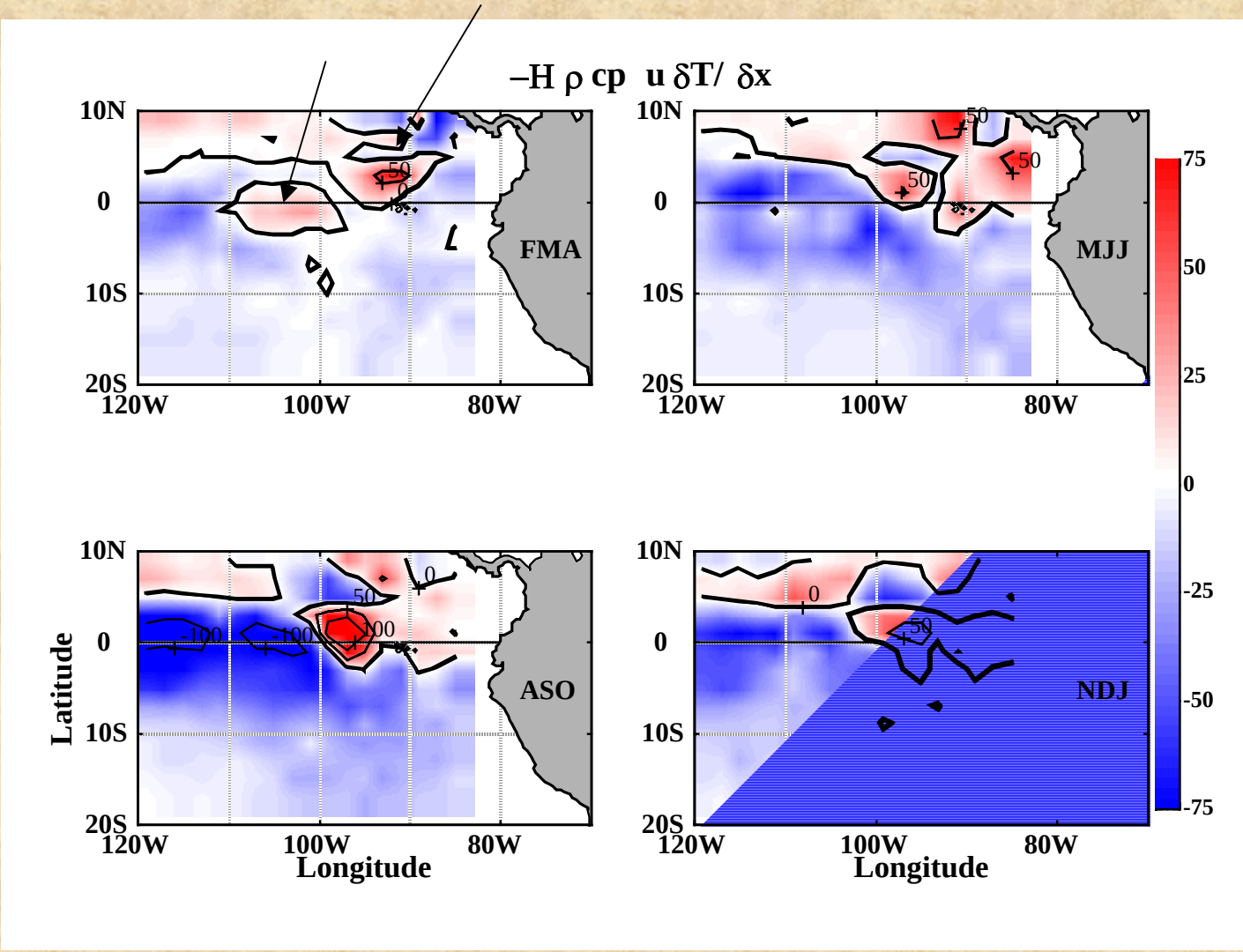
The heat balance terms: $H\rho c_p \frac{\partial T}{\partial t}$



