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NOAA Data Report ERL AOML-29

QUALITY CONTROL OF XBT DATA COLLECTED IN THE ATLANTIC OCEAN: 1990 AND 1991

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I. ABSTRACT

Delayed Mode and real-time XBT data collected in the Atlantic Ocean during 1990 and 1991 were scientifically quality controlled at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) and the results of the quality control are presented in detail as tables and figures.

II. INTRODUCTION

Temperature profiles obtained by Expendable Bathythermographs (XBT's) are collected globally by both research vessels and voluntary observing ships to satisfy requirements of operational agencies as well as research groups. For example, the data are used to initialize experimental climate forecast models. In addition, international research programs such as the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmosphere (TOGA) effort use XBT data to increase understanding of climatically important ocean processes, to validate models, and to monitor the ocean.

The Global Temperature-Salinity Pilot Project (GTSPP) was initiated to develop a protocol for providing the highest quality temperature data to forecasters and researchers. Three Data Assembly Centers (DAC's) were created to quality control (QC) temperature profiles from the global XBT network. AOML focused on the Atlantic Ocean; the Scripps Institution of Oceanography (SIO), on the Pacific Ocean; and CSIRO, Hobart, Australia, on the Indian Ocean. Initially, the DAC's performed QC on both real-time (i.e. data transmitted from ship-to-shore via satellite) and delayed mode (i.e. data provided by hard copy after completion of a cruise) data. However, the QC of the real-time data gradually was taken over by MEDS, Canada and the DAC's now concentrate on the delayed mode data.

Herein, we describe AOML's QC of XBT data collected in the Atlantic Ocean during 1990 and 1991. For various reasons both real-time and delayed mode data are reviewed, in particular, to provide the largest possible data base to future users. The QC procedures are given in Daneshzadeh et al (1994). These procedures were developed through the GTSPP and represent input from the three DAC's. The CSIRO procedures are given in Bailey et al (1994) where additional details on the various QC flags are discussed.

We begin with a description of the available 1990 and 1991 data. This is followed by the results of the QC. Finally, a measure of the representativeness of 1990 and 1991 in terms of a long-term climatology is offered.

III. AVAILABLE DATA

Plots of 1990 and 1991 data distribution are given in Figure 1 and Figure 2. Both real-time and delayed mode data are shown. Data distribution by month is given in Figure 3 for 1990 and Figure 4 for 1991. Ideally, all real-time data, and its low-resolution of the temperature profile, would be replaced by delayed mode data and its higher resolution of the identical profile. However, only a portion of the total replacement occurs. Table 1 lists the relative proportions of delayed mode and real-time data available for 1990 (i.e. the real-time data yet to be replaced by delayed mode data). Table 2 lists the same information for 1991. A concentrated effort is underway by GTSPP to increase the amount of delayed mode data submitted in a timely fashion. Table 3 provides a partial list of participating ships and the number of XBT's deployed by each.

IV. QUALITY CONTROL RESULTS

Table 4 lists the flags applied to the XBT data and their meanings. Flags are applied at each temperature-depth (T-D) pair, thus profiles can include valid as well as bad data. As used at AOML, pairs with flag values of 1 or 2 are considered good and used in analysis, those with values of 3 or 4 are not. In additions to these flags, qualifiers giving the reason for a 3 or 4 flag are listed for each T-D pair. The meaning of these qualifiers are given in Table 5; more details are provided in Daneshzadeh et al (1994) and Bailey et al (1994).

A summary of 1990 flags is given in Table 6 and flag reasons in Table 7. Similar information for 1991 is given in Tables 8 and 9. In general, about 7% of the 1990 profiles and 11% of the 1991 profiles have data that are considered unusable. The most numerous reason for a 3 or 4 flag is wire stretch which usually occurs at the lower end of the profile, providing some useable data in the upper portion of the cast.

V. HORIZONTAL TEMPERATURE DISTRIBUTIONS AND ANOMALIES

A major issue facing researchers in the World Ocean Circulation Experiment (WOCE) is the representativeness of the WOCE observational years in terms of climatological mean conditions. XBT data provide a means of determining the representativeness of the temperature structure of the upper layers of the global ocean. As a first-step in evaluating the "normalcy"

of 1990 and 1991, temperature data collected during these years are compared to a climatology developed from the XBT data.

A monthly mean climatology was generated from all available XBT data collected in the Atlantic Ocean between 1966 and 1991. The climatology was constructed from quality controlled data on a 2 degree of latitude by 2 degree of longitude grid. As data are not available at every grid point and some smoothing of the raw data fields is desirable, an interpolation package was used to construct filled fields of temperature at 150 m, 400 m, and 600 m. In addition, monthly standard deviation fields were also constructed.

Temperature anomalies relative to the appropriate long-term monthly mean value were determined at each XBT location through interpolation of surrounding average values. Those anomalies more than or less than two standard deviations from the mean are noted on Appendix 1. The long-term monthly mean temperature distributions are also shown to provide a context for reviewing the anomalies. Related discussion of the anomaly patterns will appear in later reports and publications. The monthly standard deviation fields and quadrangles with data, used in generating the climatology, are given in Appendix 2.

VI. ACKNOWLEDGMENT

This work was supported in part by a grant from NOAA's Office of Global Program's Long Term Ocean Observing Program.

VII. REFERENCES

Bailey, R., A. Gronell, H. Phillips, G. Meyers, and E. Tanner, 1994: CSIRO Cookbook for quality control of expendable bathythermograph (XBT) data. Rep. no. 220, CSIRO Marine Laboratories, Hobart, Australia, 75pp.

Daneshzadeh, Y-H. C., J.F. Festa, and S.M. Minton, 1994: Procedures used at NOAA-AOML to quality control real time XBT data collected in the Atlantic Ocean. NOAA Tech. Memo. ERL AOML-78, NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, Fl. 44pp.

Table 1: Number of profiles, broken down by month, that are either real-time (RT), delayed mode (DM) or duplicates (Dups) for 1990 data. There are 13135 real-time profiles and 5893 delayed mode profiles for 1990. After removing the duplicates from the combined RT and DM datasets the total number of profiles is 16866. There are 2162 profiles from the DM data that are higher resolution duplicates of the RT data. The remaining 3731 are actually "new" profiles, i.e. ones that were not received in real-time mode. There are still 11071 RT profiles that need to be updated, and there probably are a number of profiles that were not submitted as either RT or DM.

Month	Received RT	Received DM	Received Total	Dups	Unique RT	Unique DM	Unique Total
Jan	593	220	813	61	535	217	752
Feb	1005	391	1396	112	896	388	1284
Mar	1181	231	1412	84	1097	231	1328
Apr	1147	402	1549	183	987	379	1366
May	1174	442	1616	182	996	438	1434
Jun	972	760	1732	239	742	751	1493
Jul	1307	609	1916	282	1031	603	1634
Aug	1221	766	1987	213	1016	758	1774
Sep	1208	694	1902	324	902	676	1578
Oct	1220	583	1803	274	963	566	1529
Nov	1121	376	1497	109	1016	372	1388
Dec	986	419	1405	99	890	416	1306
	13135	5893	19028	2162	11071	5795	16866

Table 2: Number of profiles, broken down by month, that are either real-time (RT), delayed mode (DM) or duplicates (Dups) for 1991 data. There are 9951 real-time profiles and 5940 delayed mode profiles for 1991. After removing the duplicates from the combined RT and DM datasets the total number of profiles is 13056. There are 2835 profiles from the DM data that are higher resolution duplicates of the RT data. The remaining 3105 are actually "new" profiles, i.e. ones that were not received in real-time mode. There are still 7116 RT profiles that need to be updated, and there probably are a number of profiles that were not submitted as either RT or DM.

Month	Received RT	Received DM	Received Total	Dups	Unique RT	Unique DM	Unique Total
Jan	989	570	1559	231	758	570	1328
Feb	1124	571	1695	281	843	571	1414
Mar	1071	605	1676	398	673	605	1278
Apr	757	373	1130	205	552	373	925
May	846	349	1195	203	643	349	992
Jun	812	563	1375	257	555	563	1118
Jul	946	625	1571	198	748	625	1373
Aug	723	494	1217	227	496	494	990
Sep	794	446	1240	244	550	446	996
Oct	565	483	1048	180	385	483	868
Nov	690	412	1102	162	528	412	940
Dec	634	449	1083	249	385	449	834
	9951	5940	15891	2835	7116	5940	13056

Table 3: A cruise report is generated to identify problems and notify ships so that problem can be corrected as soon as possible. A list of ships that deployed more than 100 profiles is given as well as the number of real-time and delayed mode data.

Ship_name	Call_sign	Year	# of XBT's		# Flagged	
			RT	DM	RT	DM
Delaware II	316G	1990	0	126	0	16
Oregon II	316O	1990	0	224	0	15
Vreeland (FF-68)	3174	1990	0	128	0	3
Malcolm Baldrige	3175	1990	0	118	0	8
Semmes (DDG-18)	31EM	1990	0	124	0	1
Peterson (DD-969)	31TV	1990	0	159	0	7
Richmond K. Turner (CG-20)	31Z8	1990	0	180	0	1
Sea-Land Achiever	323Q	1990	0	159	0	40
Thomas S. Gates (CG-51)	3271	1990	0	192	0	1
DeYo (DD-989)	32IZ	1990	0	129	0	3
Polar Sea	32L9	1990	0	354	0	56
Oleander	32OD	1990	0	488	0	37
Chapman	32YN	1990	0	202	0	27
Renoir	35A1	1990	0	193	0	3
Csav Rapel	35BW	1990	0	158	0	1
Brisbane Star	35BY	1990	0	257	0	3
CGM Ronsard	35CV	1990	0	157	0	2
Delmas Surcouf	35LW	1990	0	319	0	3
A. Nizery	35NI	1990	0	168	0	11
Suzanne Delmas	35VM	1990	0	143	0	2
Columbus Ohio	54CA	1990	0	177	0	20
Ocean Weather Station Lima	C7L	1990	101	0	7	0
Alfred Needler	CG2683	1990	114	0	5	0
Wilfred Templeman	CGDV	1990	446	0	3	0
Platform Nordsee	DA9100	1990	317	0	1	0
Koln Express	DAKE	1990	586	0	67	0
Polar stern	DBLK	1990	171	0	10	0
Monte Rosa	DGLM	1990	159	0	14	0
Puritan	DHOU	1990	122	0	9	0
Lappland	DLEZ	1990	113	0	11	0
Pacprince	ELED7	1990	111	0	39	0
Pacprincess	ELED8	1990	110	0	15	0

Columbus Ohio	ELHL6	1990	113	0	11	0
Musson	EREA	1990	387	0	8	0
Viktor Bugayev	ERES	1990	250	0	10	0
Georgiy Ushakov	ERET	1990	242	0	4	0
Ernst Krenkel	EREU	1990	172	0	6	0
Persey III	ESGU	1990	238	0	3	0
Nour	FNBA	1990	111	0	2	0
Delmas Surcouf	FNCZ	1990	133	0	9	0
Lafayette	FNGS	1990	139	0	2	0
CGM Renoir	FNOM	1990	104	0	5	0
Cumulus	GACA	1990	264	0	16	0
Delaware II	KNBD	1990	170	0	13	0
Unknown	LAT2	1990	190	0	0	0
Unknown	LAT3	1990	120	0	0	0
Unknown	LAT4	1990	273	0	0	0
Seas Eiffel	PASF	1990	0	122	0	0
Sin Tong	PGDG	1990	159	0	13	0
Oleander	PJYG	1990	139	0	31	0
Unknown	SHIP	1990	195	0	3	0
Vladimir Parshin	UINF	1990	169	0	2	0
Professor Multanovskiy	UJFO	1990	148	0	1	0
Professor Zubov	UMFW	1990	164	0	10	0
Professor Vize	UPUI	1990	134	0	2	0
Passat	UZGH	1990	184	0	1	0
Gadus Atlantica	VC9450	1990	180	0	1	0
Aircraft	VXN8	1990	293	0	33	0
Galveston Bay	WPKD	1990	146	0	44	0
Oregon II	WTDO	1990	165	0	11	0

Ship name	Call_sign	Year	# of XBT's		# Flagged	
			RT	DM	RT	DM
		1991	0	315	0	50
Csav Rapel	3EET4	1991	30	115	5	0
Vina del Mar	CBVM	1991	56	75	8	7
Alfred Needler	CG2683	1991	189	0	2	0

Wilfred Templeman	CGDV	1991	549	0	2	0
Platform Nordsee	DA9100	1991	659	0	3	0
Koln Express	DAKE	1991	485	0	50	0
Polar Stern	DBLK	1991	181	0	6	0
Monte Rosa	DGLM	1991	162	0	36	0
Puritan	DHOU	1991	107	0	11	0
Ariana	DIDA	1991	22	128	2	3
Pacprince	ELED7	1991	11	345	2	97
Pacprincess	ELED8	1991	84	42	4	2
Columbus Ohio	ELHL6	1991	66	68	4	11
Musson	EREA	1991	275	0	5	0
Viktor Bugayev	ERES	1991	152	0	3	0
Nour	ERET	1991	299	0	9	0
Delmas Surcouf	FNBA	1991	105	0	0	0
CGM Utrillo	FNCZ	1991	15	213	3	4
Lafayette	FNGS	1991	44	179	4	7
CGM Renoir	FNOM	1991	45	111	7	2
Cumulus	GACA	1991	336	0	158	0
Tilly	H8CB	1991	0	156	0	4
Rowan Bank	J8FN	1991	1	386	0	48
Algoa Bay	J8FO	1991	99	409	11	60
Delaware II	KNBD	1991	51	54	1	5
Sea Wolf	KNFG	1991	15	256	5	71
Bain Bridge	NJUL	1991	0	133	0	1
Hamilton	NMAC	1991	0	150	0	2
Virginia (CGM-38)	NVYA	1991	0	124	0	2
Oleander	PJJU	1991	151	0	58	0
Unknown	SHIP	1991	1273	0	41	0
Unknown	TUNI	1991	208	0	0	0
Vladimir Parshin	UINF	1991	121	0	0	0
Passat	UZGH	1991	164	0	2	0
West Moor	V2PM	1991	278	0	36	0
Gadus Atlantica	VC9450	1991	508	0	10	0
Lady Hammond	VC9616	1991	178	0	1	0
Galveston Bay	WPKD	1991	70	516	38	222
Malcolm Baldrige	WTER	1991	75	175	2	9
West Moor	ZCAQ9	1991	0	182	0	21

Table 4: Scientific Quality Control (QC) procedures were developed to set flags on the temperature-depth profiles without changing or deleting data values from any profile. Every profile is examined and each data point is assigned one of the following 5 flag values. One of 11 reasons (Table 5) is given for each flag value of 3 or 4.

Flag	Quality	Description
0	none	These data have not yet been quality controlled.
1	good	These data are of good quality, no errors have been identified.
2	"probably" good	These data are of probably good quality, some unusual features are present but these can not be identified as erroneous features.
3	"probably" bad	These data are of suspect quality, some unusual, and probably erroneous features are observed.
4	bad	These data are of bad quality, obviously erroneous values are observed.
5	data changed	These data have been changed.

Table 5: Reasons for flags 3 or 4, see Daneshzadeh et al (1994) and Bailey et al (1994) for additional detail.

Code	Description
CT	Constant temperature, Hit bottom error
FS	Fine structure error: Leakage, PET fault, Cusping, Sticking bit
ML	Mixed layer error: Bowing
NG	No good profile
PE	Position error
SF	Surface Feature error: surface anomaly, chopped surface
TE	Time error
TI	Temperature inversion error: wire stretch
TG	Temperature gradient error: insulation penetration, spikes, high frequency
TO	Temperature offset error
UR	Under resolved

Table 6: The total number of profiles, duplicates, good profiles (flag value assigned 1 or 2), bad profiles (flag value assigned 3 or 4), and the number of flags are shown broken down by month for 1990 data.

Mon	Total Profiles	Dups	RT	DM	Good Profiles	Bad Profiles	flag 1	flag 2	flag 3	flag 4
Jan	813	61	535	217	720	32	711	9	24	8
Feb	1396	112	896	388	1191	93	1171	20	83	10
Mar	1412	84	1097	231	1291	37	1226	65	32	5
Apr	1549	183	987	379	1310	56	1270	40	44	12
May	1616	182	996	438	1375	59	1337	38	38	21
Jun	1732	239	742	751	1394	99	1375	19	76	23
Jul	1916	282	1031	603	1534	100	1495	39	84	16
Aug	1987	213	1016	758	1642	132	1613	29	109	23
Sep	1902	324	902	676	1460	118	1426	34	84	34
Oct	1803	274	963	566	1321	208	1304	17	132	76
Nov	1497	109	1016	372	1281	107	1262	19	68	39
Dec	1405	99	890	416	1213	93	1195	18	55	38
	19028	2162	11071	5795	15732	1134	15385	347	829	305

Table 7: The total number of reasons given to 1990 data for each profile with a flag value of 3 or 4. A profile may contain more than one reason (i.e. bad surface feature in upper 3.7 m and hit bottom feature).

Month	FS	ML	CT	TG	NG	TI	SF	PE	TE	UR	TO
Jan	0	0	3	5	8	14	0	0	0	0	2
Feb	0	0	7	31	9	32	0	0	0	0	14
Mar	2	0	2	8	0	5	0	0	0	0	20
Apr	4	0	7	13	6	7	0	0	0	0	19
May	6	0	3	14	8	7	0	0	0	0	21
Jun	6	0	6	30	8	22	0	0	0	0	27
Jul	10	0	10	37	7	11	0	0	0	0	25
Aug	0	2	8	78	5	17	0	0	0	0	22
Sep	6	0	11	50	3	13	0	0	0	0	37
Oct	3	0	18	101	7	38	0	0	0	0	41
Nov	1	0	9	39	3	25	0	0	0	0	31
Dec	2	1	14	24	5	23	0	0	0	0	25
	40	3	98	430	69	214	0	0	0	0	284

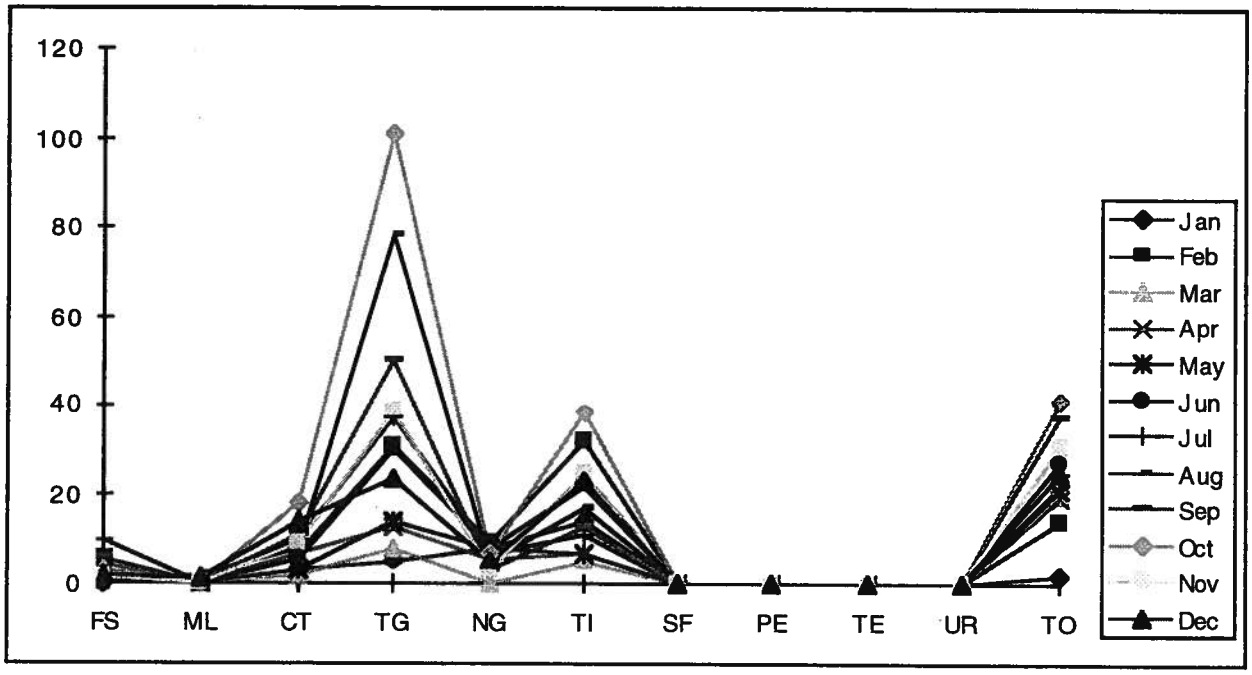
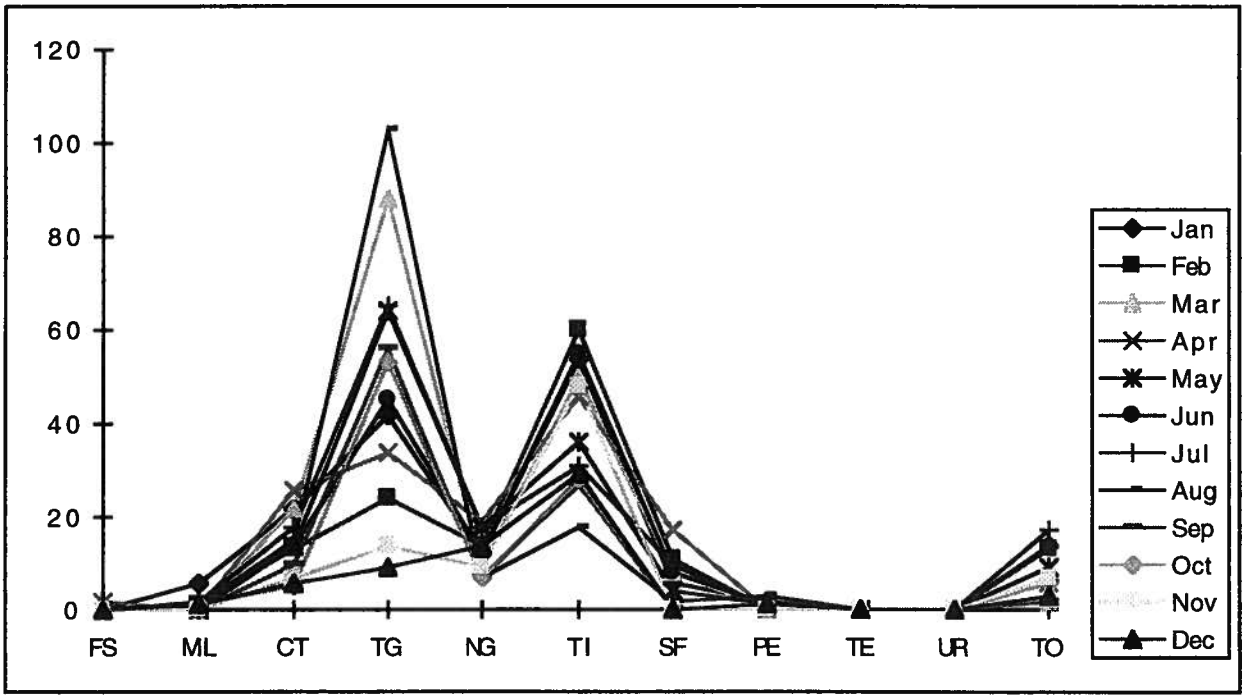


Table 8: The total number of profiles, duplicates, good profiles (flag value assigned 1 or 2), profiles (flag value assigned 3 or 4), and the number of flags are shown broken down by month for 1991 data.

Mon	Total Profiles	Dups	RT	DM	Good Profiles	Bad Profiles	flag 1	flag 2	of 3	4
Jan	1559	231	758	570	1176	152	1164	12	117	35
Feb	1695	281	843	571	1288	126	1275	13	94	32
Mar	1676	398	673	605	1129	149	1121	8	90	59
Apr	1130	205	552	373	786	139	776	10	77	62
May	1195	203	643	349	850	142	844	6	115	27
Jun	1375	257	555	563	983	135	975	8	84	51
Jul	1571	198	748	625	1219	154	1217	2	99	55
Aug	1217	227	496	494	837	153	821	16	119	34
Sep	1240	244	550	446	898	98	874	24	57	41
Oct	1048	180	385	483	770	98	757	13	88	10
Nov	1102	162	528	412	855	85	826	29	77	8
Dec	1083	249	385	449	773	61	759	14	45	16
	15891	2835	7116	5940	11564	1492	11409	155	1062	430

Table 9: The total number of reaons given to 1991 data for each profile with a flag value of 3 or 4. A profile may contain more than one reason (i.e. bad surface feature in upper 3.7 m and hit bottom feature).

Month	FS	ML	CT	TG	NG	TI	SF	PE	TE	UR	TO
Jan	0	6	22	42	12	54	6	2	0	0	14
Feb	0	1	13	24	14	60	11	0	0	0	13
Mar	0	0	22	88	9	50	8	0	0	0	2
Apr	2	0	26	34	19	46	17	0	0	0	6
May	0	0	14	64	18	36	4	1	0	0	9
Jun	0	0	14	45	12	55	8	1	0	0	6
Jul	0	2	18	65	18	31	10	0	0	0	17
Aug	0	1	15	103	7	18	2	3	0	0	6
Sep	0	0	10	56	7	27	0	0	0	0	2
Oct	0	1	5	53	7	28	0	0	0	0	6
Nov	0	0	7	14	9	48	0	0	0	0	7
Dec	0	1	6	9	14	29	0	1	0	0	3
	2	12	172	597	146	482	66	8	0	0	91



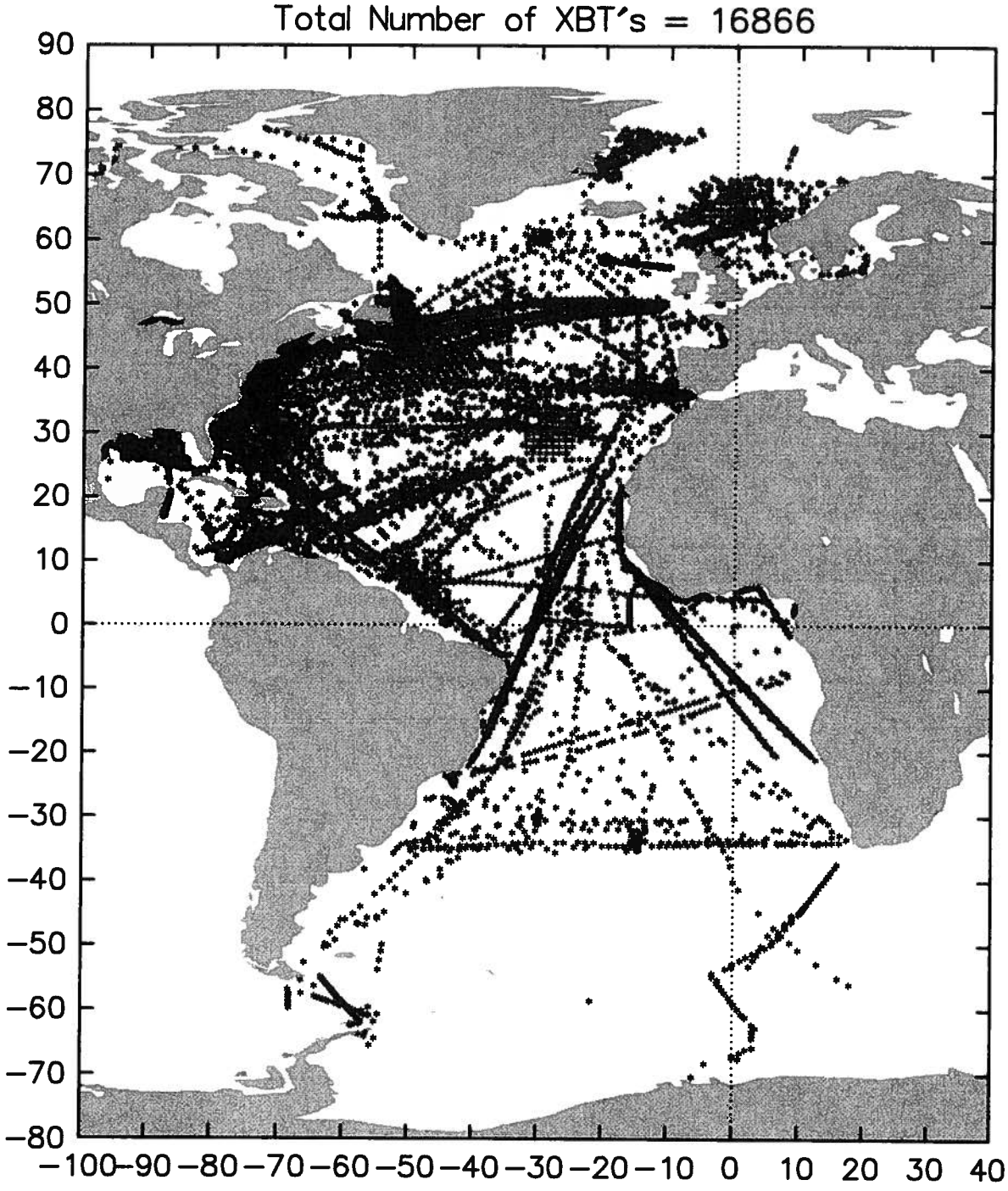


Figure 1: 1990 XBT Locations

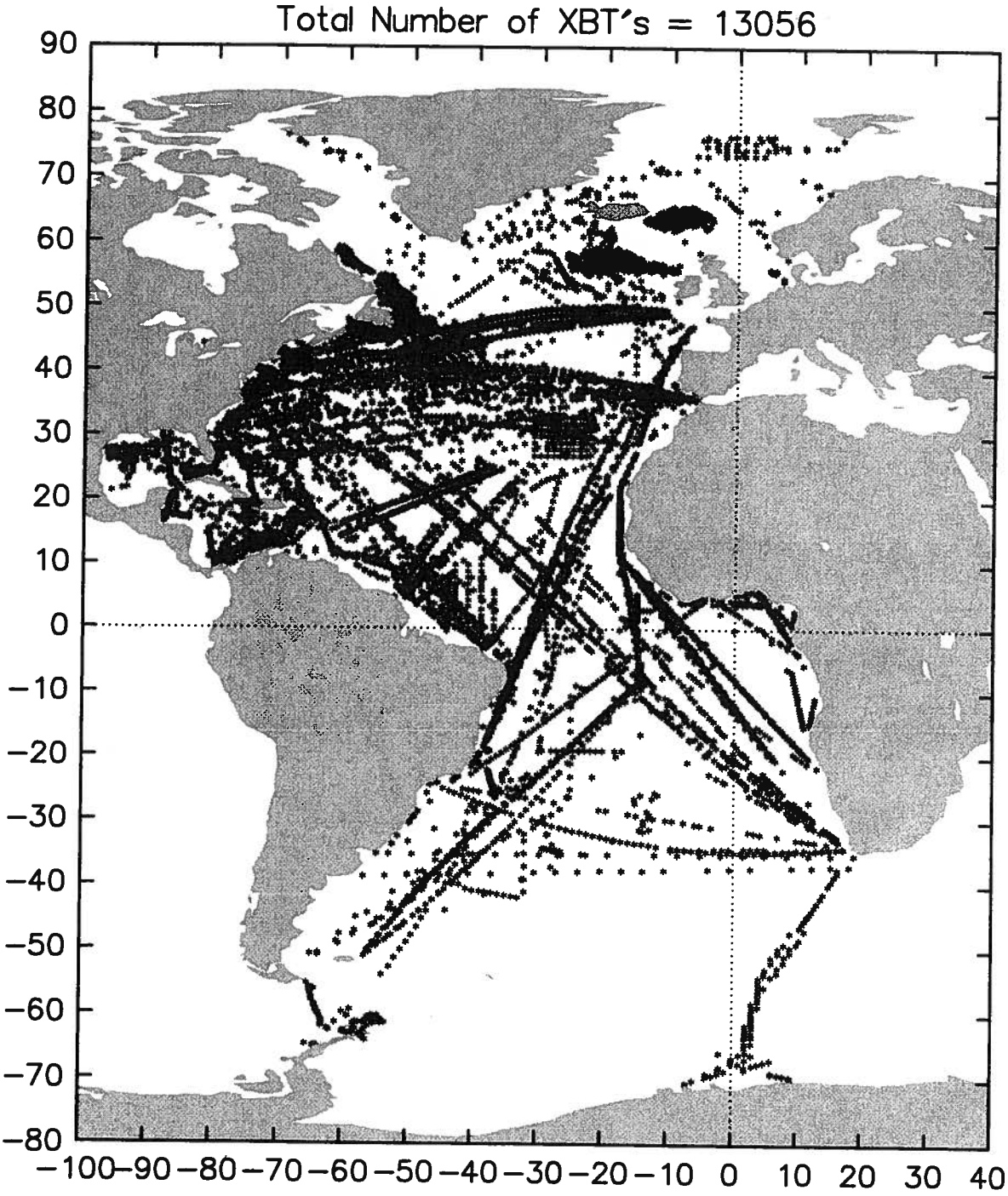


Figure 2: 1991 XBT locations

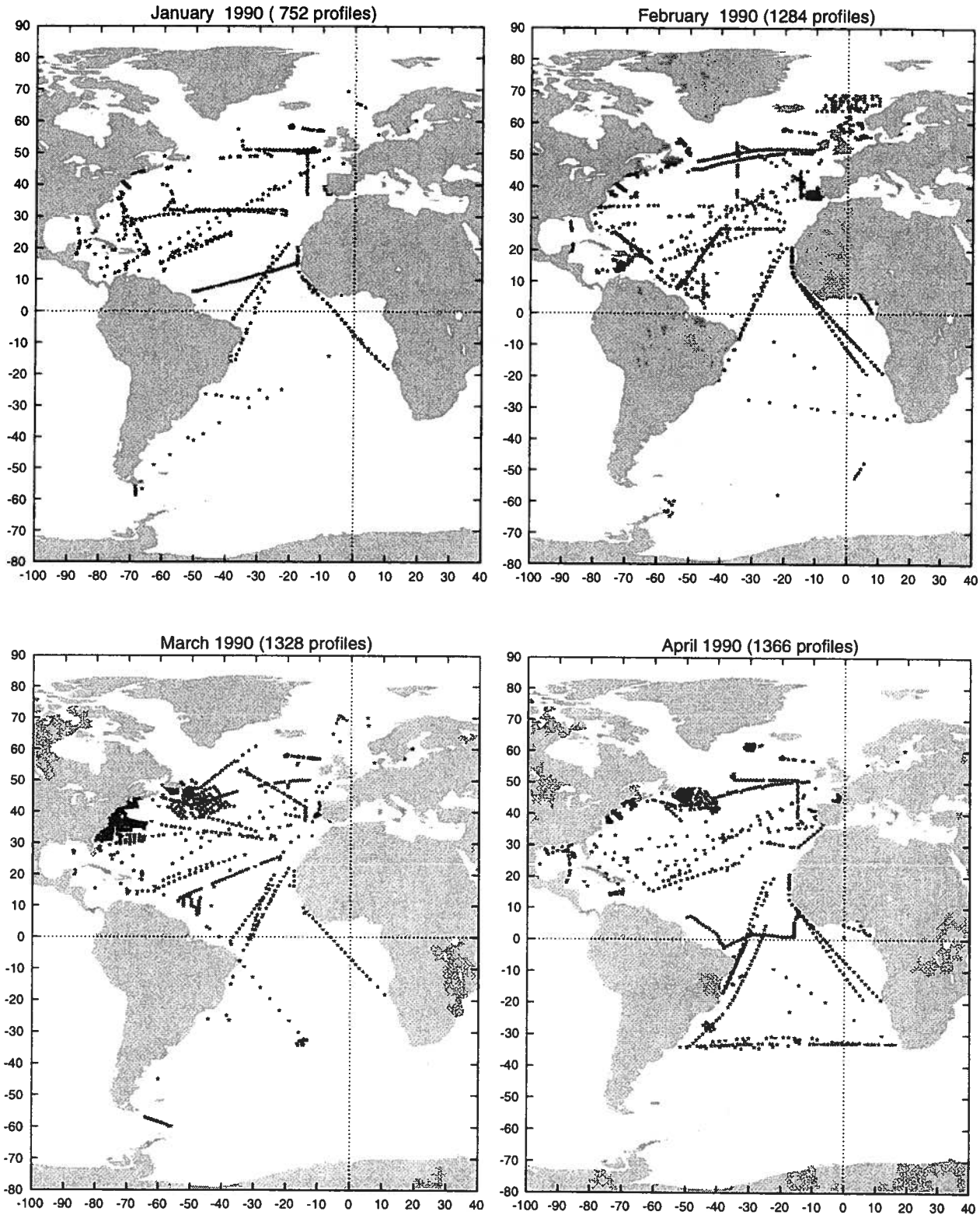


Figure 3a: 1991 Observations (January - April)

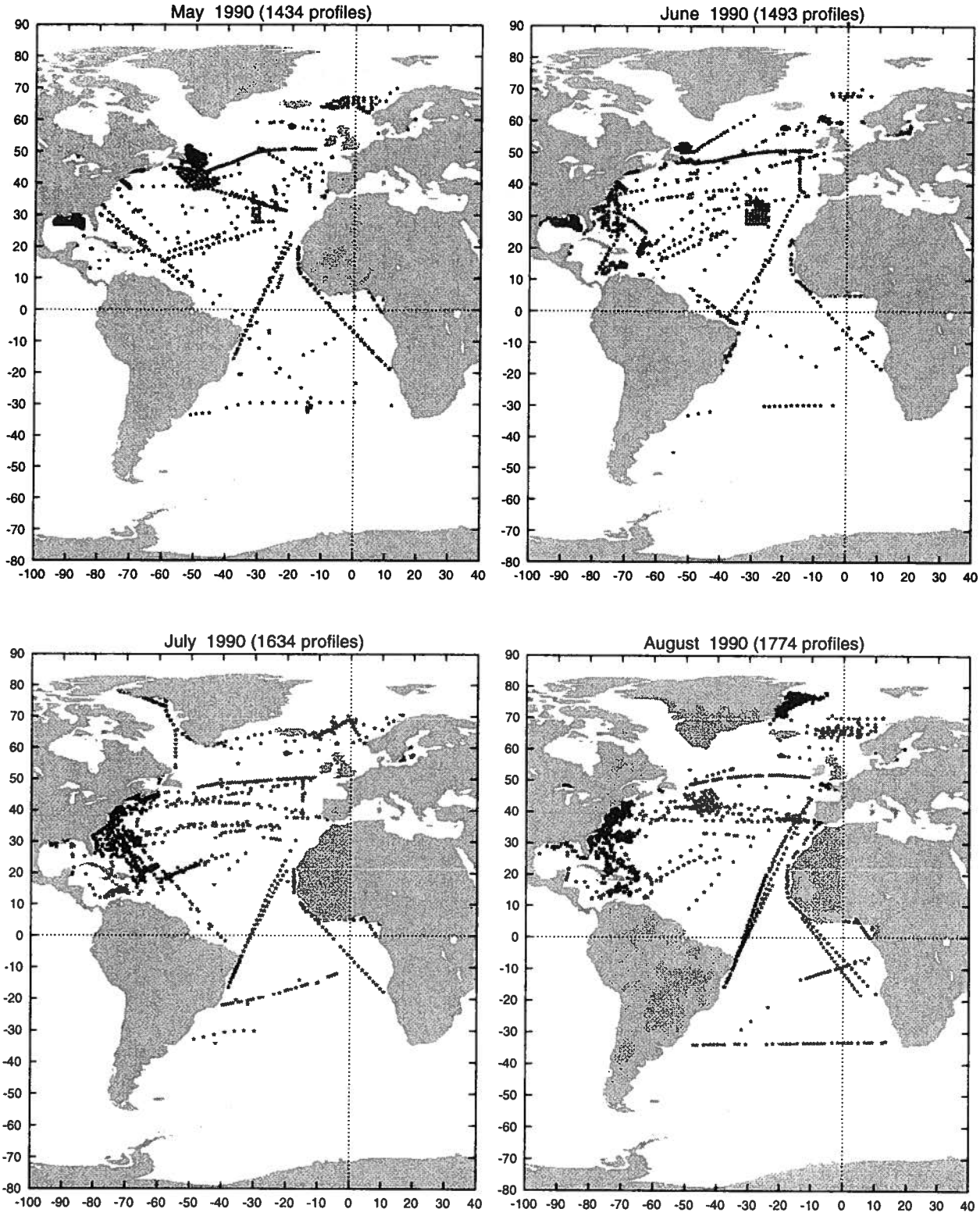


Figure 3b: 1991 Observations (May - August)

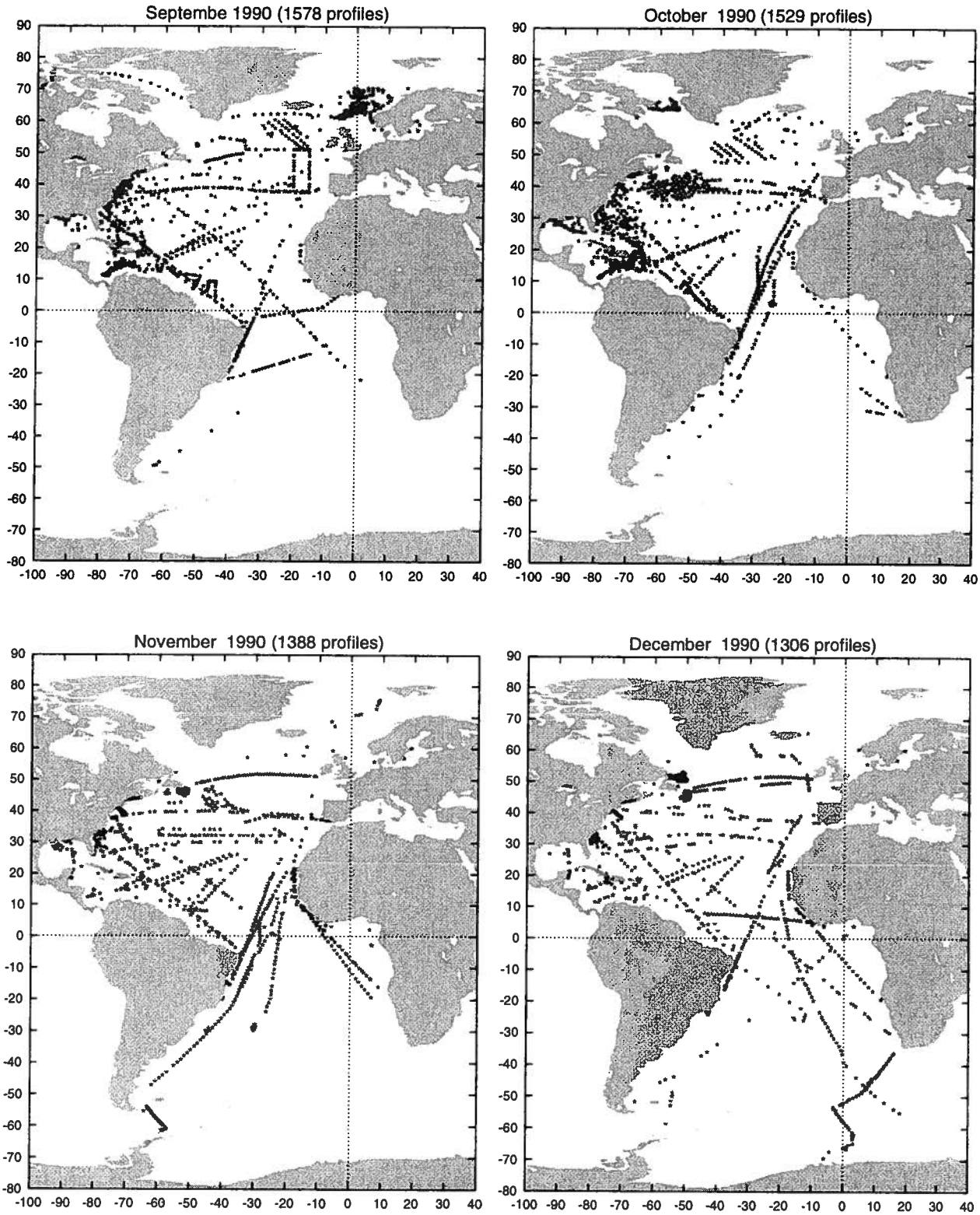


Figure 3c: 1991 Observations (September - December)

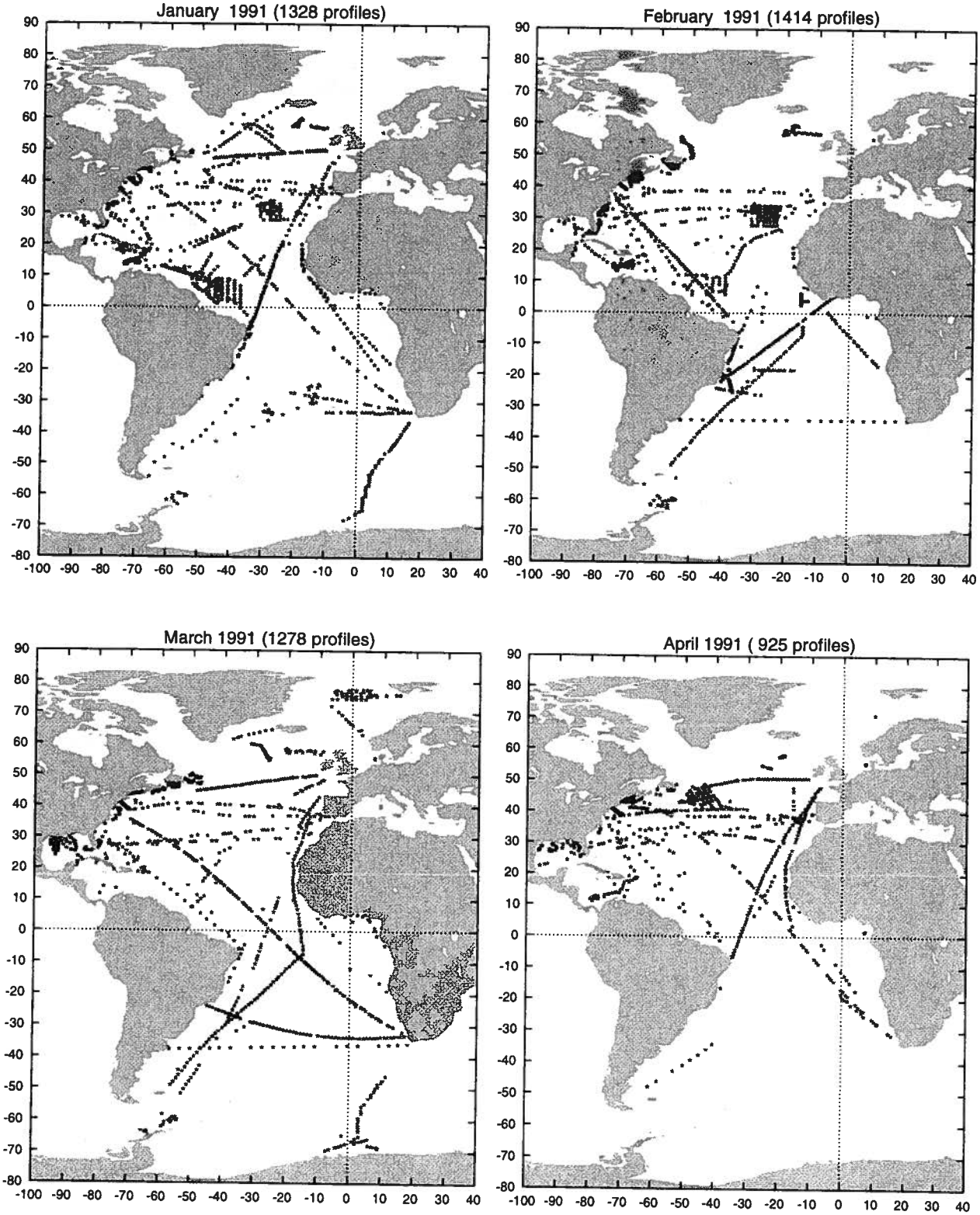


Figure 4a: 1991 Observations (January - April)

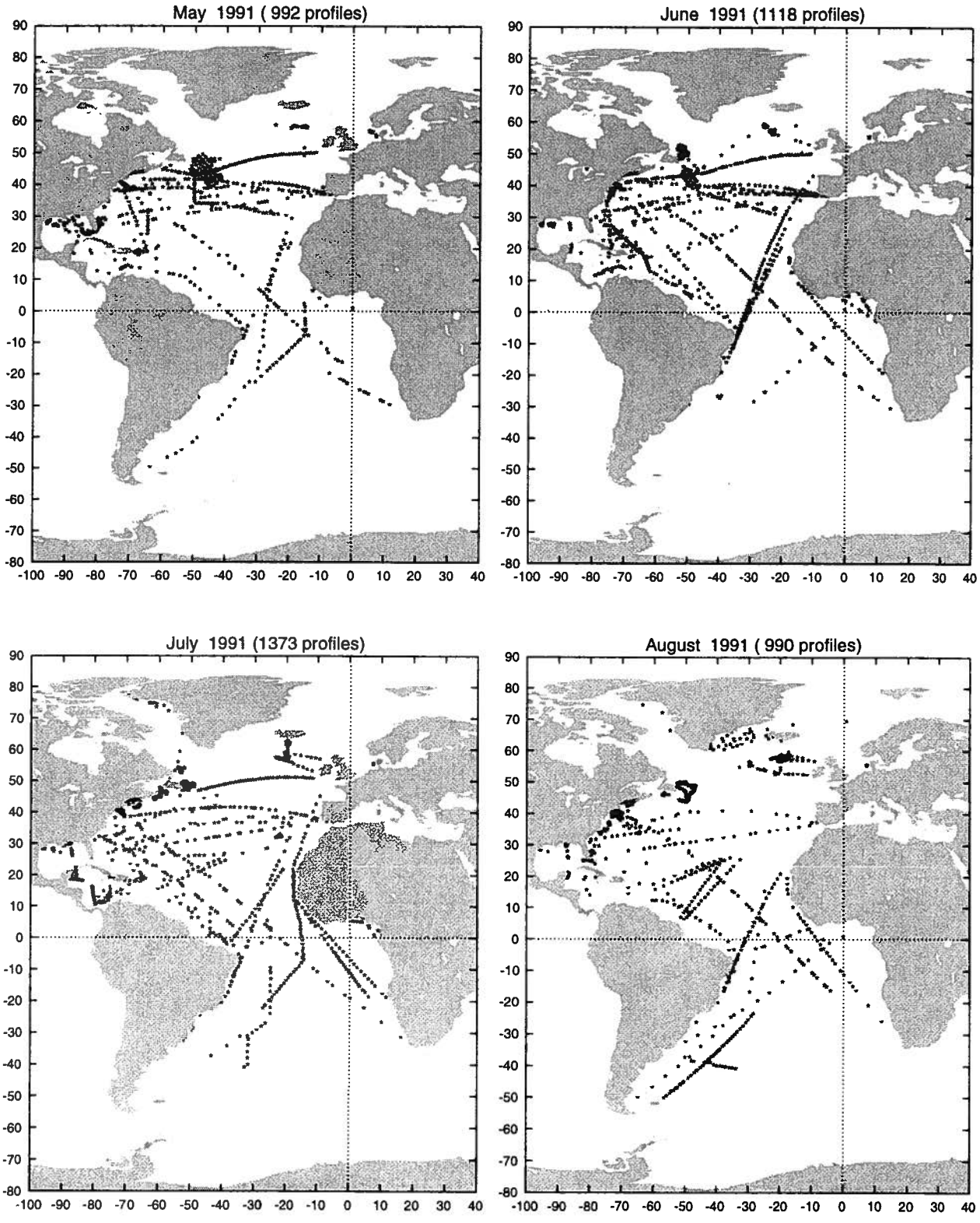


Figure 4b: 1991 Observations (May - August)