The heat balance terms: Q_{net}

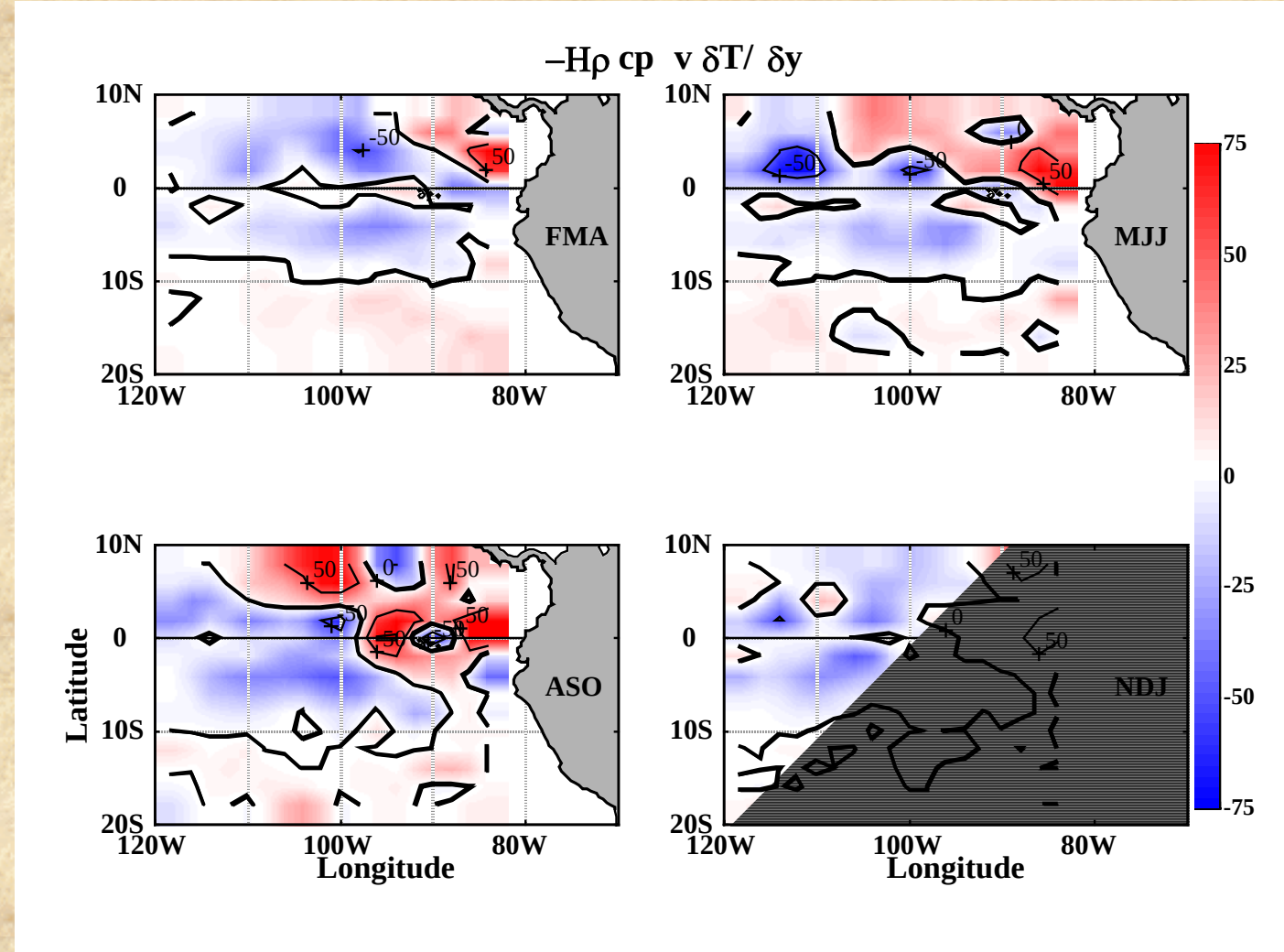


The heat balance terms: $H\rho c_p u_d \frac{\partial T}{\partial x}$

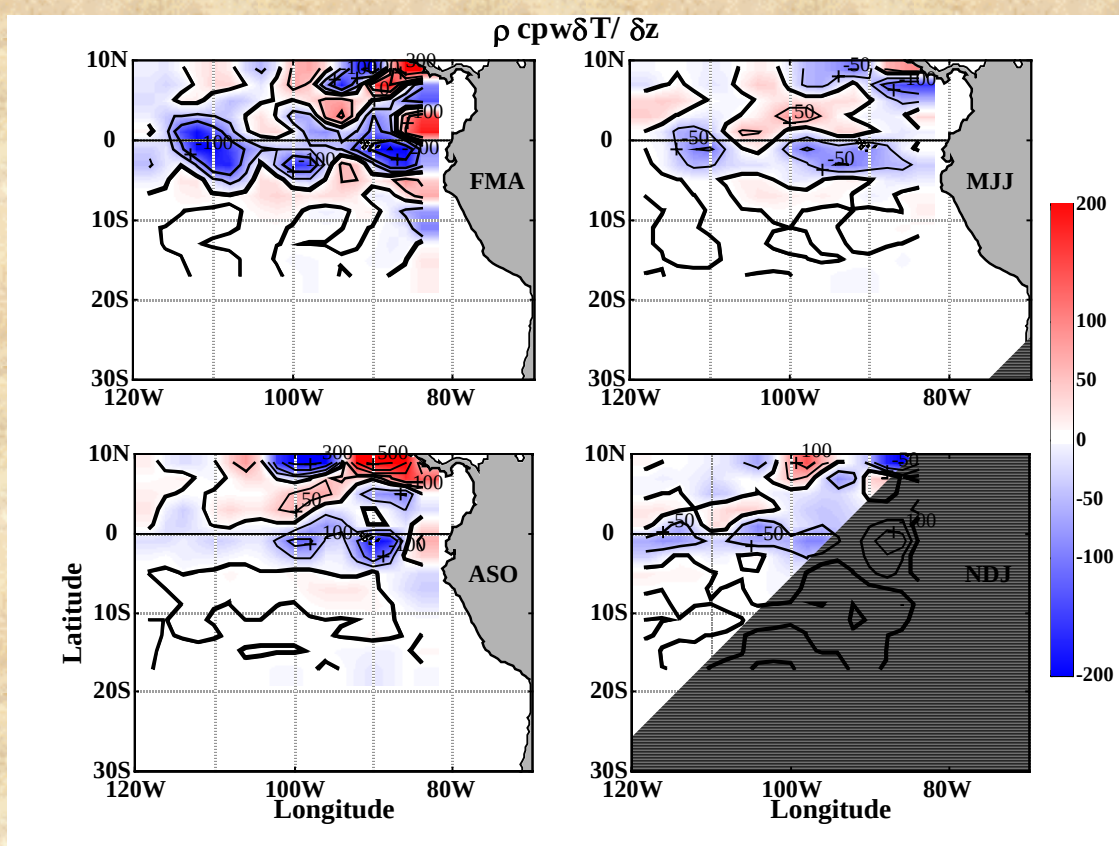


The heat balance terms:

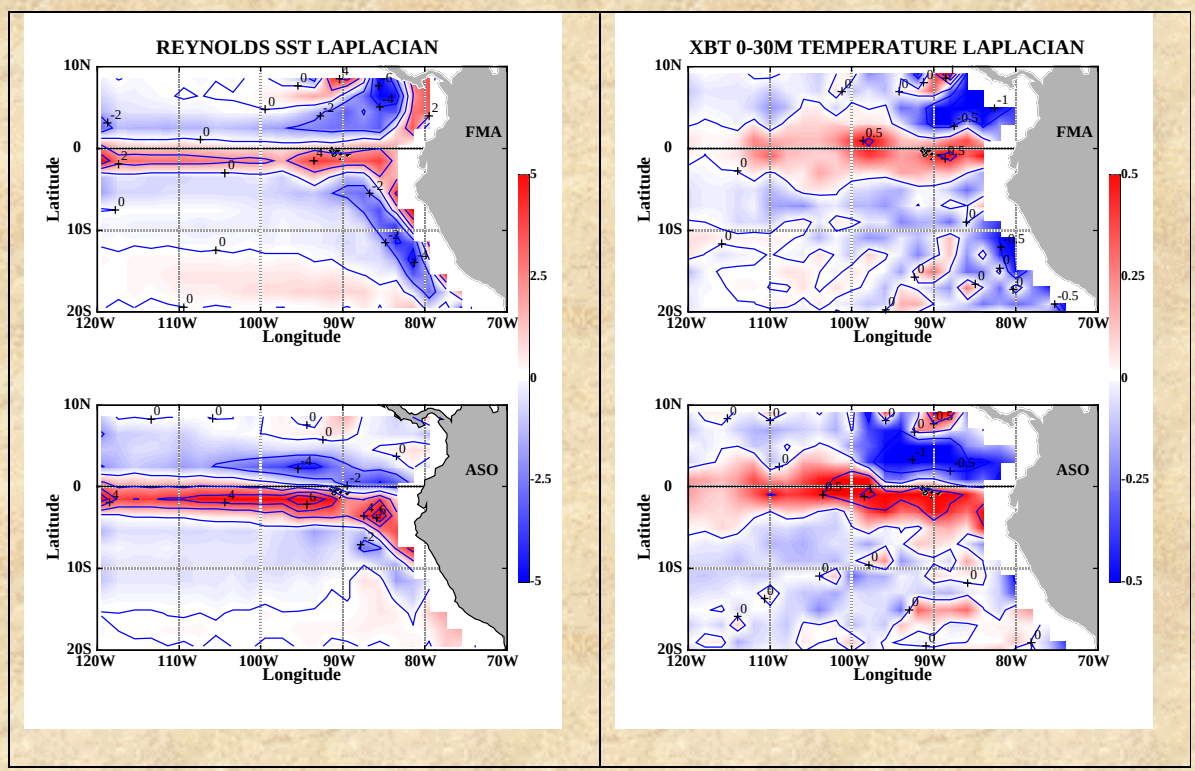
$$H\rho c_p (v_d)\frac{\partial T}{\partial y}$$