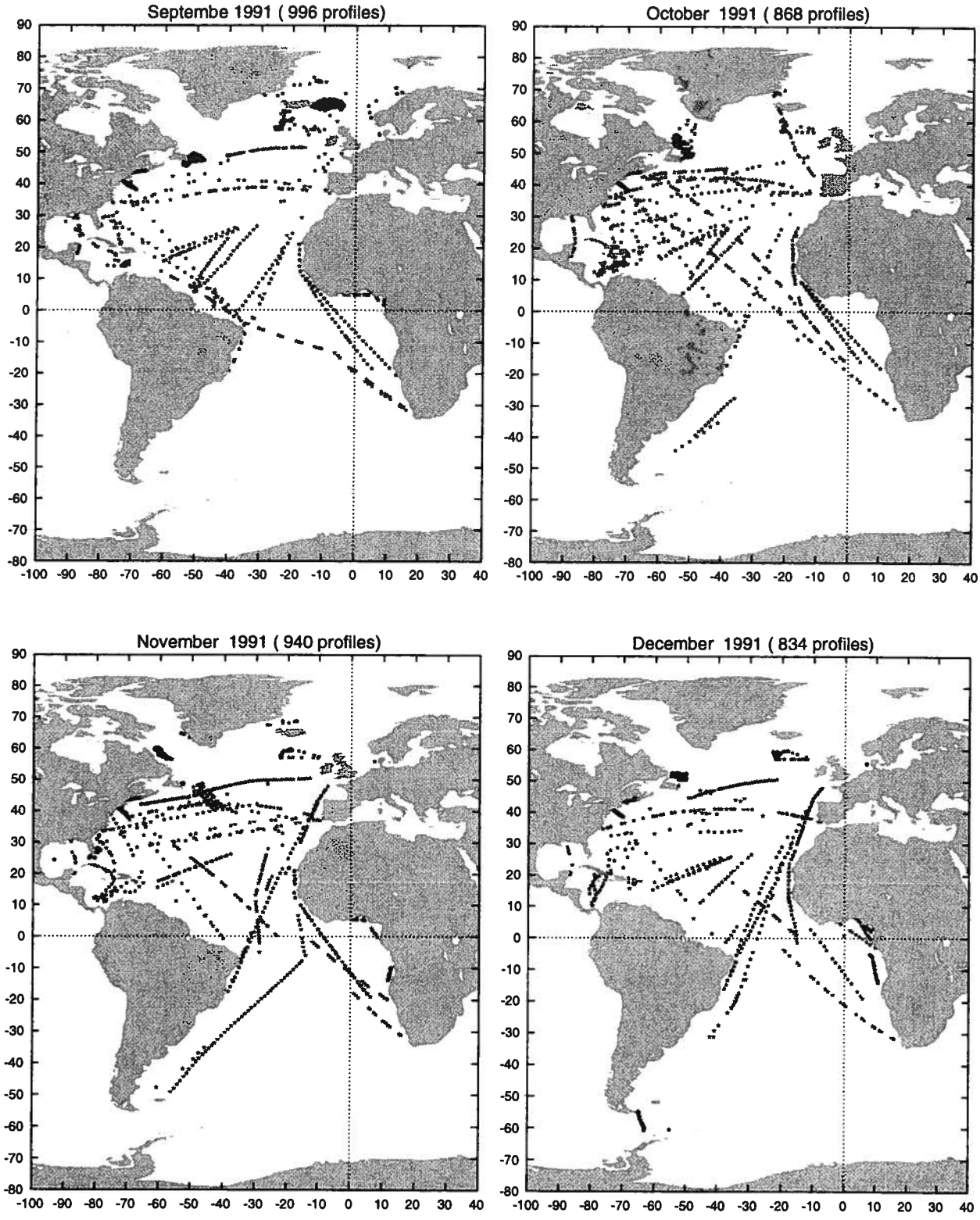
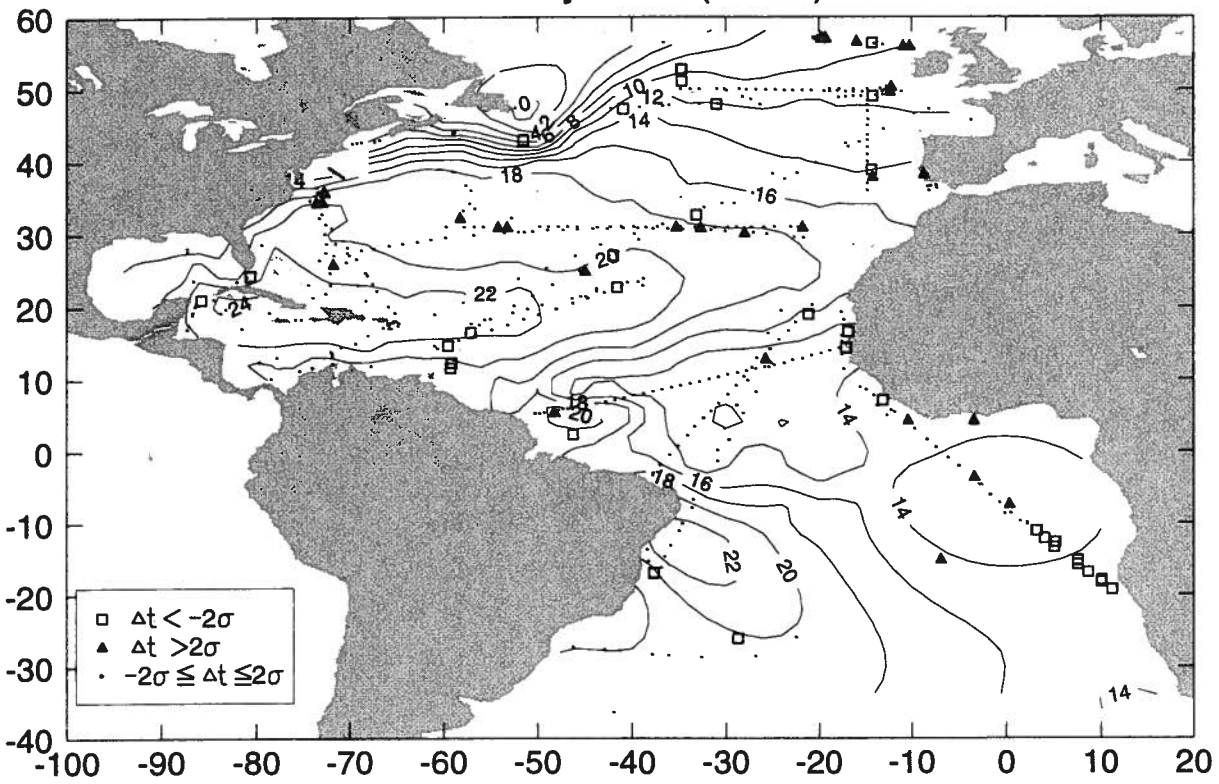


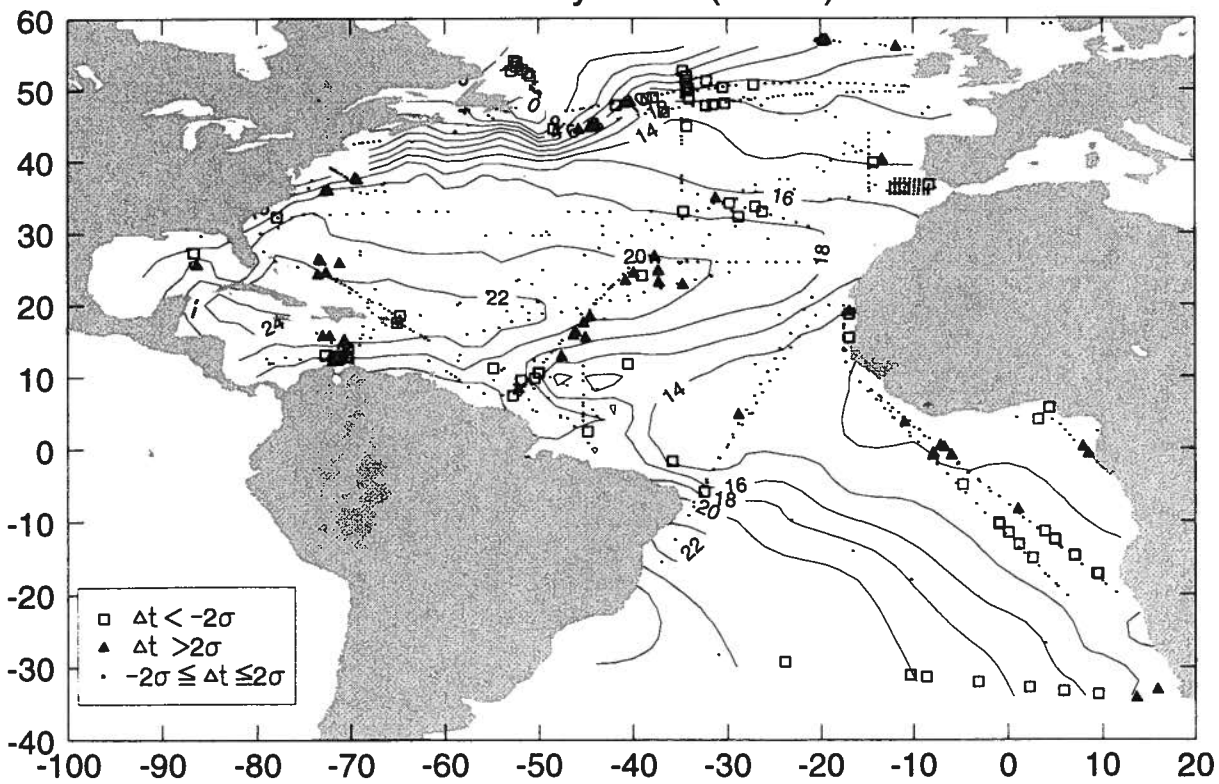
Figure 4c: 1991 Observations (September - December)

APPENDIX 1:

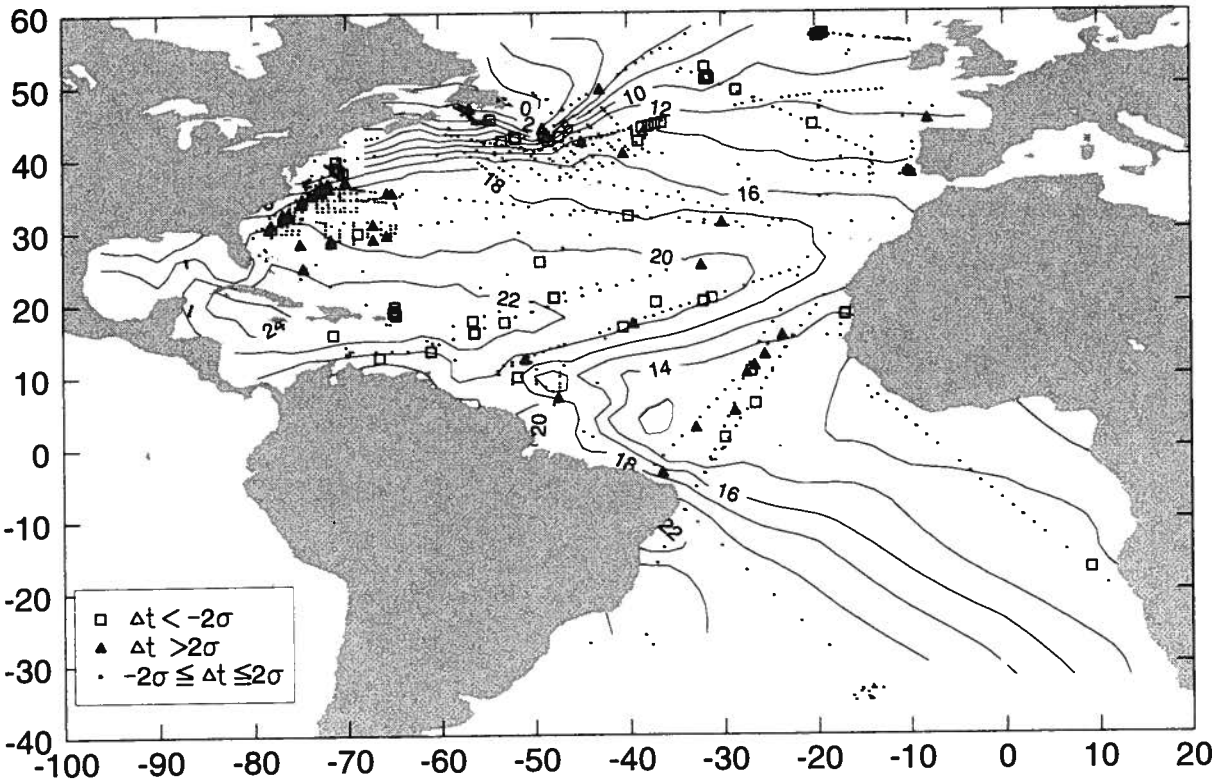
January 1990 (150m)



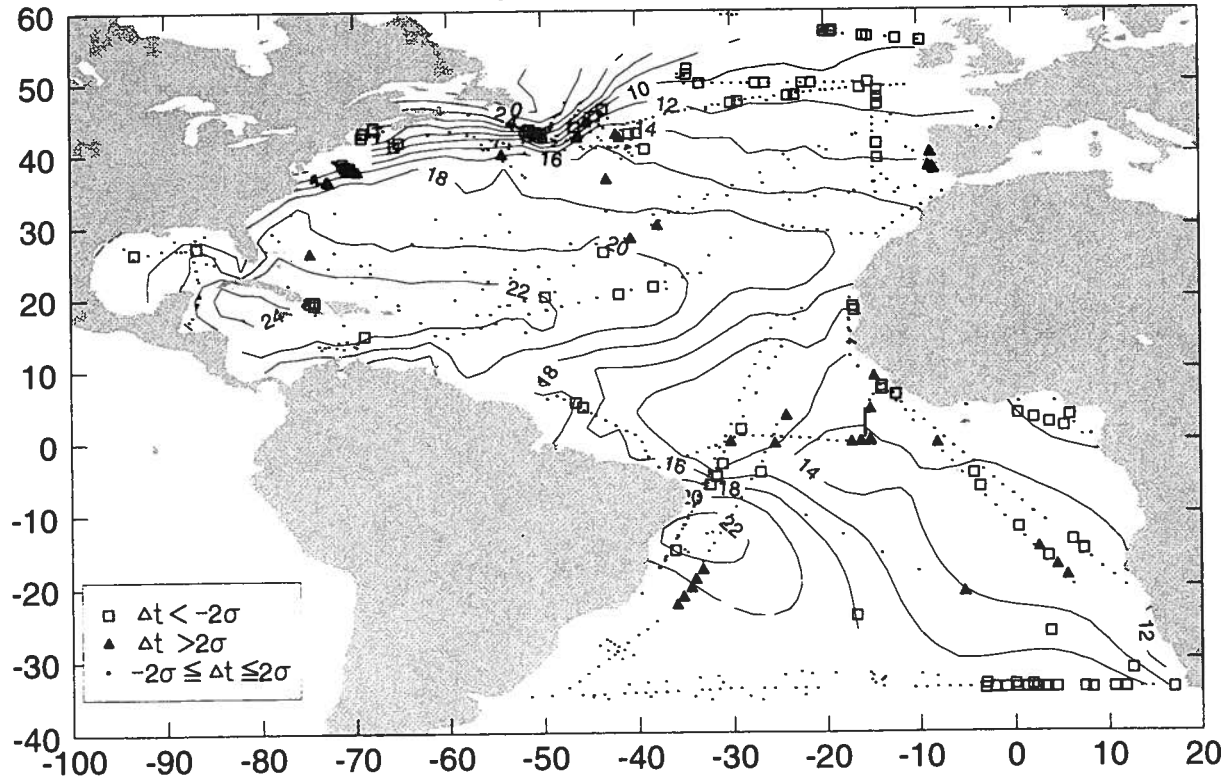
February 1990 (150m)



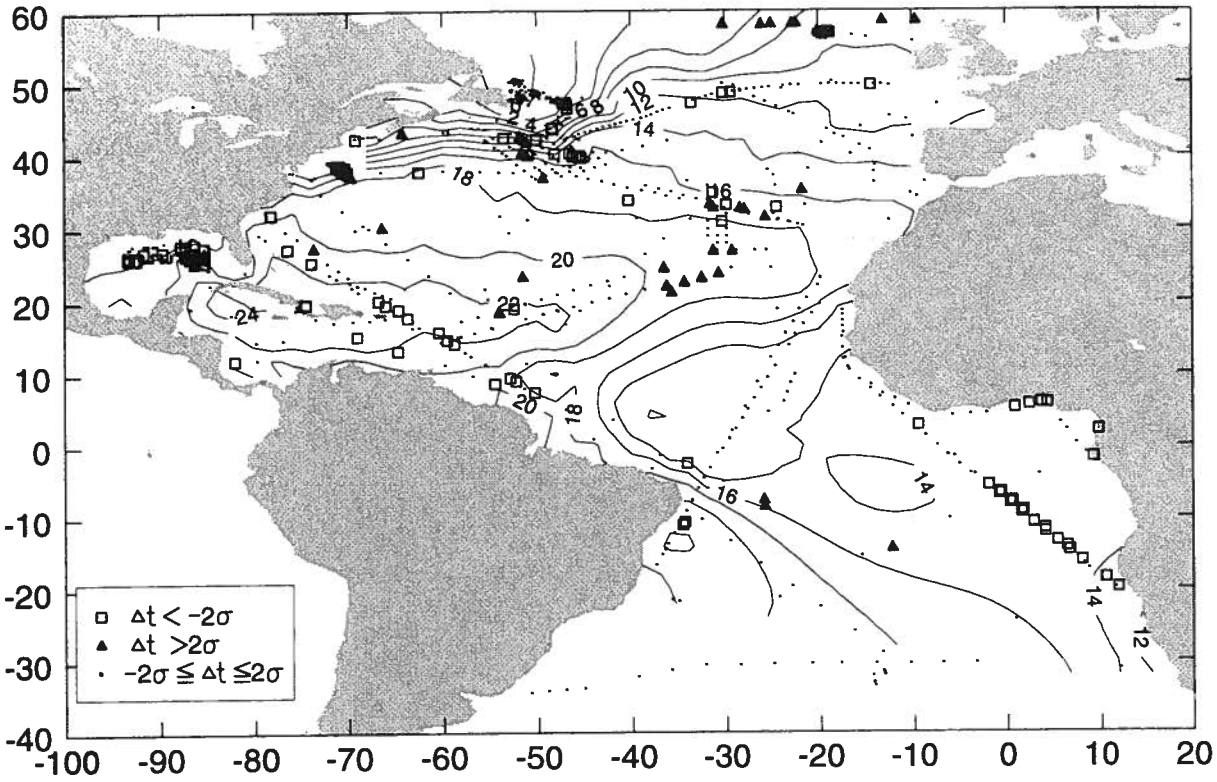
March 1990 (150m)



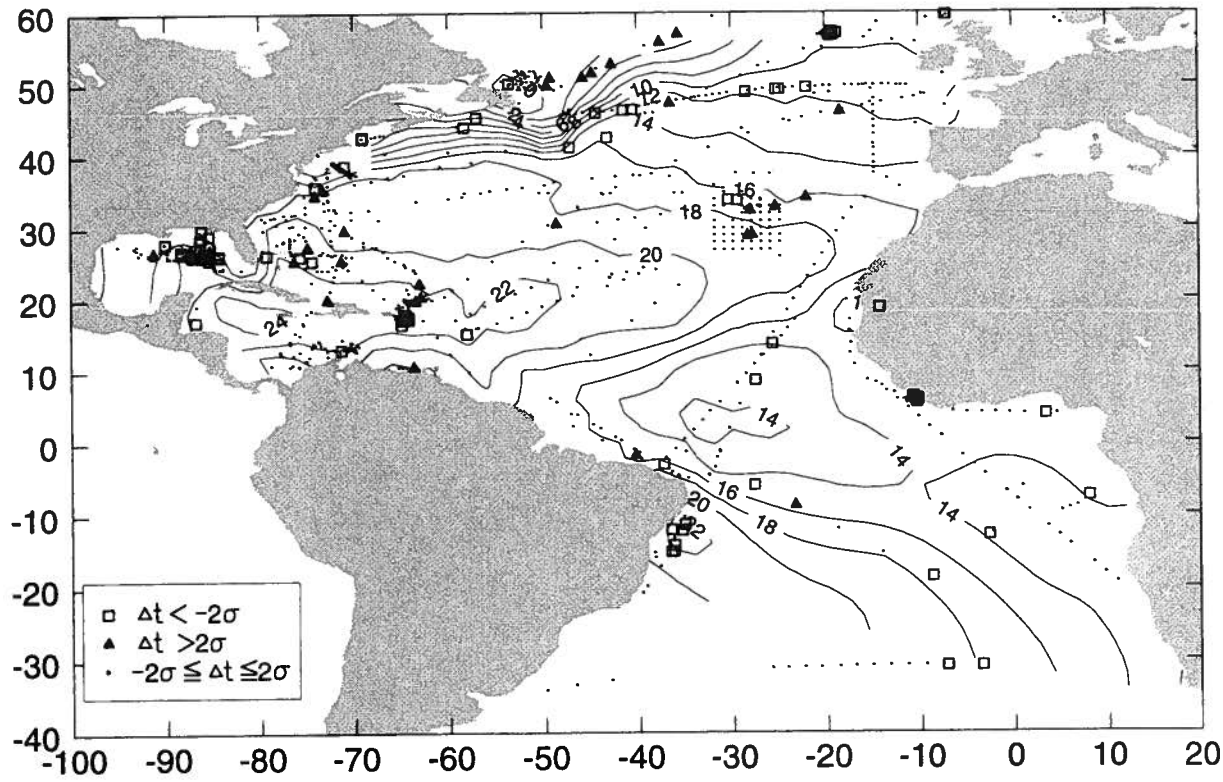
April 1990 (150m)

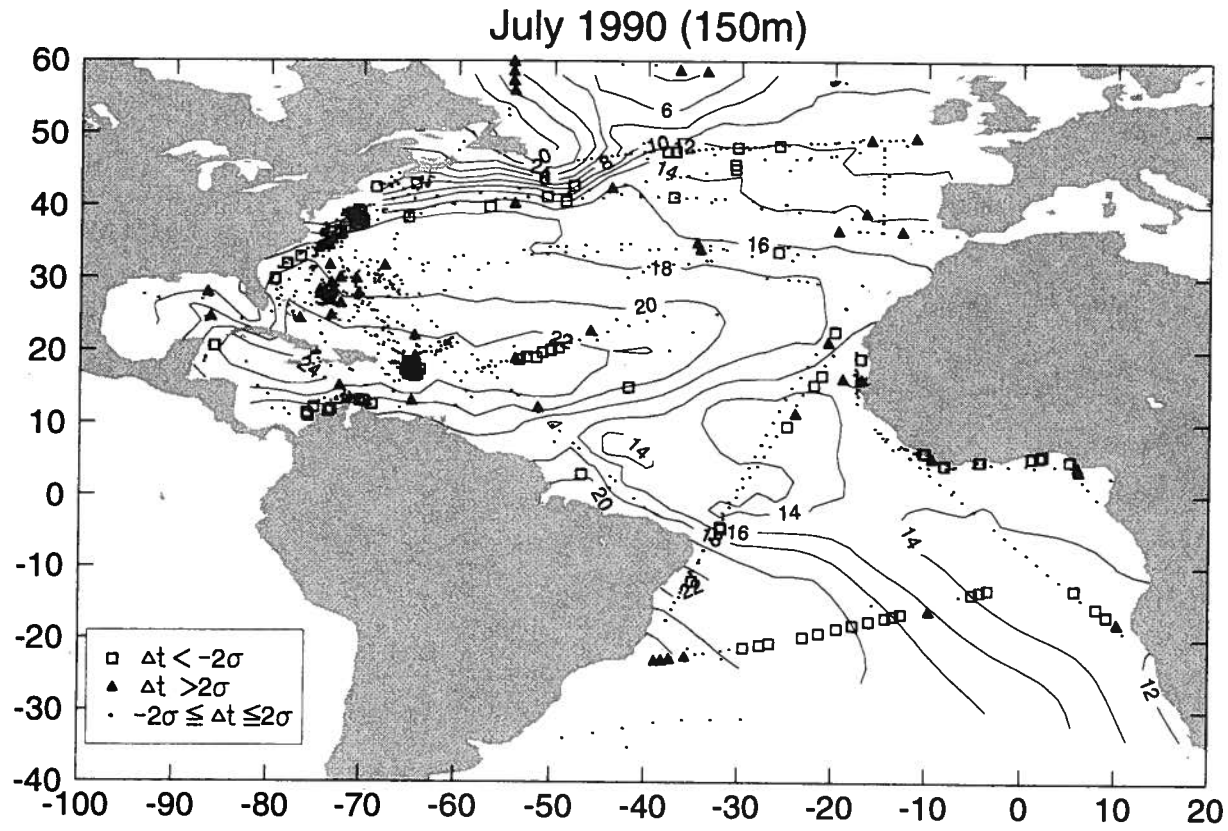


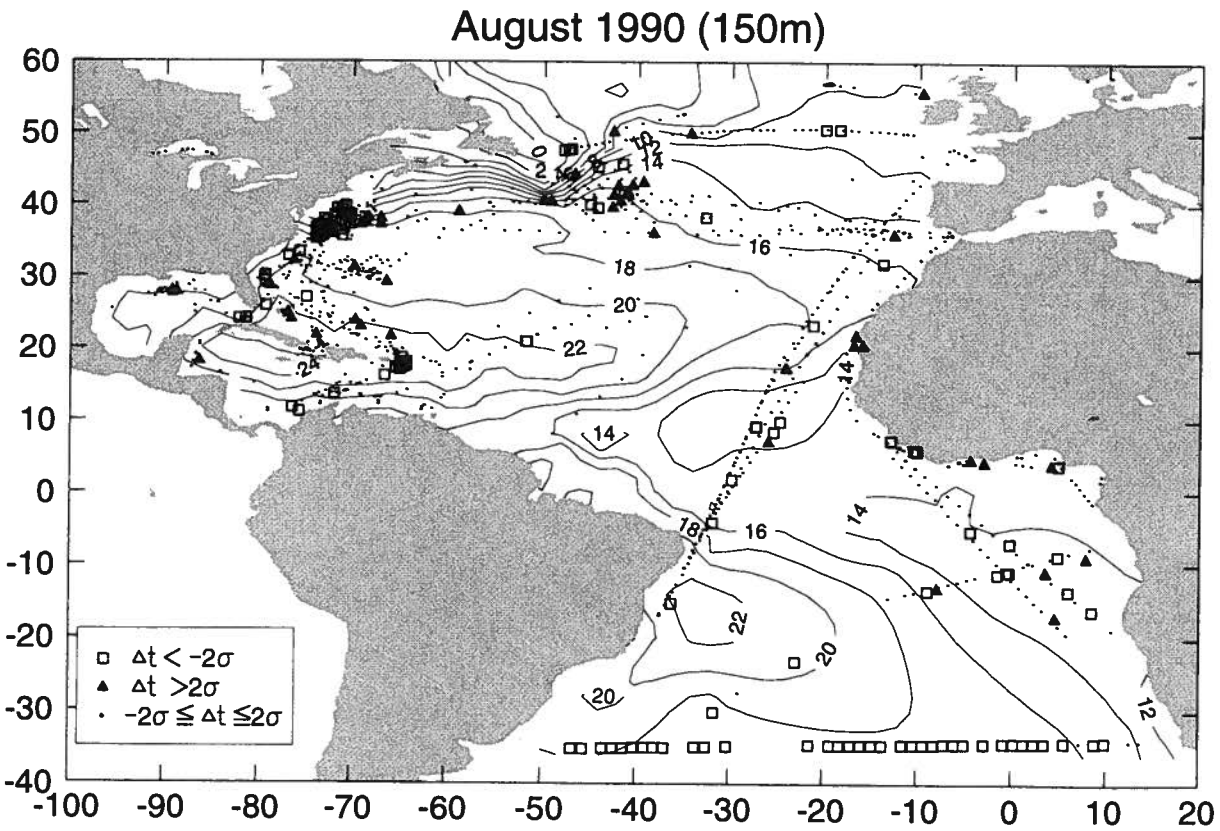
May 1990 (150m)



June 1990 (150m)




July 1990 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


August 1990 (150m)
Δt < -2σ
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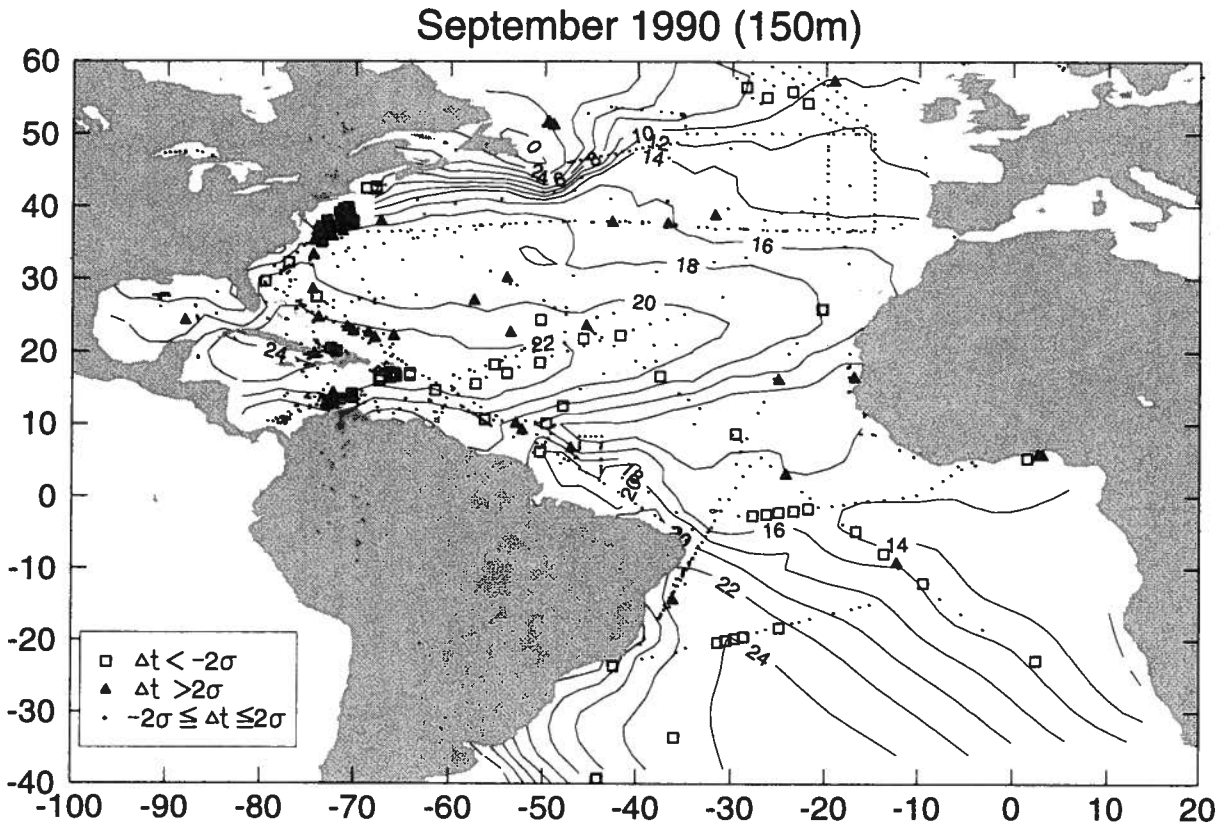
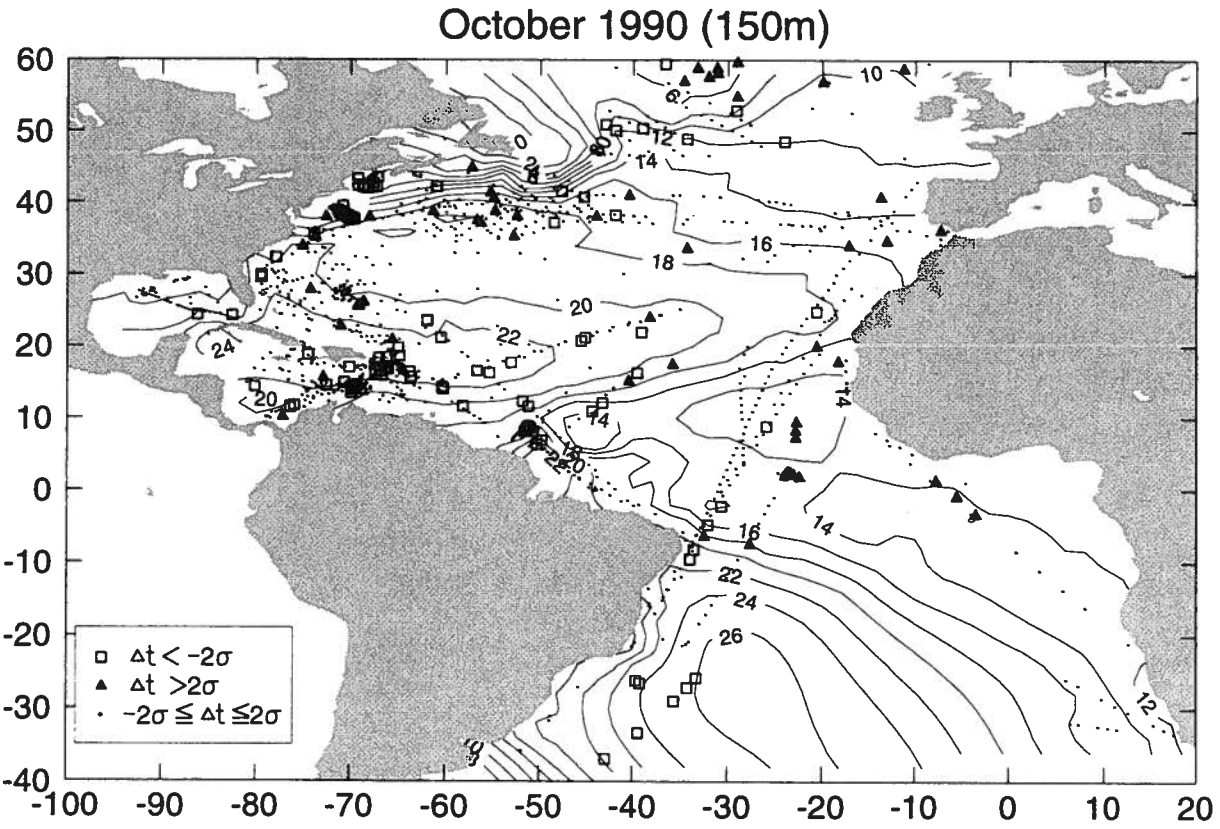
-2σ ≦ Δt ≦2σ


September 1990 (150m)
□ Δt < -2σ
▲ Δt >2σ
· -2σ ≦ Δt ≦2σ


October 1990 (150m)
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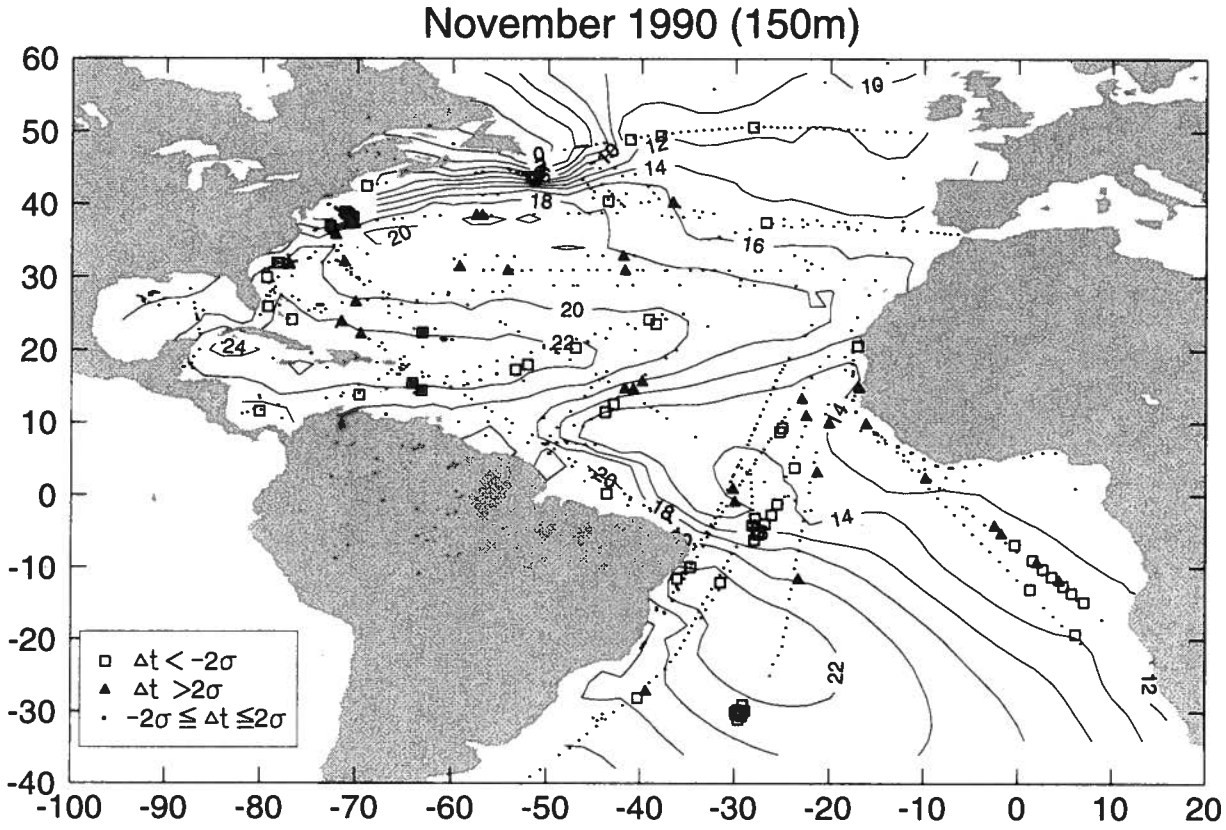
▲ Δt >2σ
· -2σ ≦ Δt ≦2σ


November 1990 (150m)
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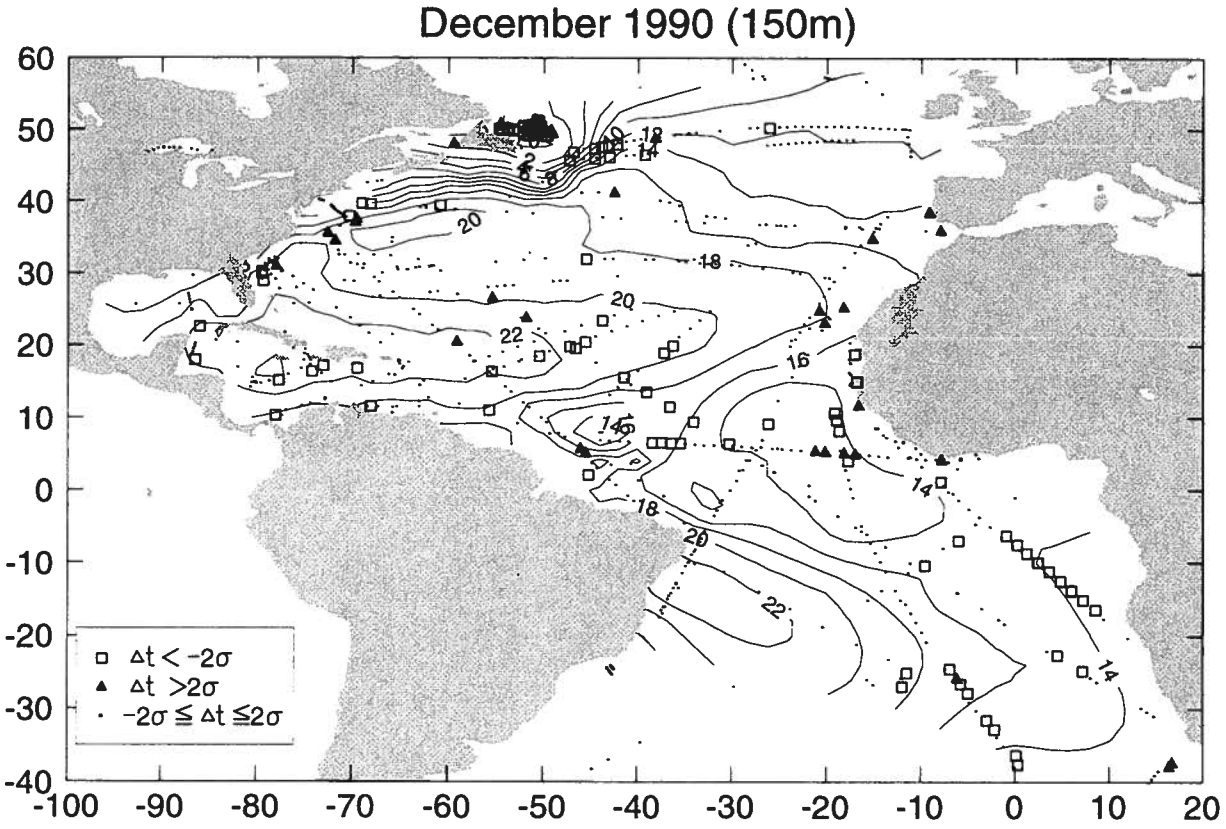
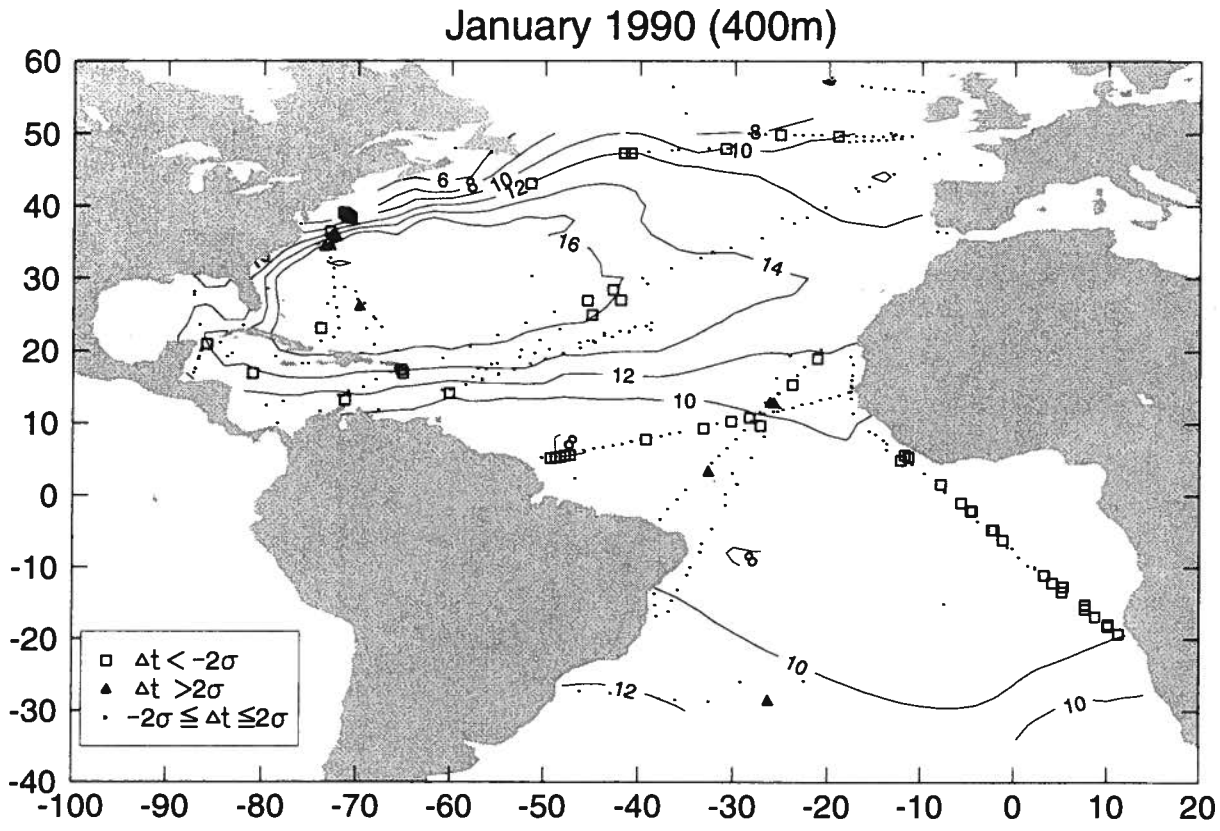
· -2σ ≦ Δt ≦2σ


December 1990 (150m)
□ Δt < -2σ
▲ Δt >2σ
· -2σ ≦ Δt ≦2σ


January 1990 (400m)
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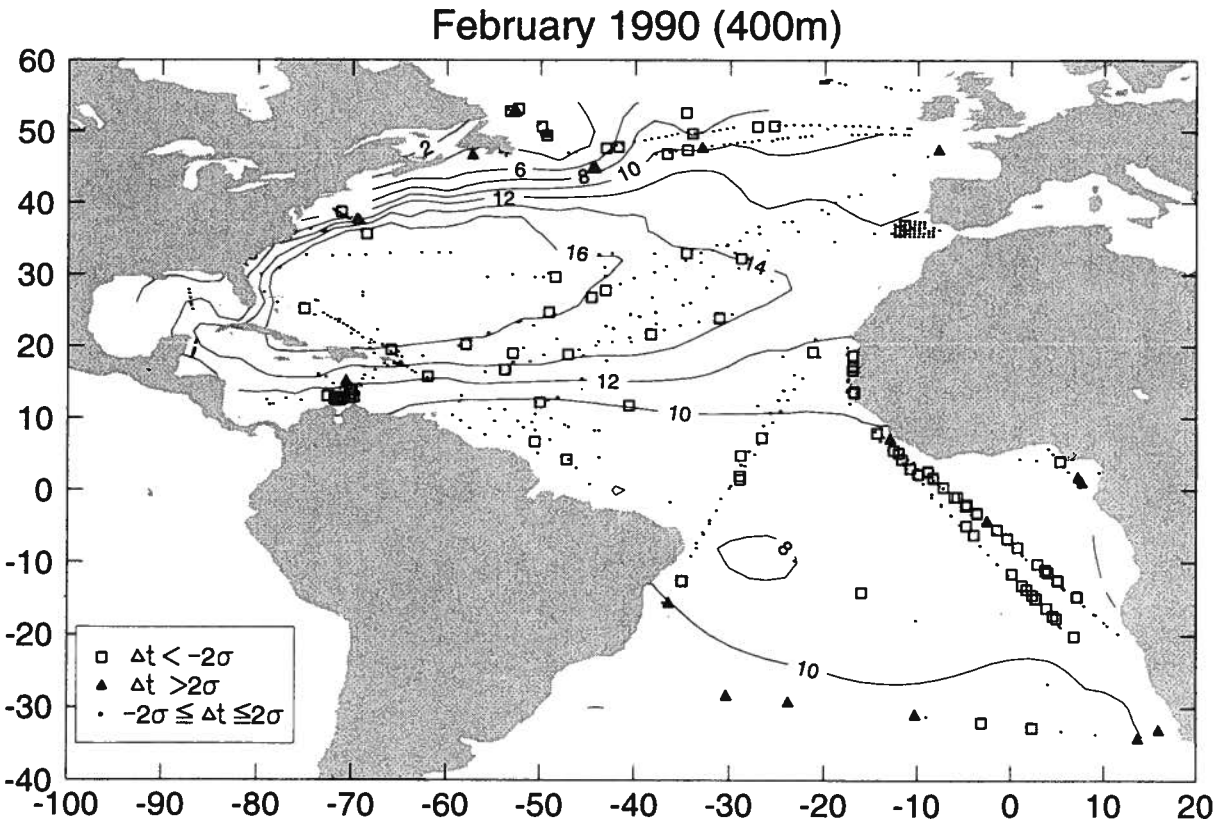
-2σ ≦ Δt ≦2σ