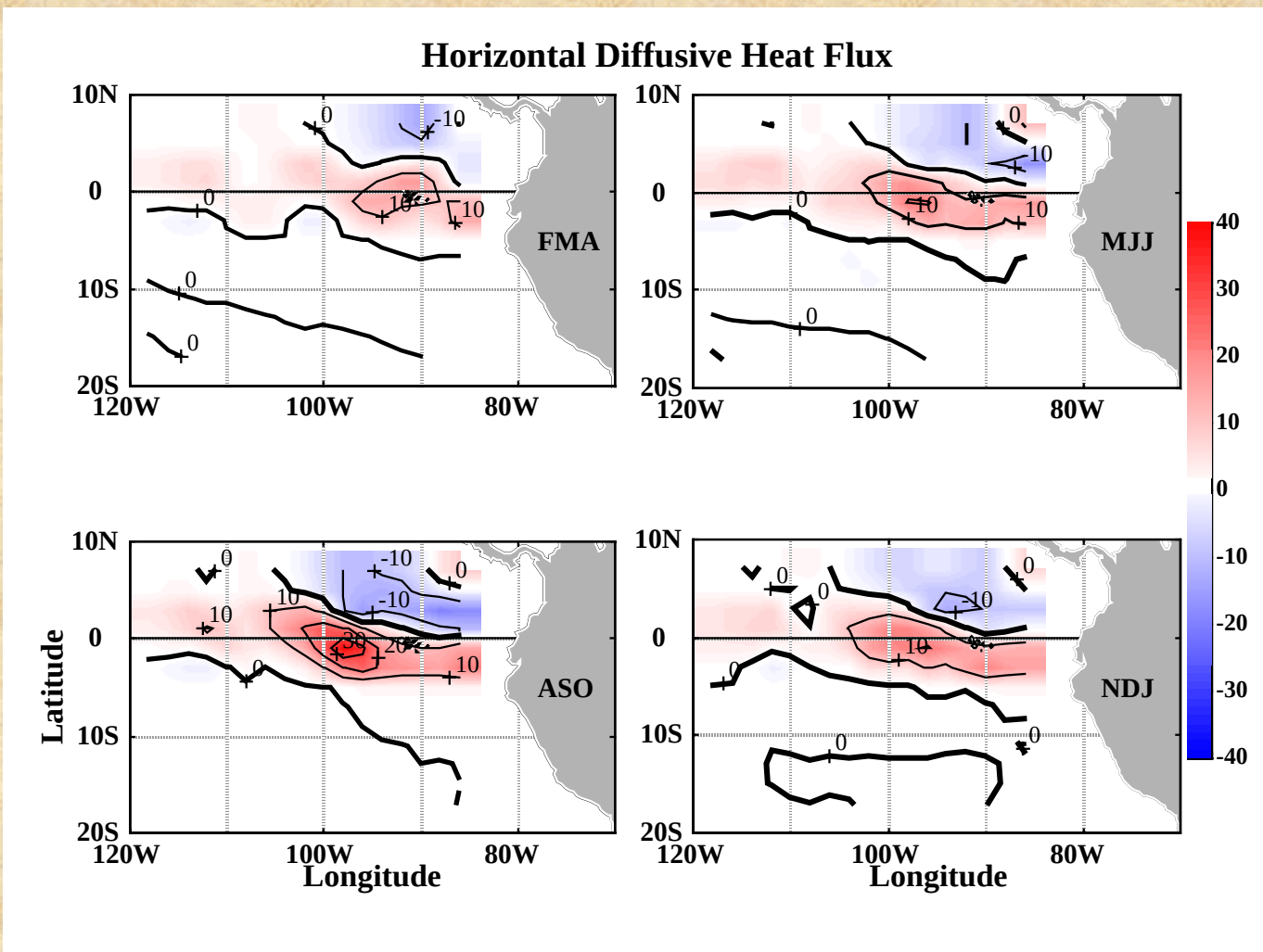
The heat balance terms: $H\rho c_p w \frac{\partial T}{\partial z}$



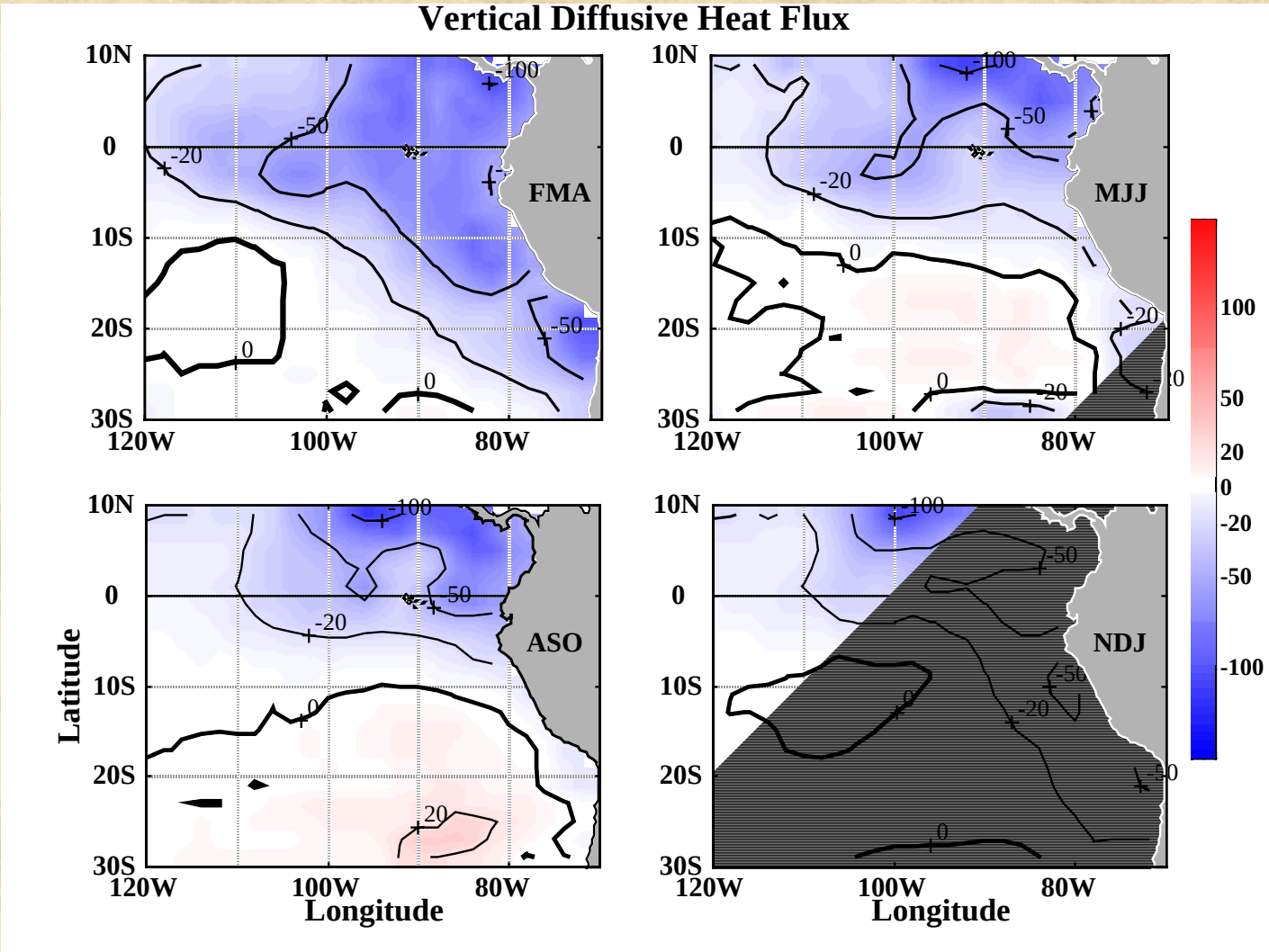
The heat balance terms: $H\rho c_p K_{xy} \nabla_H^2 T$