February 1990 (400m)
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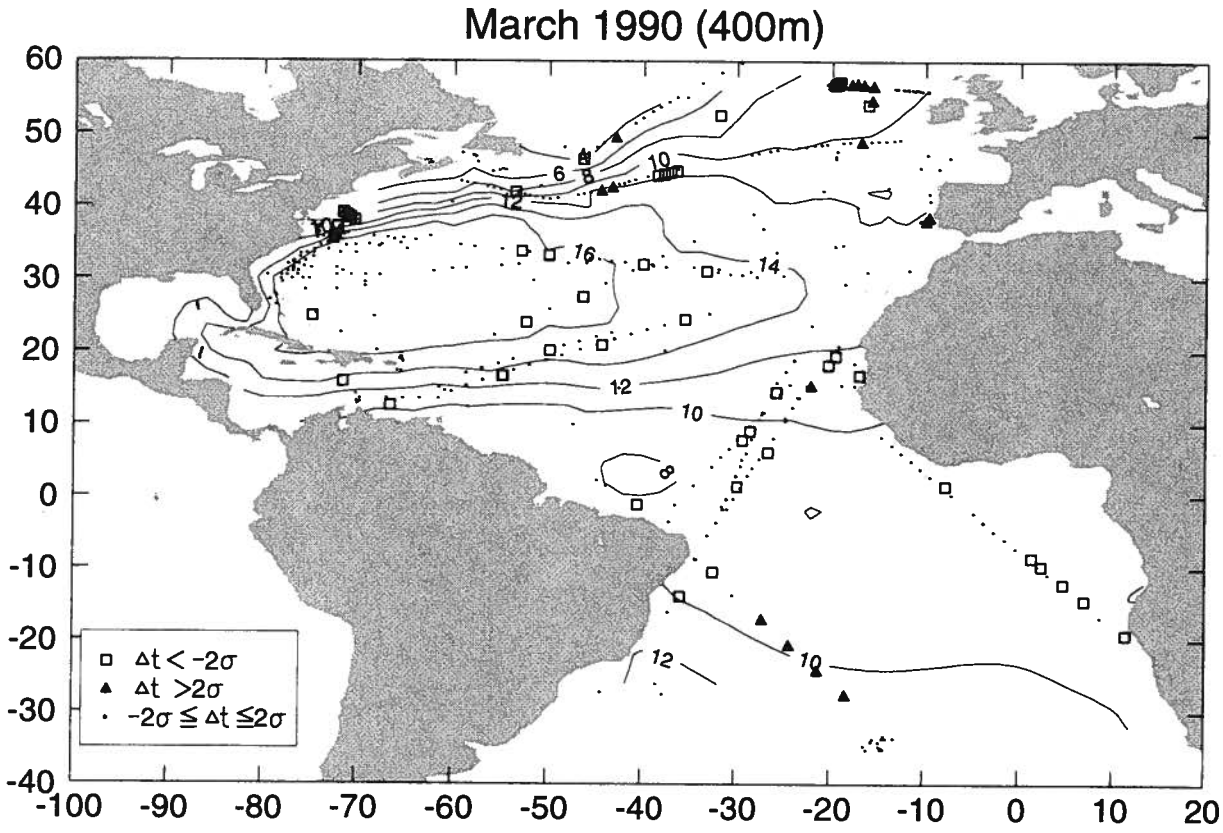
-2σ ≦ Δt ≦2σ


March 1990 (400m)
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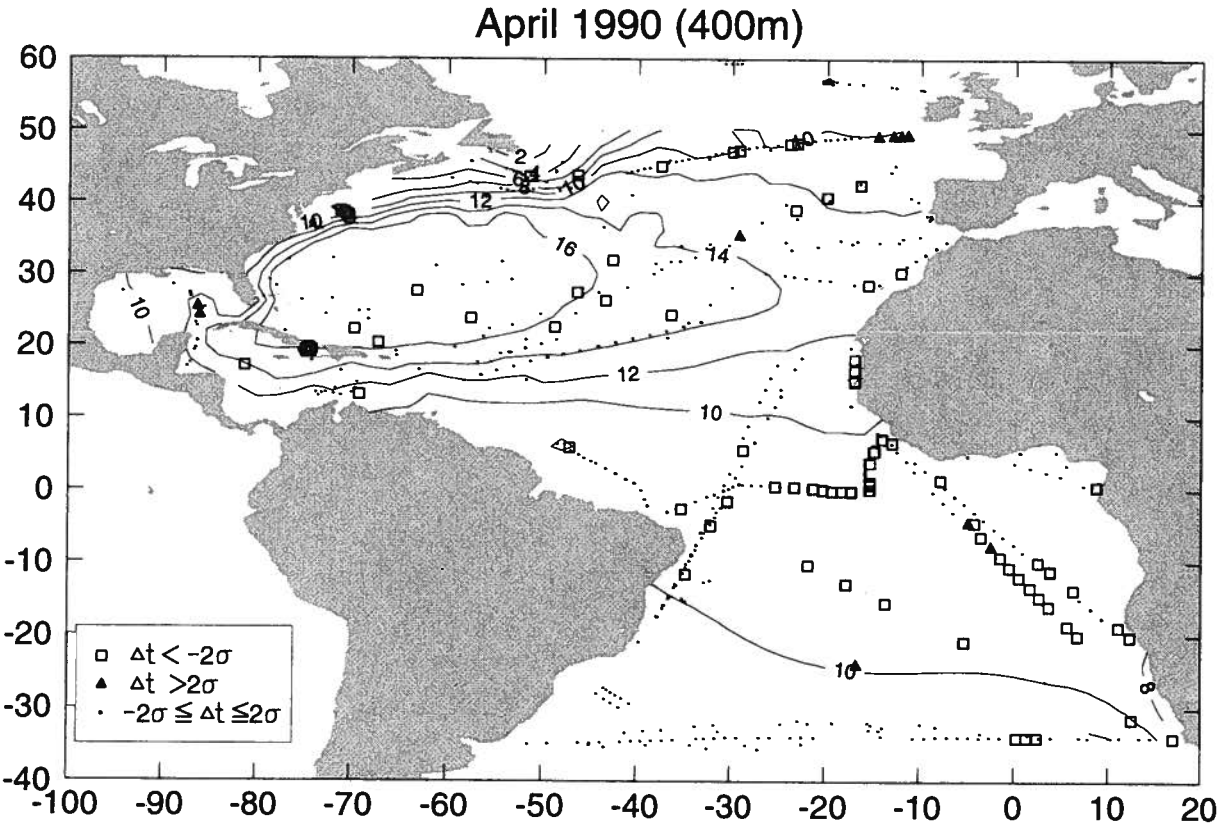
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


April 1990 (400m)
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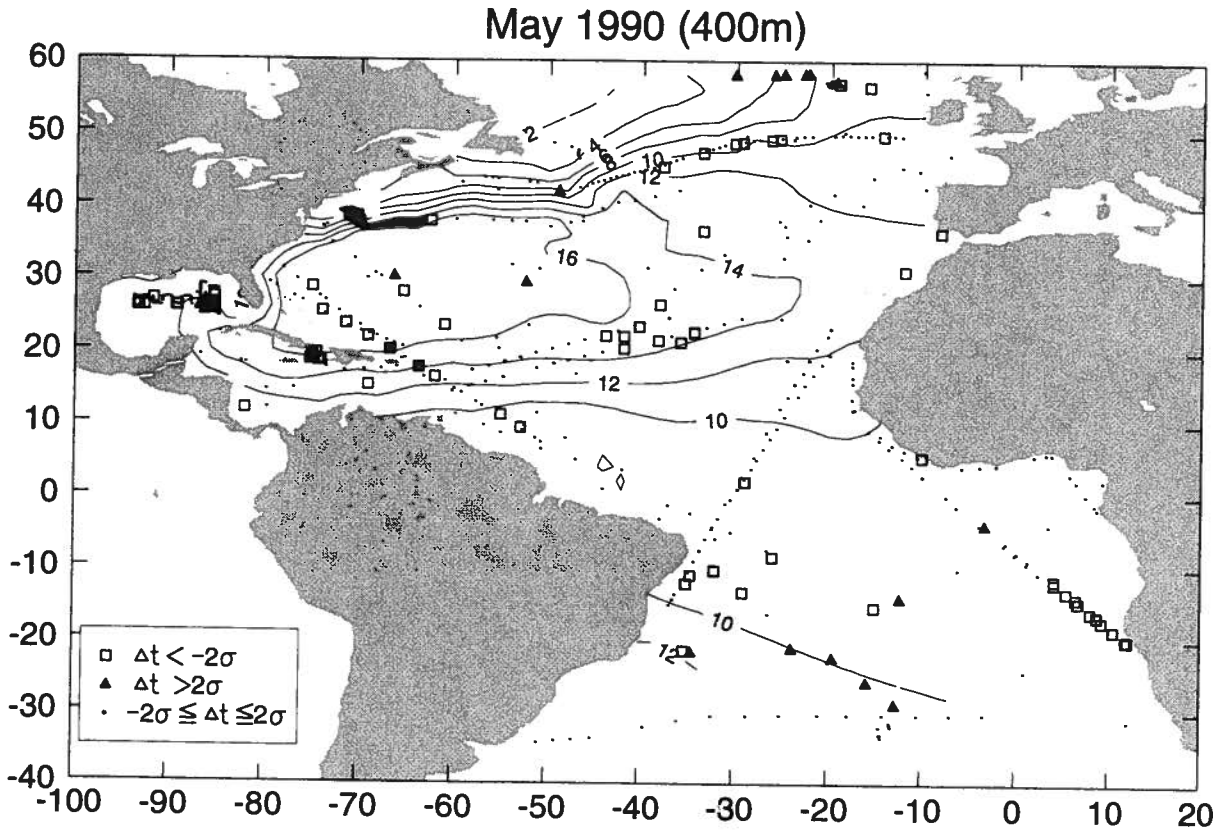
Δt >2σ
-2σ ≦ Δt ≦2σ


May 1990 (400m)
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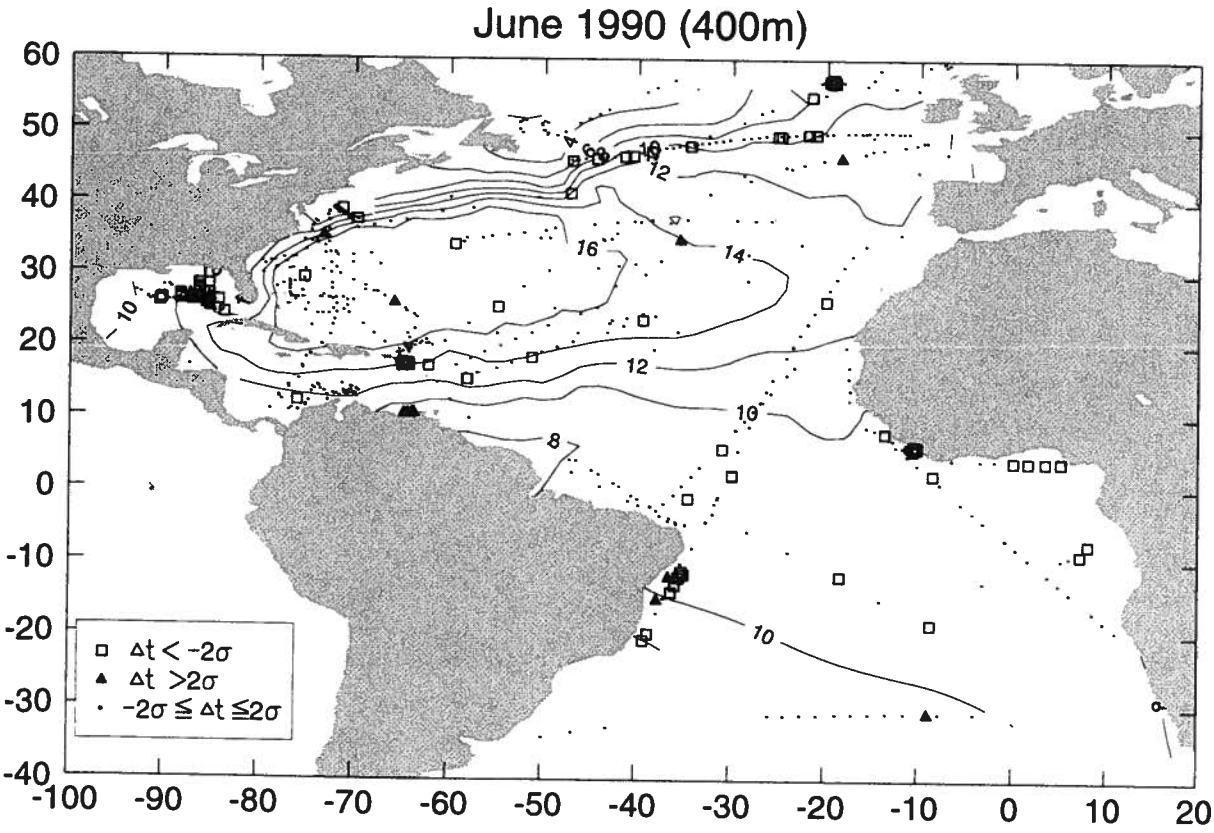
Δt < -2σ
Δt >2σ
-2σ ≤ Δt ≤2σ


June 1990 (400m)
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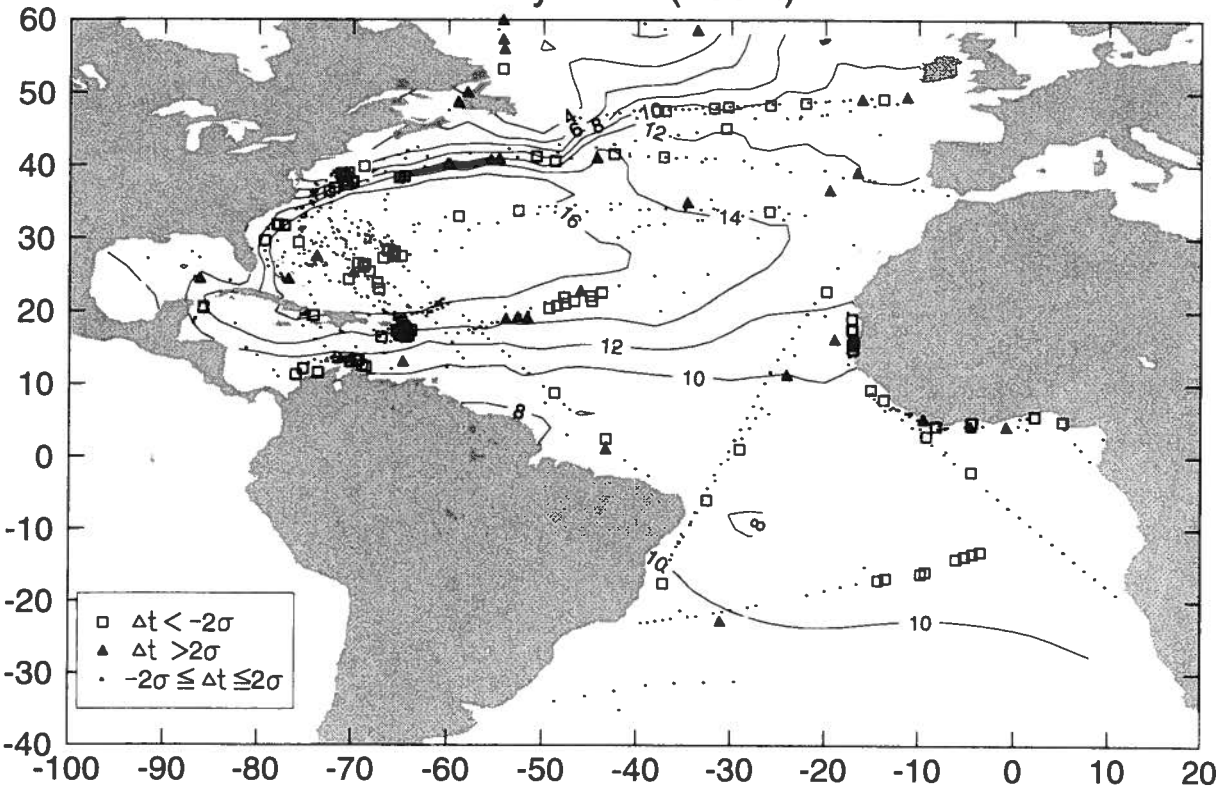
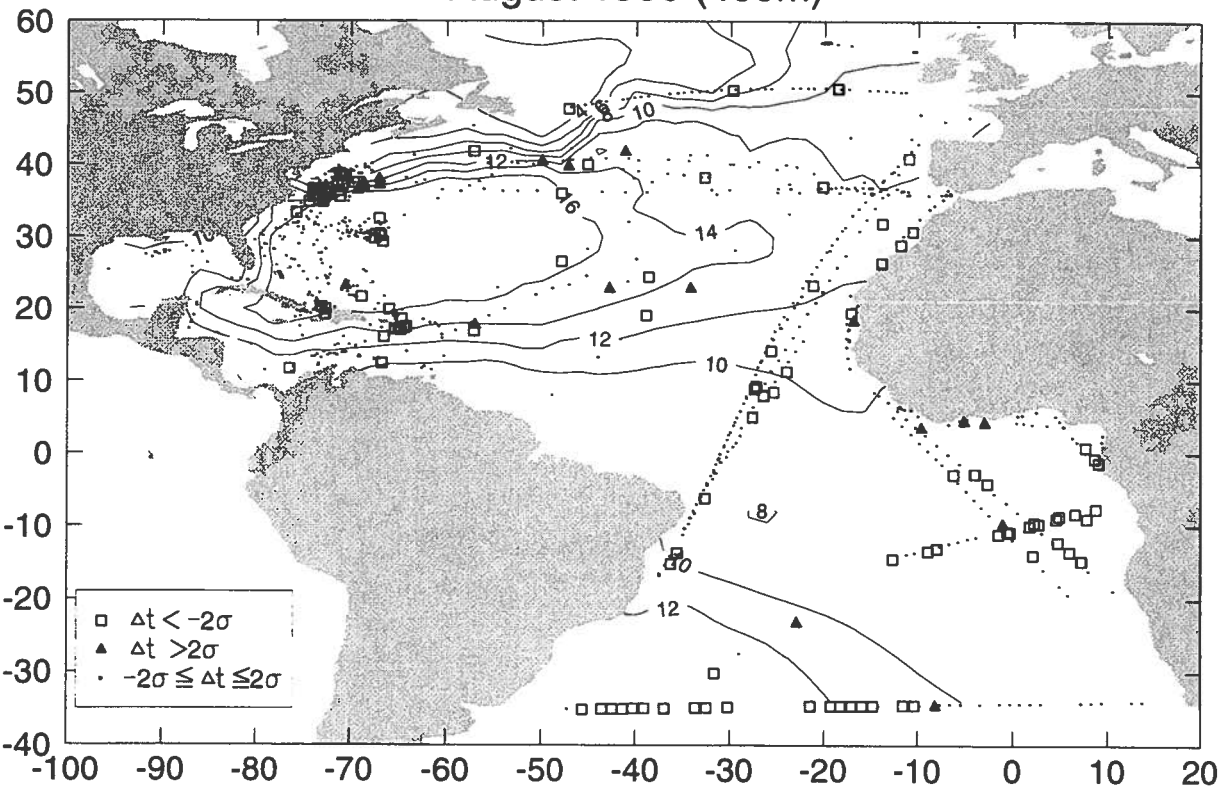
Δt < -2σ
Δt >2σ
-2σ ≤ Δt ≤2σ

July 1990 (400m)



August 1990 (400m)



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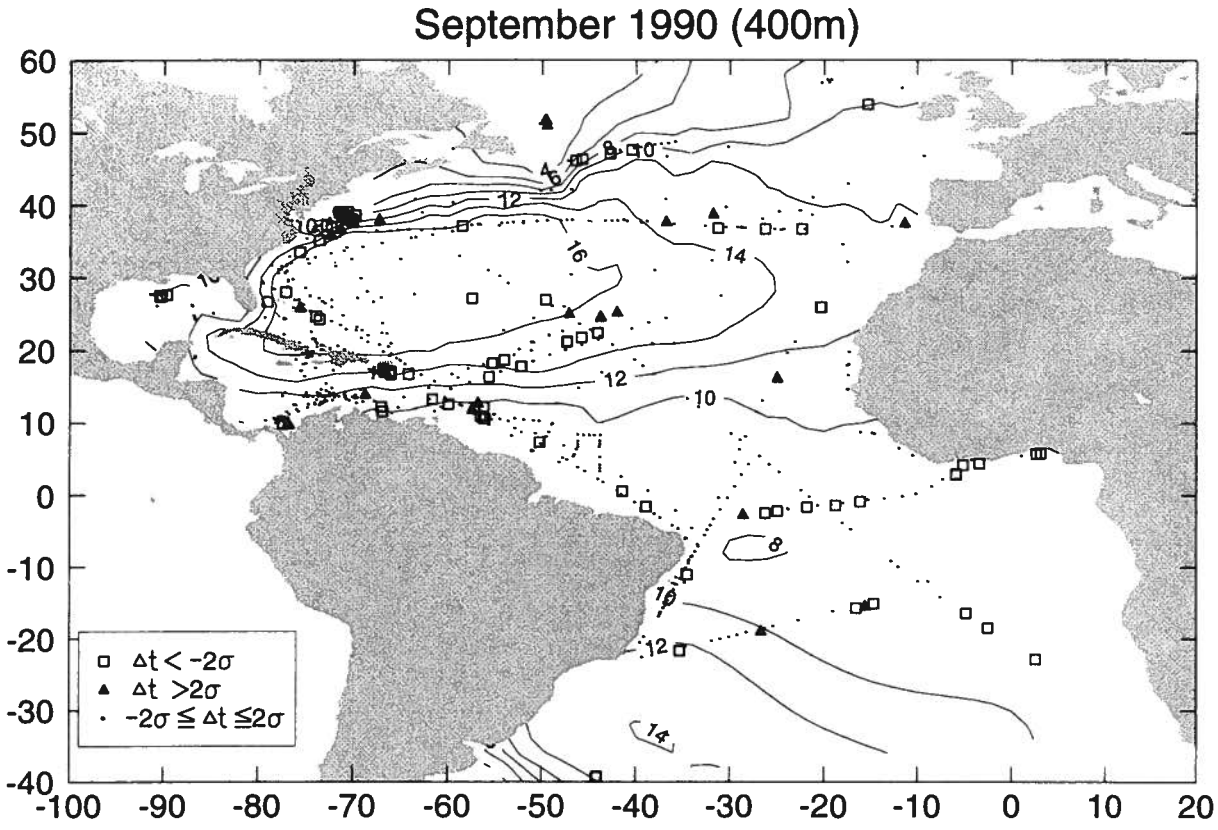
Miami, Florida 33149


September 1990 (400m)
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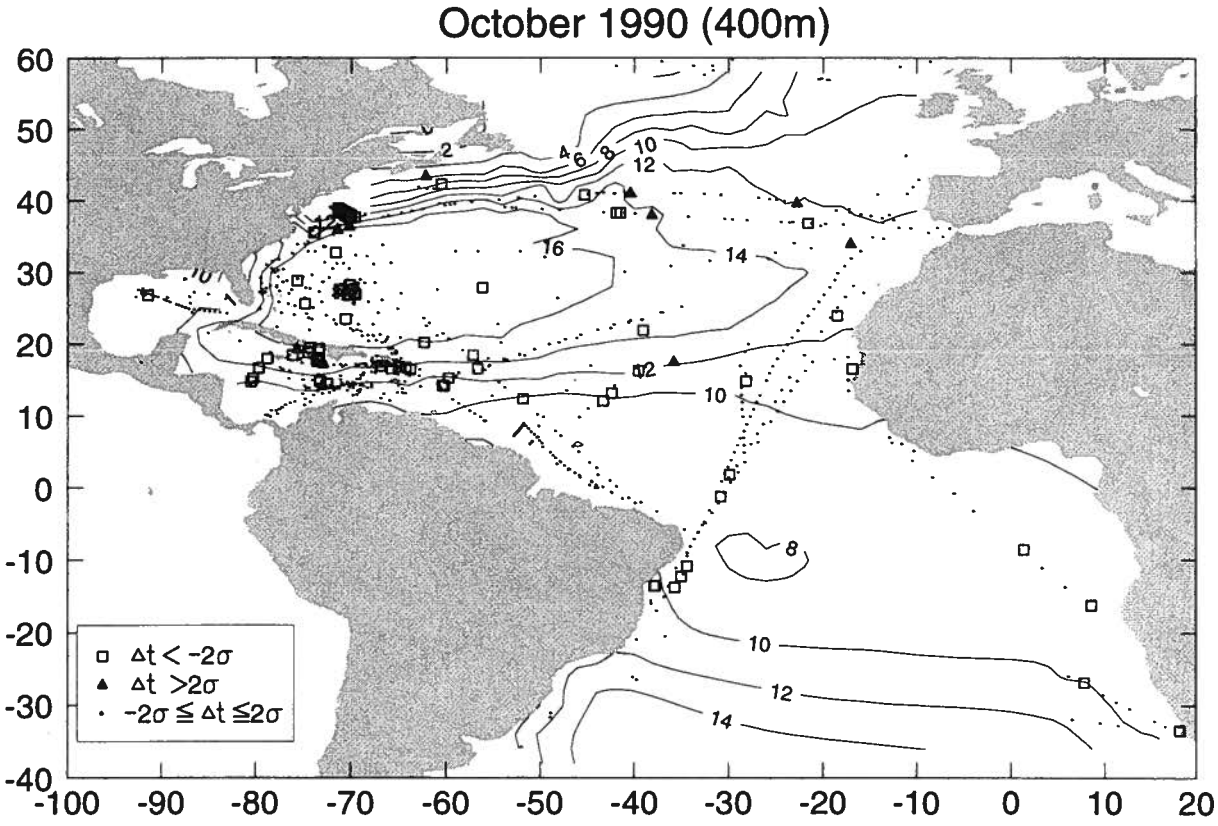
Δt >2σ
-2σ ≦ Δt ≦2σ


October 1990 (400m)
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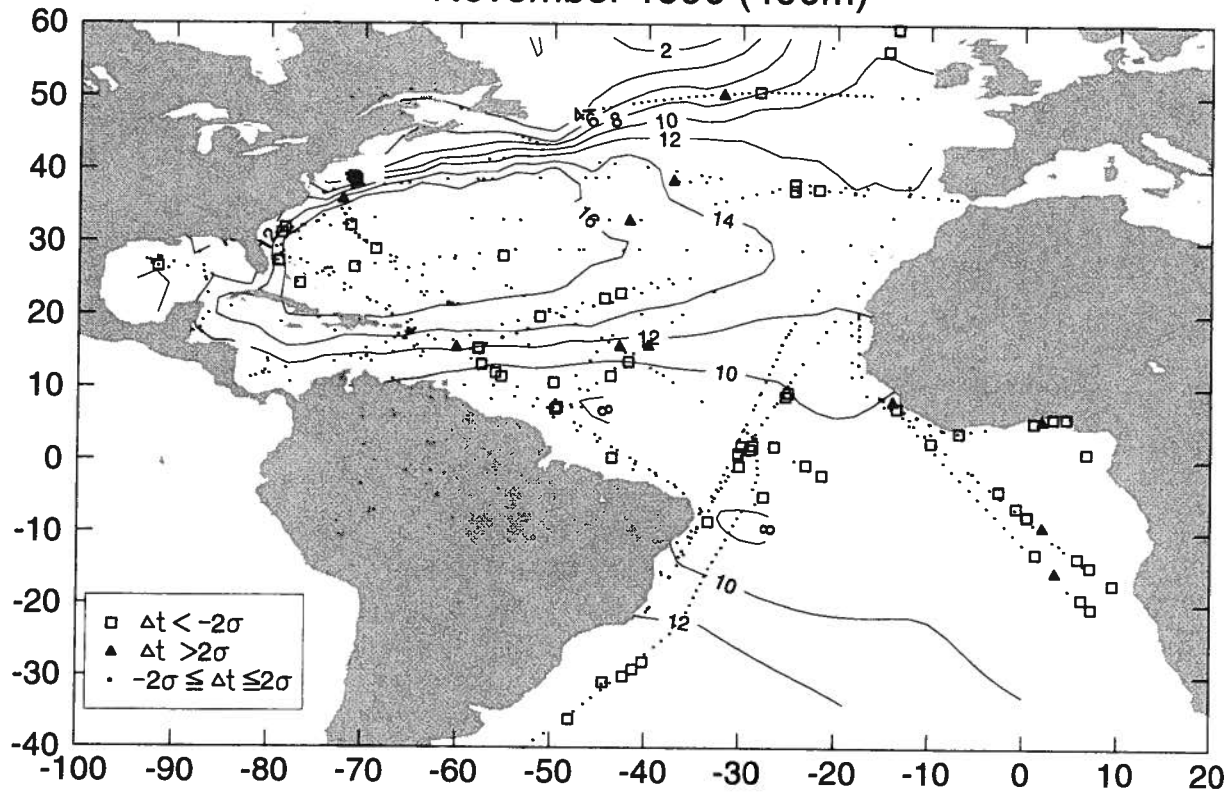
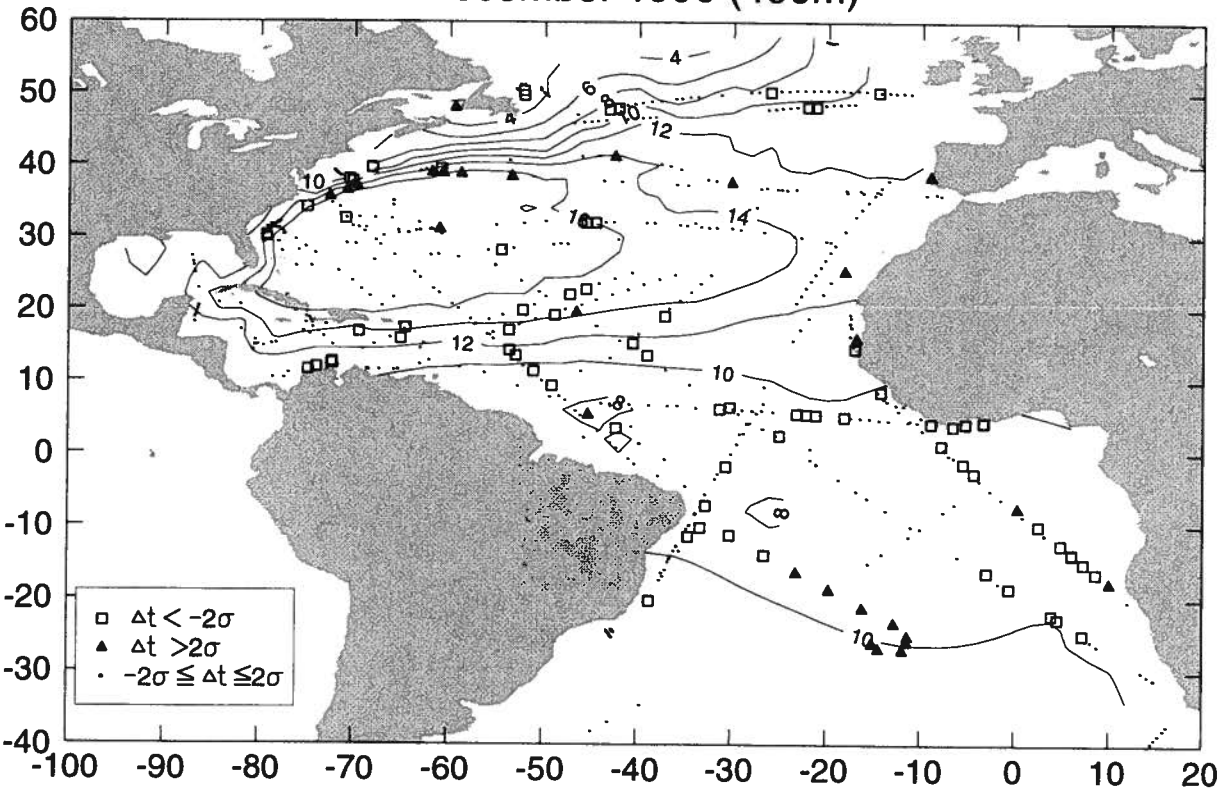
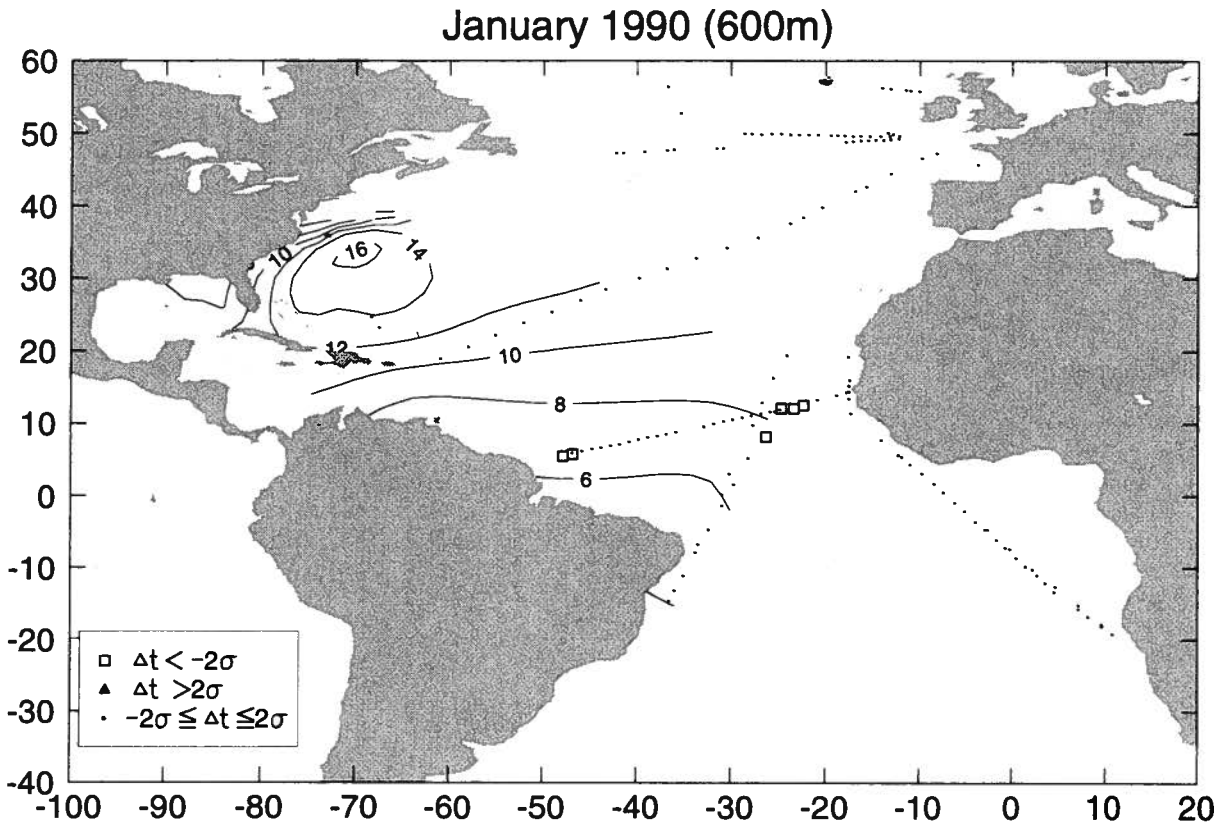
November 1990 (400m)



December 1990 (400m)




January 1990 (600m)
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Δt < -2σ
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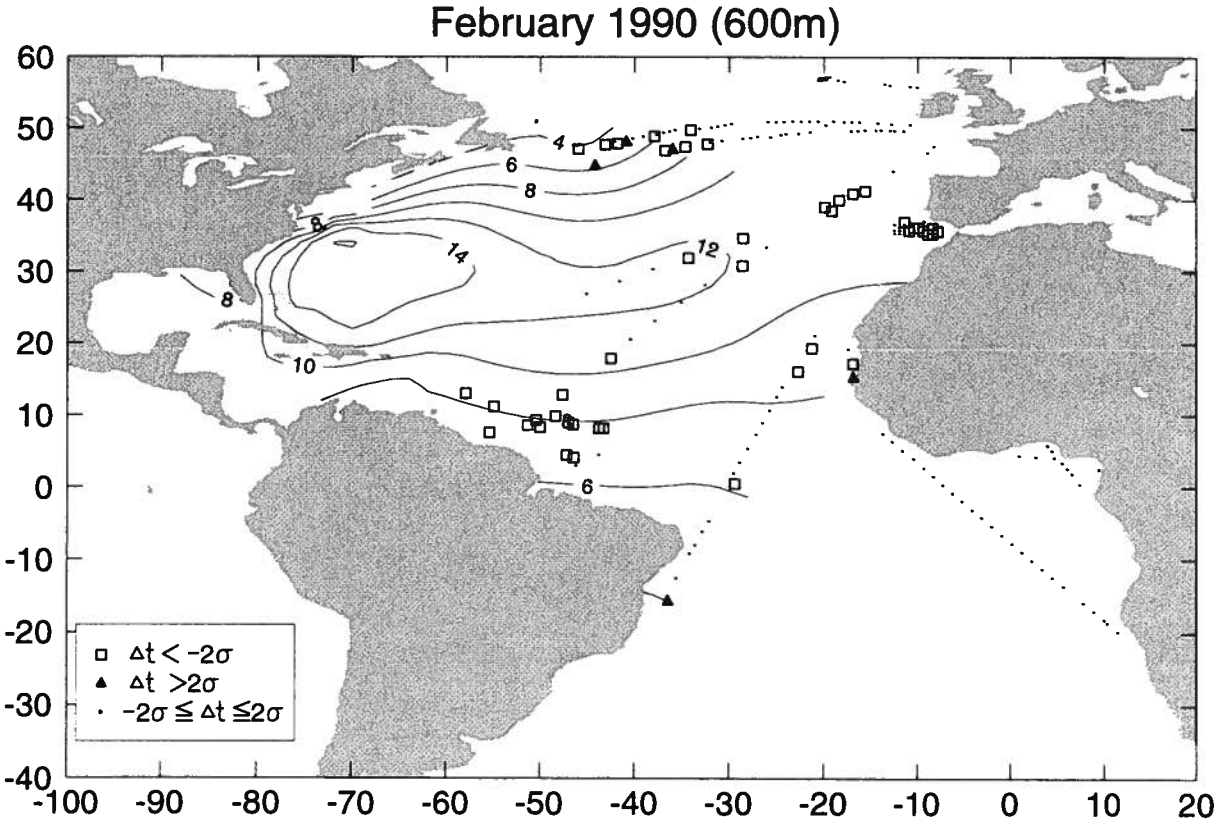
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Δt < -2σ
Δt >2σ
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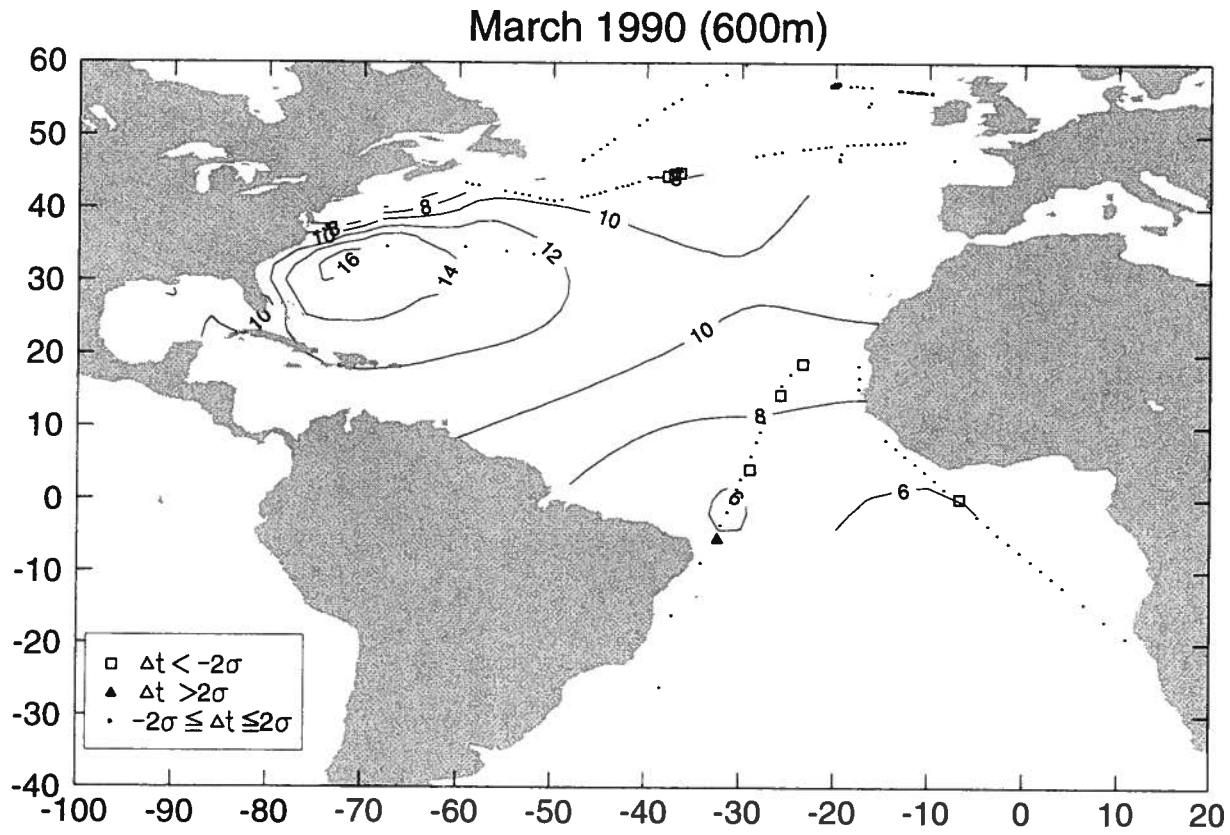
March 1990 (600m)
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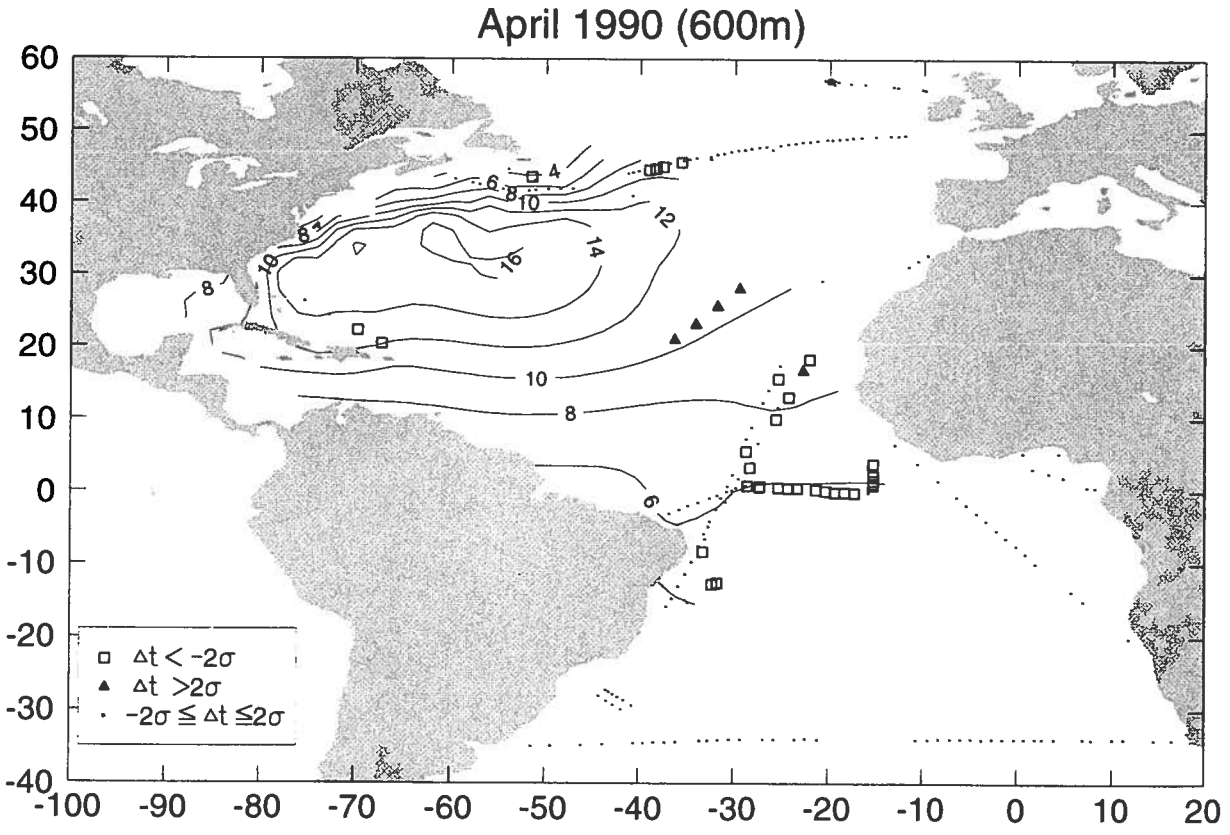
April 1990 (600m)
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Δt < -2σ
Δt >2σ
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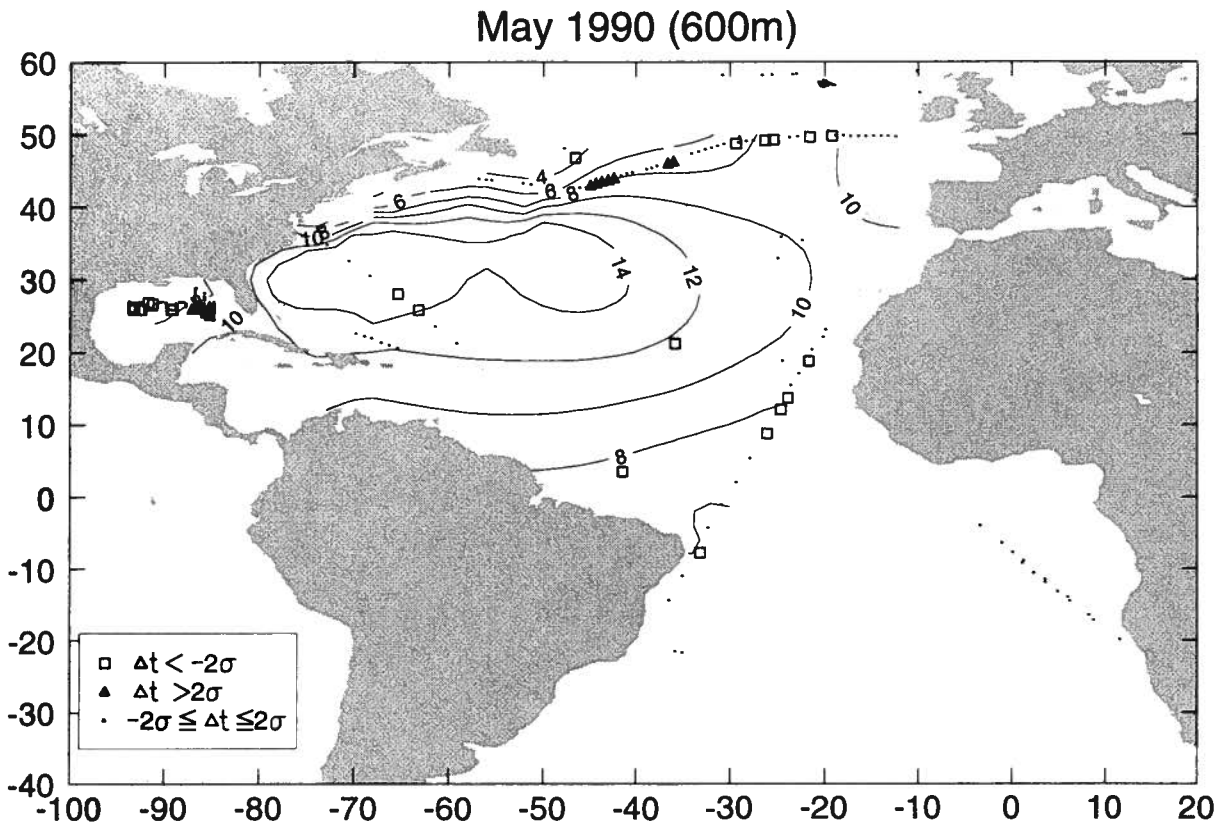
May 1990 (600m)
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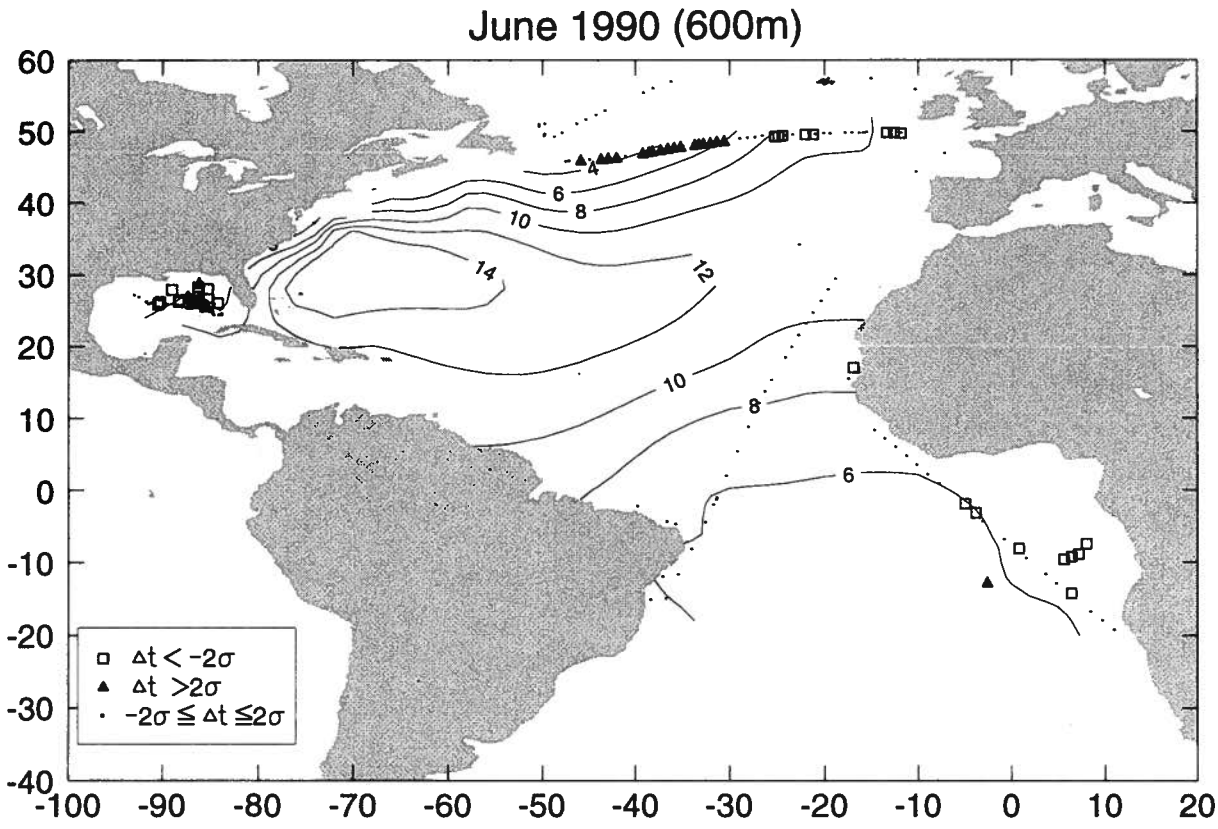
June 1990 (600m)
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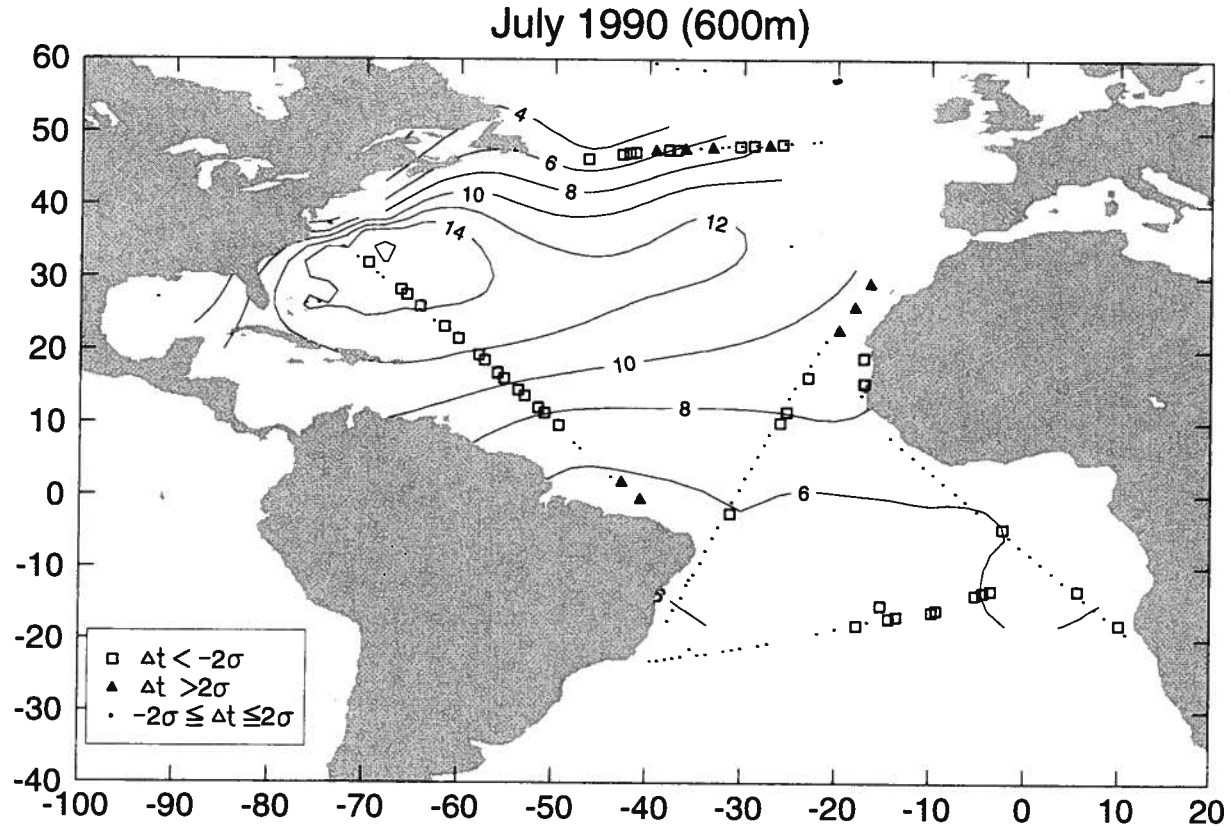
Δt >2σ
-2σ ≤ Δt ≤2σ