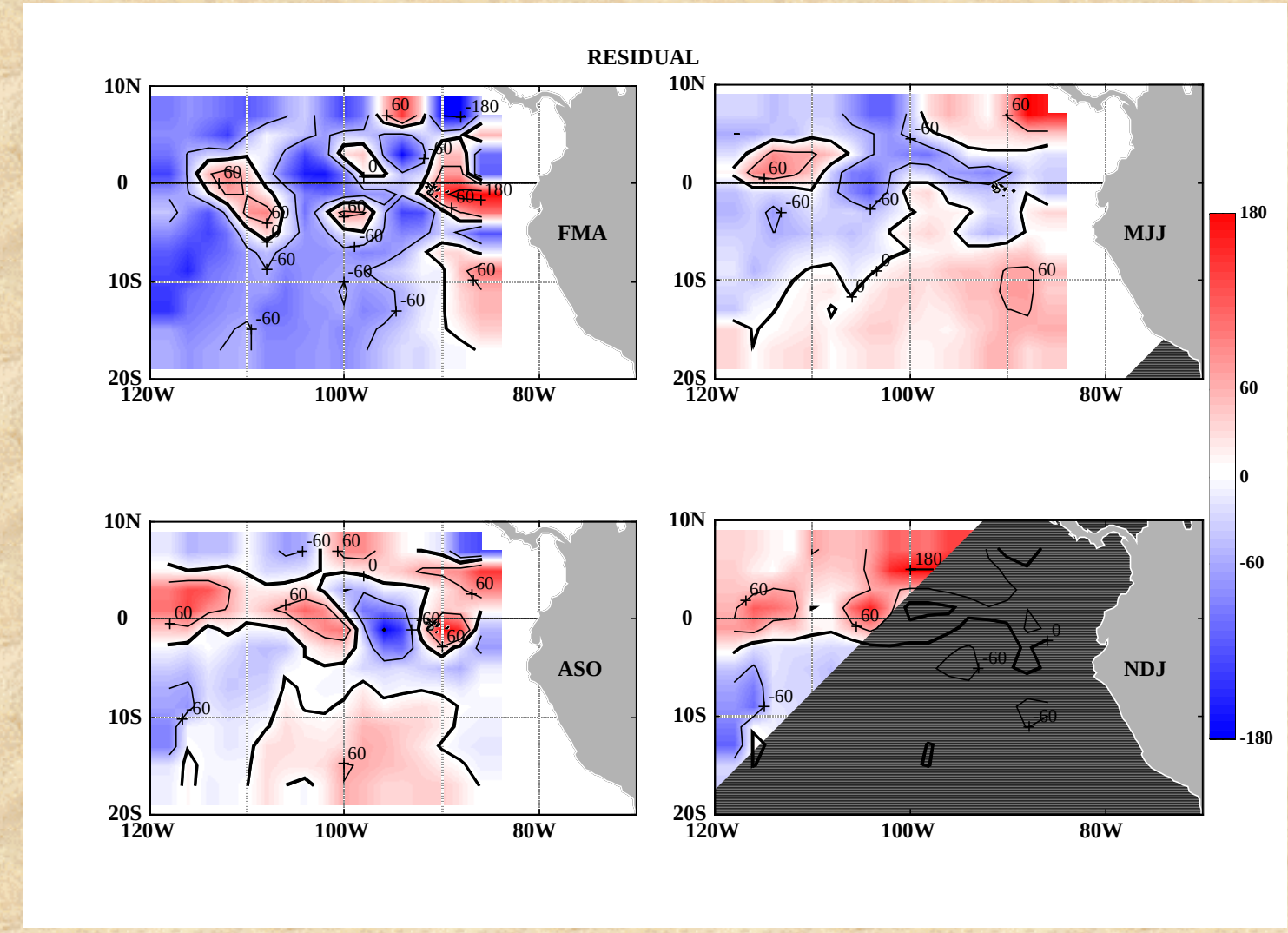
The heat balance terms: $H\rho c_p K_{xy} \nabla_H^2 T$



The heat balance terms: $H\rho c_p K_z \delta T/\delta z_{30m}$

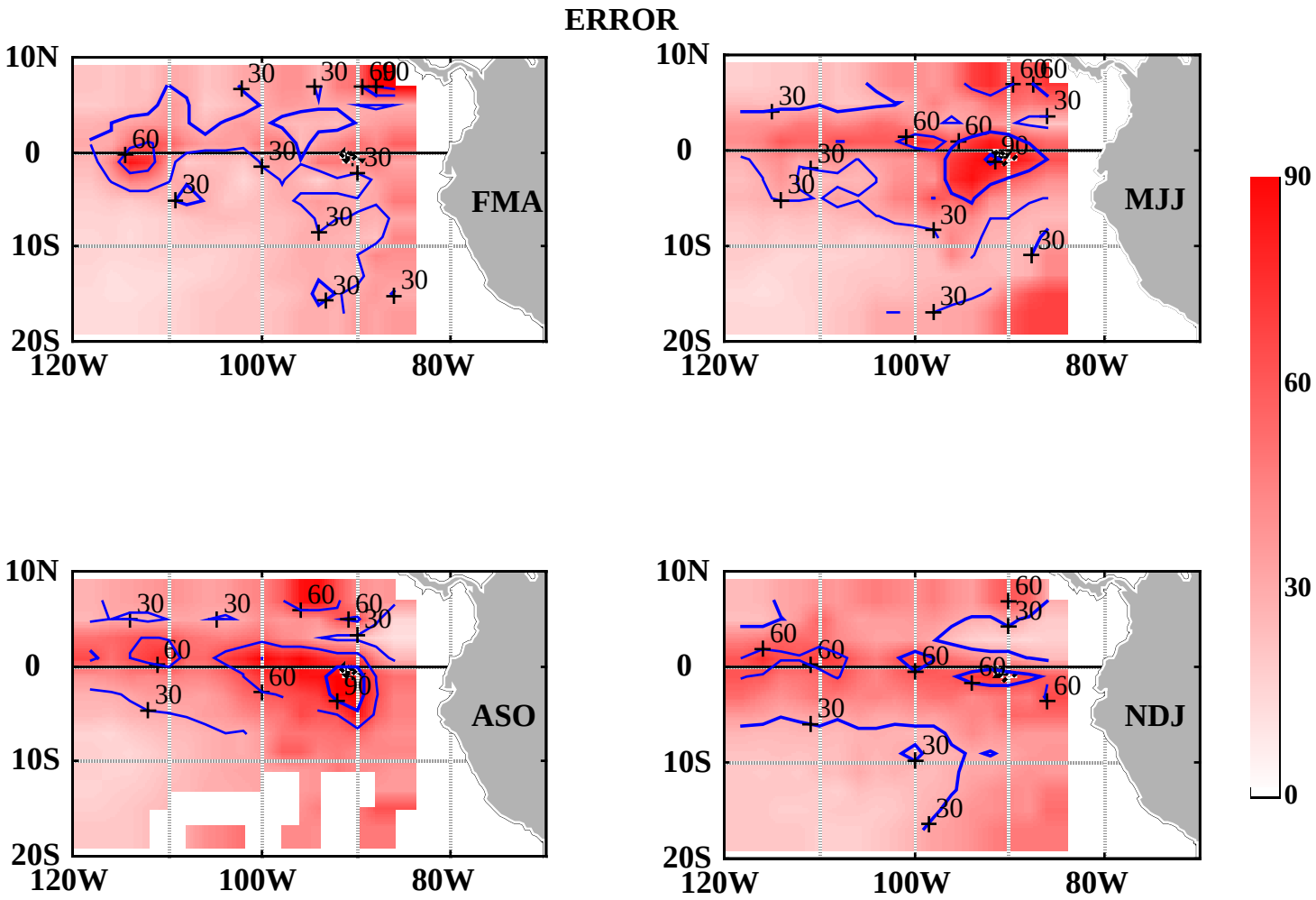


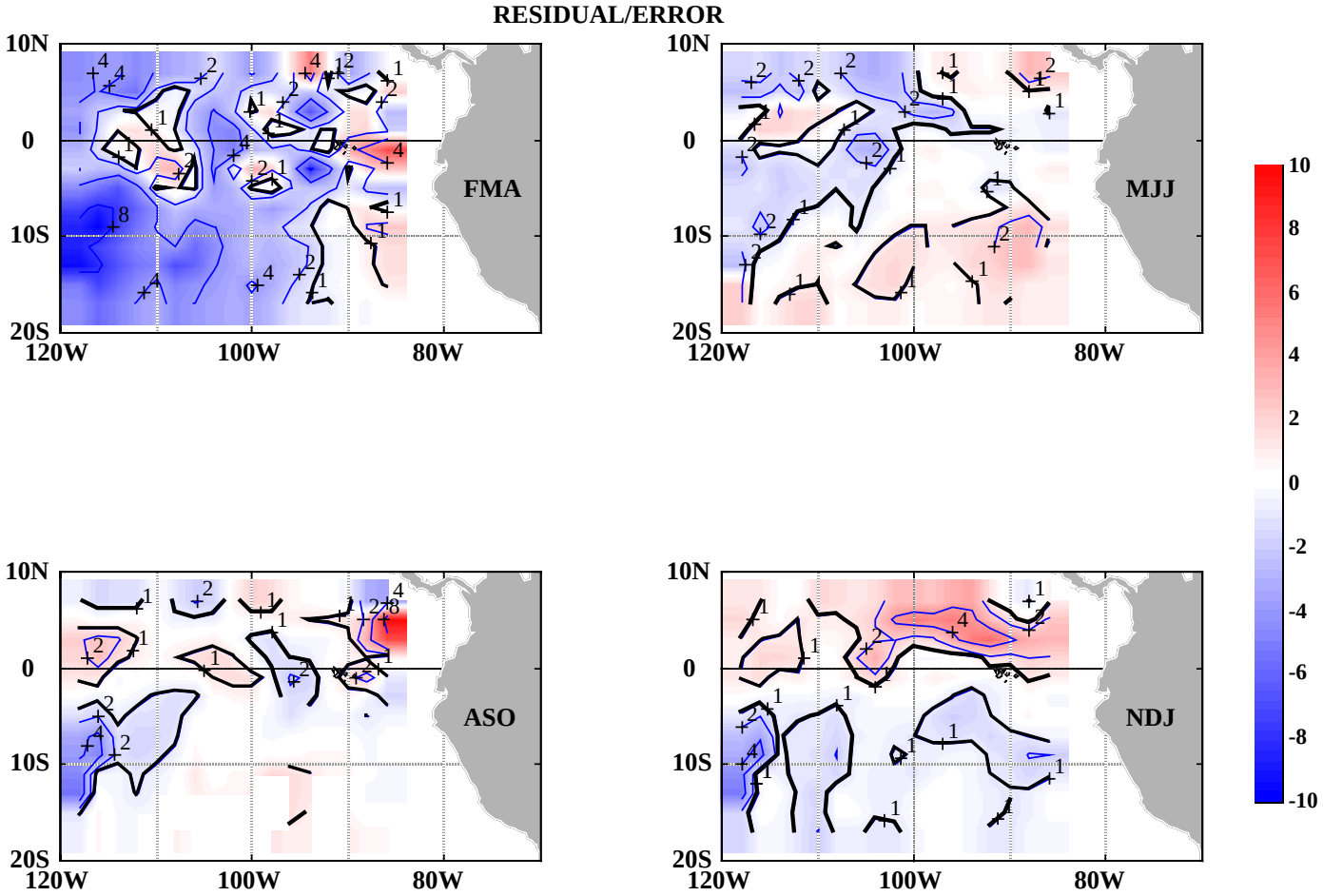
$$residual = \frac{\partial T}{\partial t} + (u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}) - \frac{1}{\rho c_p}\left[\nabla H\, k_H (\nabla T) + \frac{\partial (k_z(z)\frac{\partial T}{\partial z})}{\partial z} + Q_n\right]$$