July 1990 (600m)
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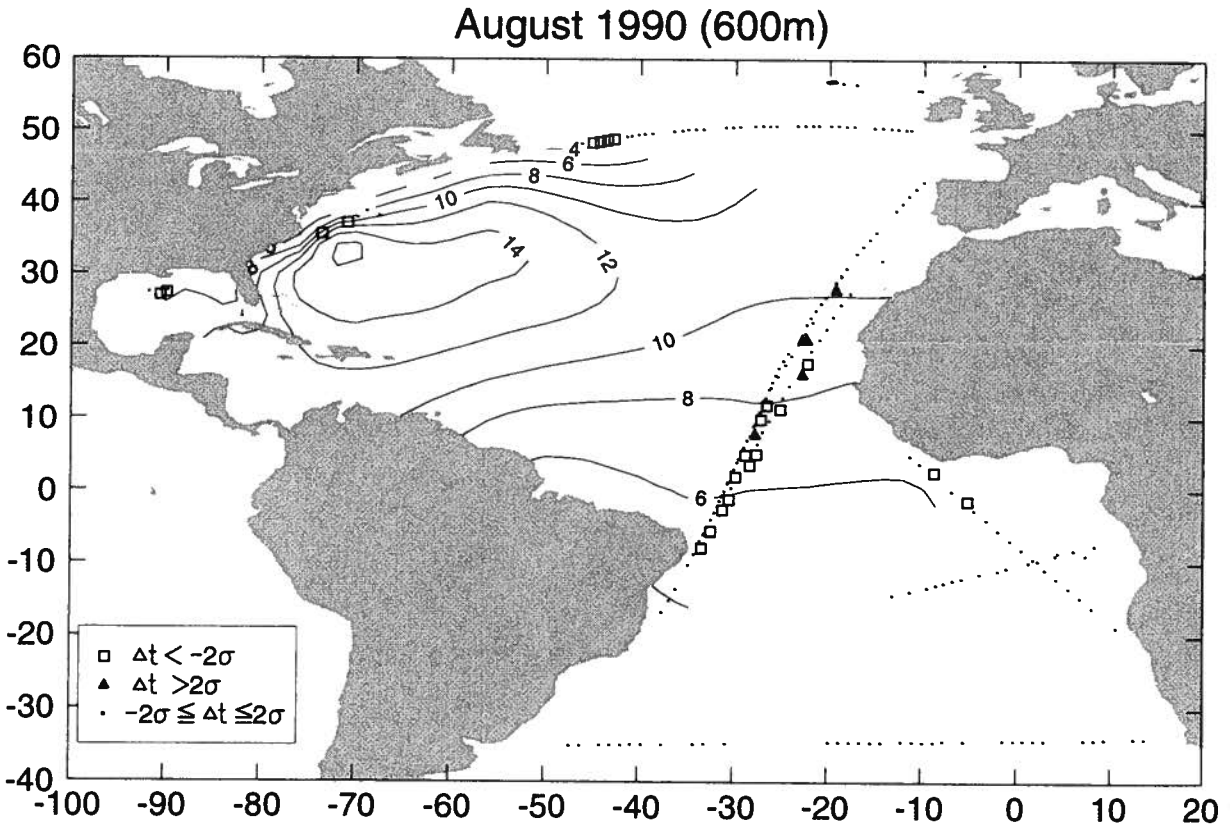
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ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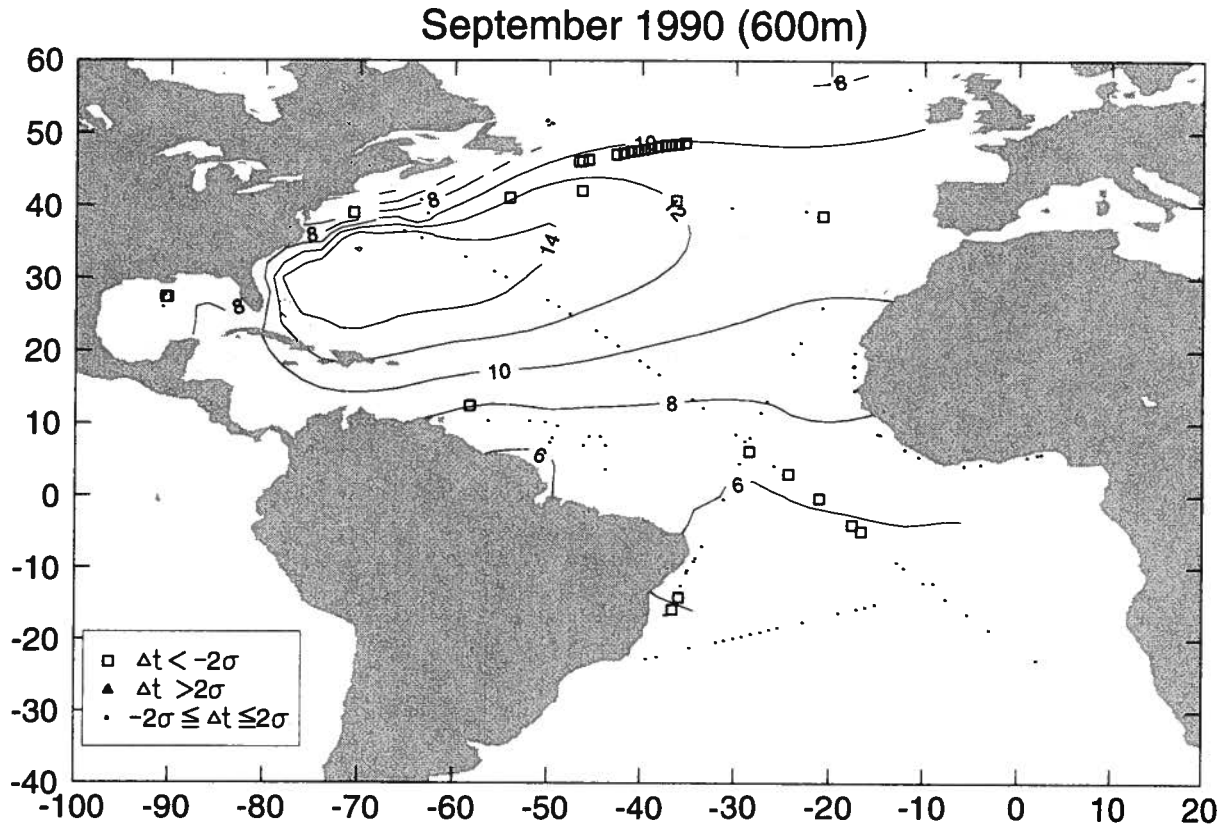
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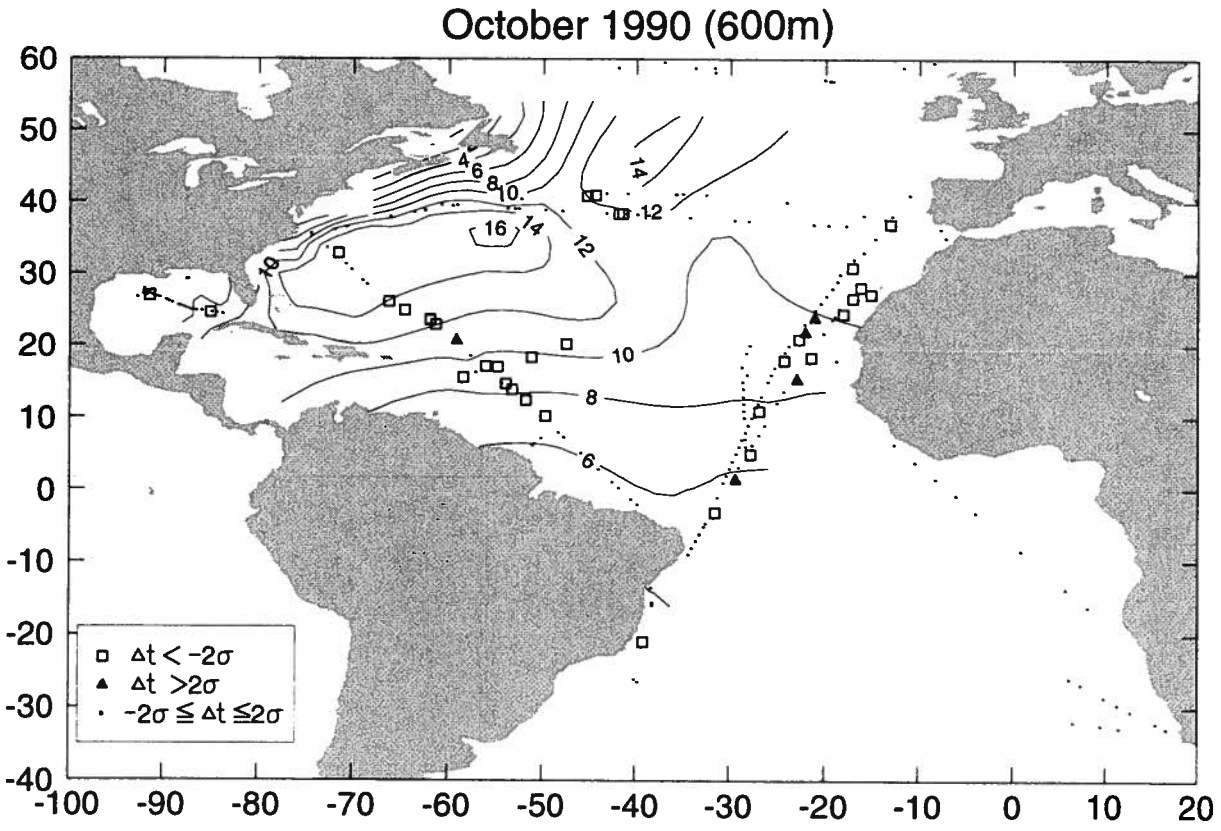
Δt >2σ
-2σ ≦ Δt ≦2σ


October 1990 (600m)
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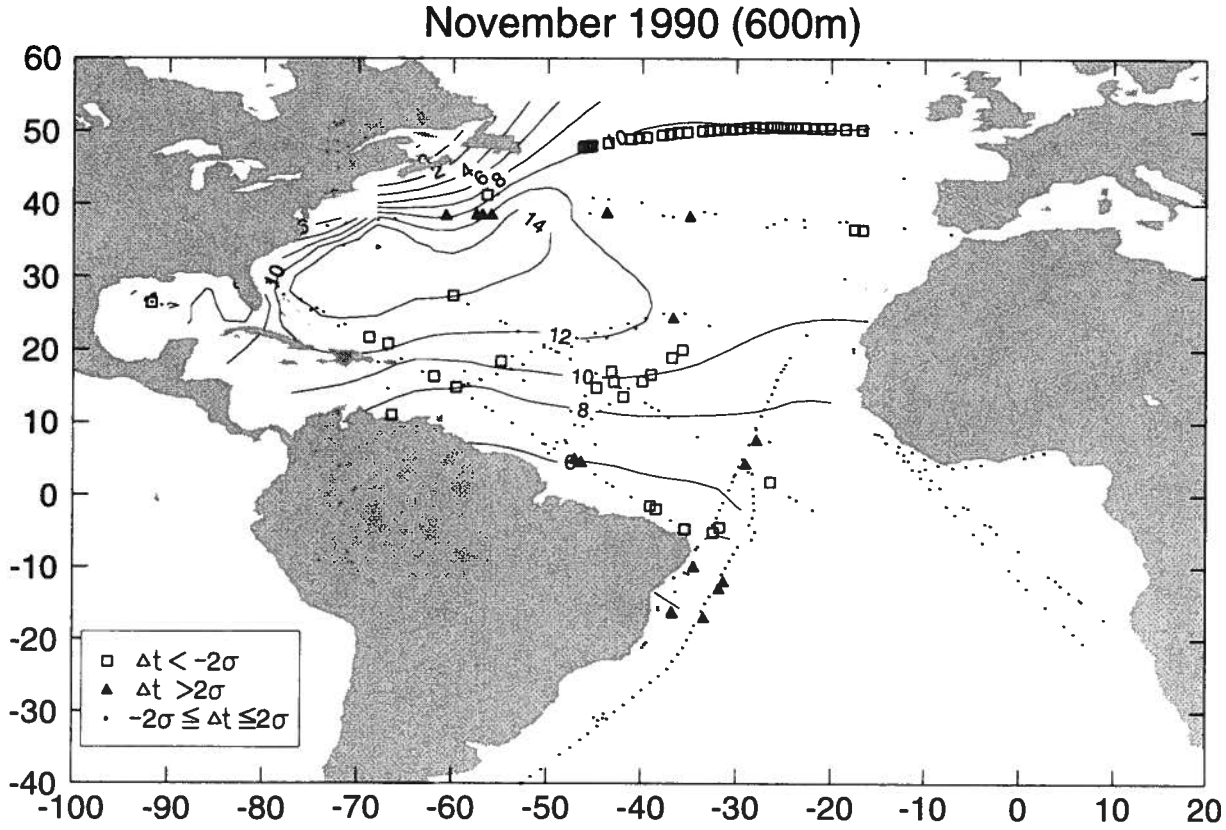
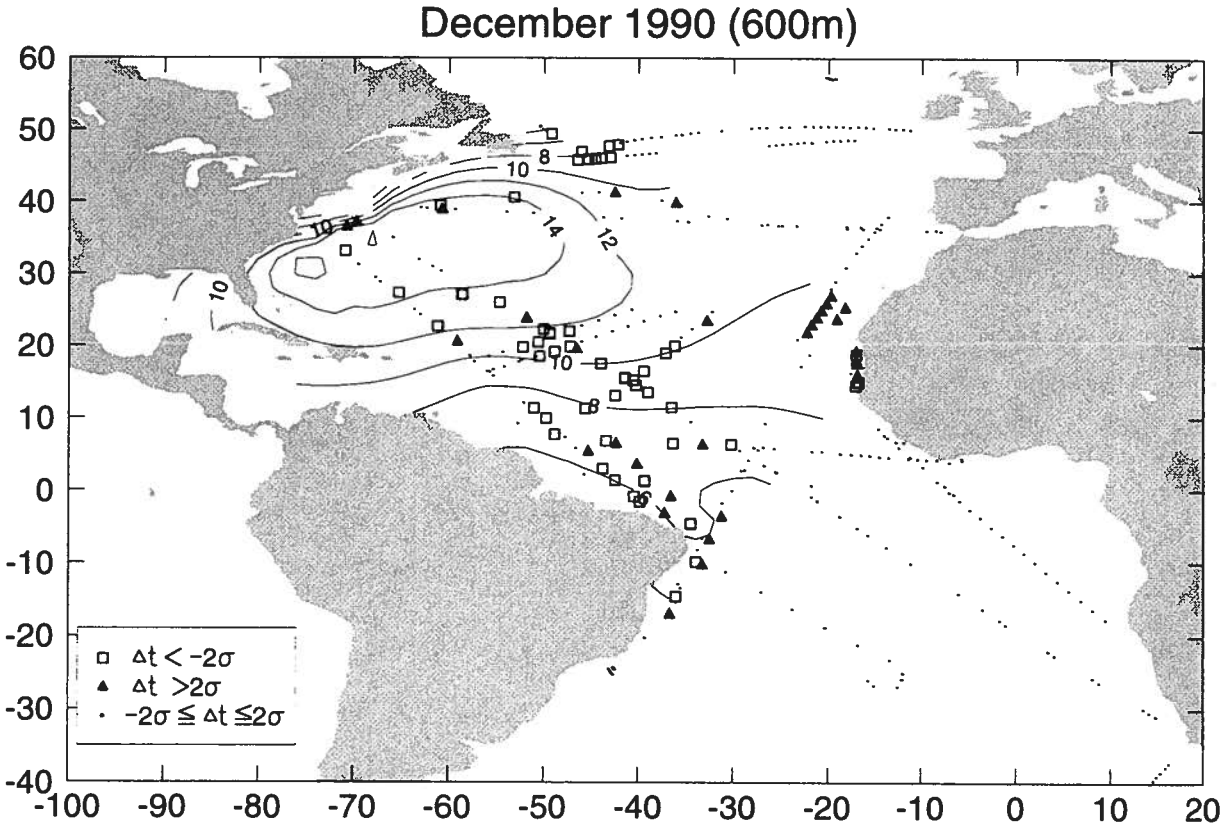
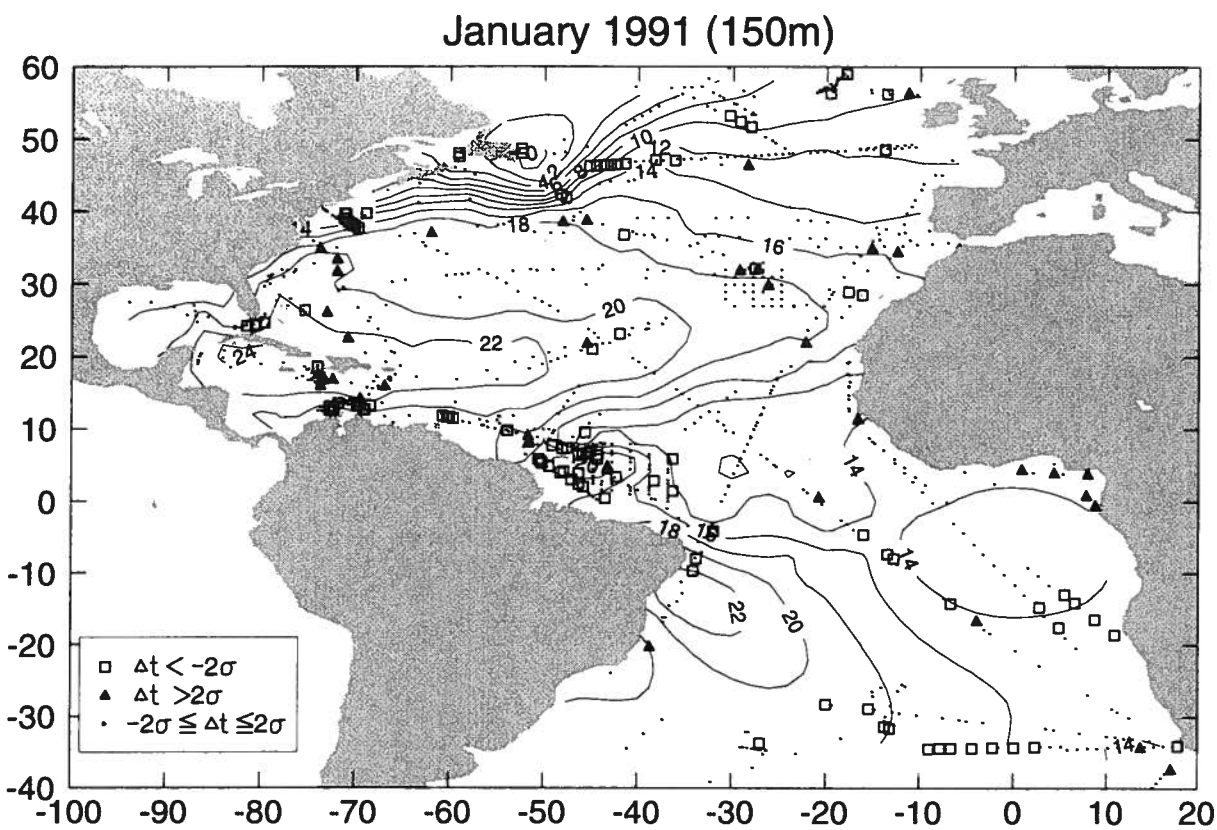
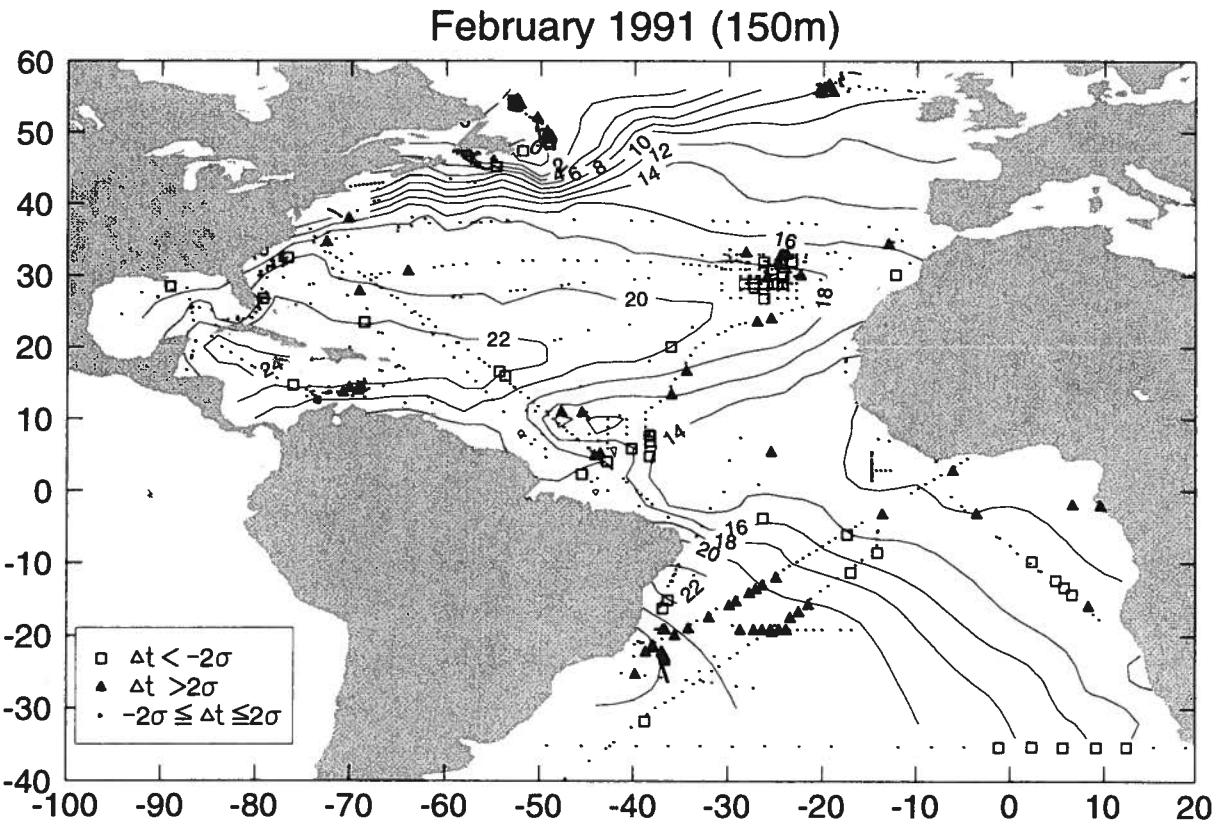
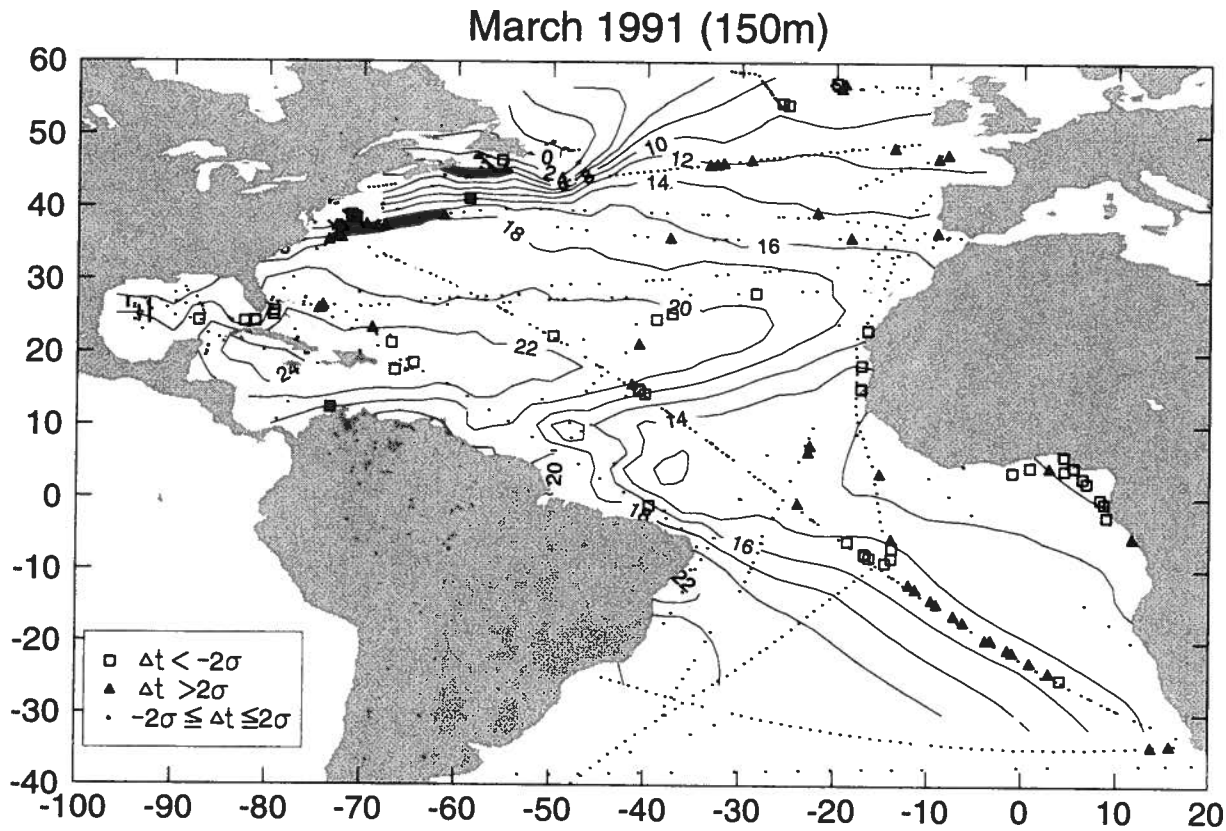
Δt >2σ
-2σ ≦ Δt ≦2σ


November 1990 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


December 1990 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


January 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≤ Δt ≤2σ


February 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≤ Δt ≤2σ


March 1991 (150m)
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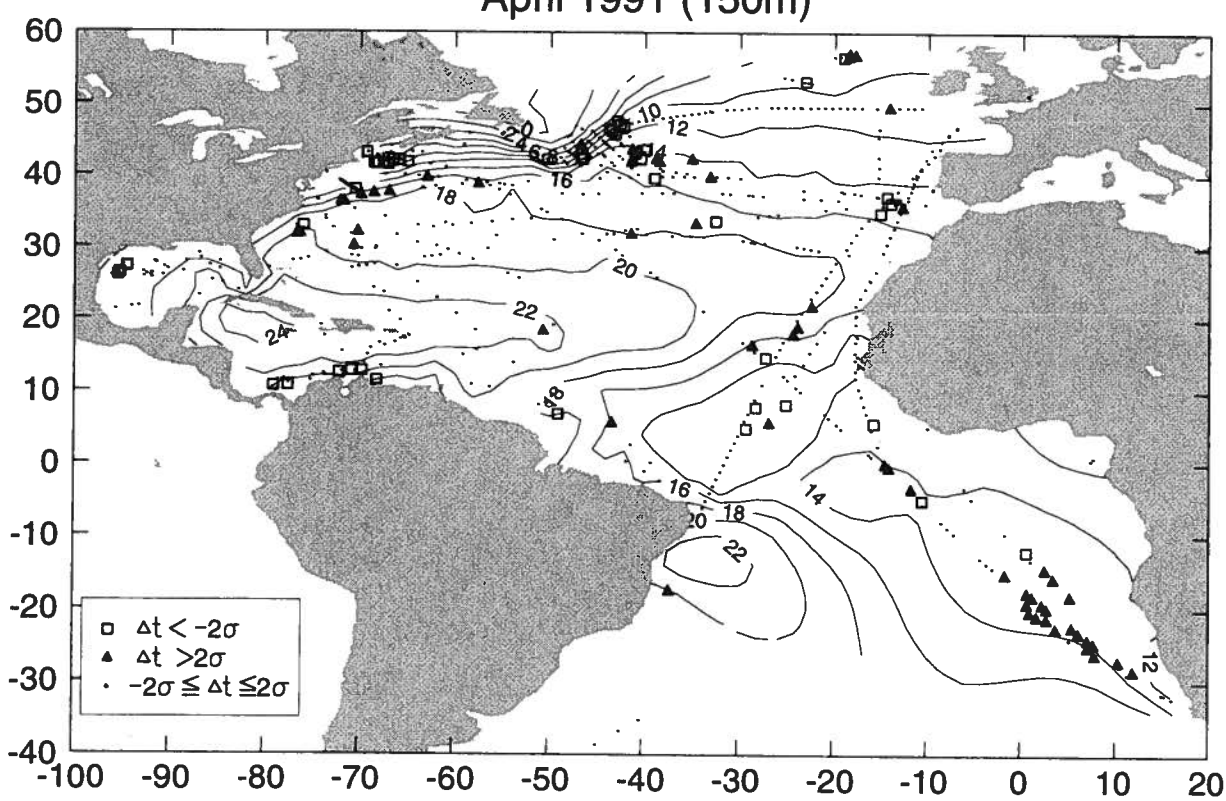
-2σ ≦ Δt ≦2σ


April 1991 (150m)
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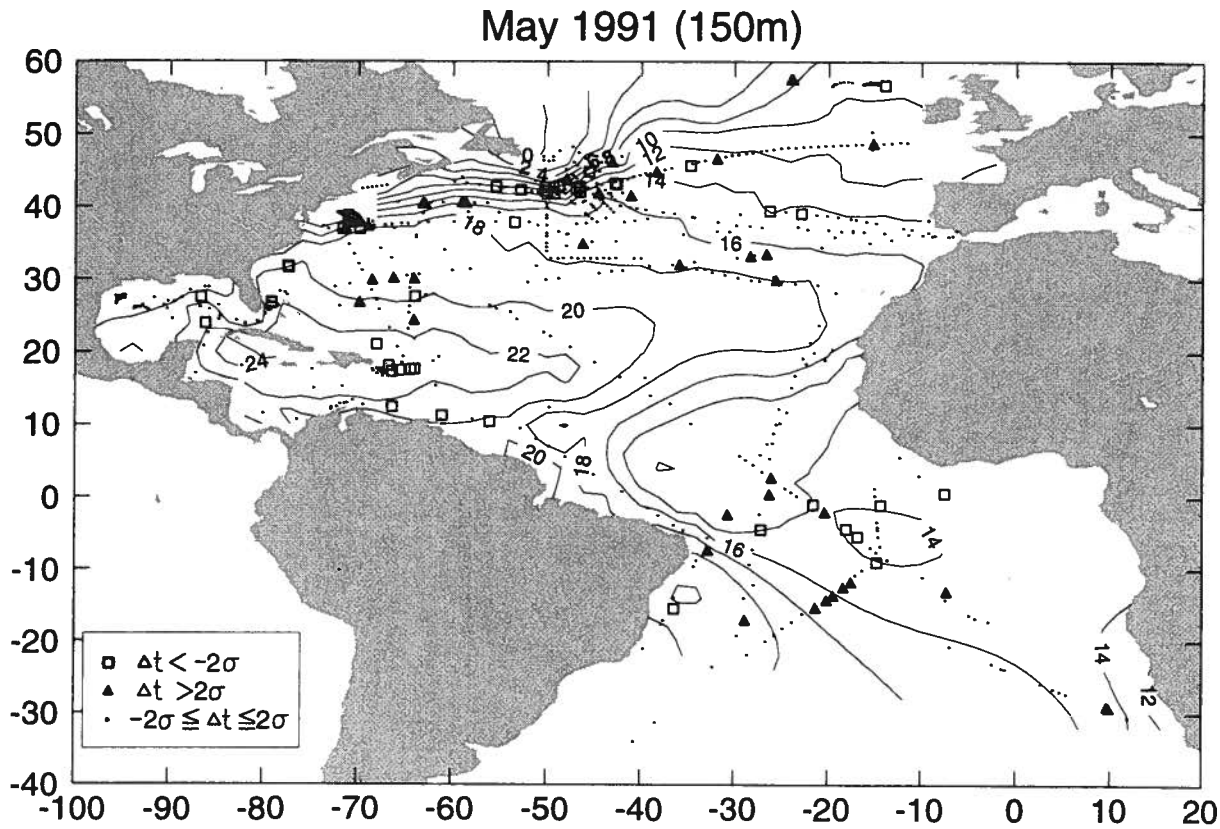
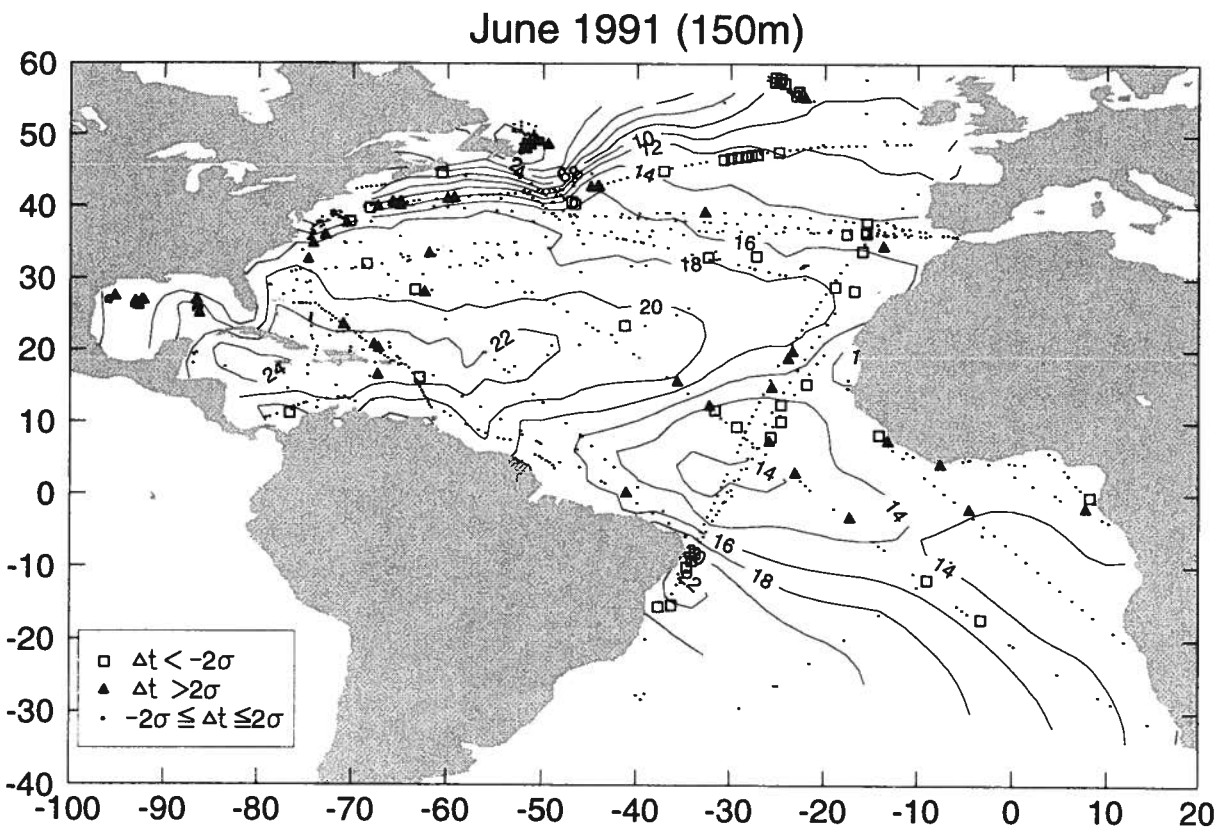
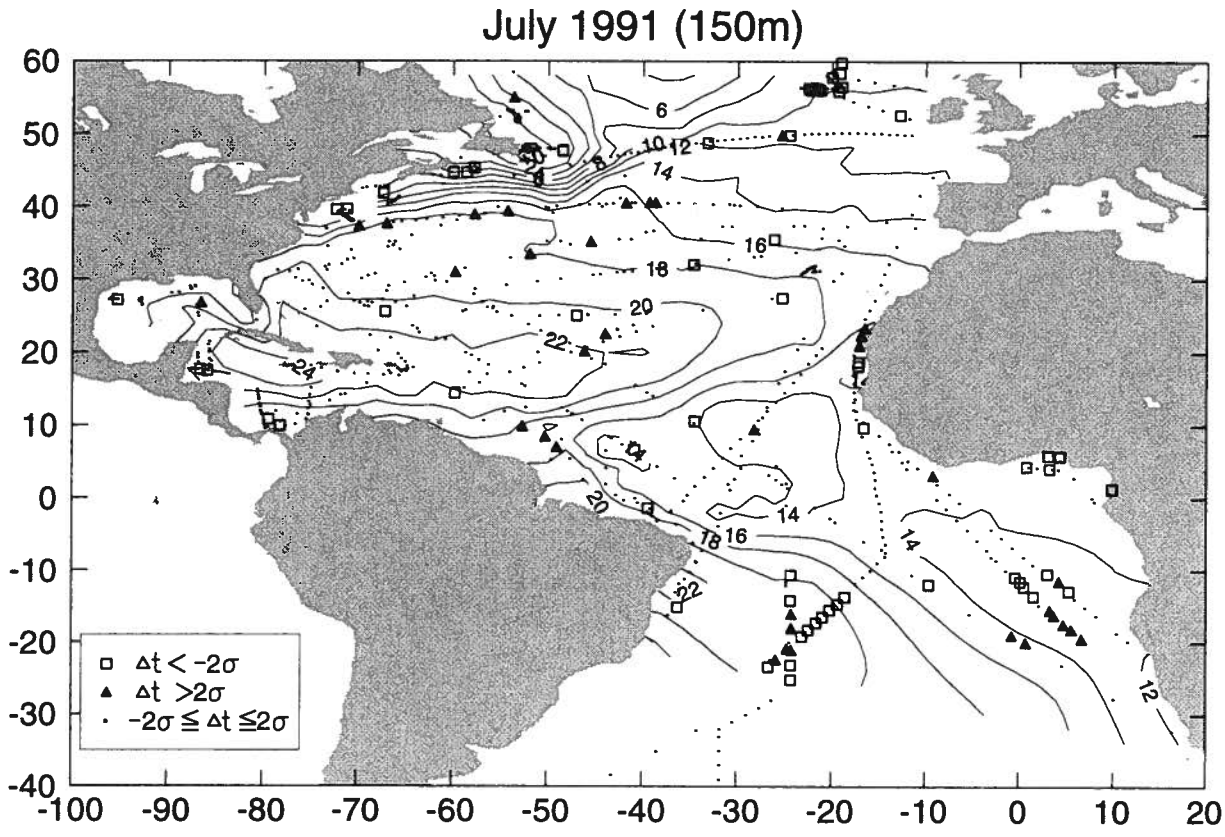