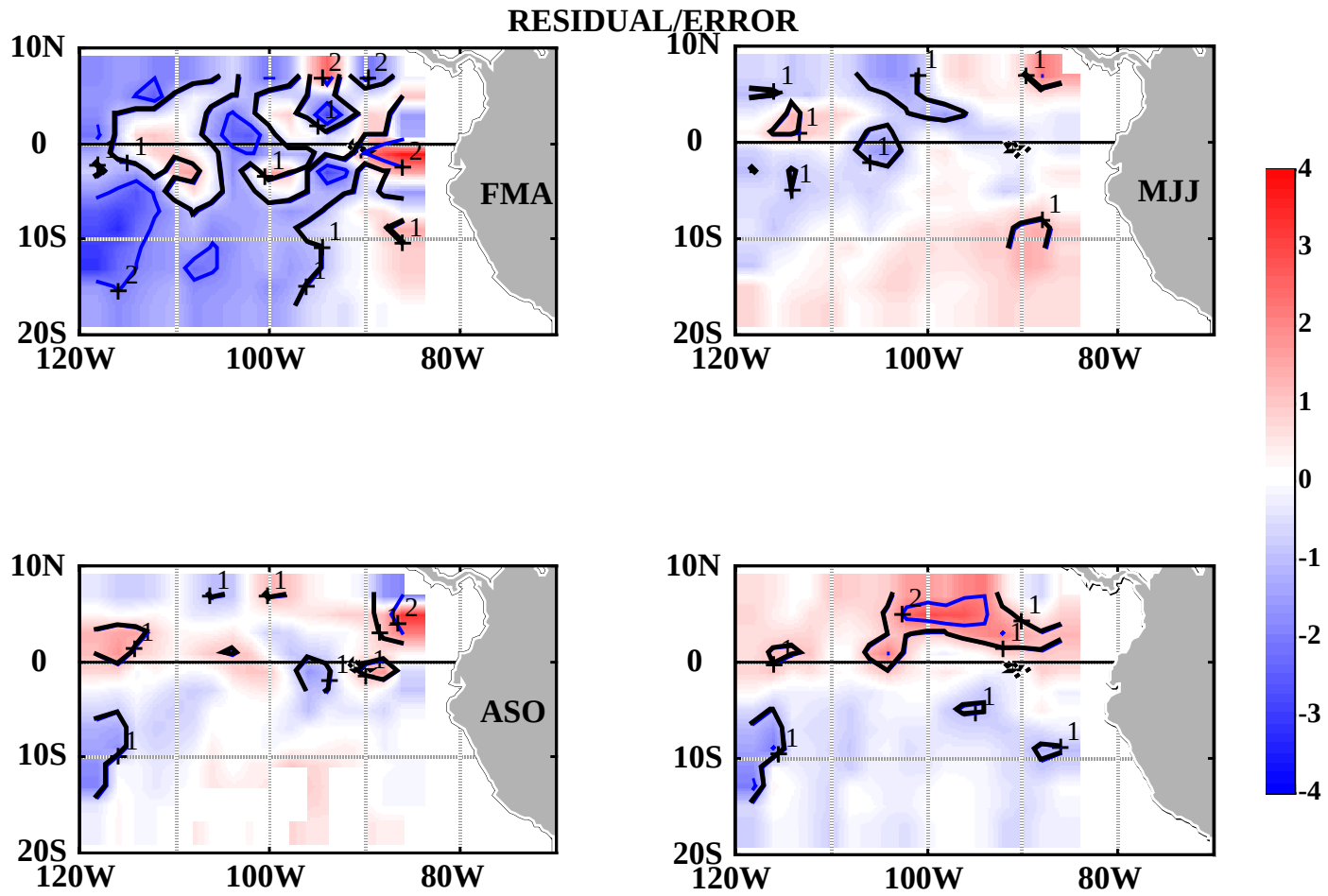


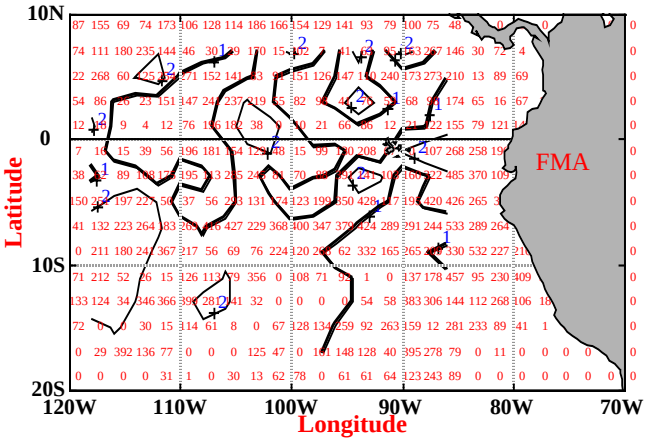
Average residual for the entire ETP domain and its SEM. A 4 x 4 decorrelation scale has been assumed. Units are Wm^{-2}.

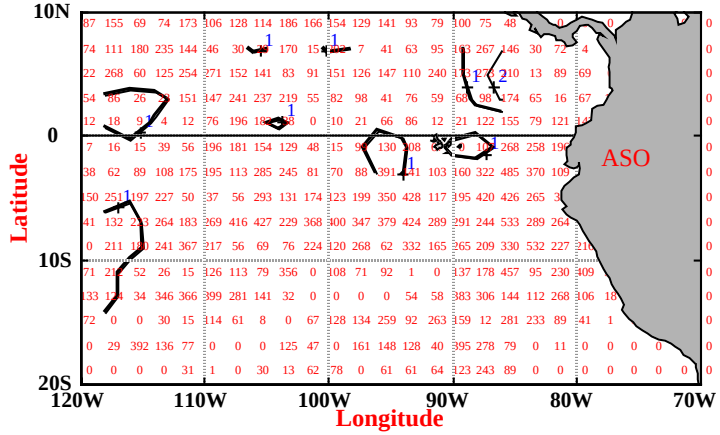
SEASON	MEAN	SEM
FMA	-28.03	19.73
MJJ	-23.46	13.80
ASO	-30.14	18.44
NDJ	-26.94	11.50
MEAN	-27.14	15.87

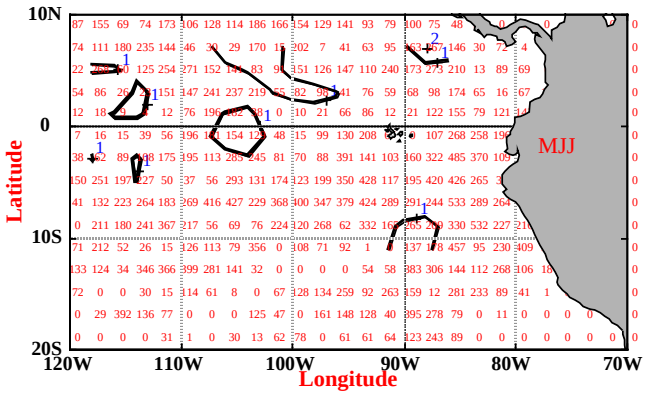

ERROR
10N
0
10S
20S
120W
100W
80W
FMA
MJJ
ASO
NDJ
90
60
30
0

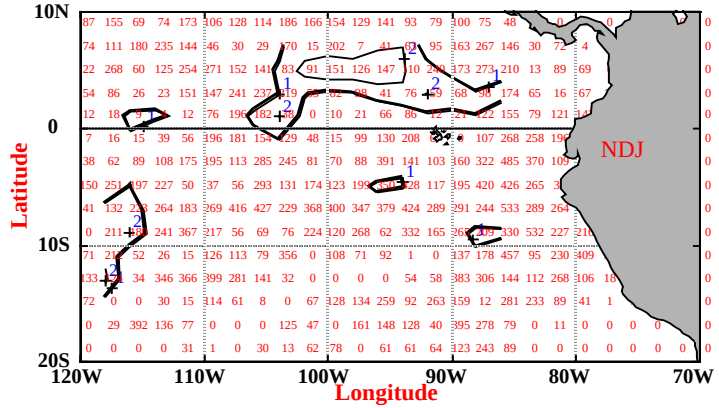

RESIDUAL/ERROR
10N
0
10S
20S
120W
100W
80W
FMA
MJJ
ASO
NDJ
10
8
6
4
2
0
-2
-4
-6
-8
-10


RESIDUAL/ERROR
10N
0
10S
20S
120W
100W
80W
FMA
MJJ
ASO
4
3
2
1
0
-1
-2
-3
-4


FMA
10N
0
10S
20S
120W
110W
100W
90W
80W
70W
Latitude
Longitude


ASO
10N
0
10S
20S
120W
110W
100W
90W
80W
70W
Latitude
Longitude

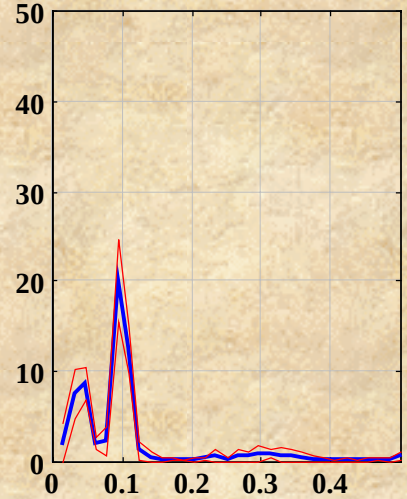

MJJ
10N
0
10S
20S
120W
110W
100W
90W
80W
70W
Latitude
Longitude


NDJ
10N
0
10S
20S
120W
110W
100W
90W
80W
70W
Latitude
Longitude

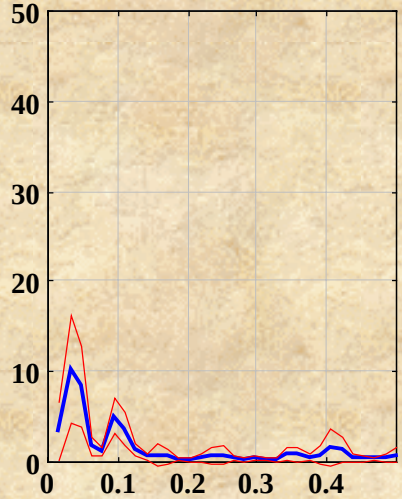
The zonal differences

SPECTRUM OF THE 0-30M AVERAGE TEMPERATURE IN THE ETP

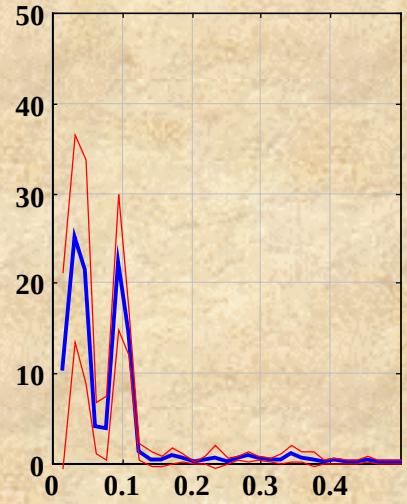
ENTIRE ETP



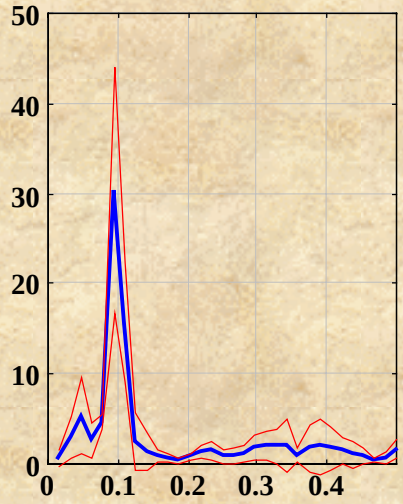
NORTHERN BOX: 4 -10 N



EQUATORIAL BOX: 2 N-4 S



SOUTHERN BOX: 10 S-20 S



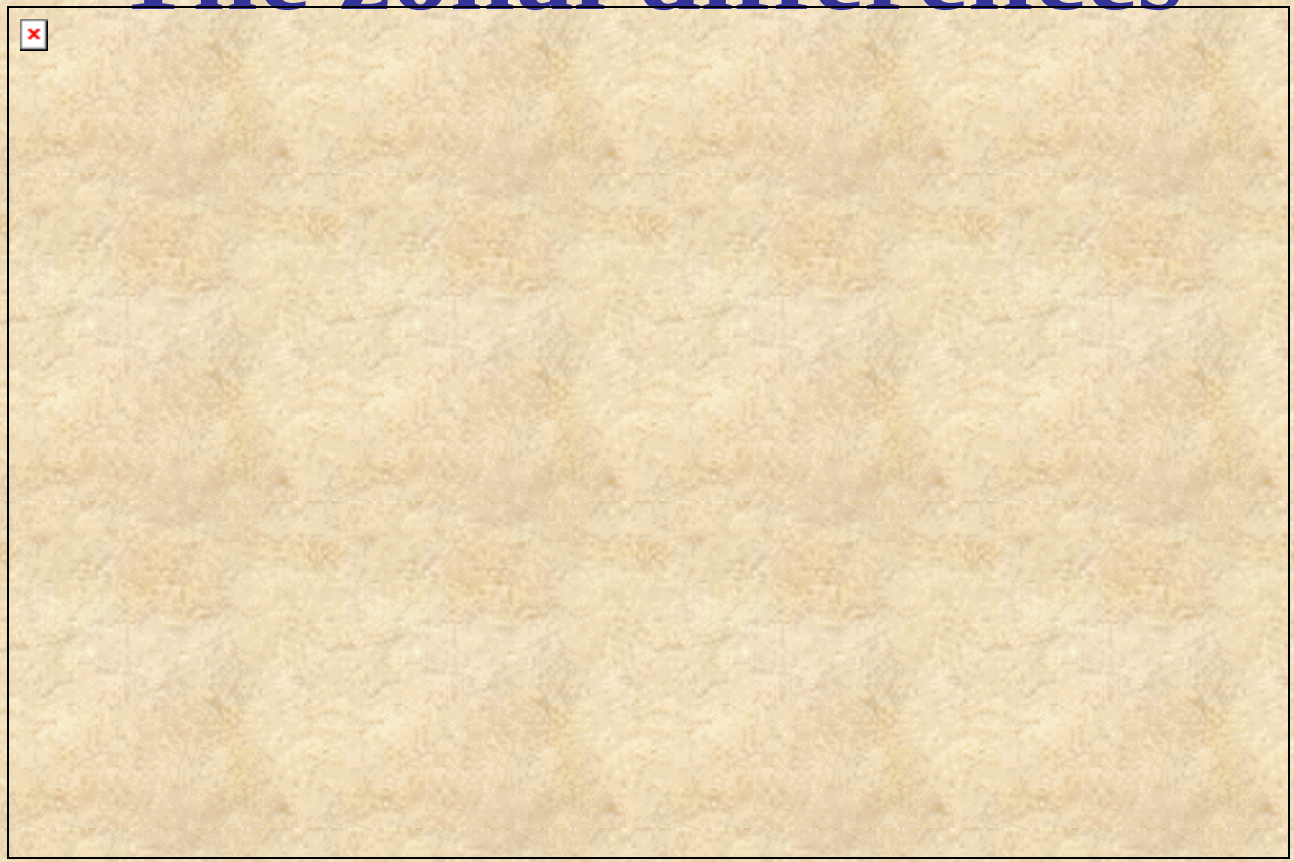
The zonal differences

	Qt		Qv		Qd		Q_{NET}		residual	error
NORTH	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**		
FMA	-14.57	2.29	-10.28	10.30	-44.54	4.70	102.13	1.82	-61.88	19.12
MJJ	-28.89	1.91	10.56	5.74	-41.44	4.80	27.75	2.64	-25.75	15.09
ASO	1.87	1.92	20.97	5.92	-40.43	5.33	19.27	2.80	2.07	15.98
NDJ	41.59	2.28	-16.95	7.07	-39.01	4.44	27.38	2.53	70.17	16.31
									-3.85	

The zonal differences

	Qt		Qv		Qd		Q_{NET}		residual	error
EQUAT.	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**		
FMA	-18.34	1.97	-91.02	14.28	-49.64	1.80	146.54	1.71	-24.22	19.76
MJJ	-32.02	1.82	-76.76	9.77	-32.71	1.66	104.03	3.72	-26.58	16.96
ASO	6.20	2.07	-97.89	14.44	-9.13	1.77	112.70	6.39	0.53	24.67
NDJ	44.15	1.95	-80.32	8.88	-15.38	1.36	120.95	5.43	18.90	17.62
									-7.84	

The zonal differences



	Qt		Qv		Qd		Q_{NET}		residual	error
SOUTH	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**		
FMA	-14.29	1.74	-4.16	0.78	-13.46	2.34	59.33	1.86	-56.00	6.73
MJJ	-28.53	1.41	-8.40	0.99	1.66	0.59	-44.81	1.88	23.02	4.87
ASO	2.36	1.39	-15.36	1.18	1.76	0.29	4.96	2.51	11.00	5.36
NDJ	40.47	1.66	-10.39	0.68	-3.50	0.82	76.53	1.70	-22.18	4.86

The zonal differences

The zonal differences

From Observations					**From models**	
This study	Wyrtki, 1981	Enfield, 1986	Swenson and Hansen, 1999	Wang and McPhaden, 1999	Kessler et al., 1998	Borovikov et al., 2001
Q*net*,Q*v*,*x* **Qv,*z*,** *Qd,z*	***Qnet,*** ***Qv,x*** ***Qv,z*** ***Qd,z***	**Q*net*,** **Q*v*,*y*,** **Q*d*,*z*,** *Qd,xy*	**Q*v*,*y*** **Q*d*,*xy***	**Q*net*,Q*v*,*x*,** **Q*v*,*y*, Q*w*,*z***	**Q*net*,** **Q*v*,*z*** Q*v*,*x*	**Q*net*, Q*v*,*z*,** **Q*d*,*z*,** Q*v*,*x*