May 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


June 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


July 1991 (150m)
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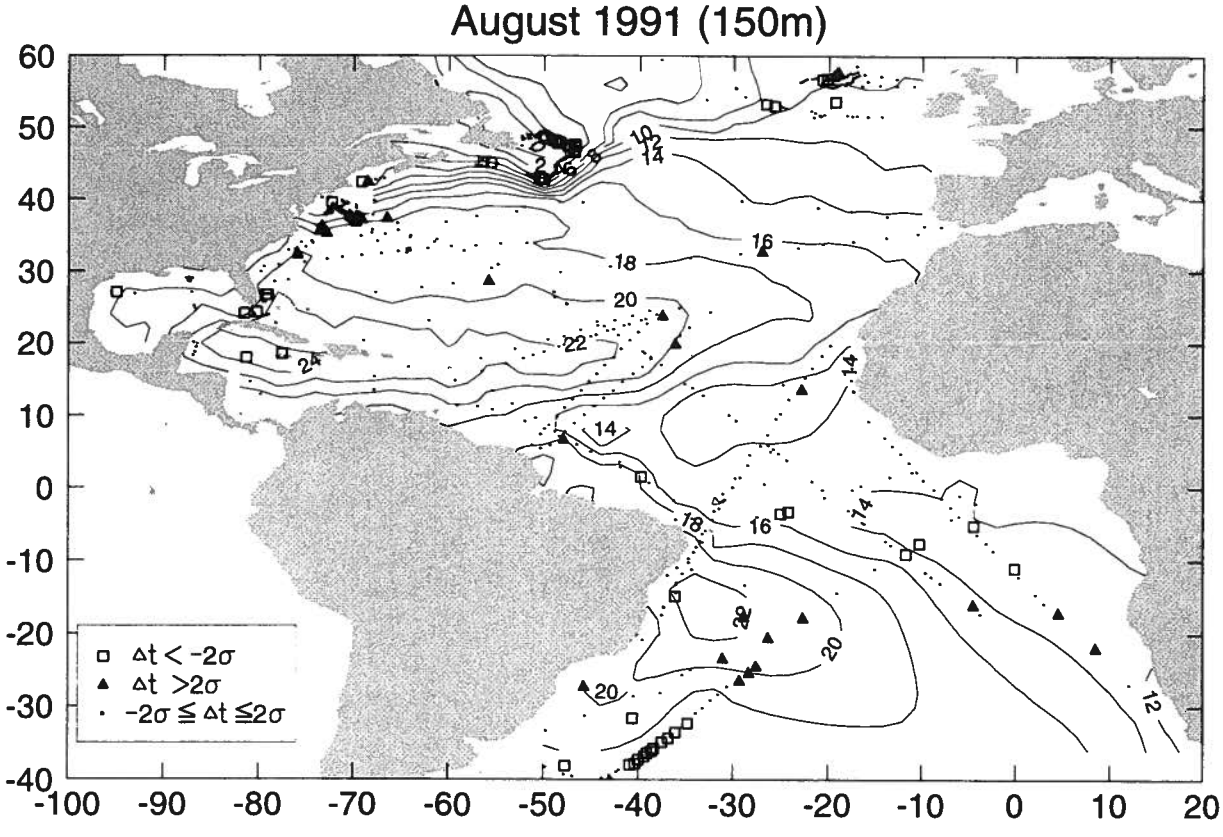
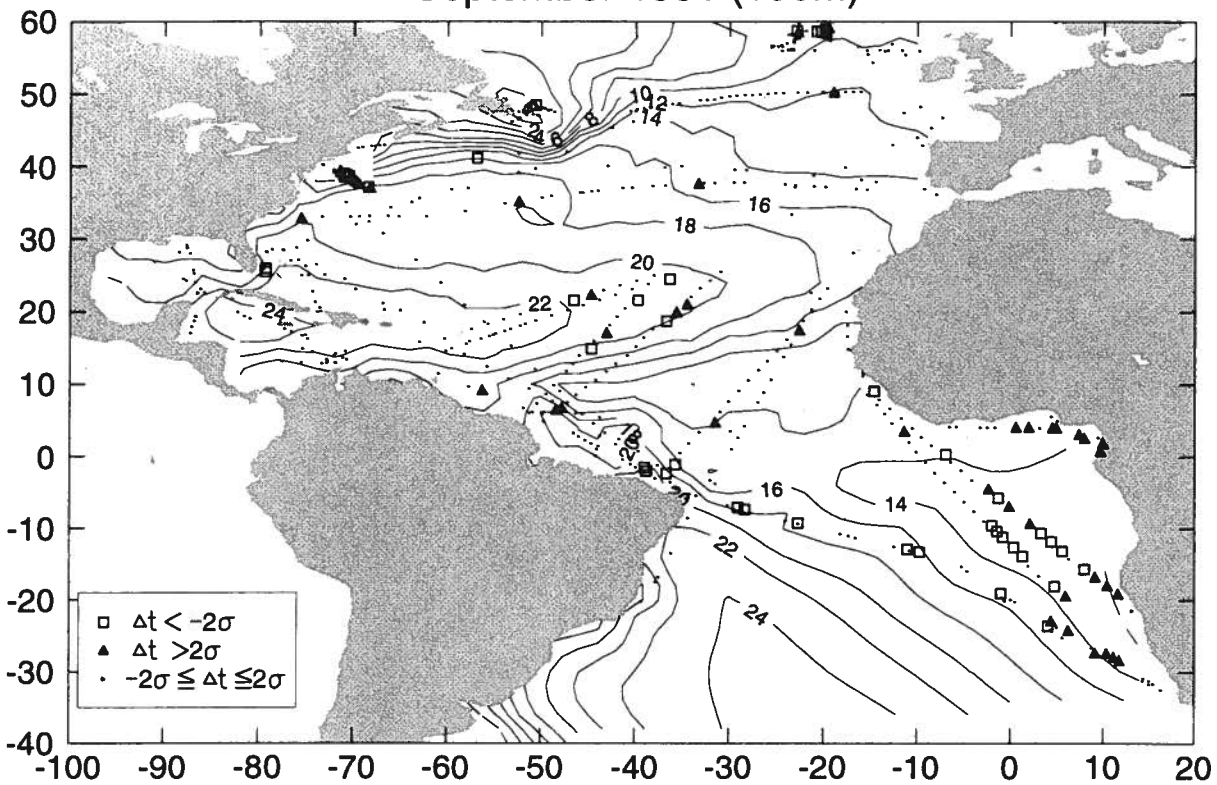
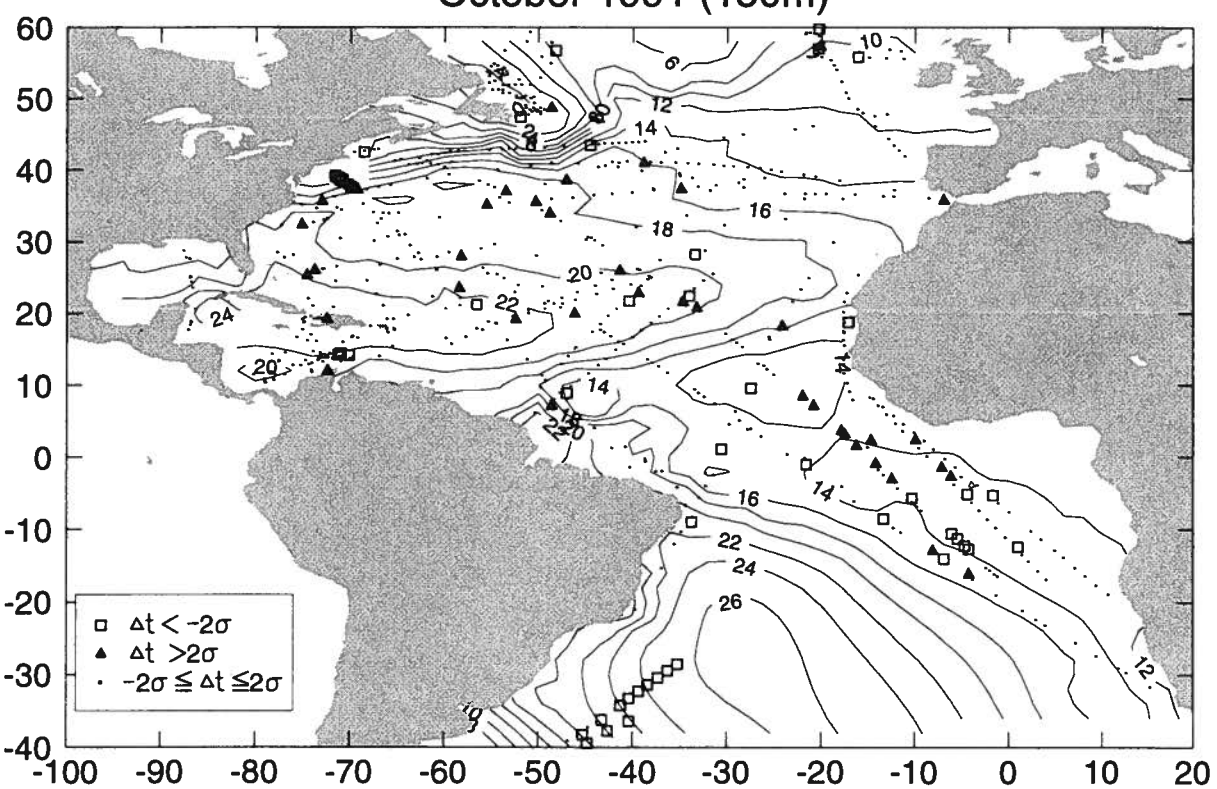
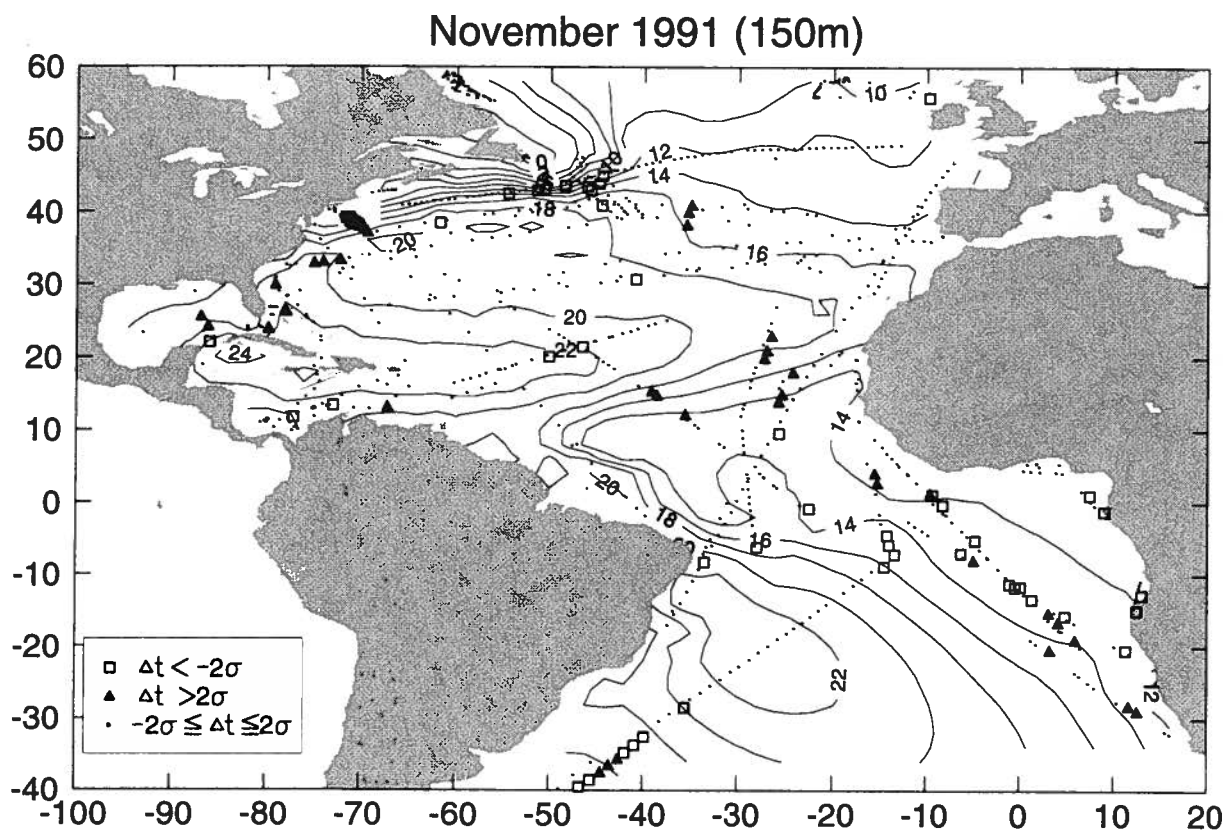
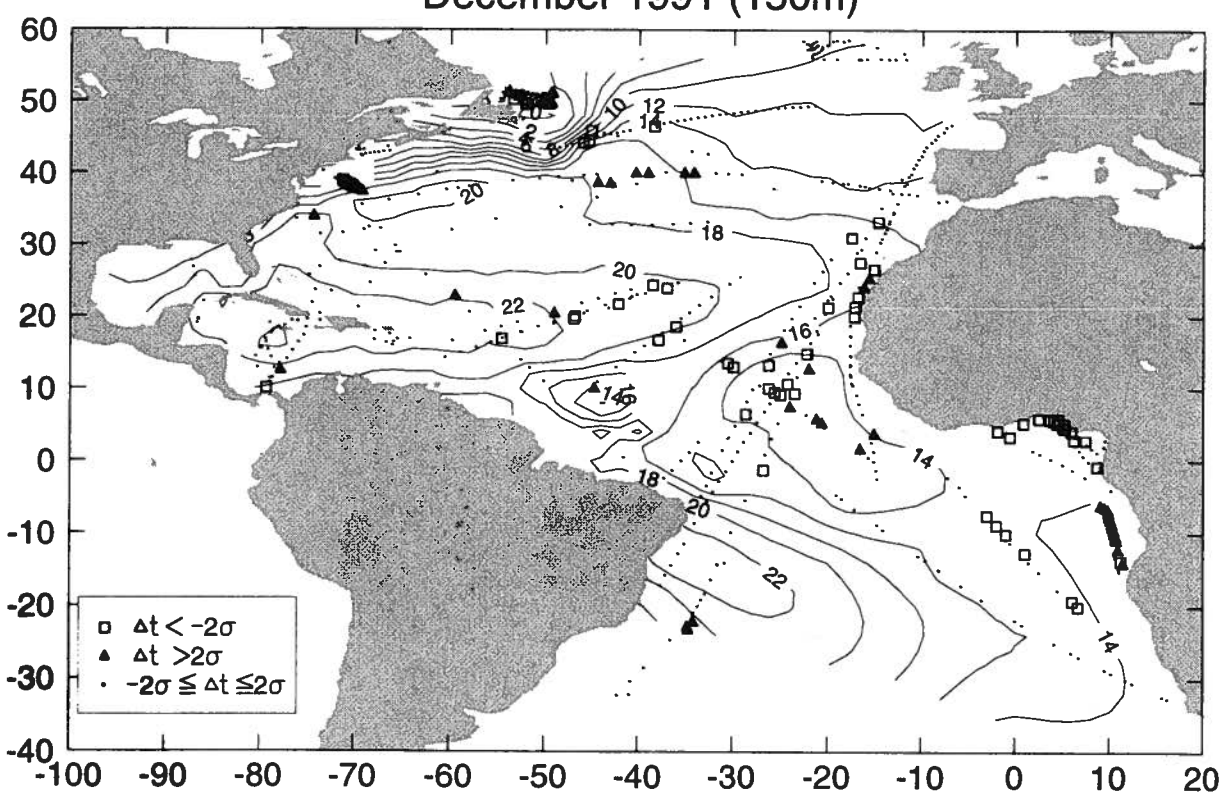
Δt >2σ
-2σ ≦ Δt ≦2σ

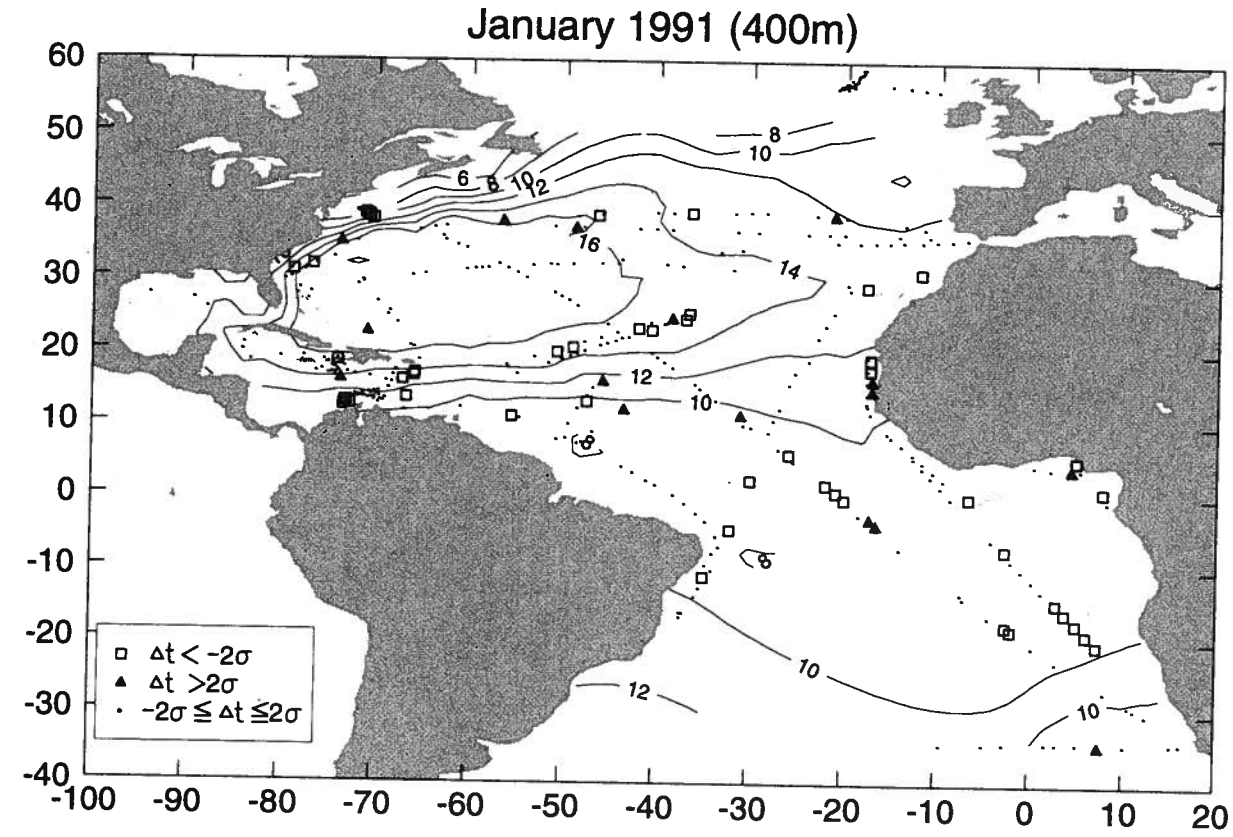

August 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

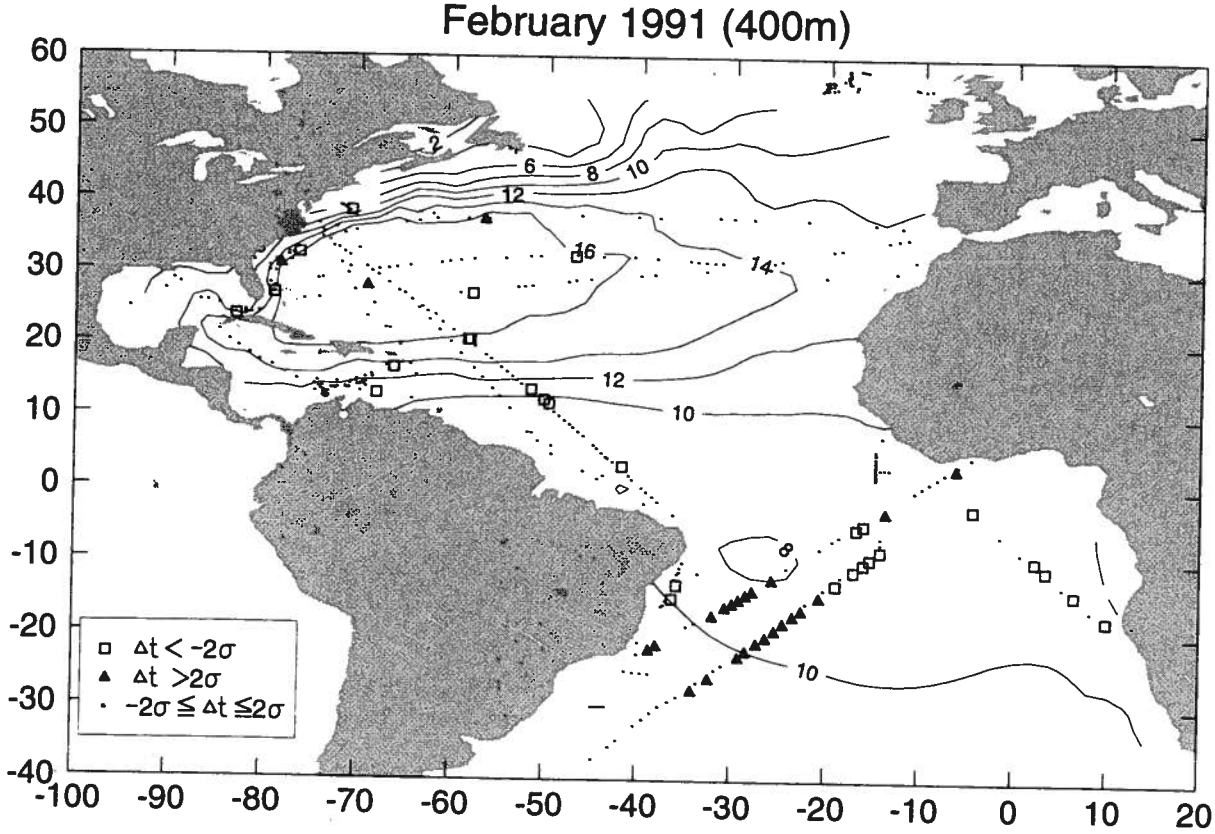

September 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

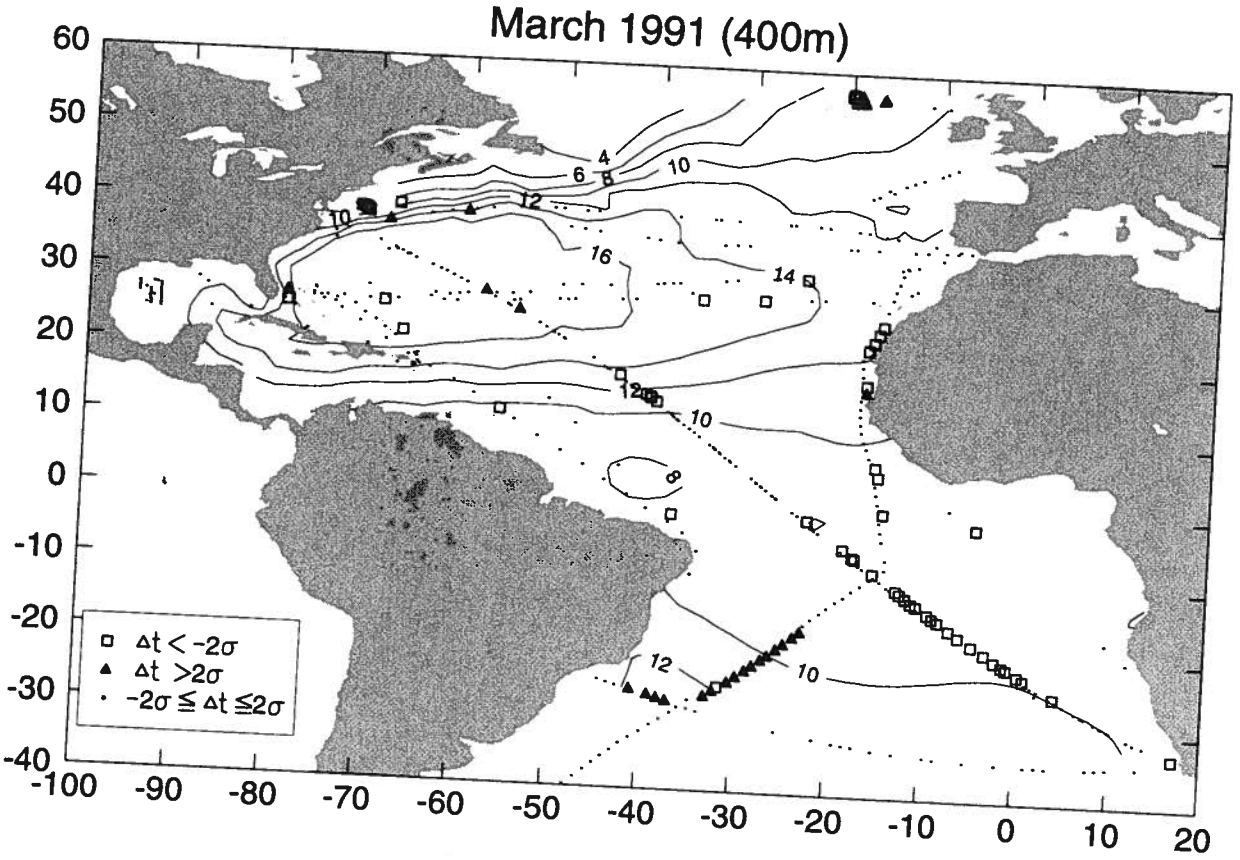

October 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

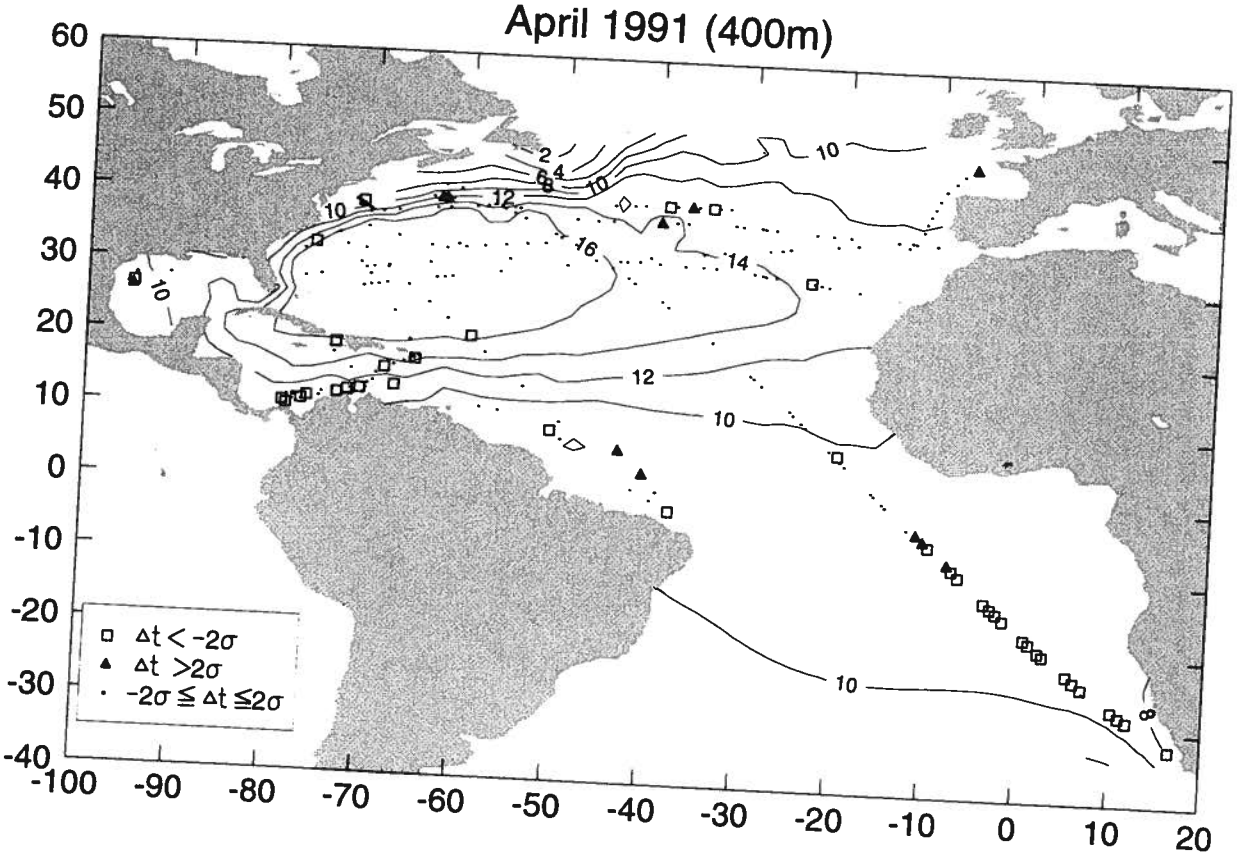

November 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


December 1991 (150m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

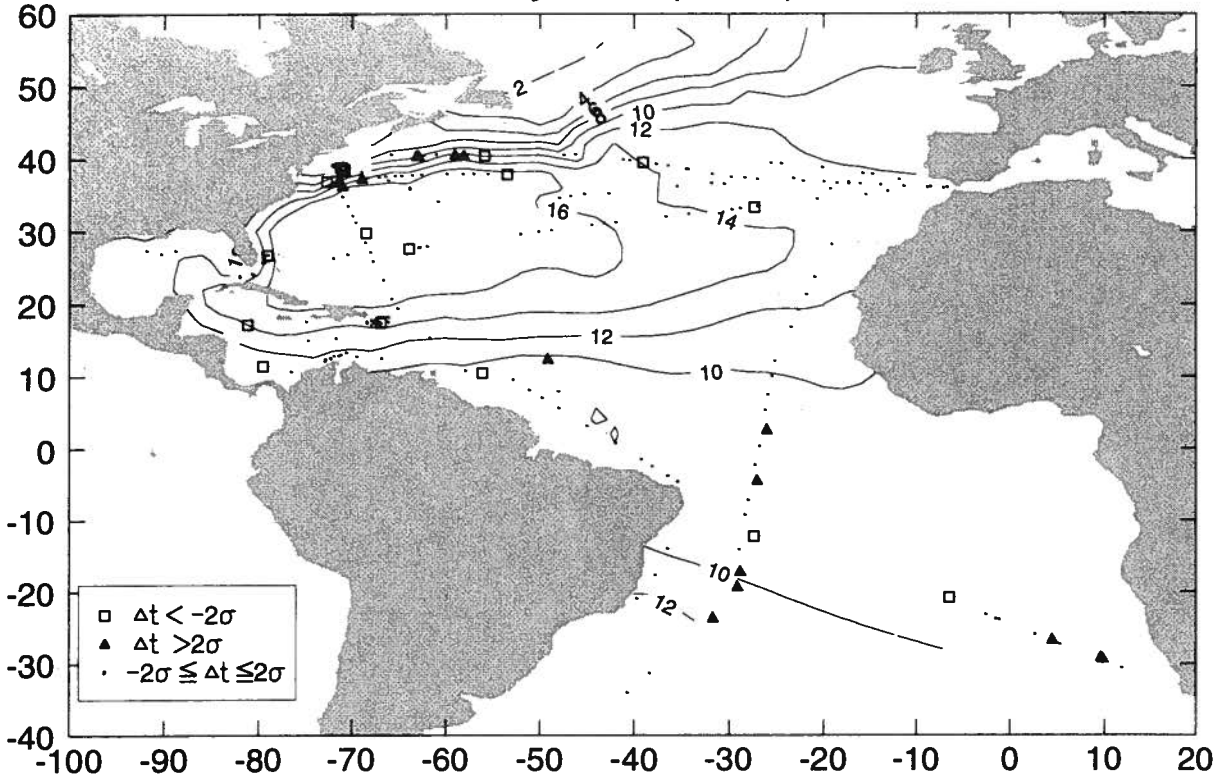

January 1991 (400m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


February 1991 (400m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

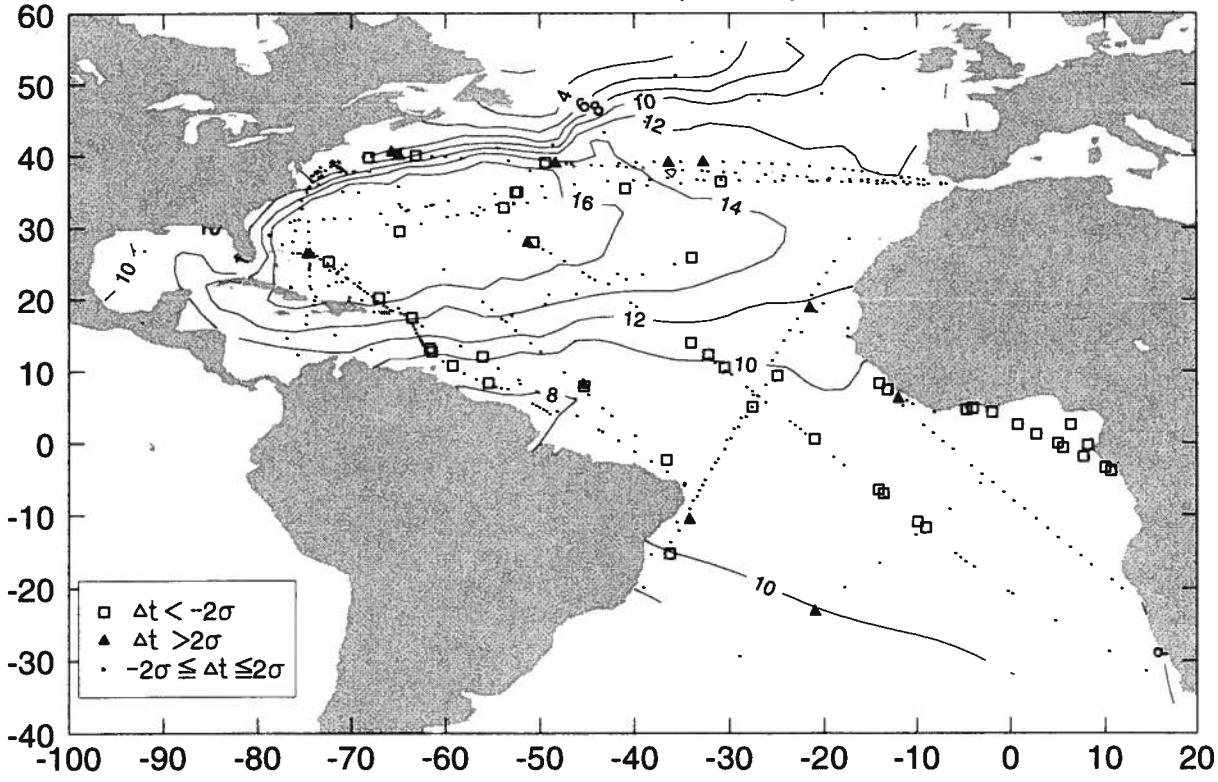

March 1991 (400m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


April 1991 (400m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

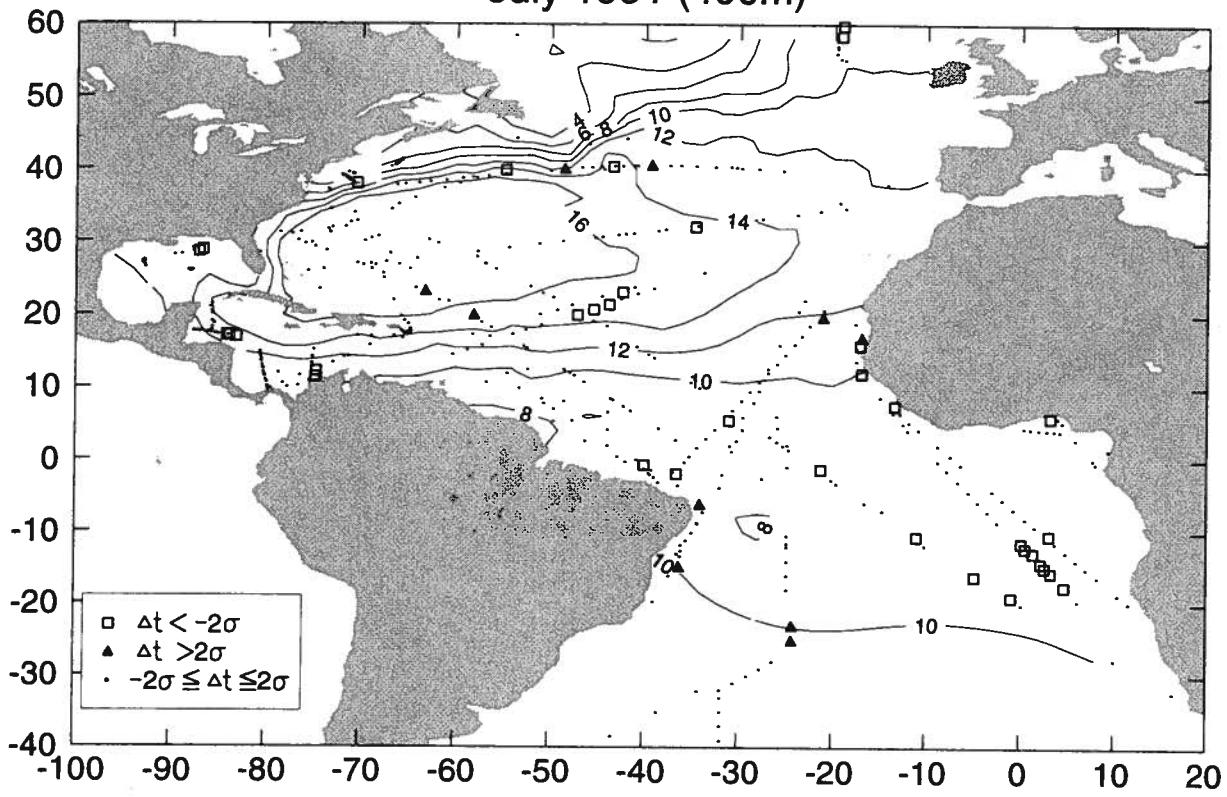
May 1991 (400m)



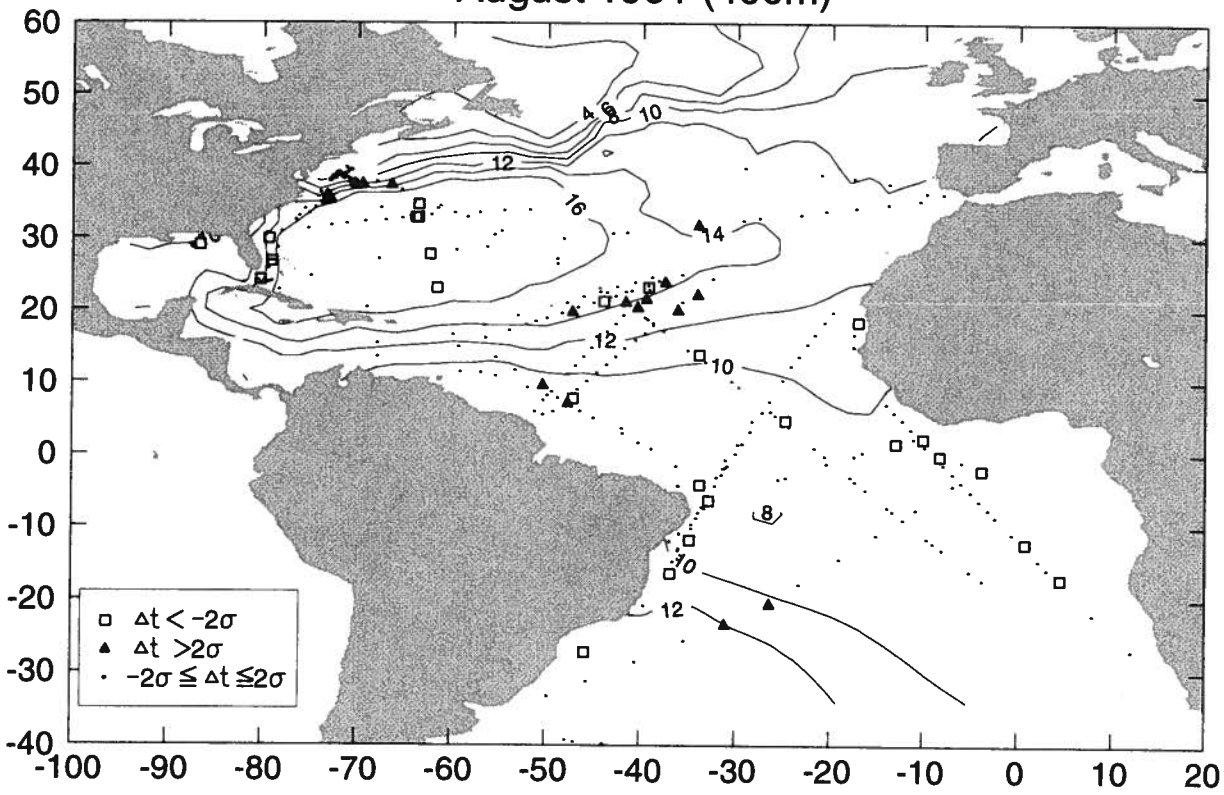
June 1991 (400m)

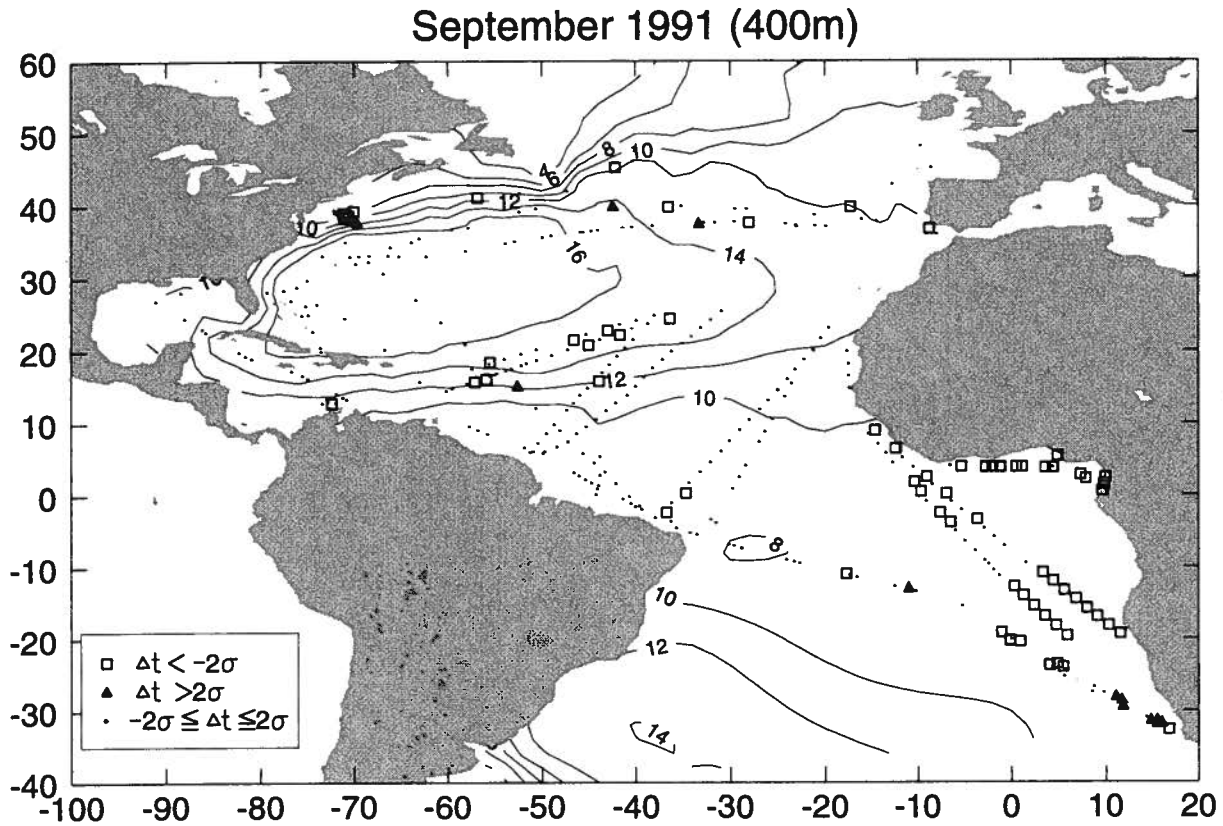


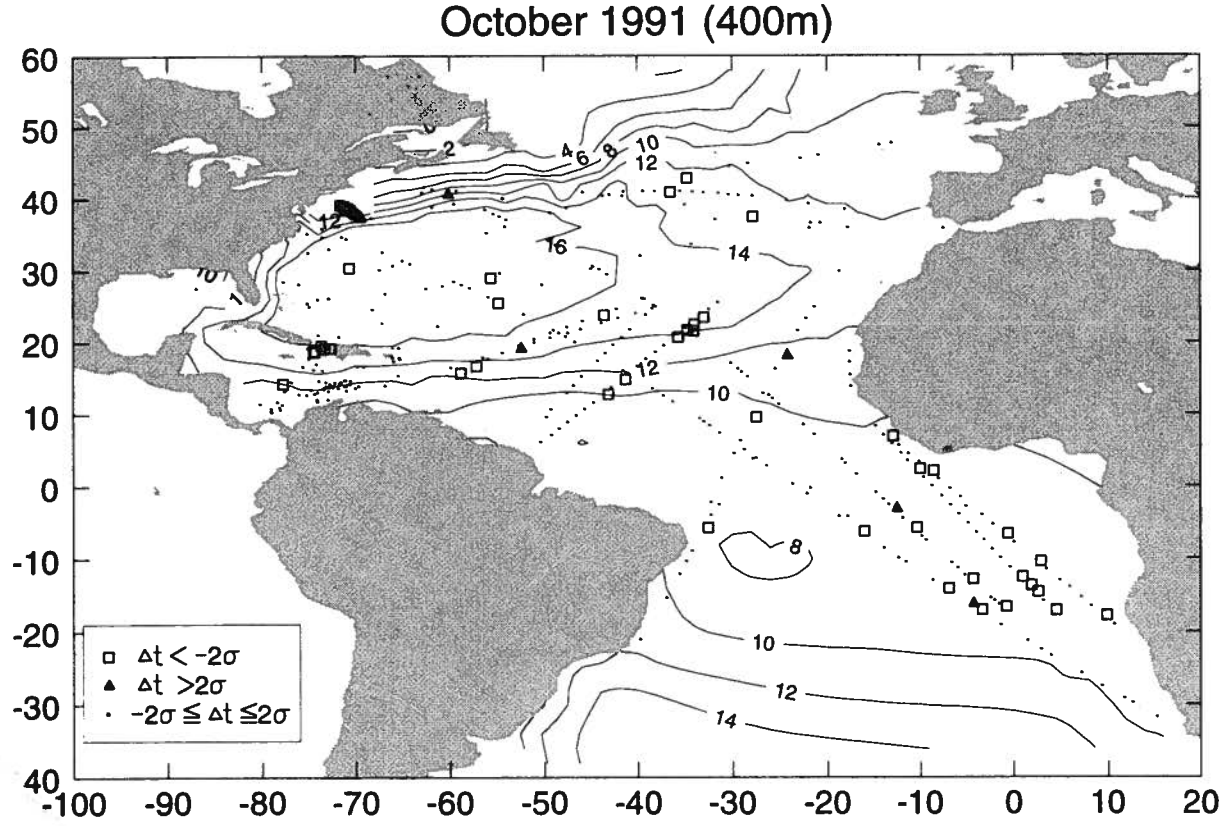
July 1991 (400m)

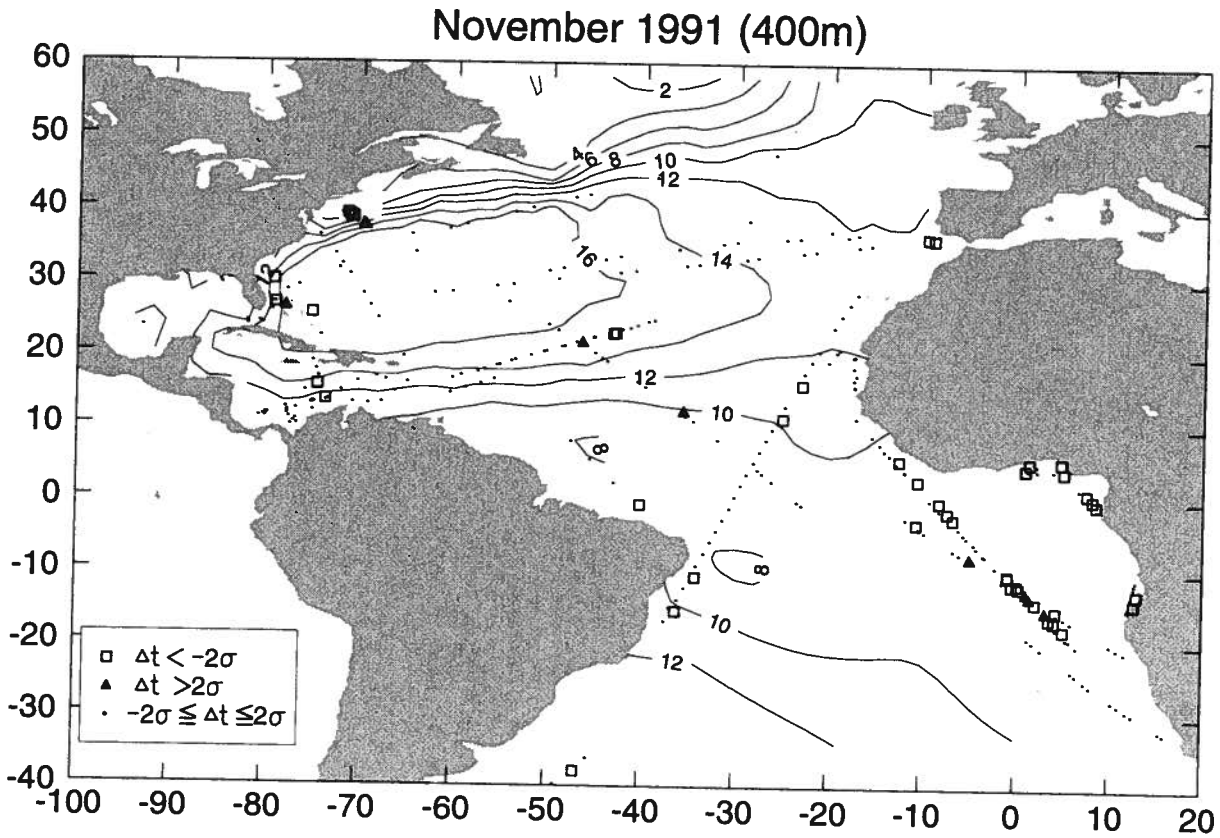


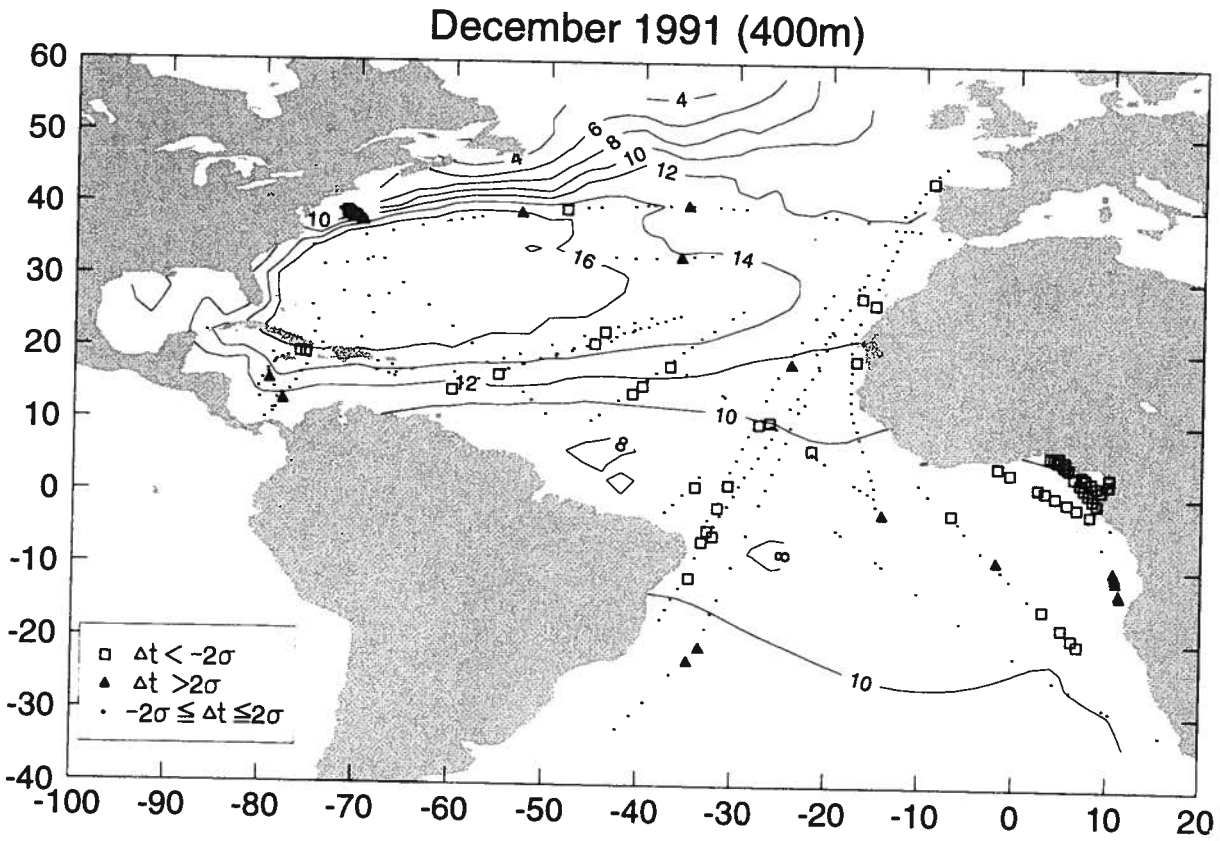
August 1991 (400m)