2 N Š4 S	5 N-5 S	5 N-5 S	4 N-4 S	0 , 110 W	2 N-2 S	2 N-2 S

Summary and Discussion

For the first time, the oceanic heat balance based on observational data is examined **beyond** the equatorial band in the ETP.

This examination includes:

1. A description of the annual means and seasonal cycle of thermal field beyond 95°W: SST, upper layer temperature, mixed layer depth, and the thermocline depth (20°C and 16°C).
2. The estimation of all the terms of the heat balance equation for the ETP, including terms usually computed as residuals, such as the vertical diffusivity.

Summary and Discussion

- Three different regimes have been identified:
  - the NECC-ITCZ regime (4°-10°N, or NB),
    - Qnet and Qd (-30 -45Wm-2)
  - the cold tongue-SEC one (2°N-4°S, or EB),
    - Qnet, Qv(72%), Qd (22%)
  - and the slow westward drift (10°-20°S, or SB).
    - Qnet and Qt

Summary and Discussion

- overall analysis of the residuals shows that they can be attributed to various problems
  - errors in the surface flux,
  - errors in estimation of the storage rate (T(z) data base),
  - and errors in the data used to derive ocean flux divergence terms, including inadequate data coverage.
- annual average of the residuals in the heat balance equation is negative, between –5 and –10Wm^{-2} for the ETP.
- residuals imply much larger errors between seasons (-28 Wm^{-2}) than in the annual mean (-10Wm^{-2}) .

Future Research

- The analysis presented could be improved using new data sets, such as
  - 10 years of SSM/I wind
  - New surface fluxes climatology, SOC
  - New thermal analysis with minimum subjective intervention (BMRC)
  - New assimilation schemes that provide surface circulation
- This data would allow:
  - To use the mixed layer depth and to compare this results with the fixed slab used here
  - To include the upwelling area off Peru
  - To improve error calculation

Research needed

- Experiments to measure the spatial variability of the vertical diffusivity coefficients in the equatorial and northern box areas, and probably for the upwelling area off Peru not resolved by the present study data.
- direct wind observations over the upwelling area off Peru for validation of satellite wind products
- Process study within the VOCAL program, for the next call 2007-2008
- Long term observations east of 95°W