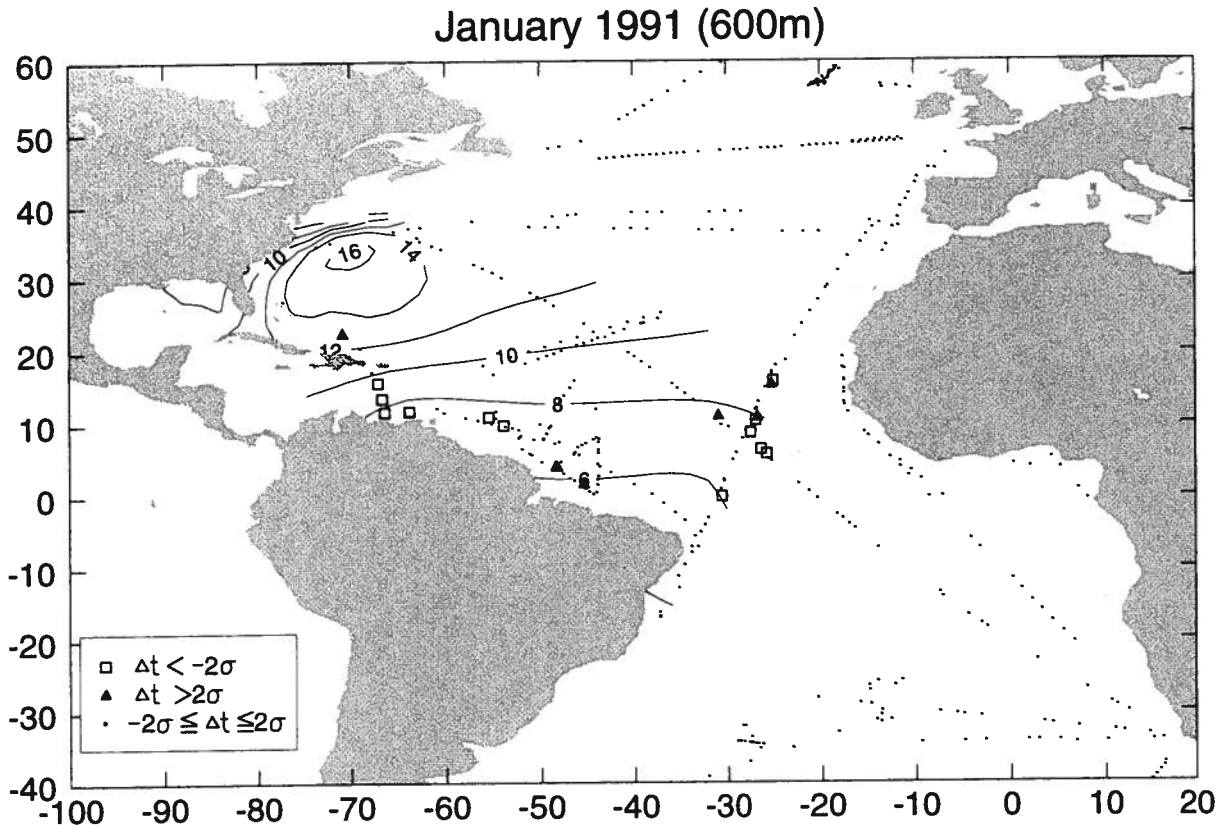


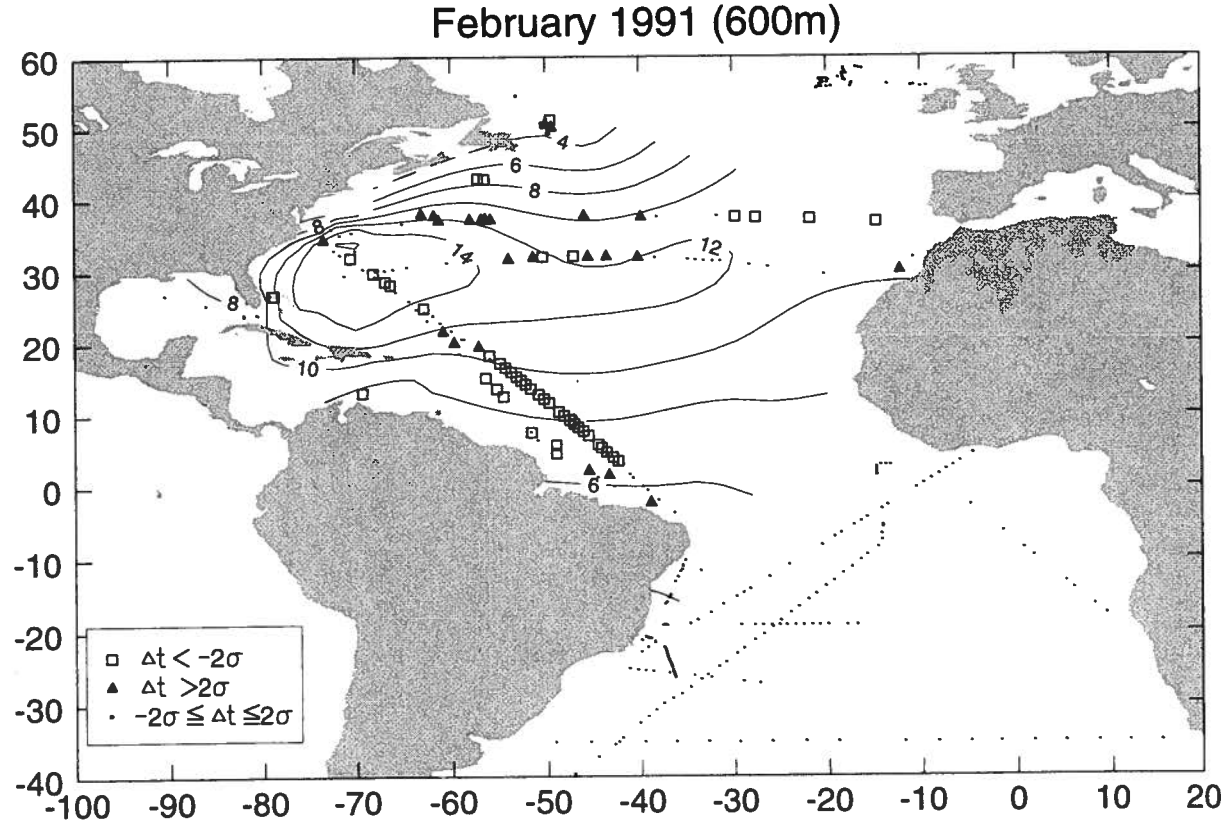

September 1991 (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


October 1991 (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

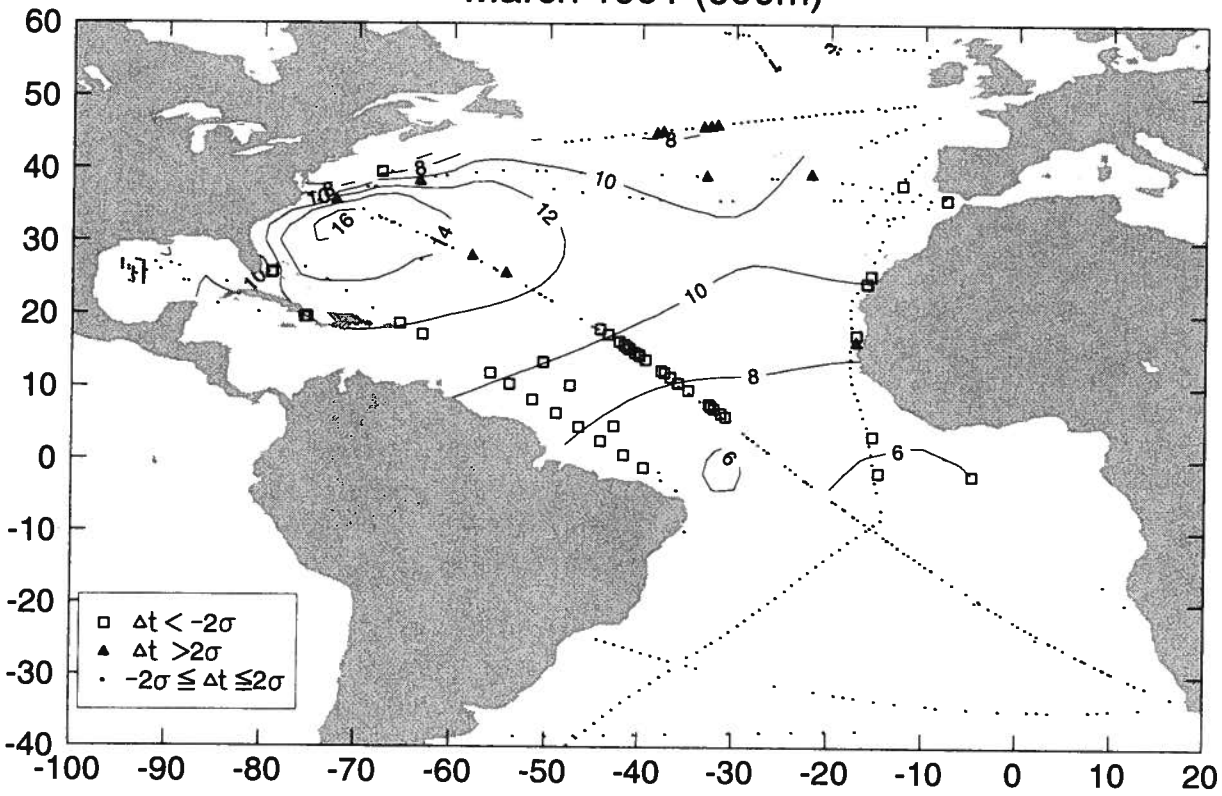

November 1991 (400m)
□ Δt < -2σ
▲ Δt >2σ
· -2σ ≦ Δt ≦2σ


December 1991 (400m)
□ Δt < -2σ
▲ Δt >2σ
· -2σ ≦ Δt ≦2σ

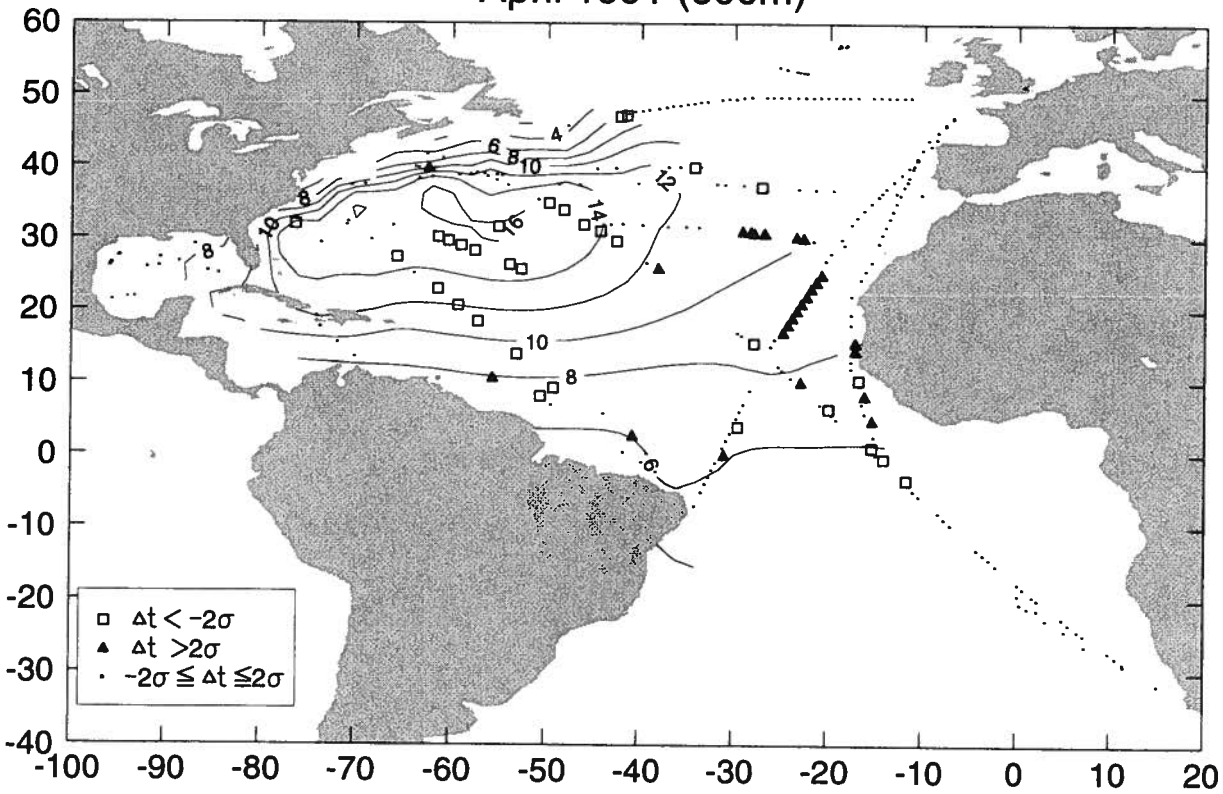

January 1991 (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
10
16
14
12
10
8
6
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


February 1991 (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
4
6
8
8
14
12
8
10
6
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

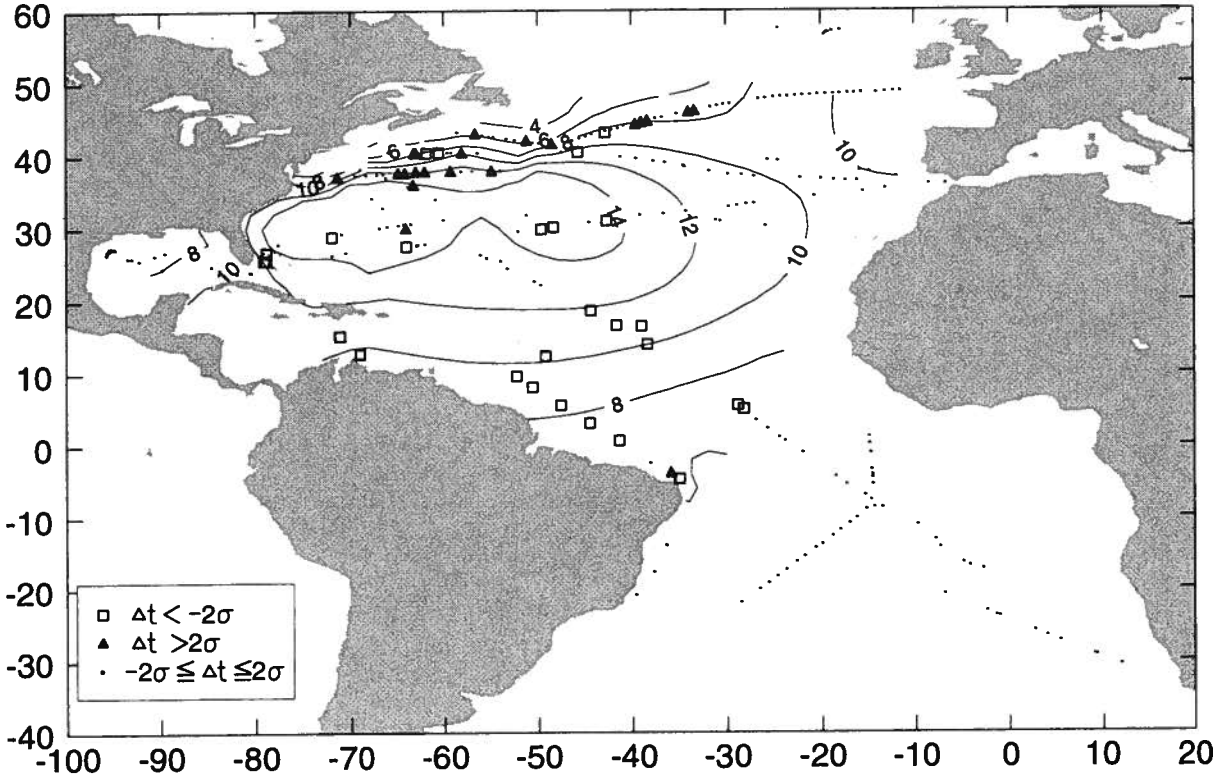
March 1991 (600m)



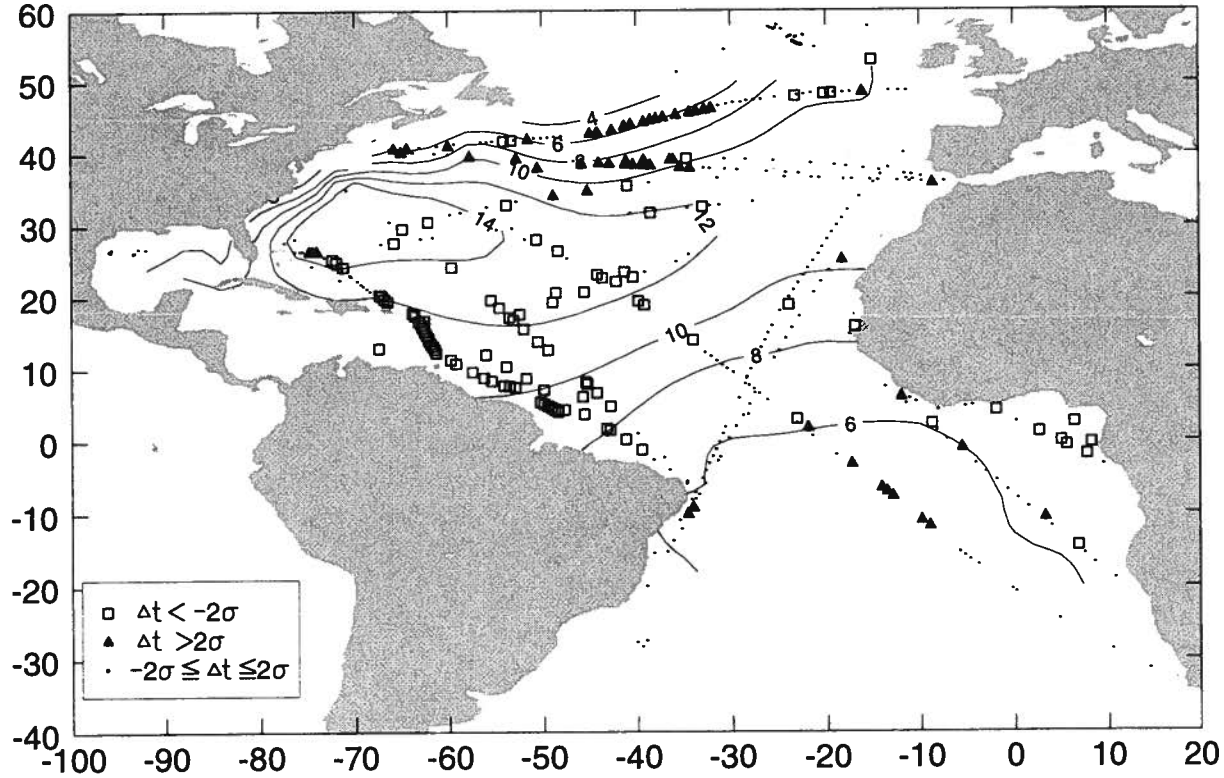
April 1991 (600m)

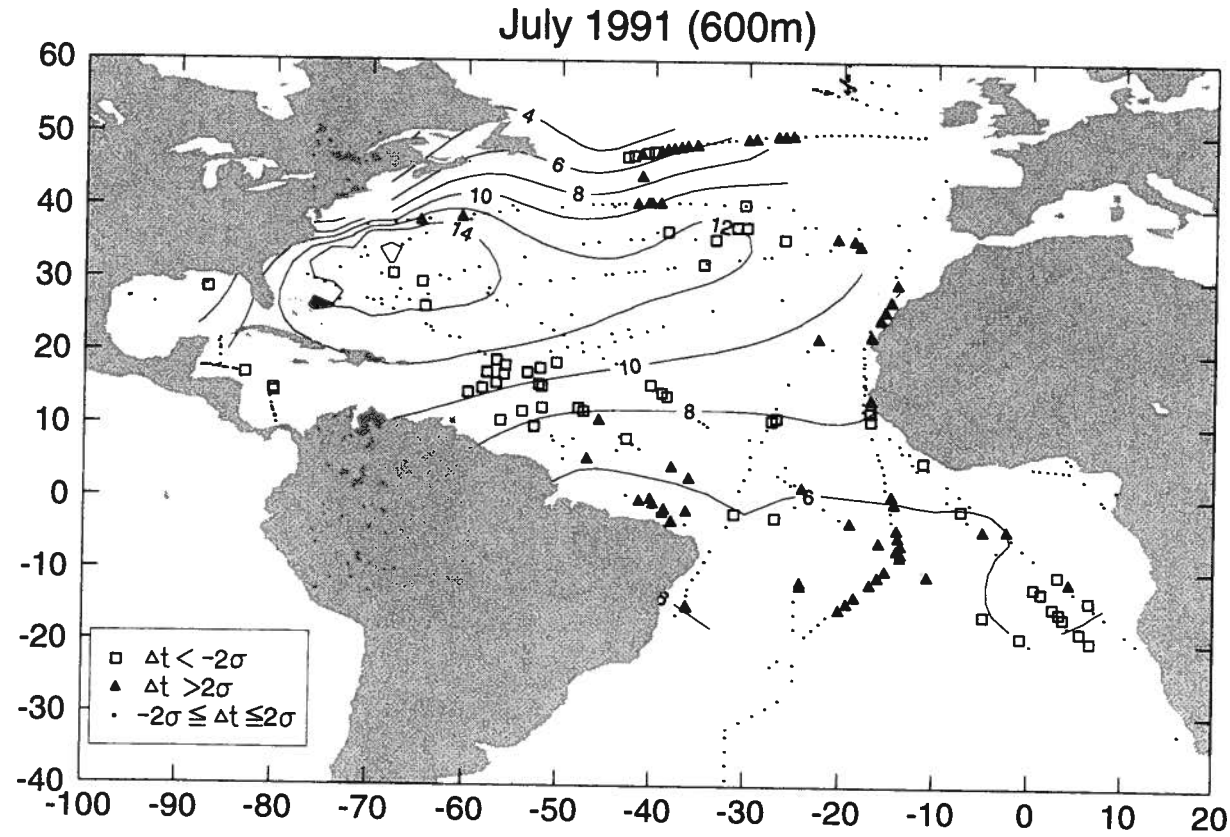


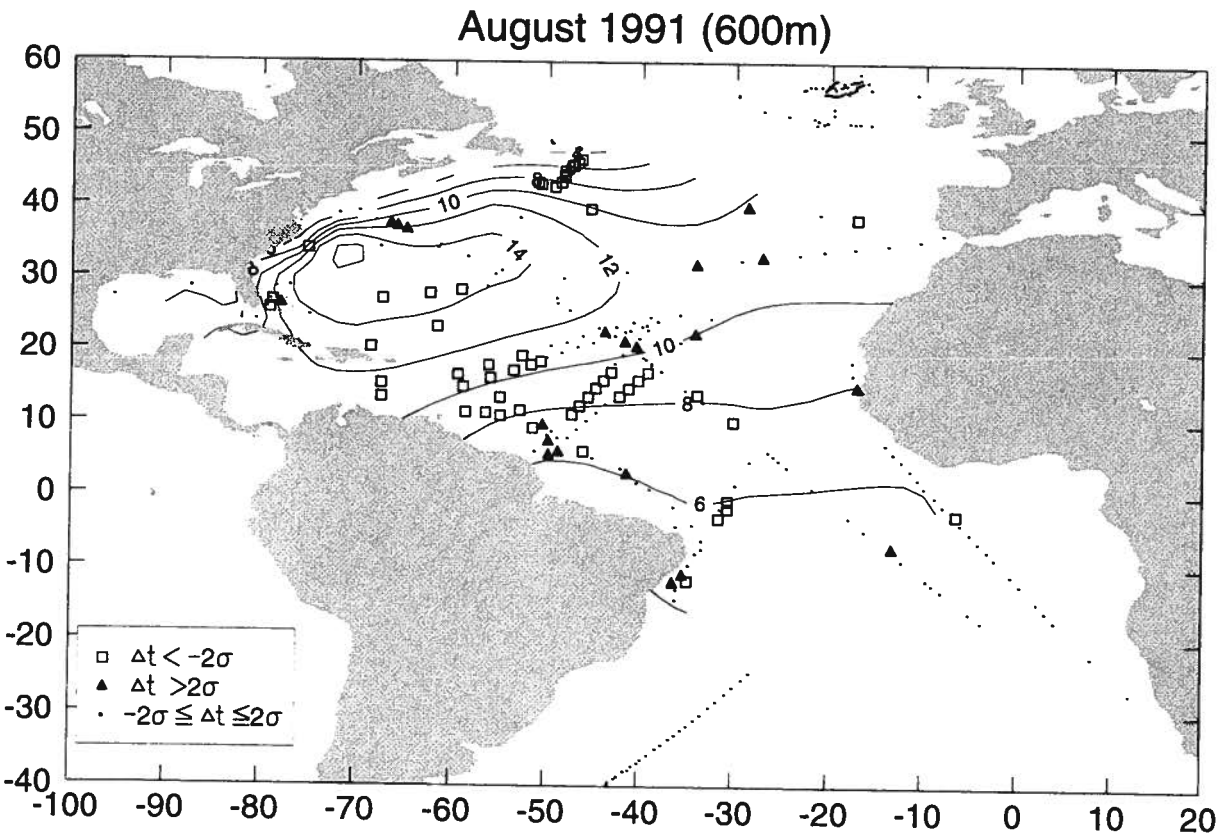
May 1991 (600m)

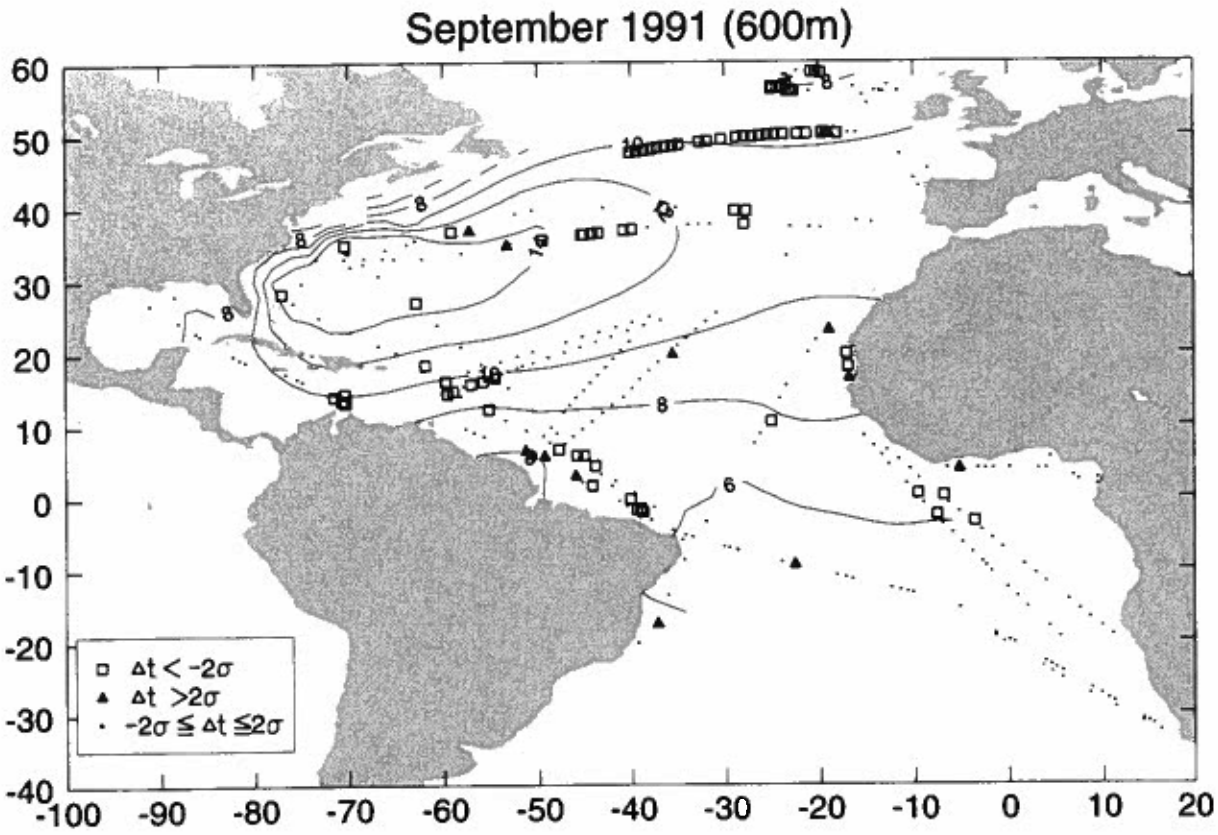


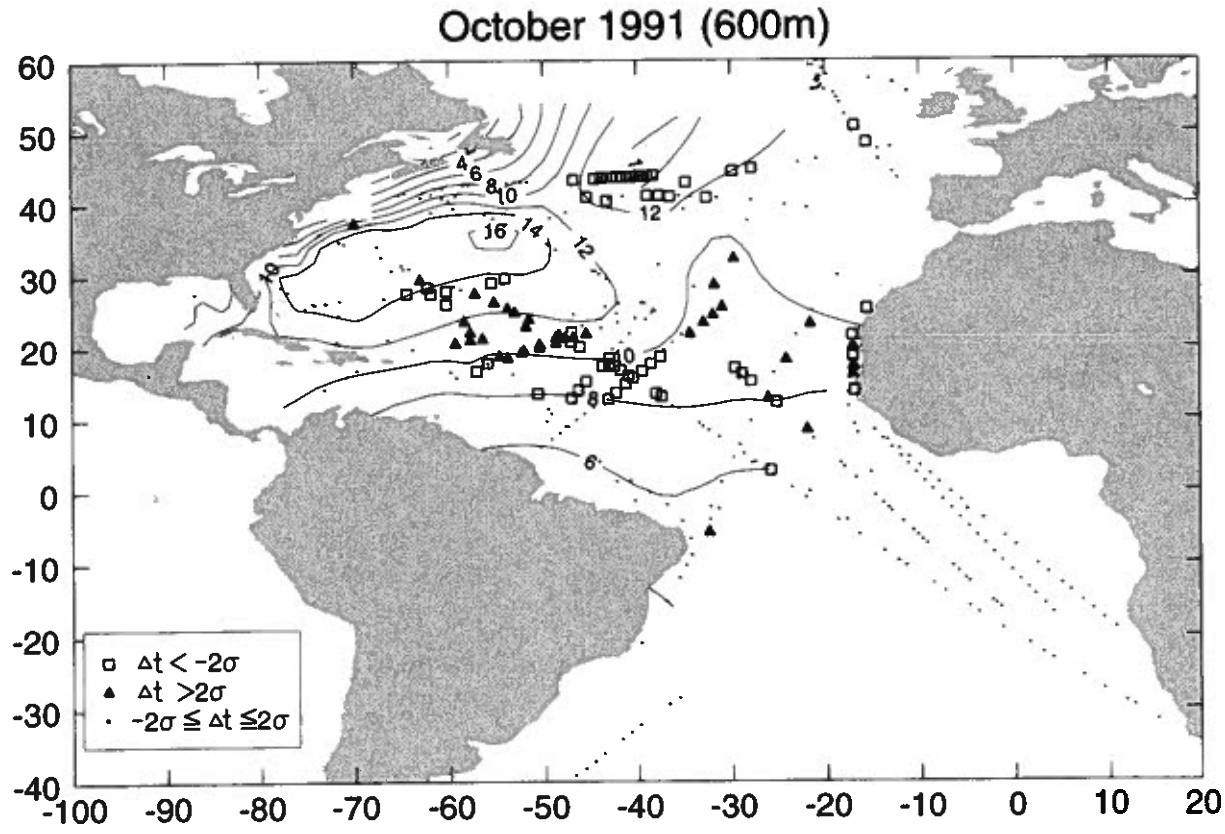
June 1991 (600m)

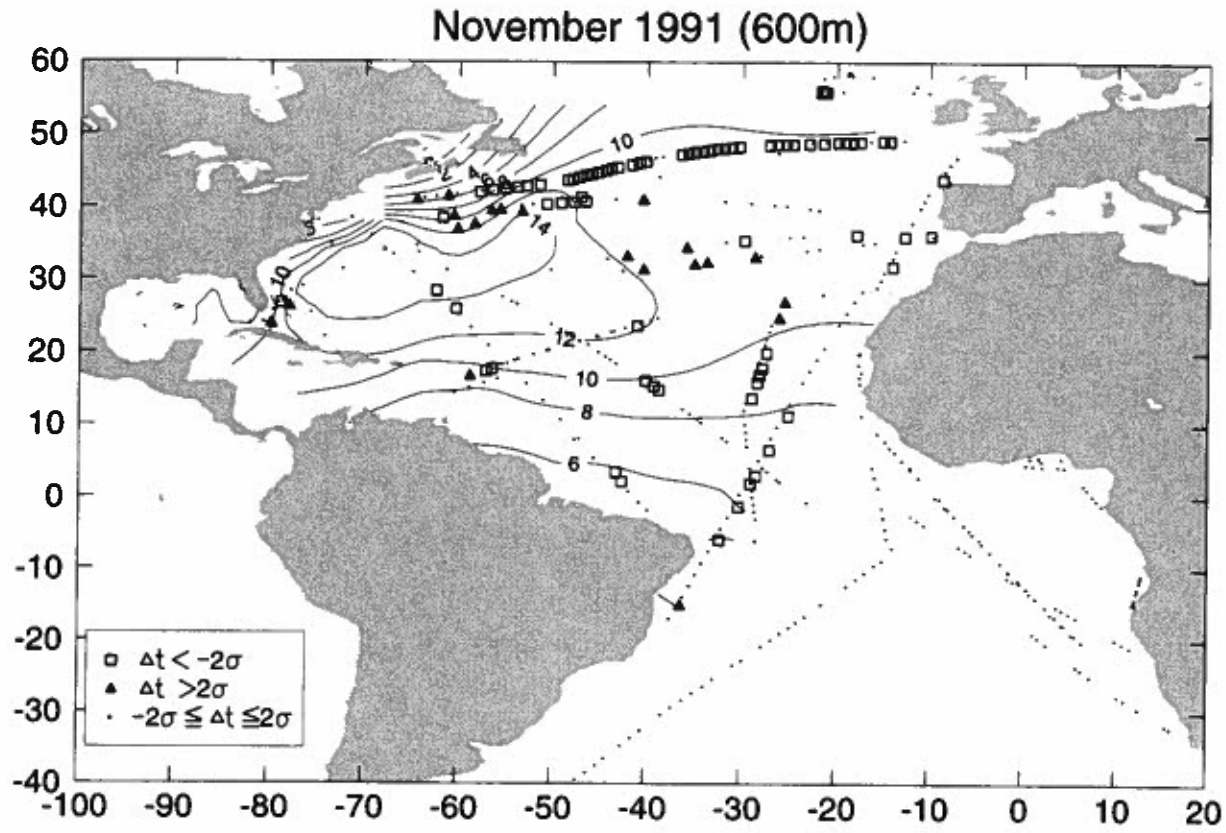


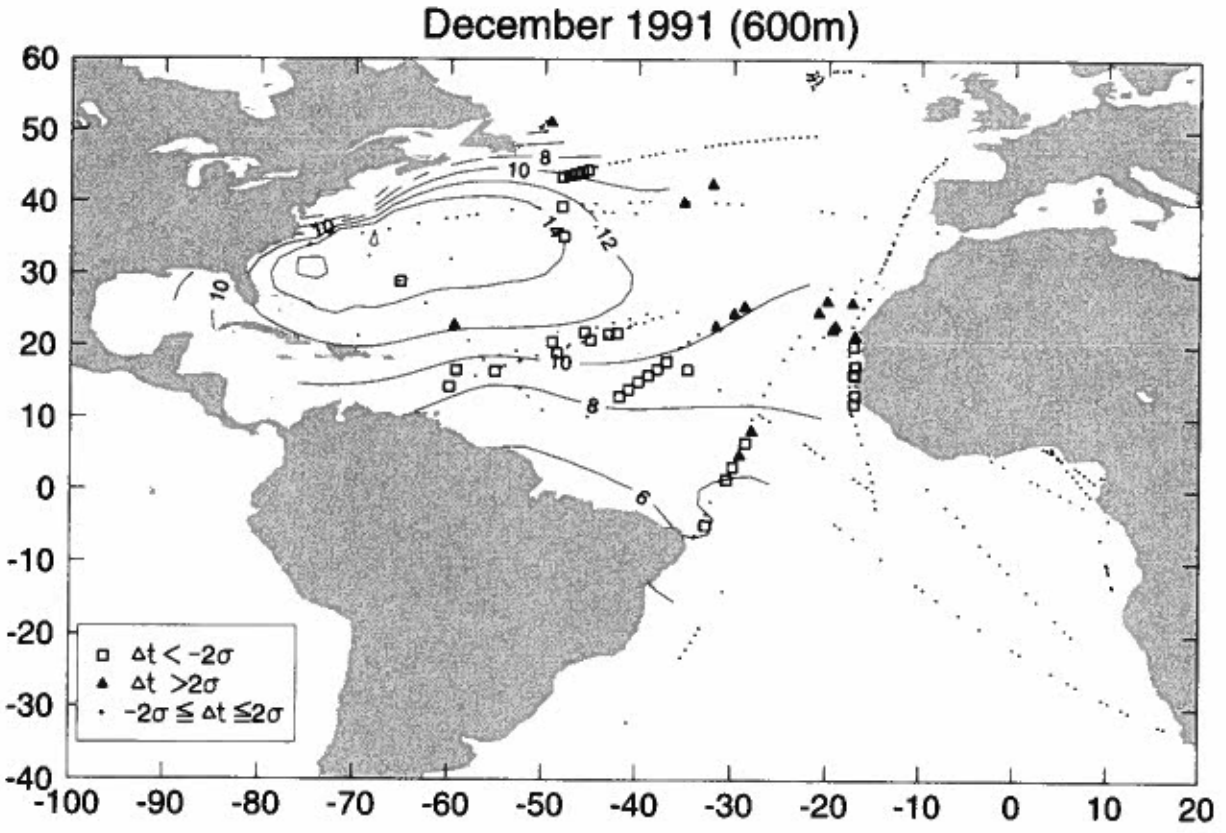

July 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


August 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

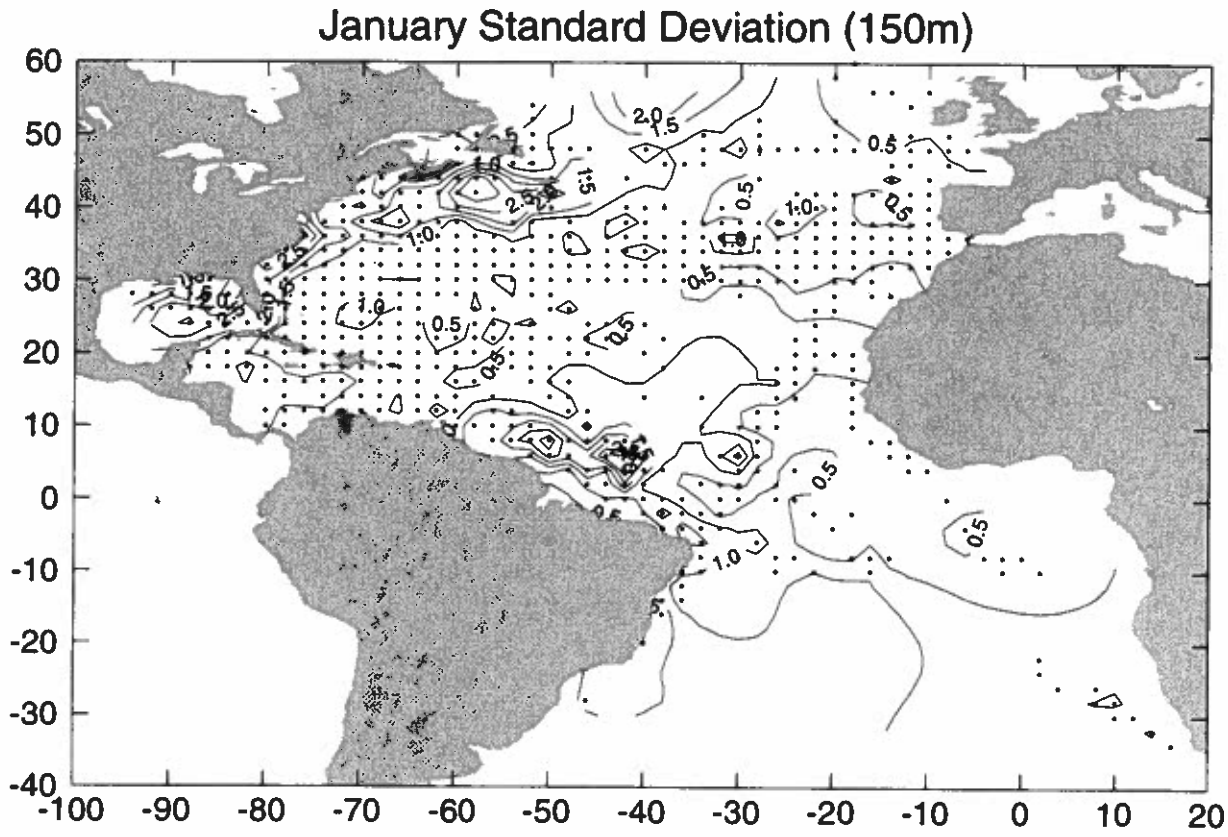

September 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

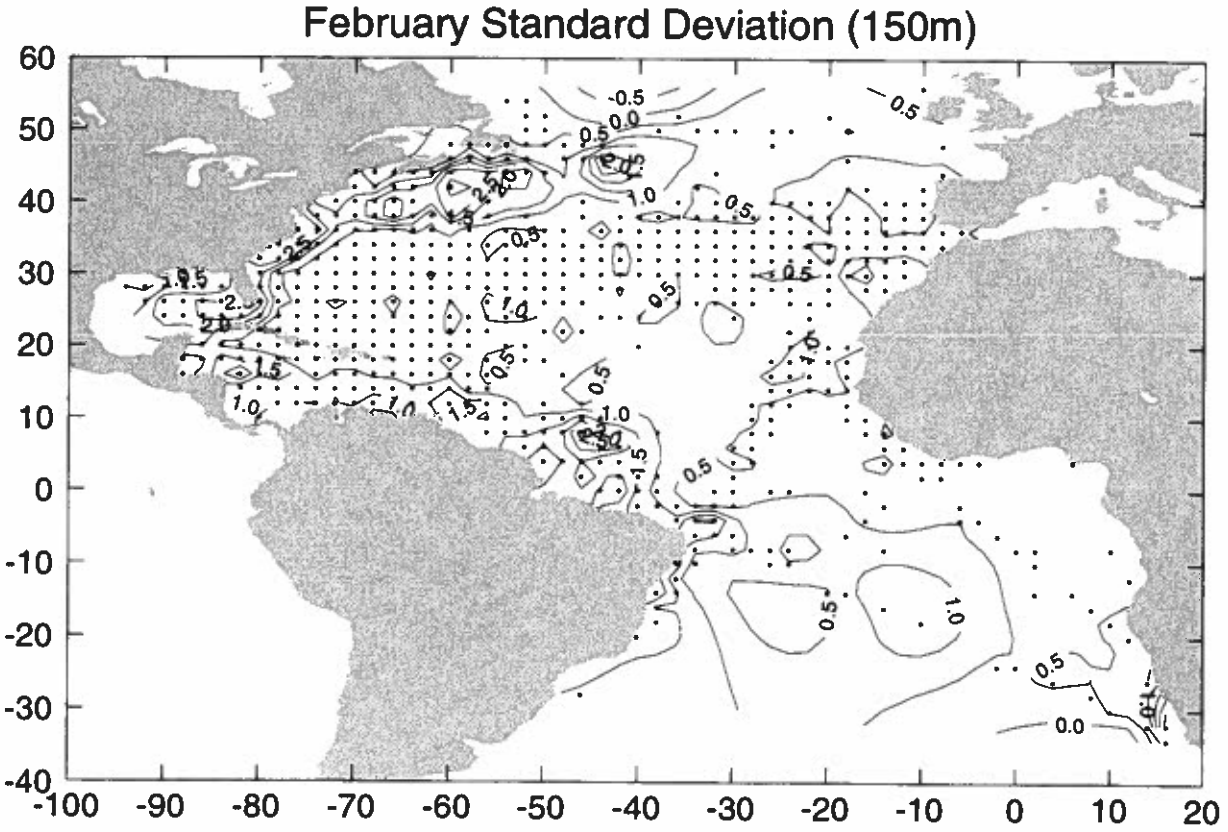

October 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ


November 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

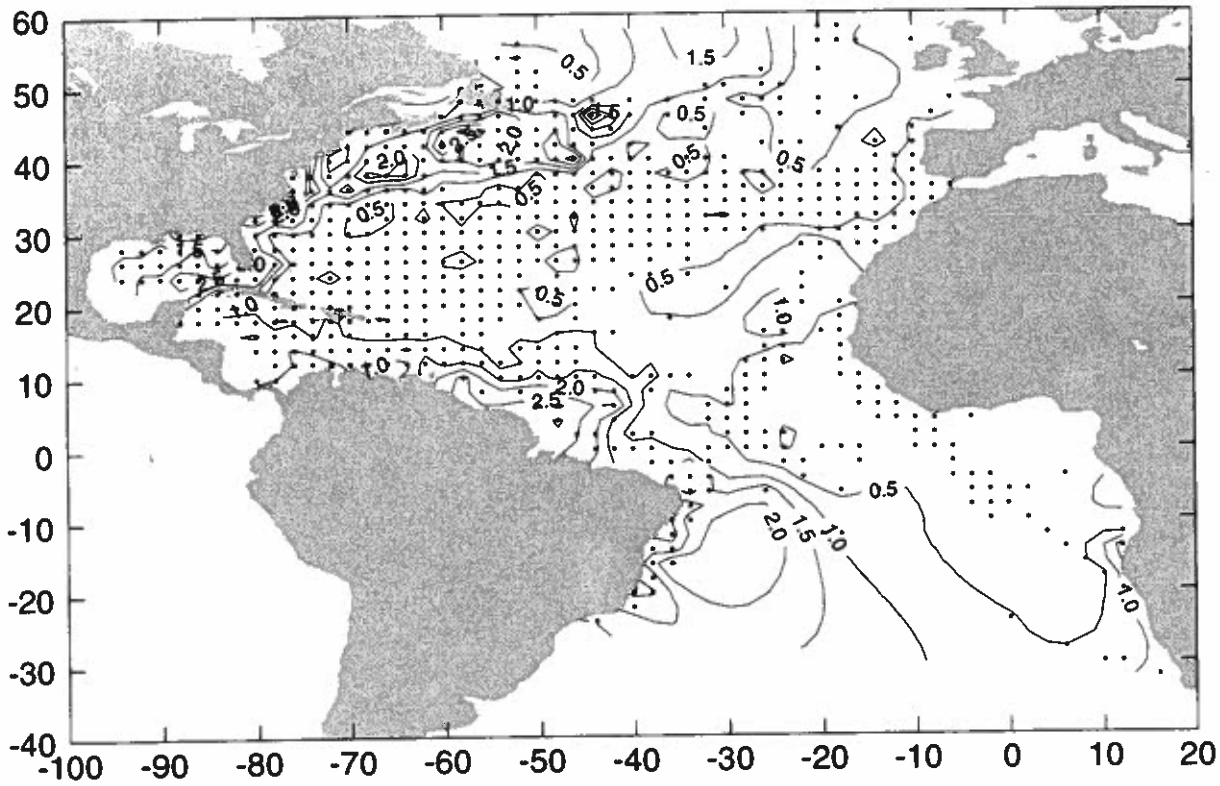

December 1991 (600m)
Δt < -2σ
Δt >2σ
-2σ ≦ Δt ≦2σ

APPENDIX 2:

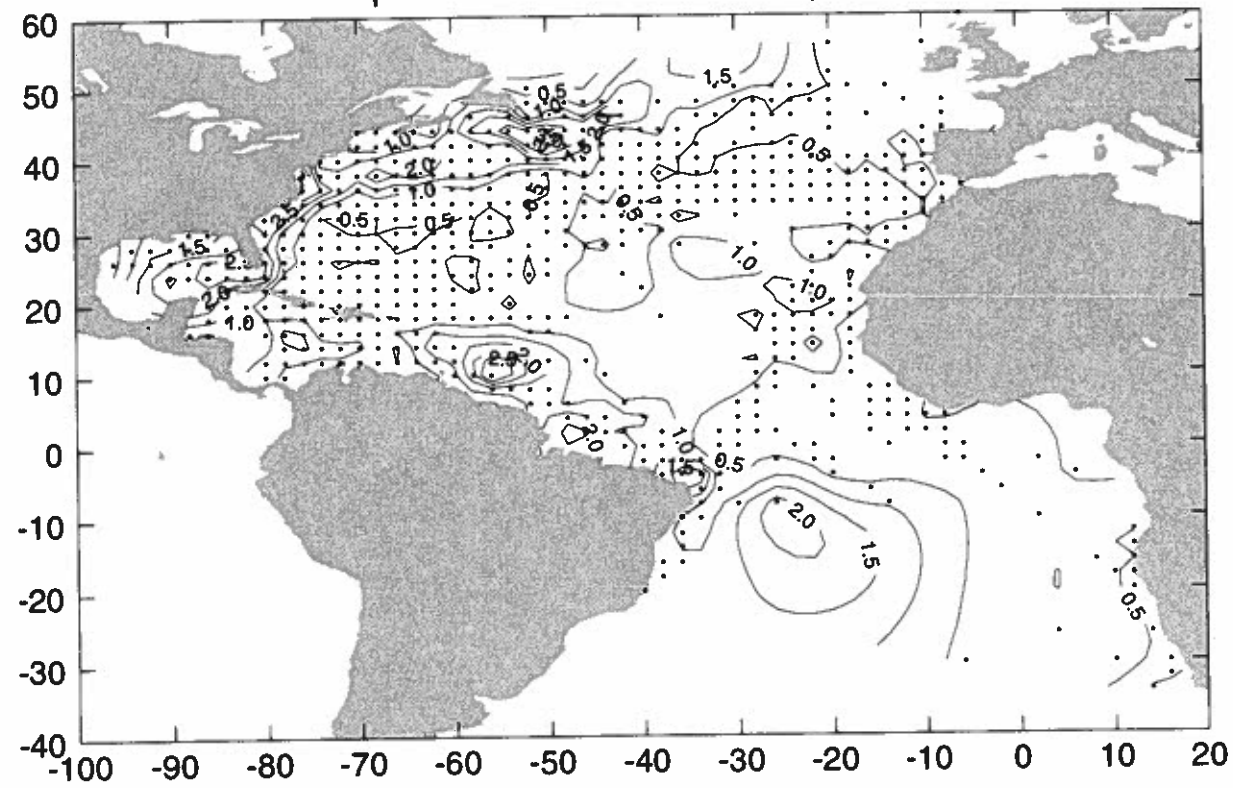

January Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20


February Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

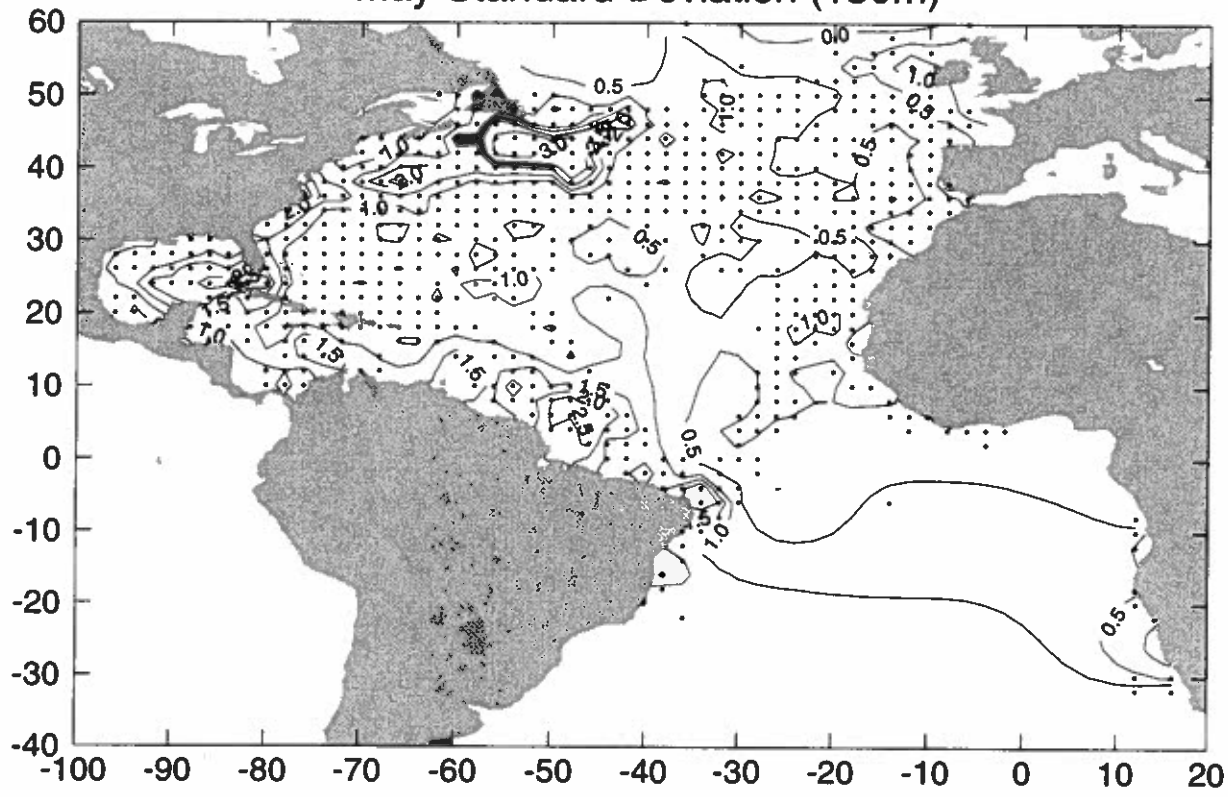
March Standard Deviation (150m)



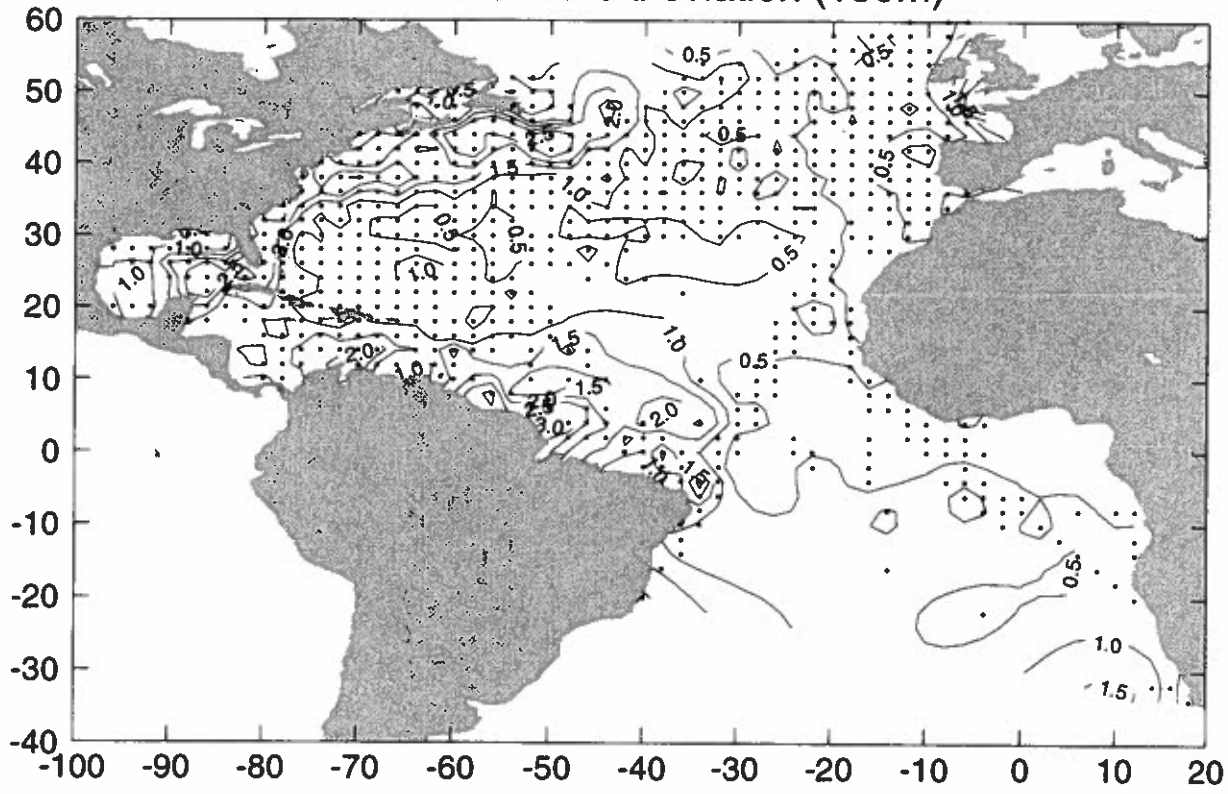
April Standard Deviation (150m)



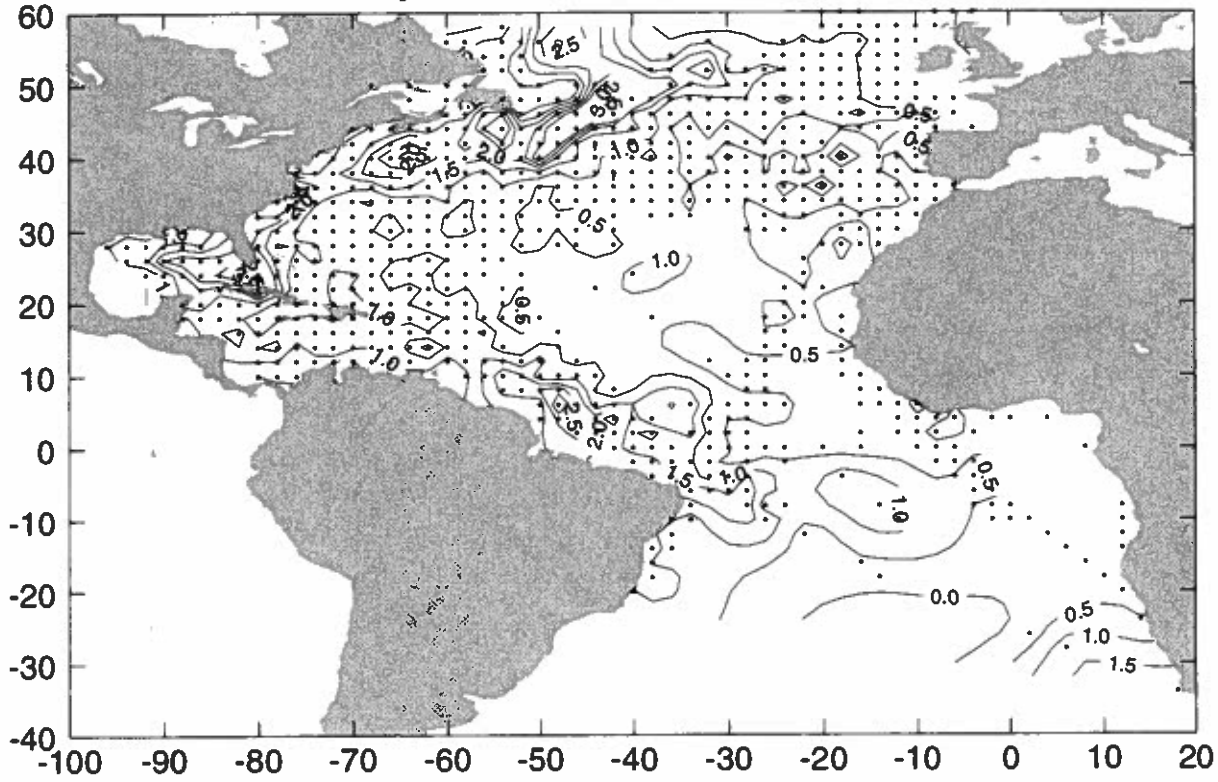
May Standard Deviation (150m)



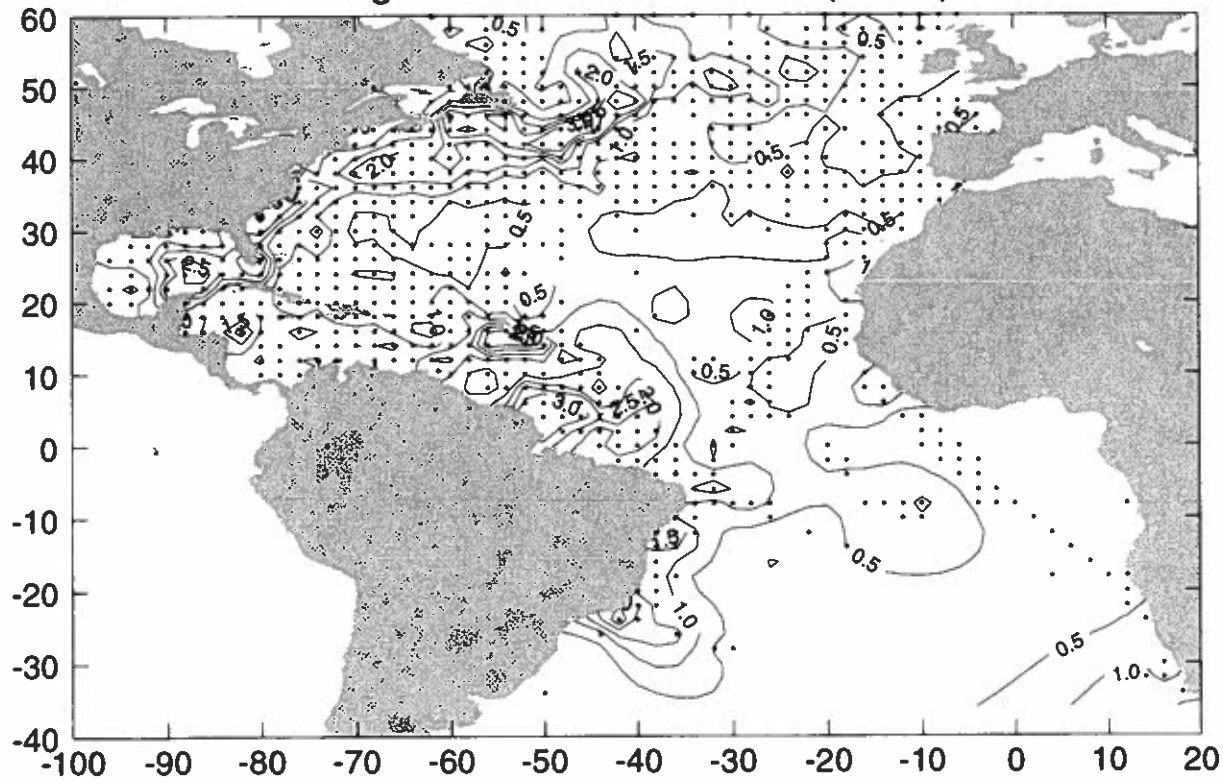
June Standard Deviation (150m)

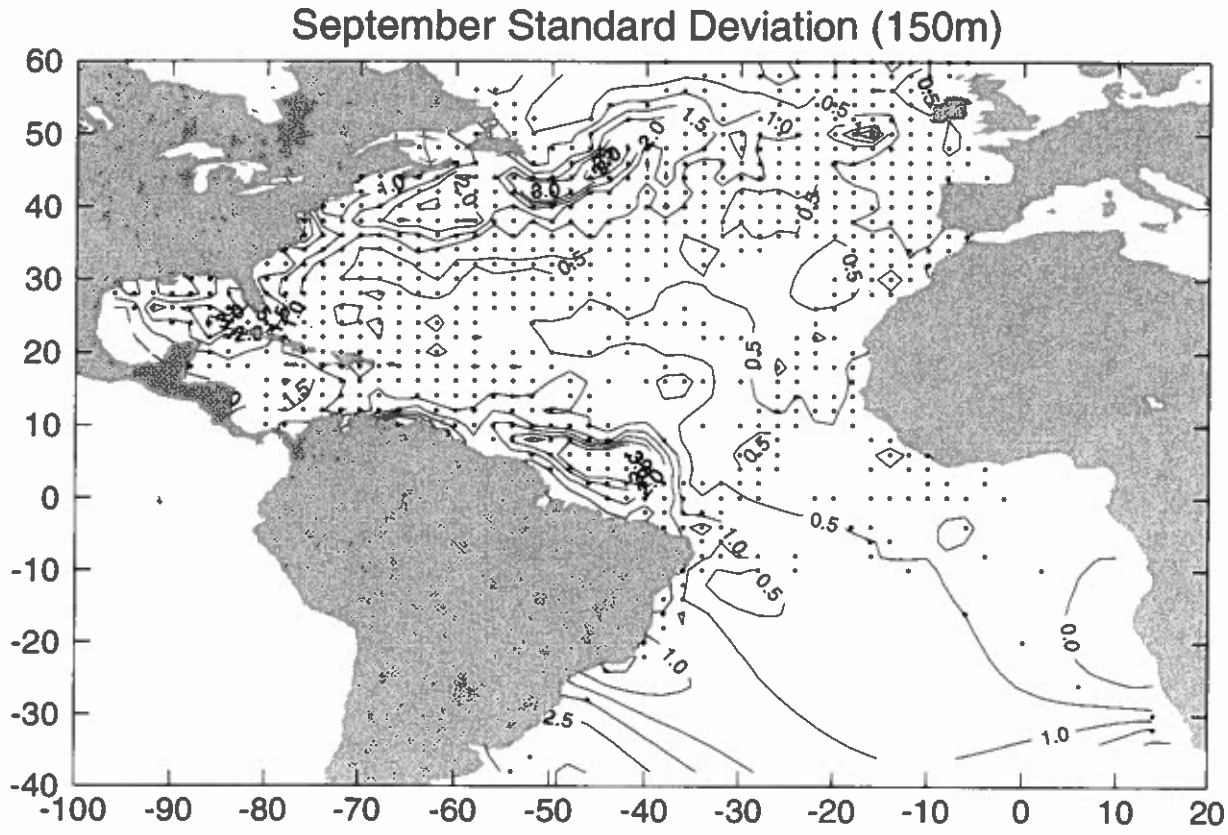


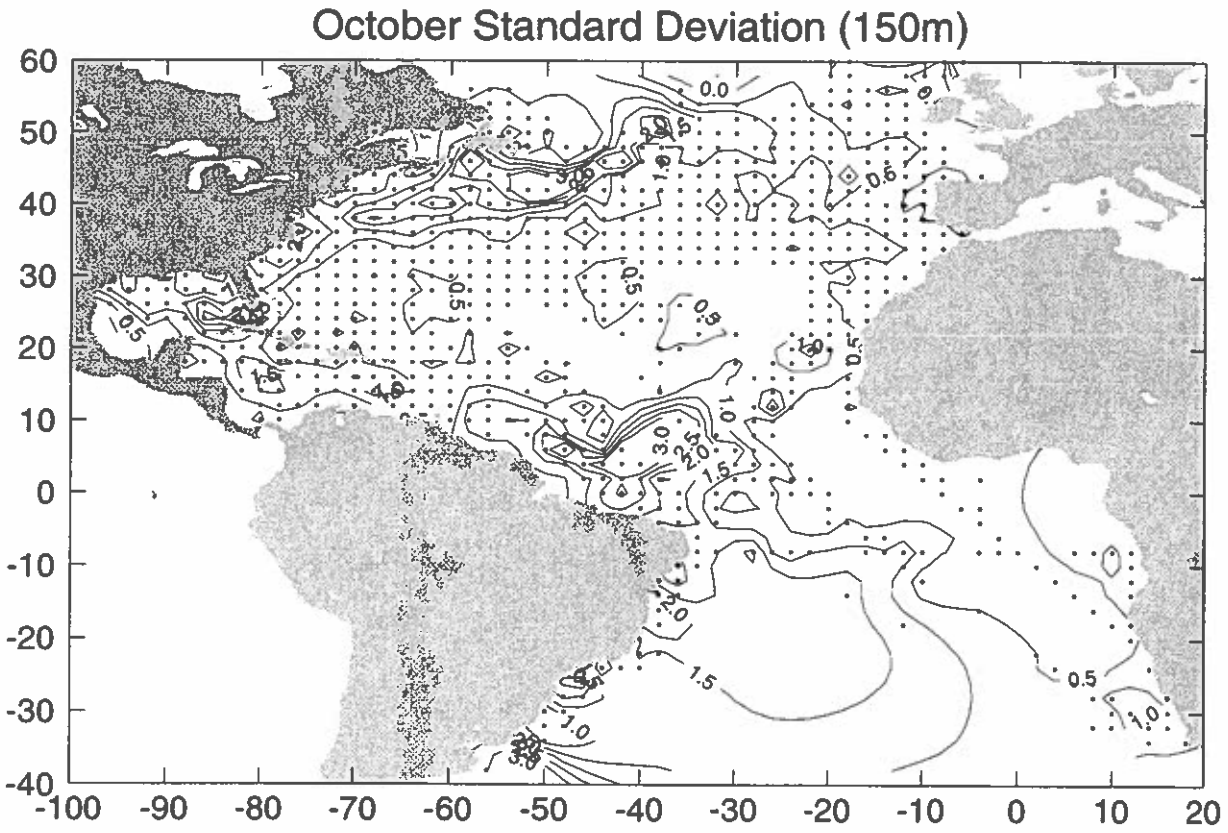
July Standard Deviation (150m)

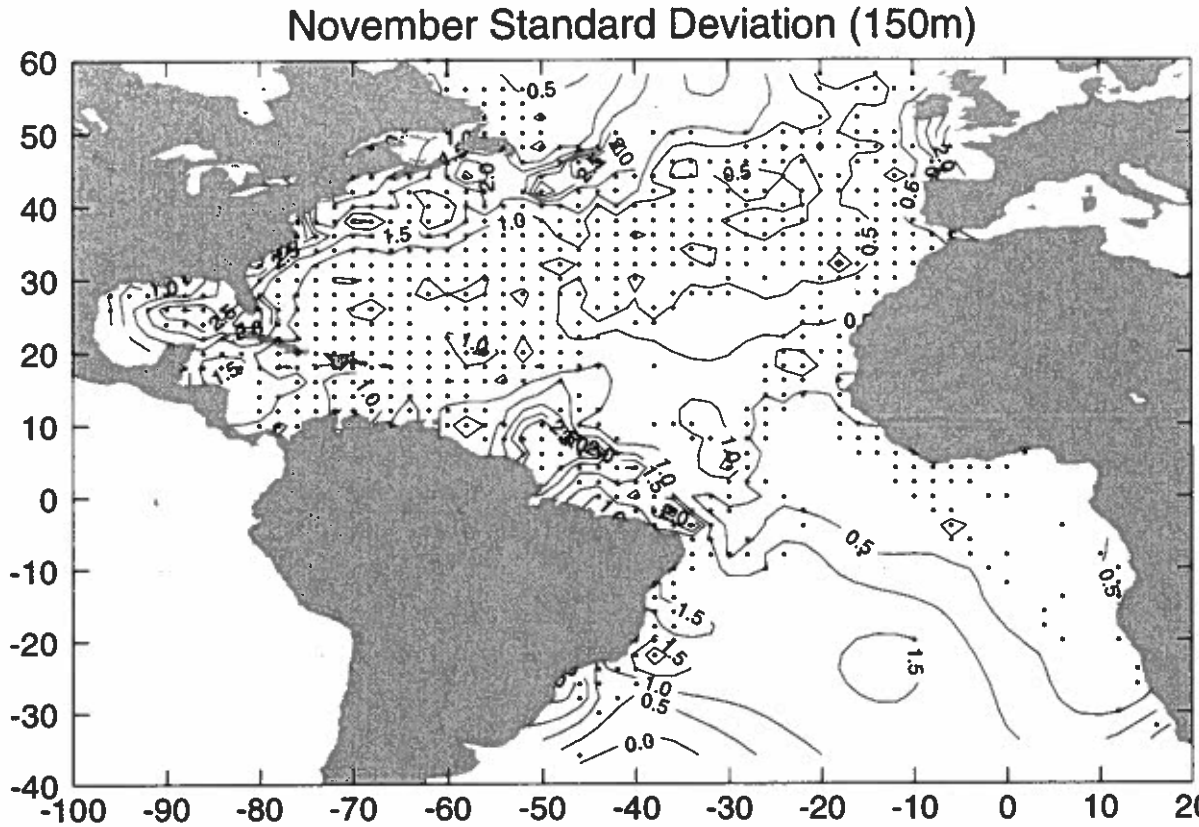


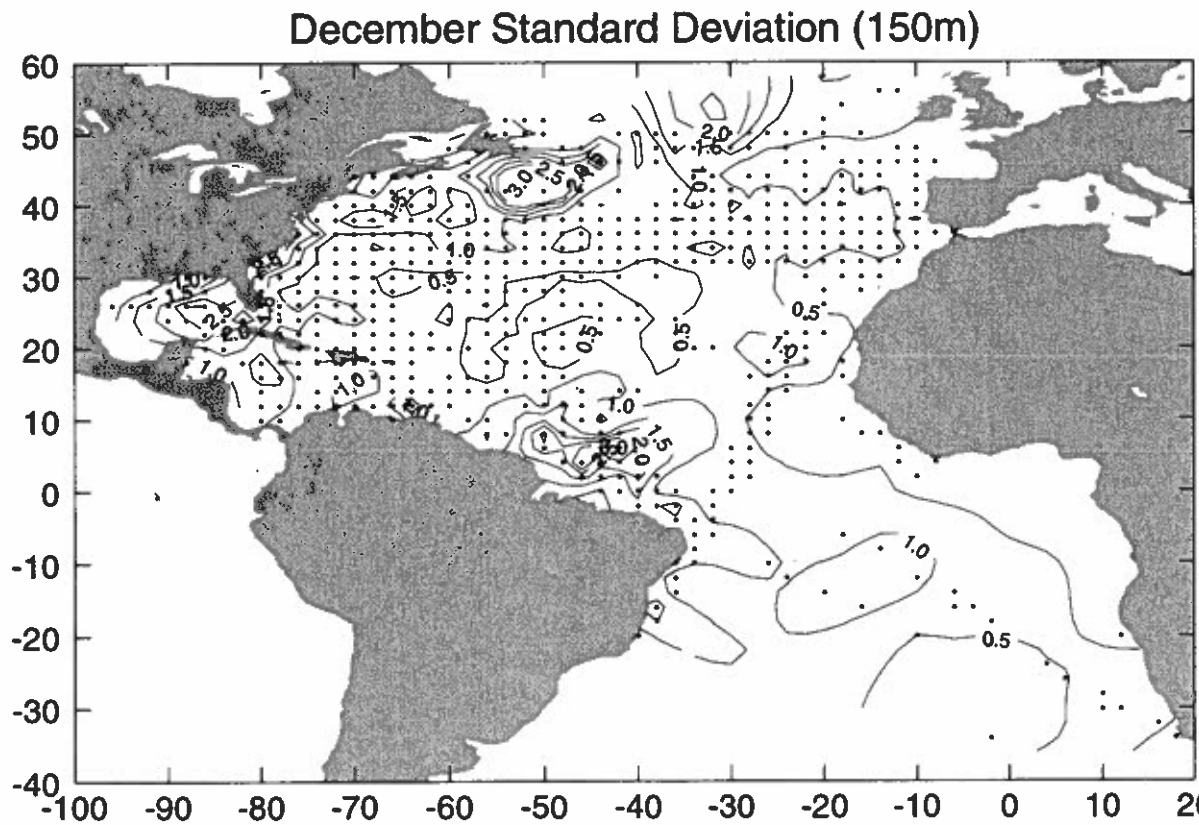
August Standard Deviation (150m)

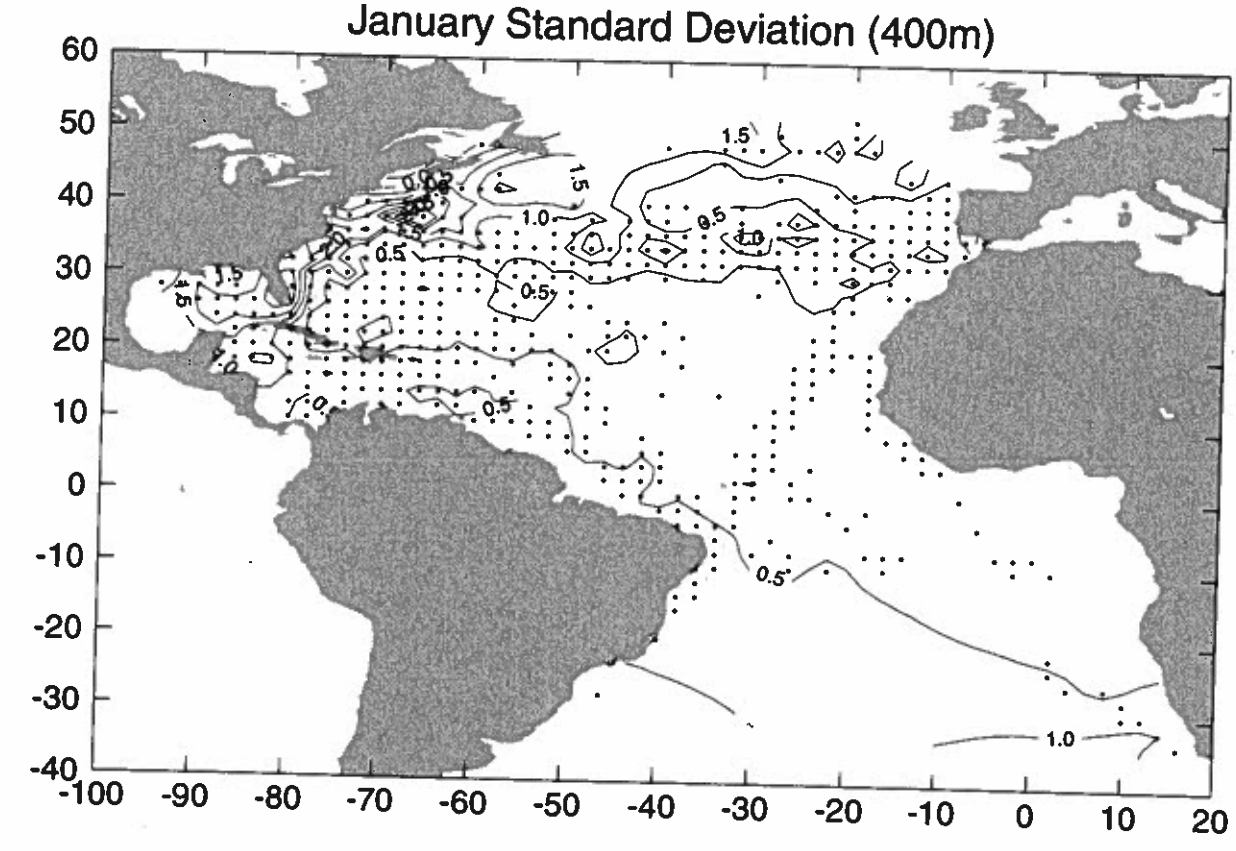


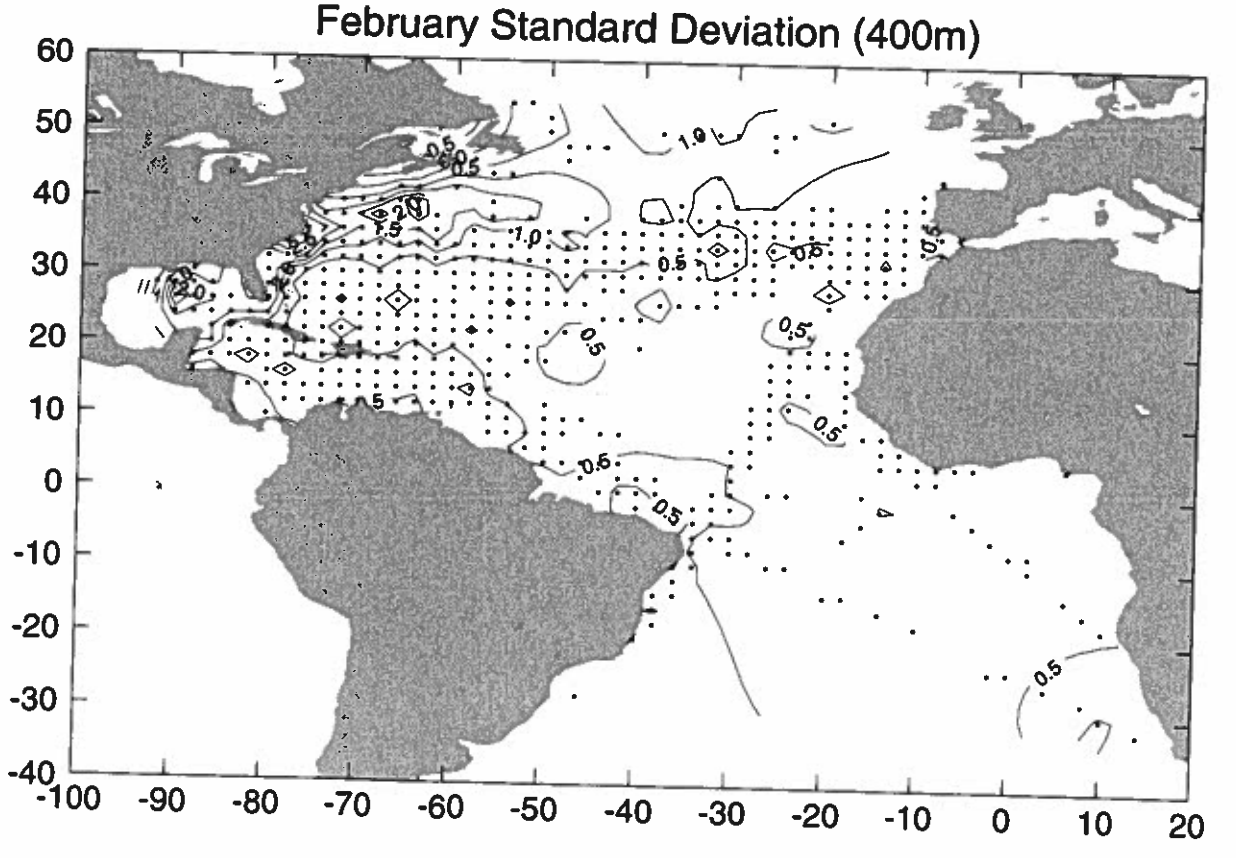

September Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

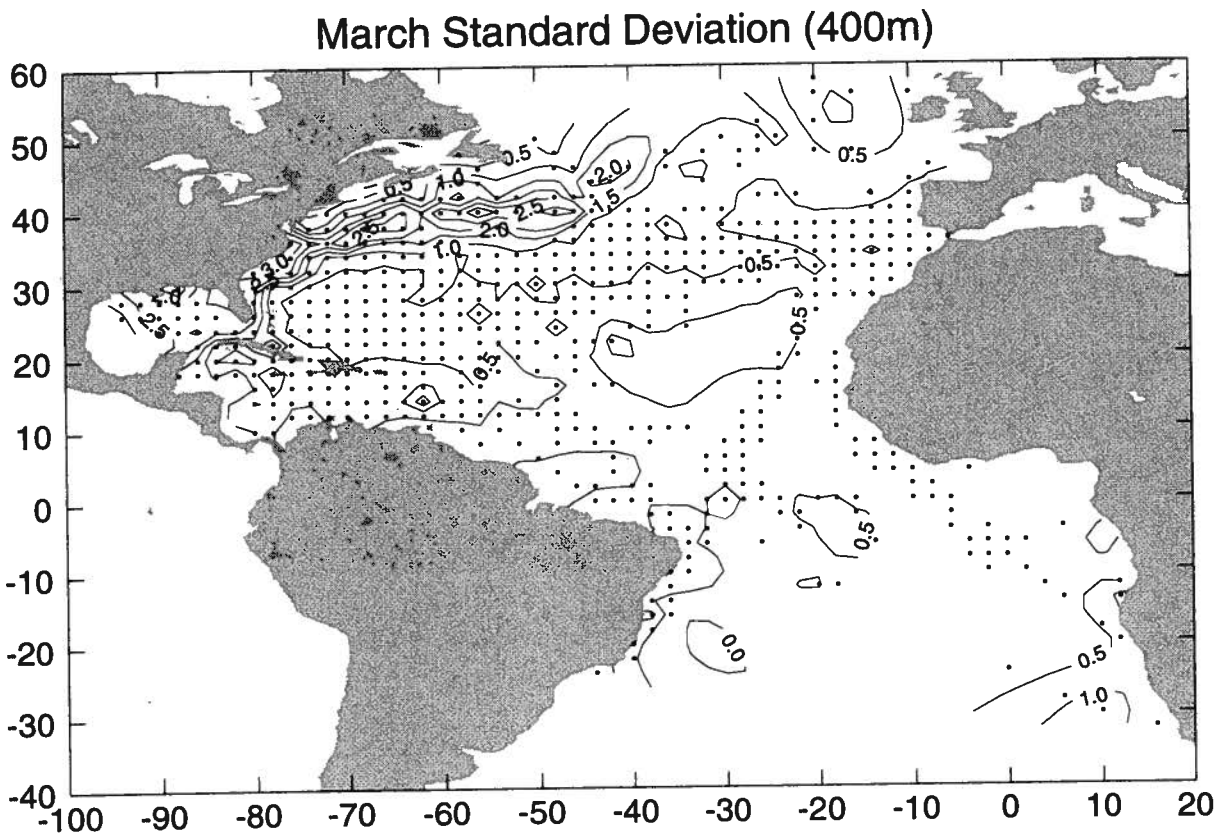

October Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

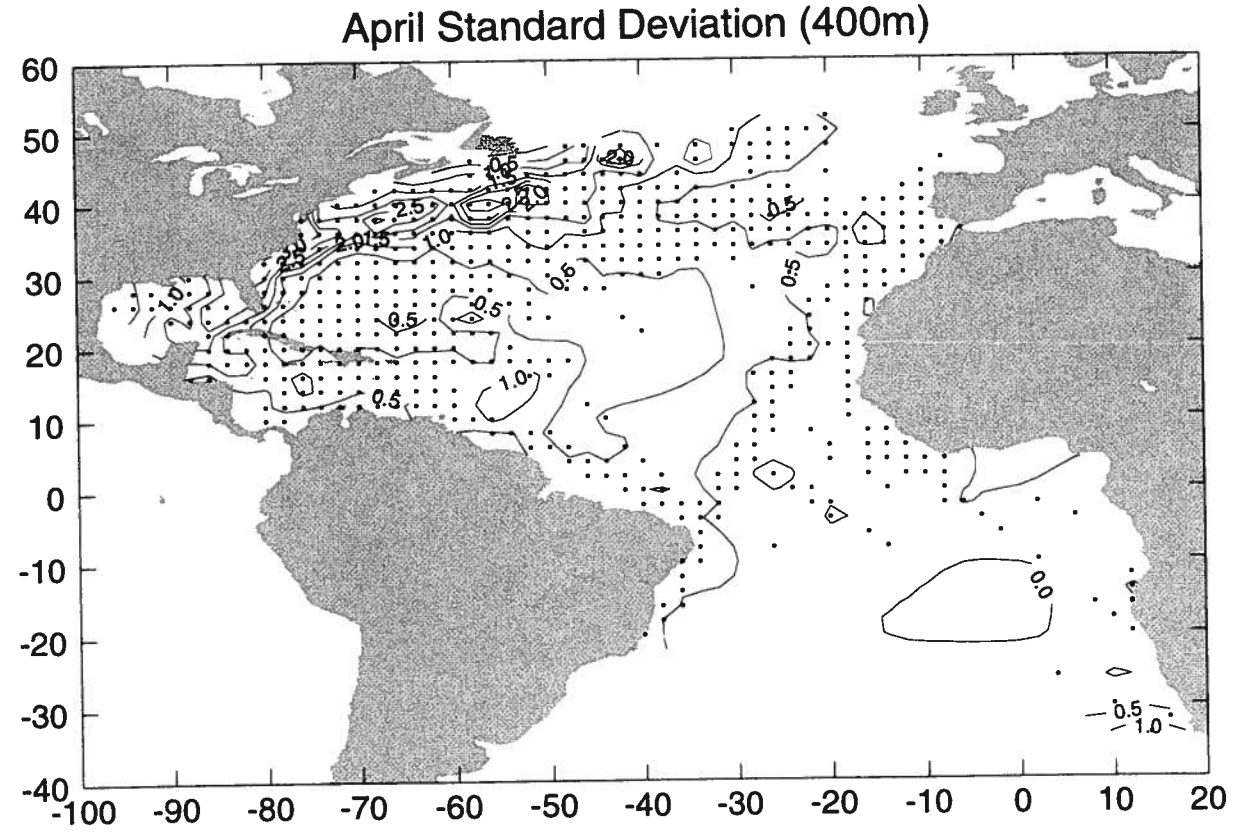

November Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

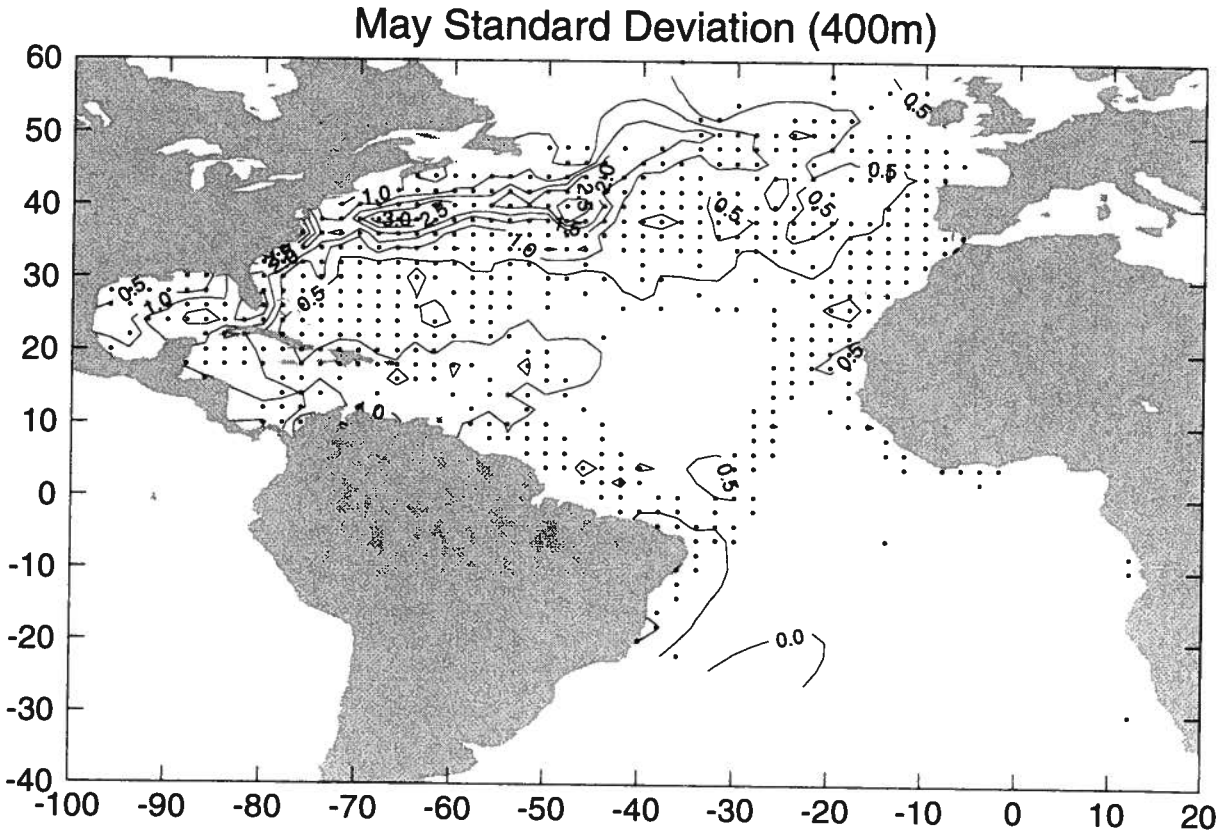

December Standard Deviation (150m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

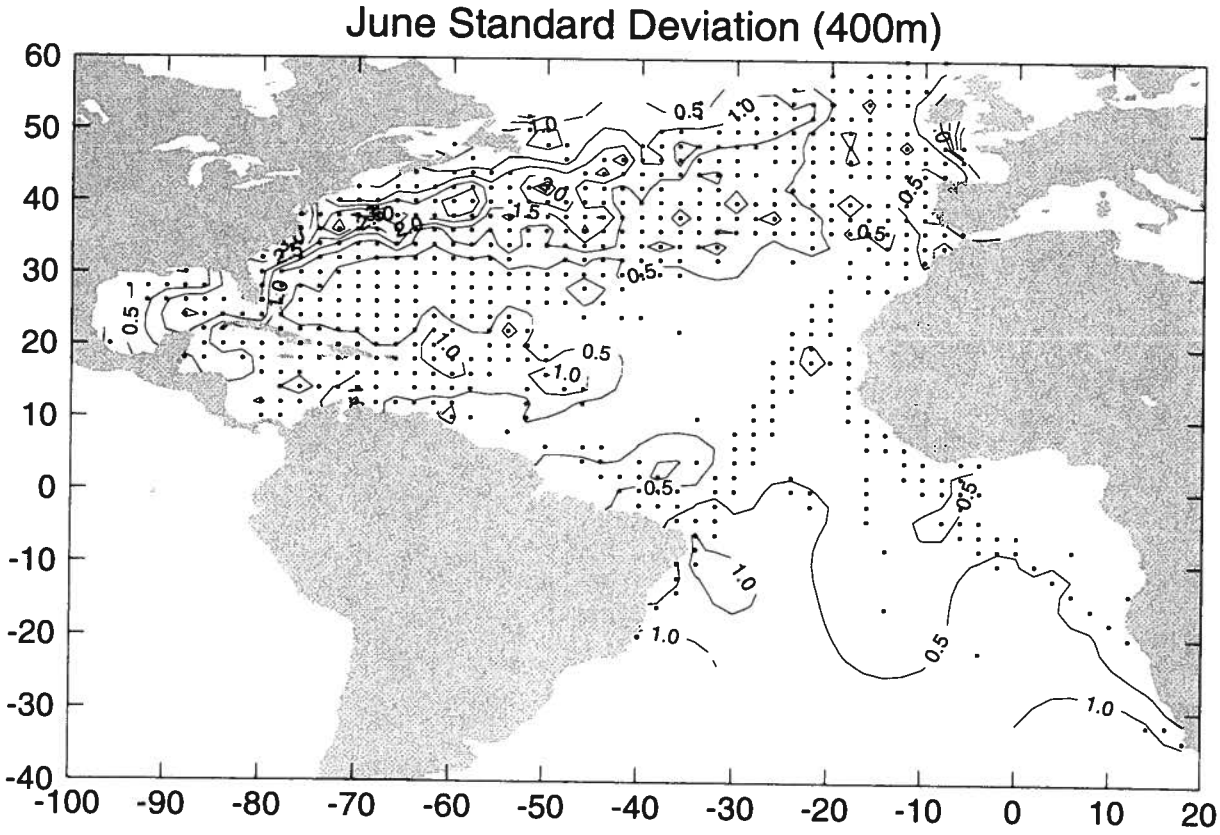

January Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
1.5
1.0
0.5

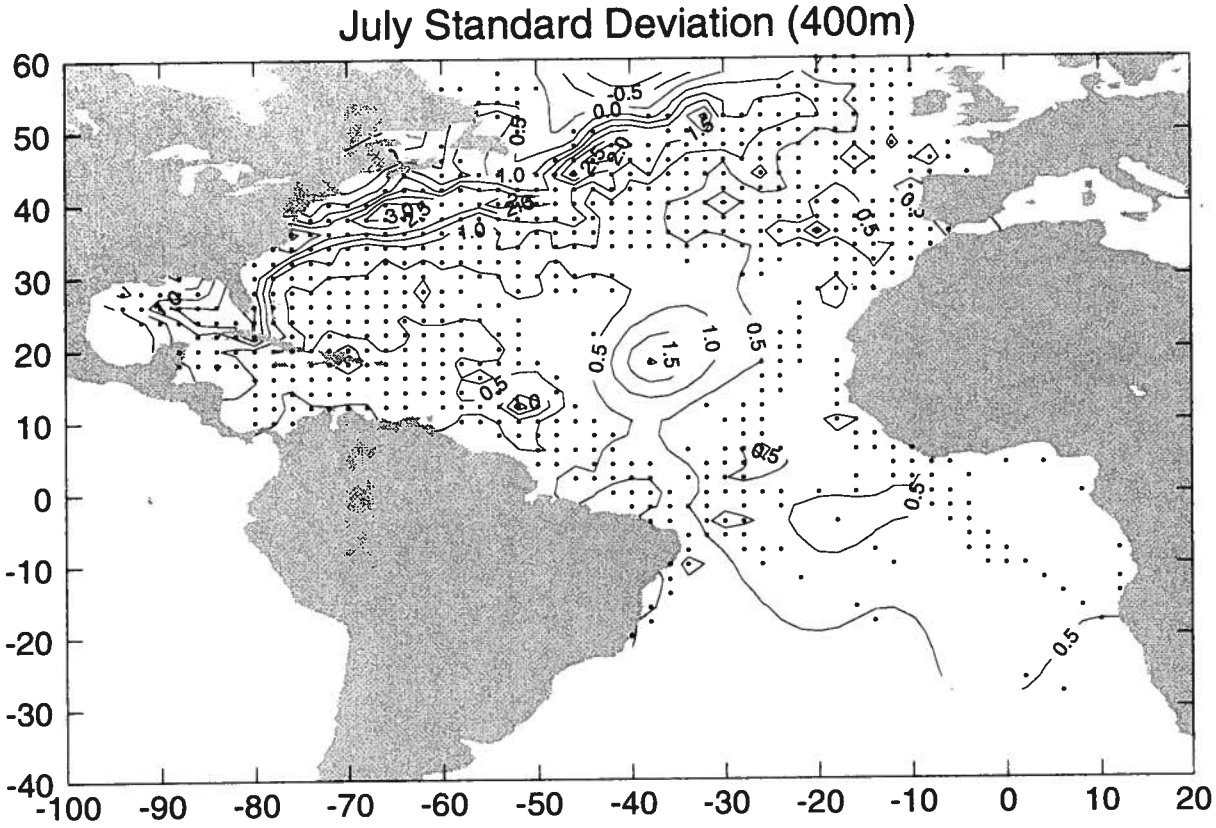

February Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
1.5
1.0
0.5

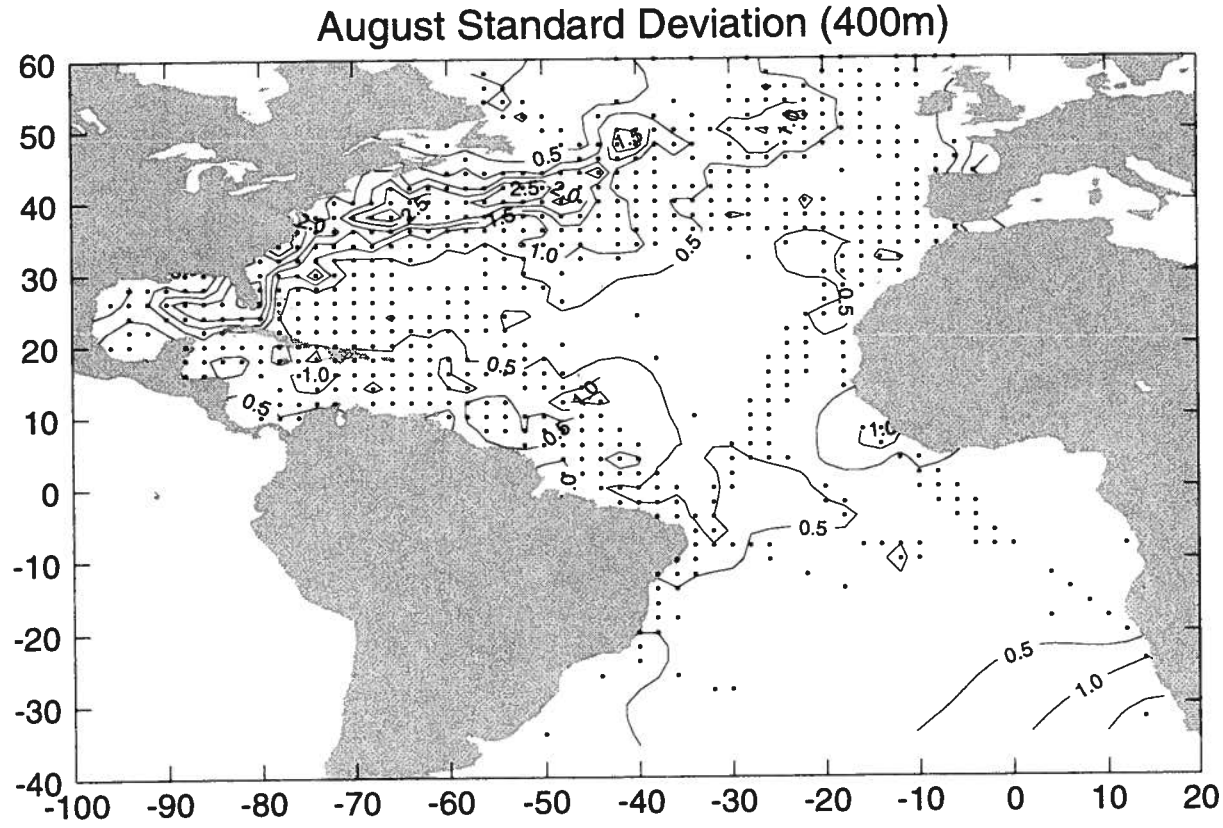

March Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
3.0
0.0

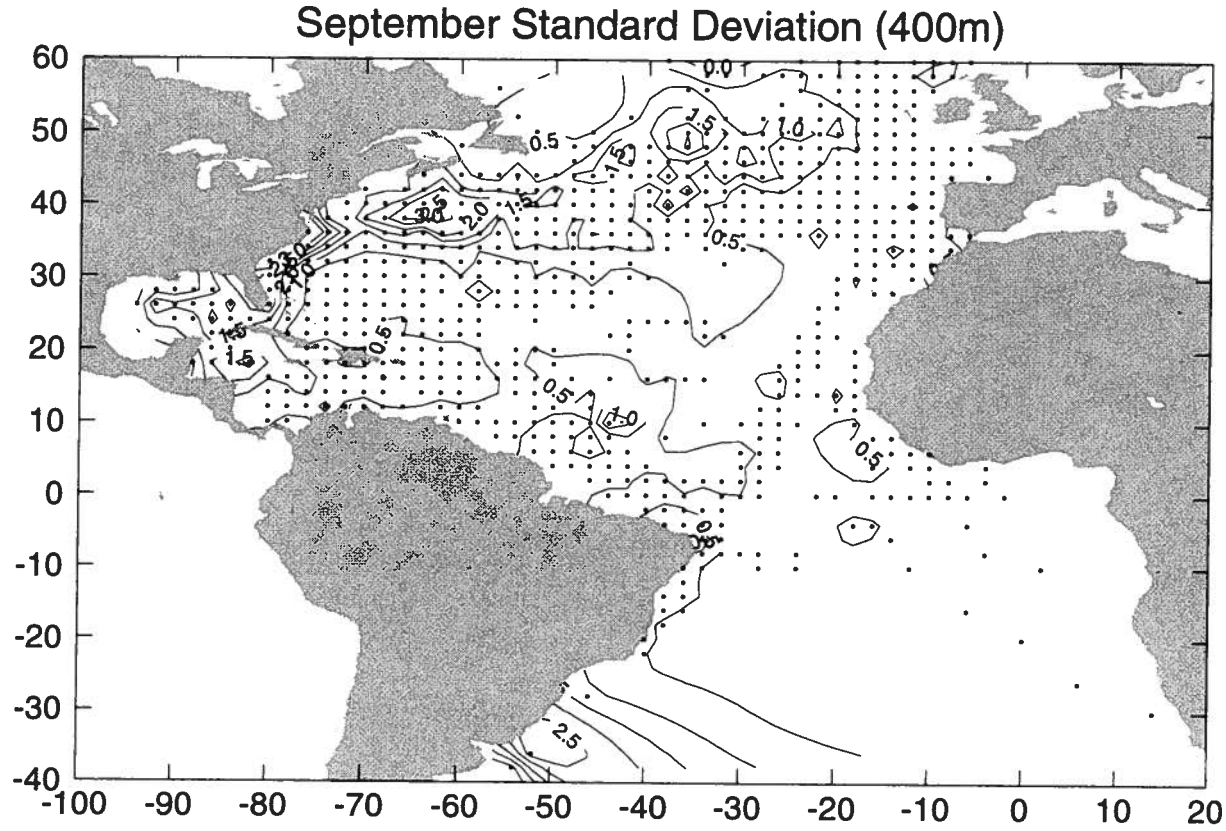

April Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
0.0

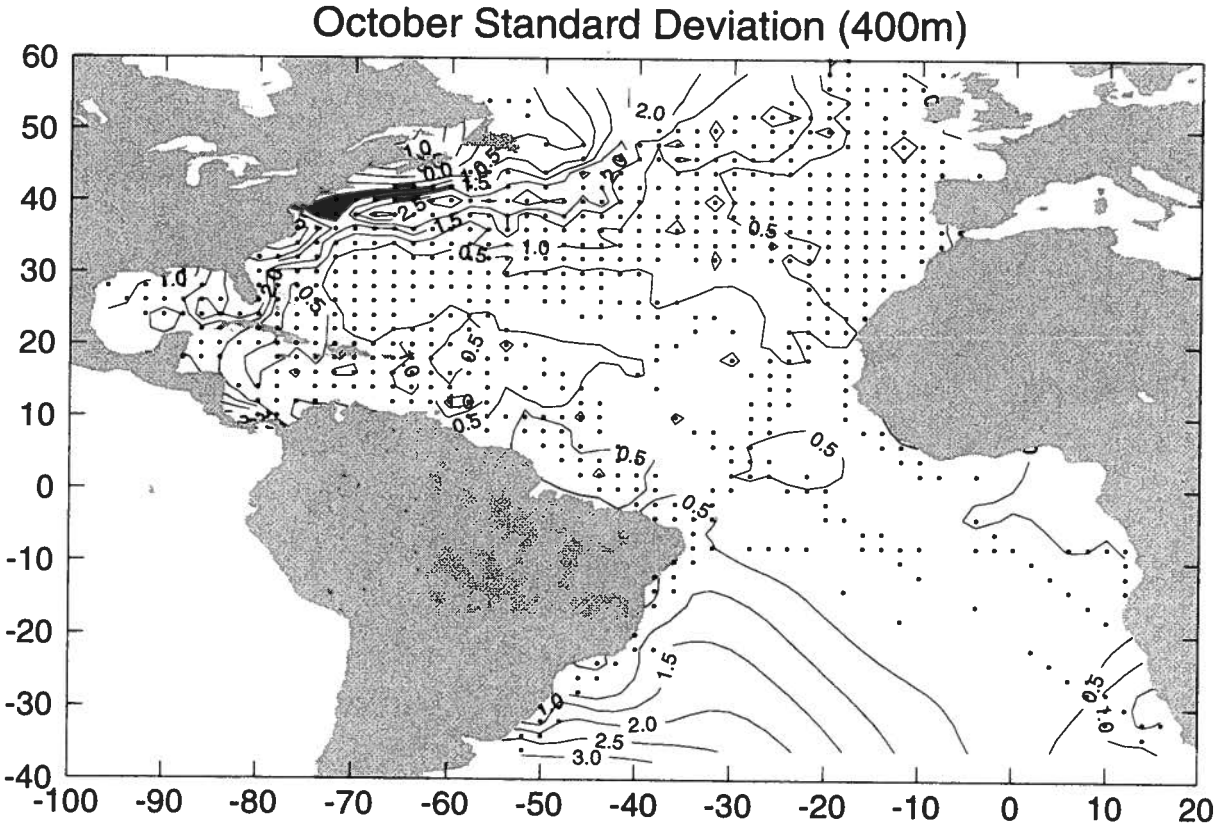

May Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
3.0
0.0

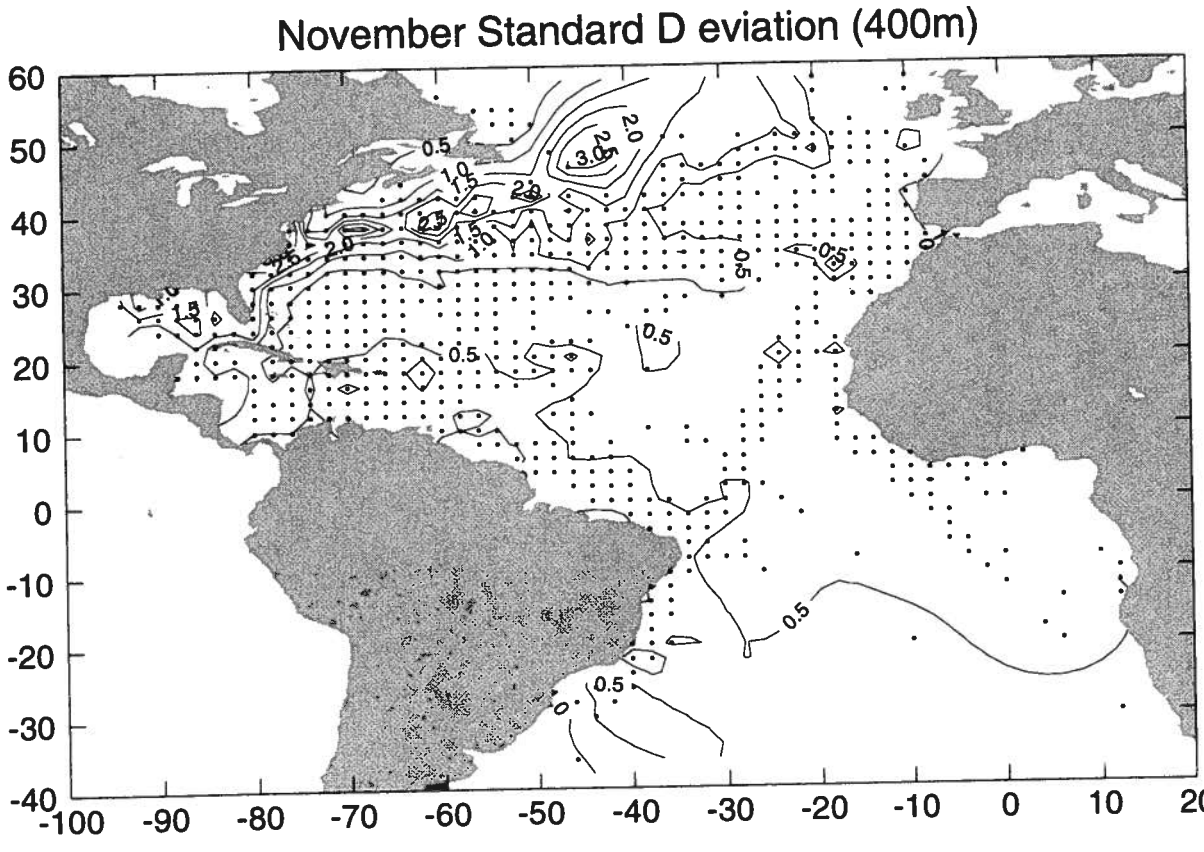

June Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
3.0

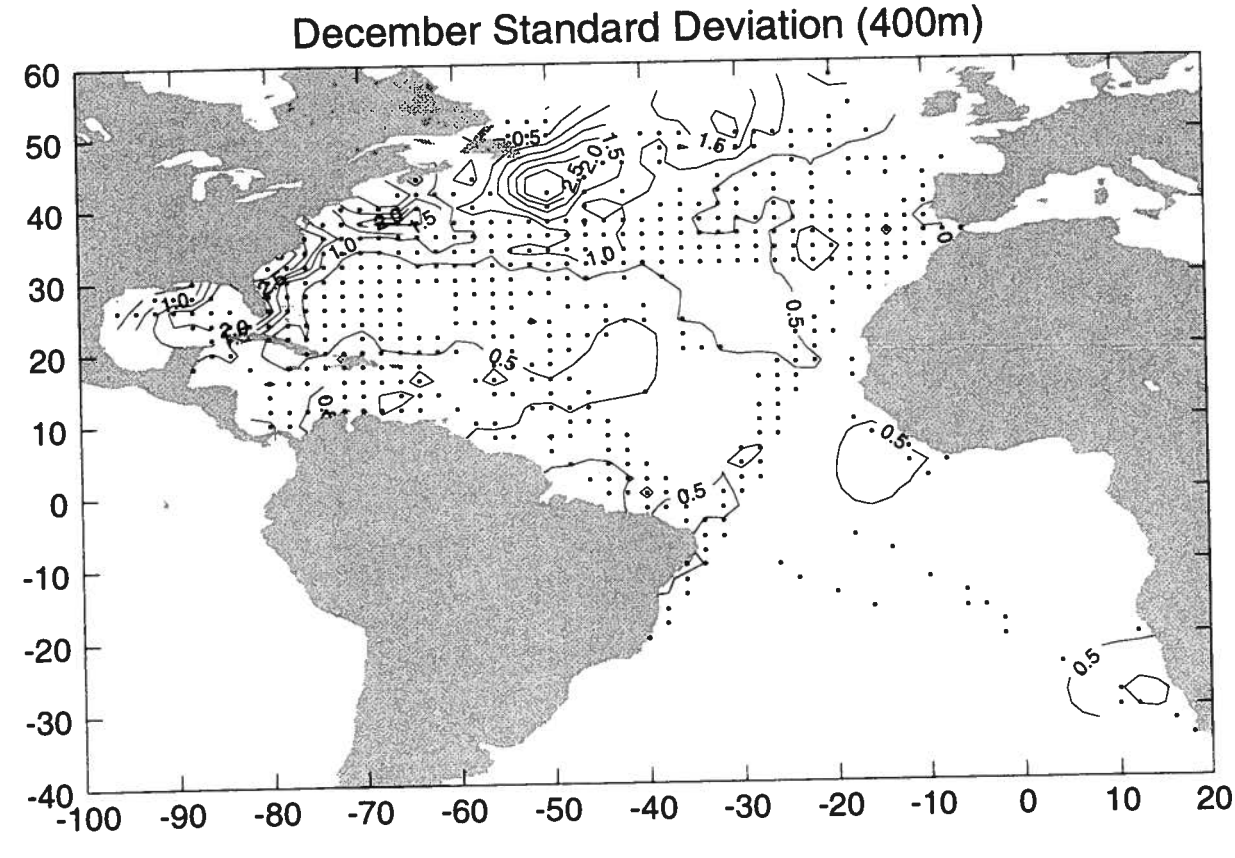

July Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

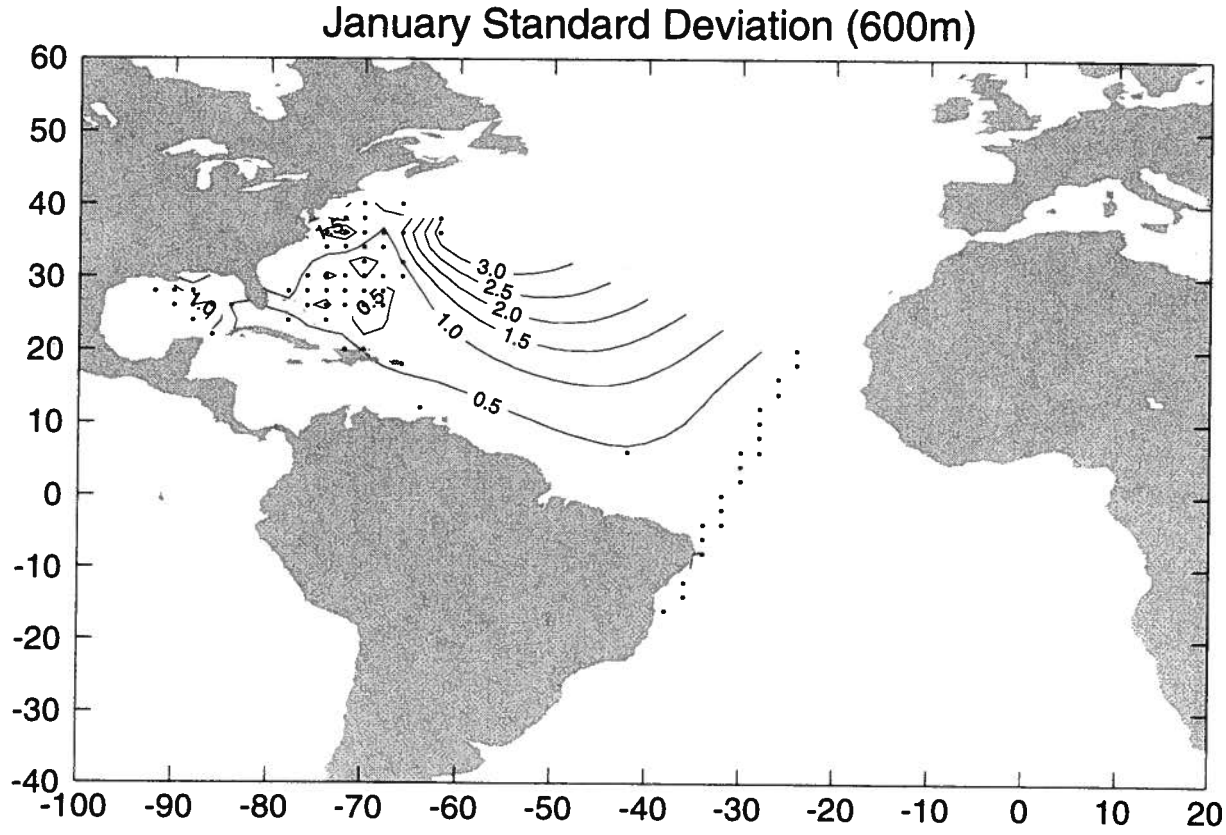

August Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

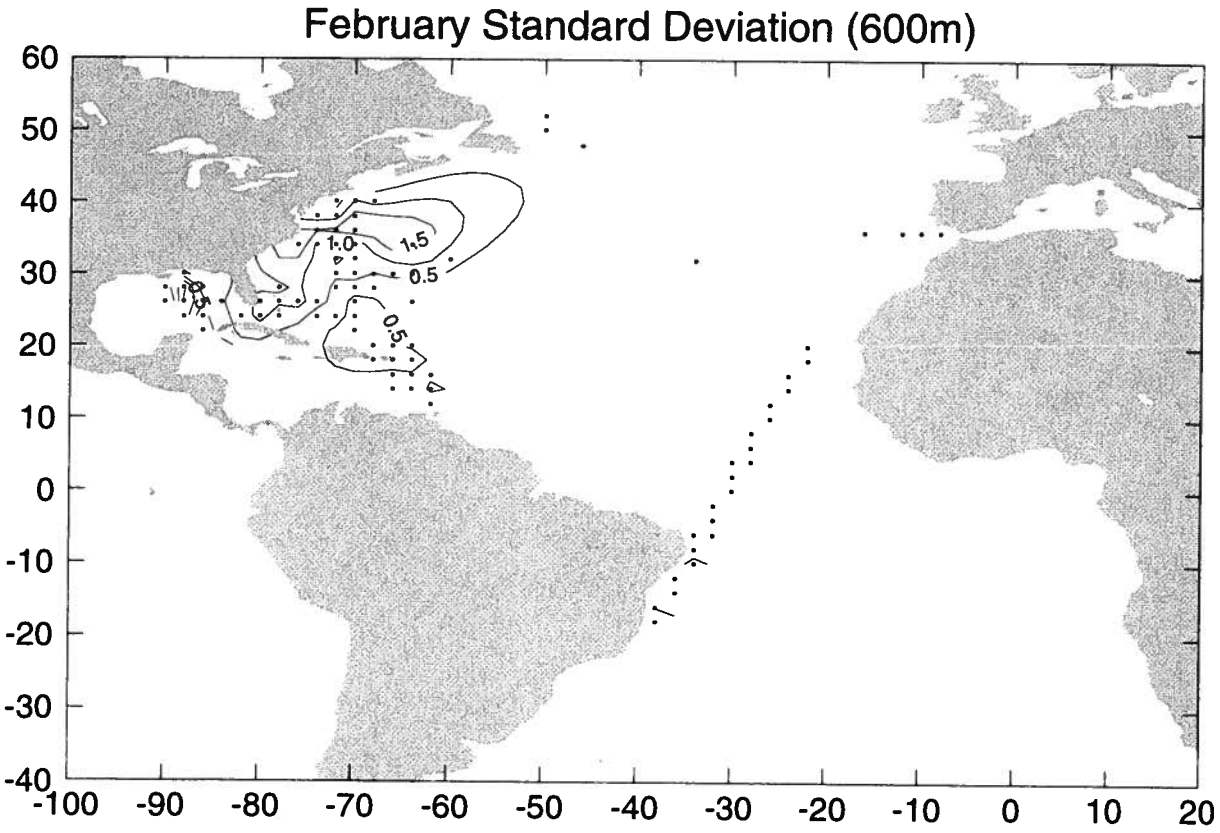

September Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

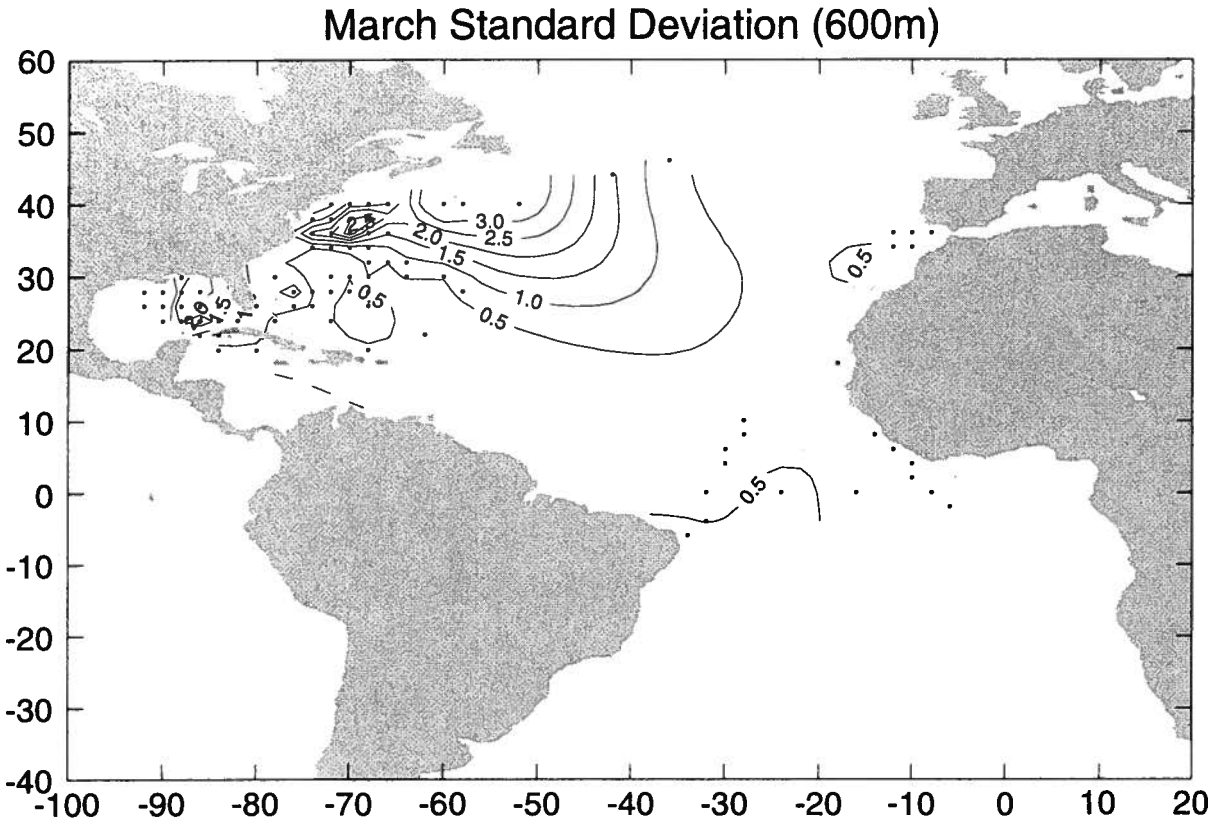

October Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20

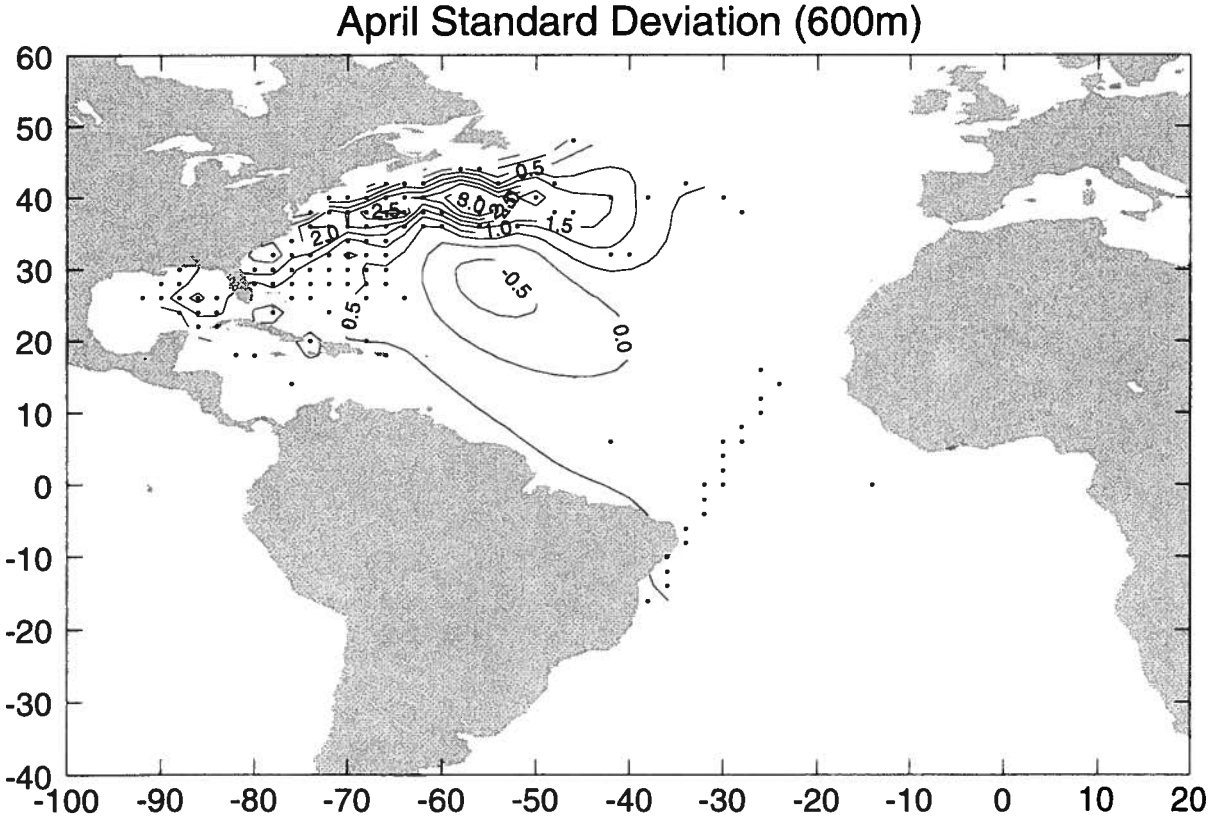

November Standard D eviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
3.0


December Standard Deviation (400m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5
2.0
2.5
3.0

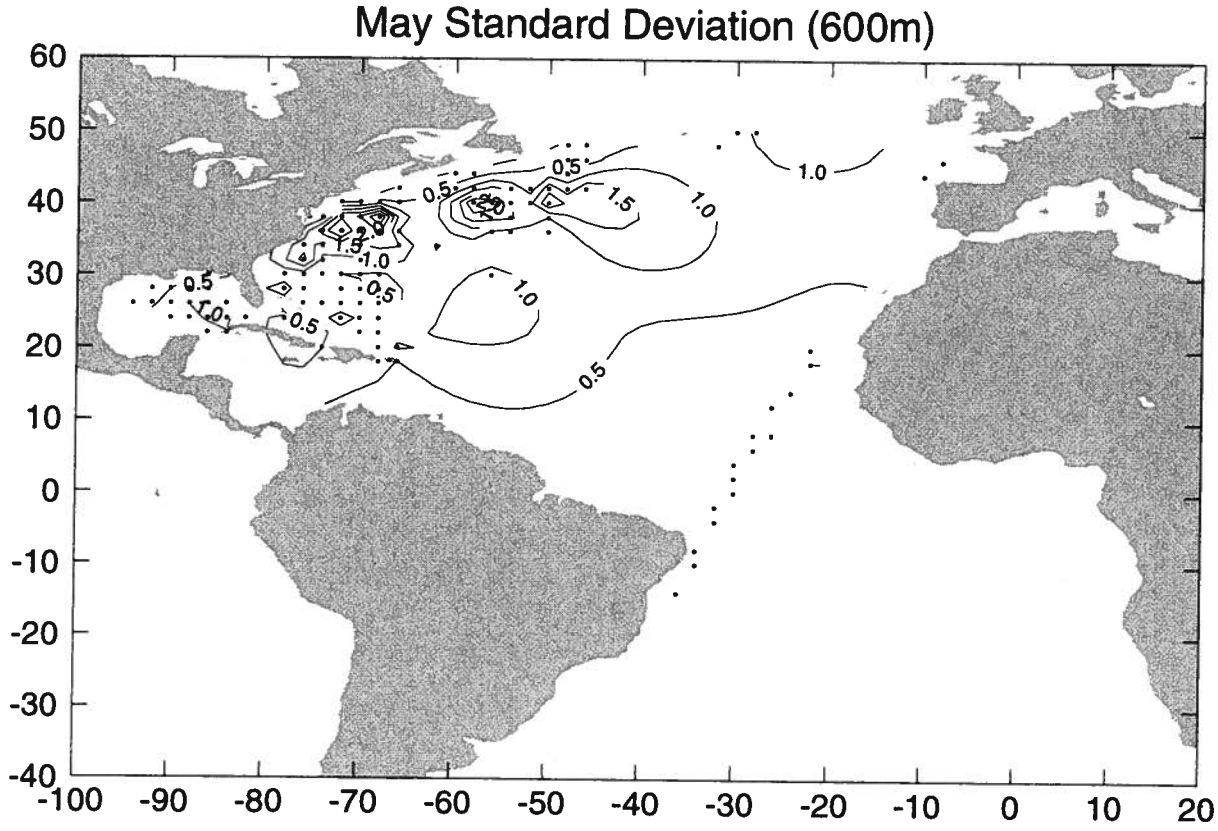

January Standard Deviation (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
3.0
2.5
2.0
1.5
1.0
0.5
1.0
0.5


February Standard Deviation (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
1.0
1.5
0.5
0.5

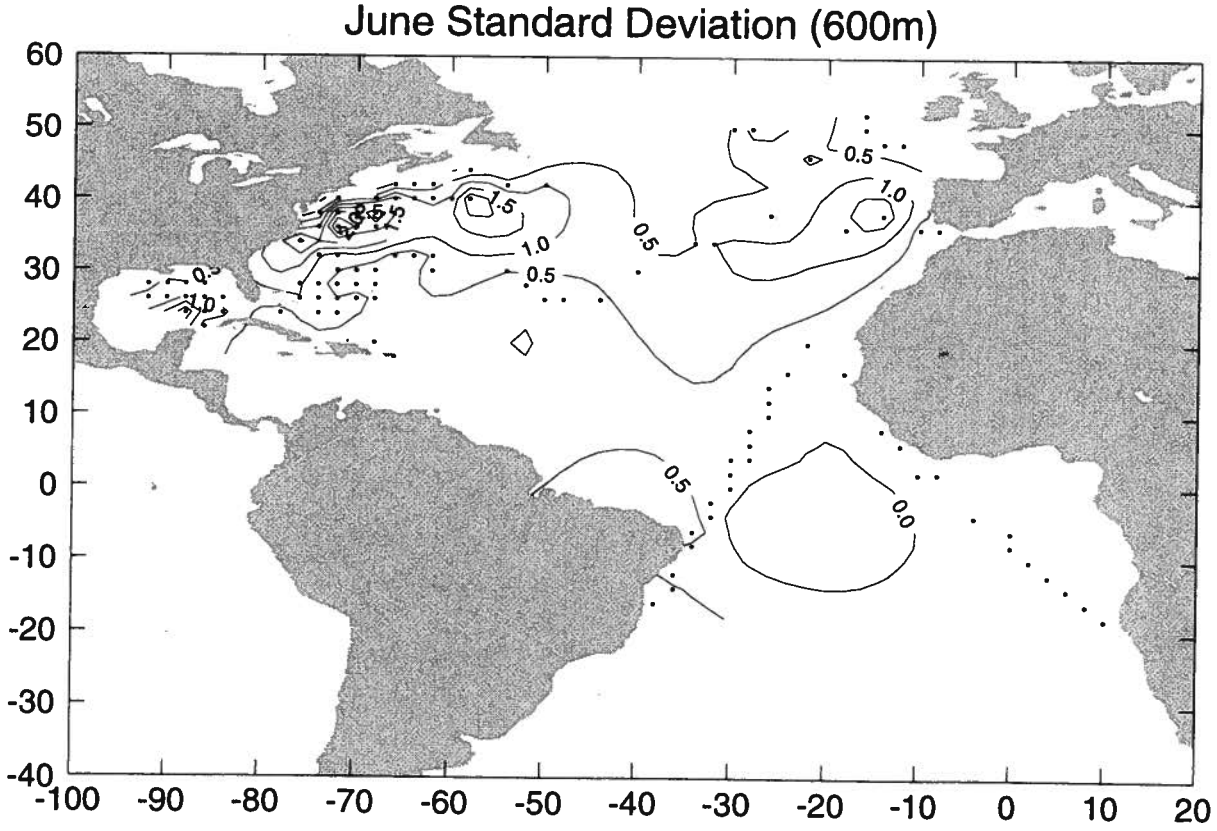

March Standard Deviation (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
3.0
2.5
2.0
1.5
1.0
0.5
0.5
0.5
0.5
0.5

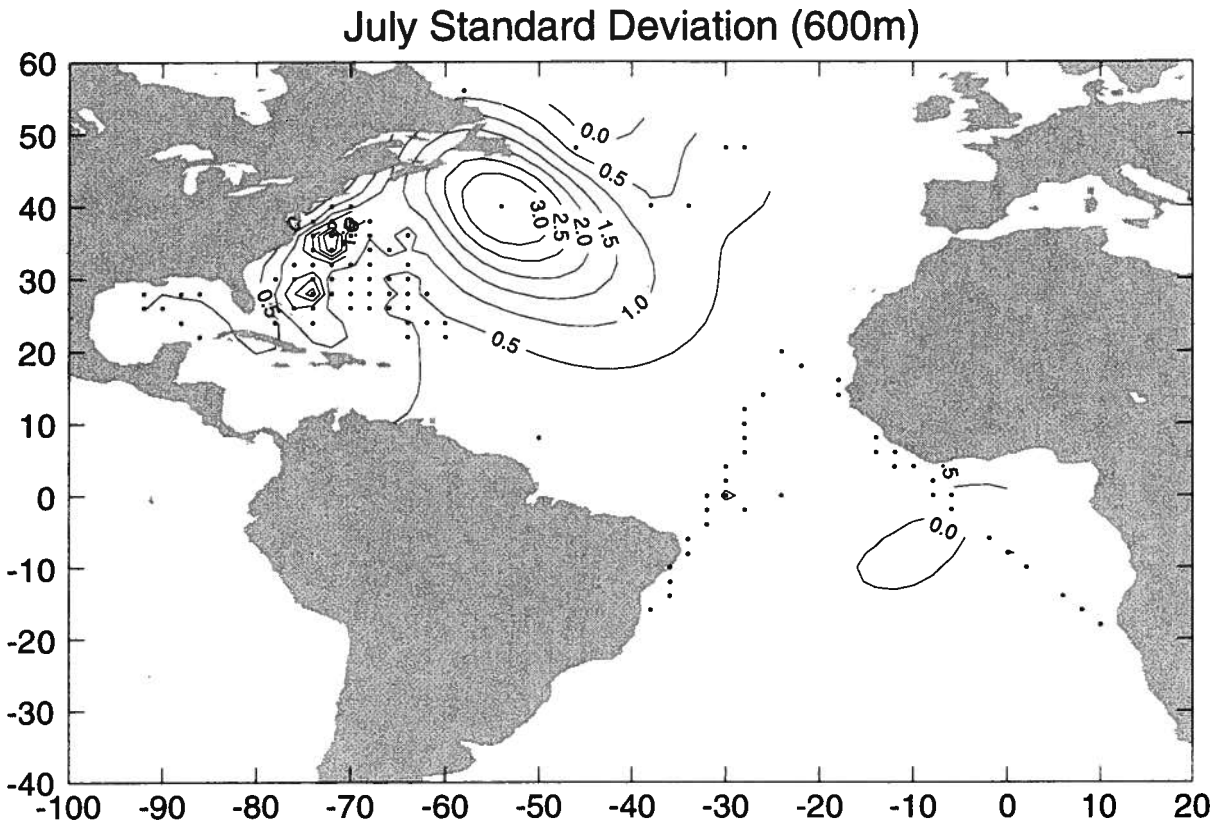

April Standard Deviation (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
2.5
2.0
1.5
1.0
0.5
0.5
0.0

May Standard Deviation (600m)



June Standard Deviation (600m)




July Standard Deviation (600m)
60
50
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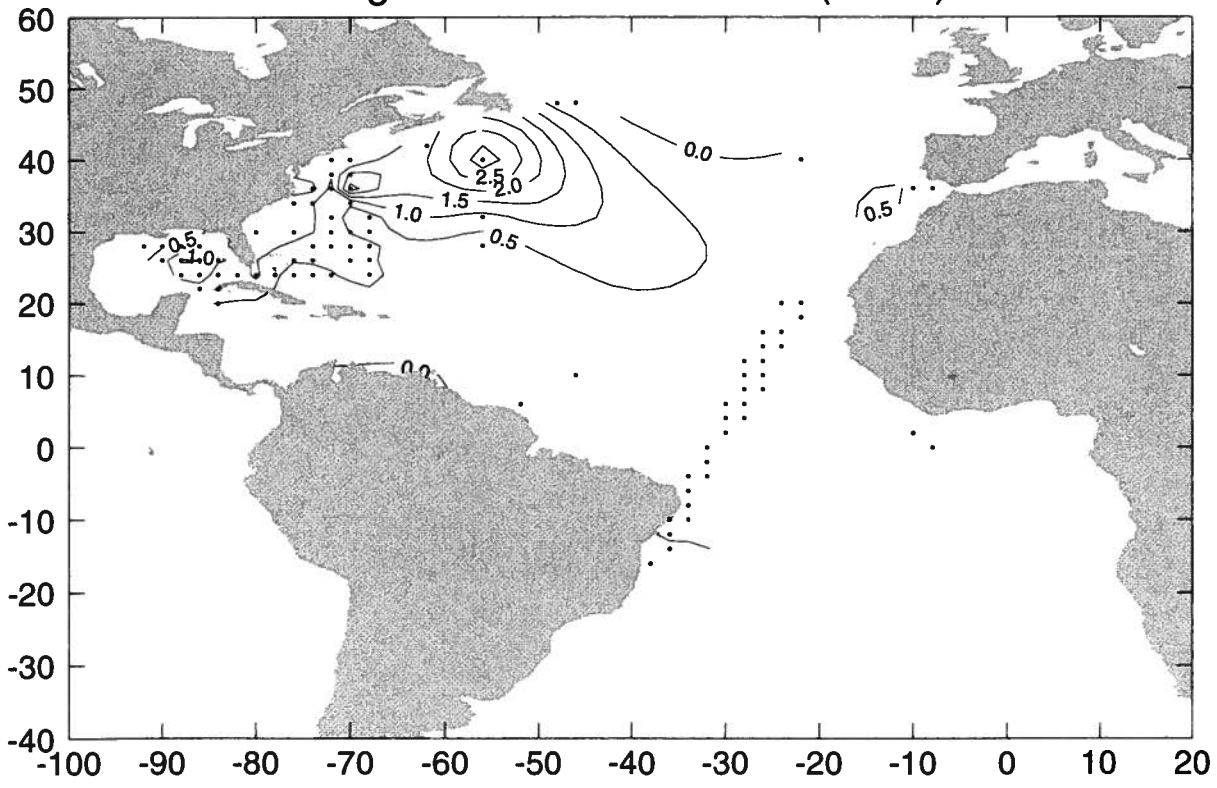
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.0
0.5
1.0
1.5
2.0
2.5
3.0


August Standard Deviation (600m)
60
50
40
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10
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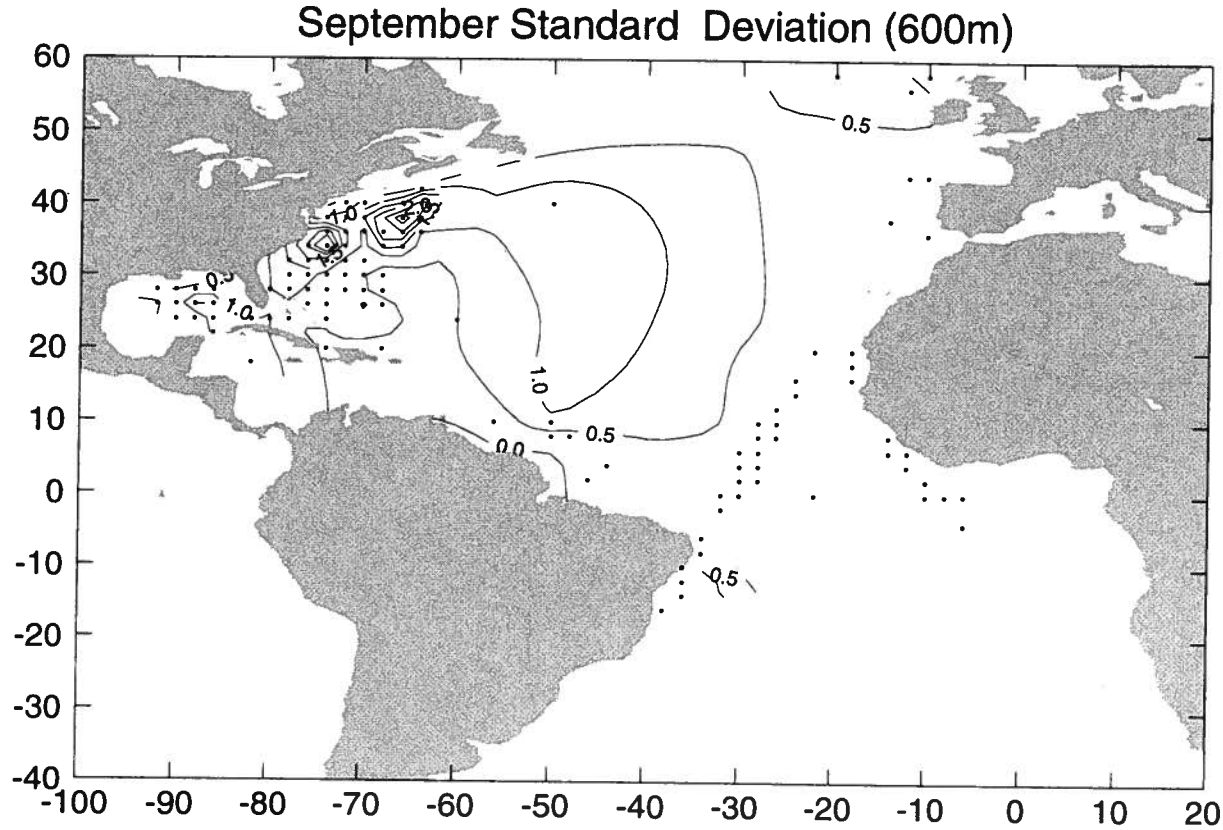
-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.0
0.5
1.0
1.5
2.0
2.5


September Standard Deviation (600m)
60
50
40
30
20
10
0
-10
-20
-30
-40
-100
-90
-80
-70
-60
-50
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-30
-20
-10
0
10
20
0.5
1.0
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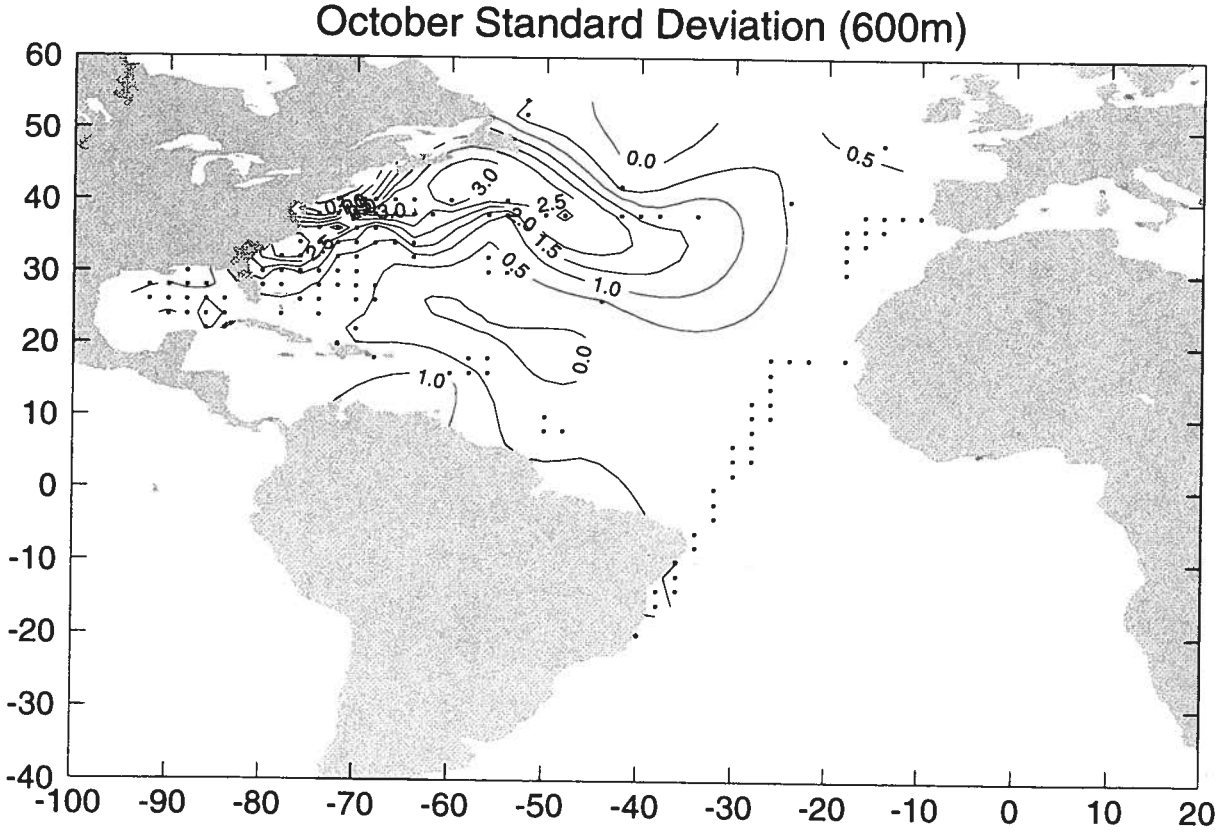
October Standard Deviation (600m)
60
50
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30
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10
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-10
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-100
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-80
-70
-60
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-20
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1.0
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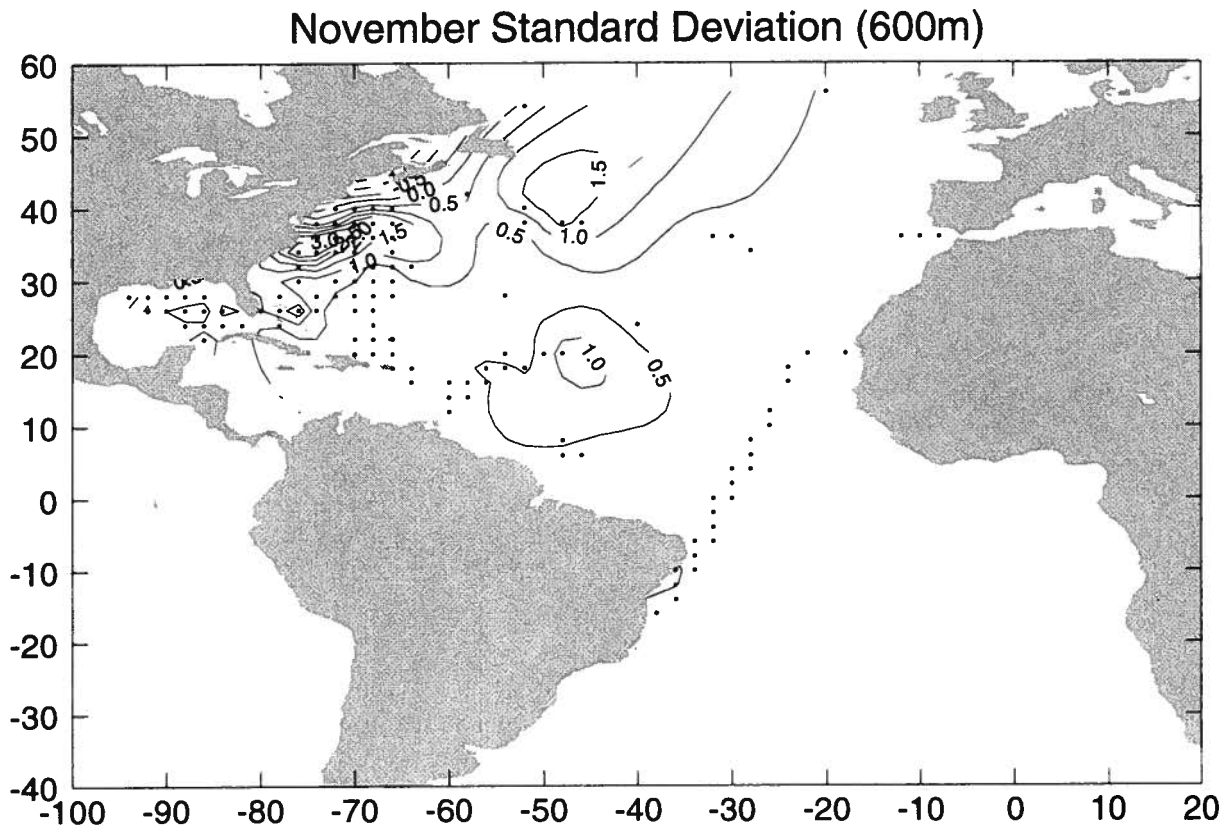
November Standard Deviation (600m)
60
50
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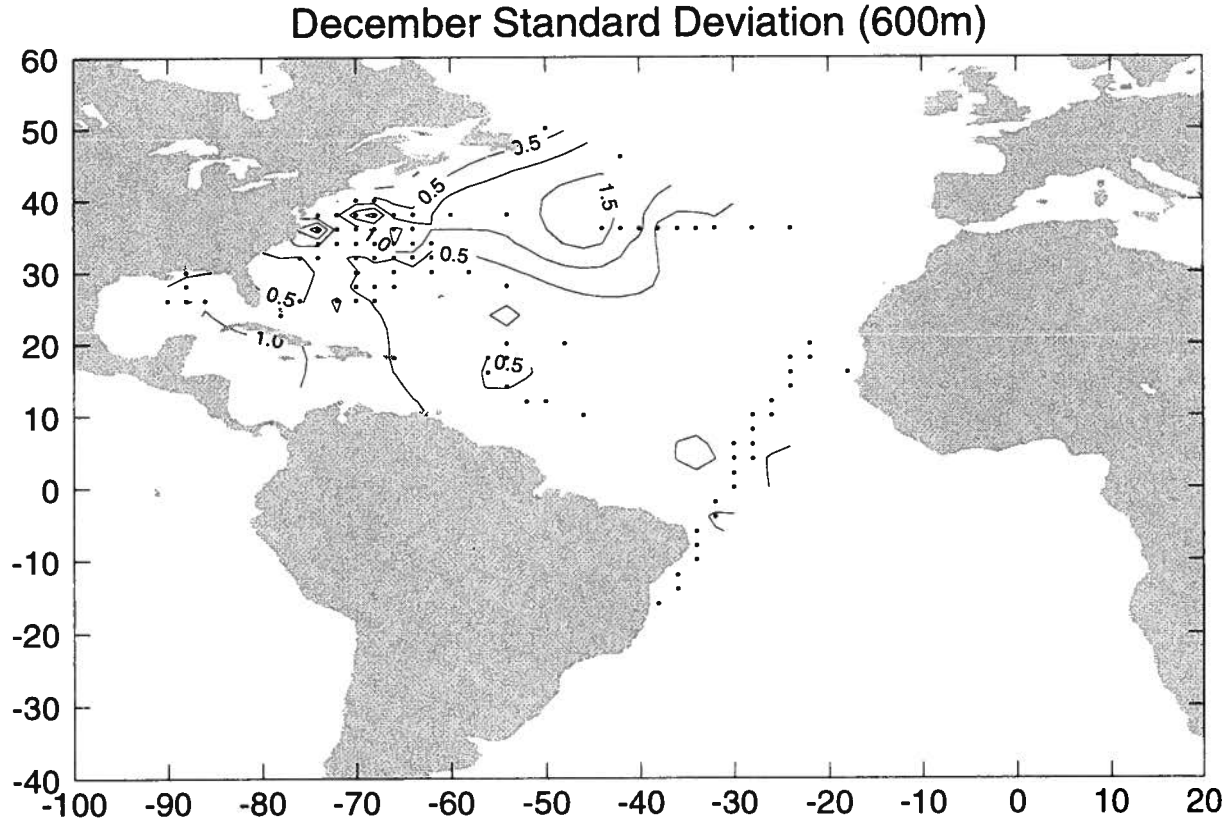
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5


December Standard Deviation (600m)
60
50
40
30
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-10
-20
-30
-40
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20
0.5
1.0
1.5