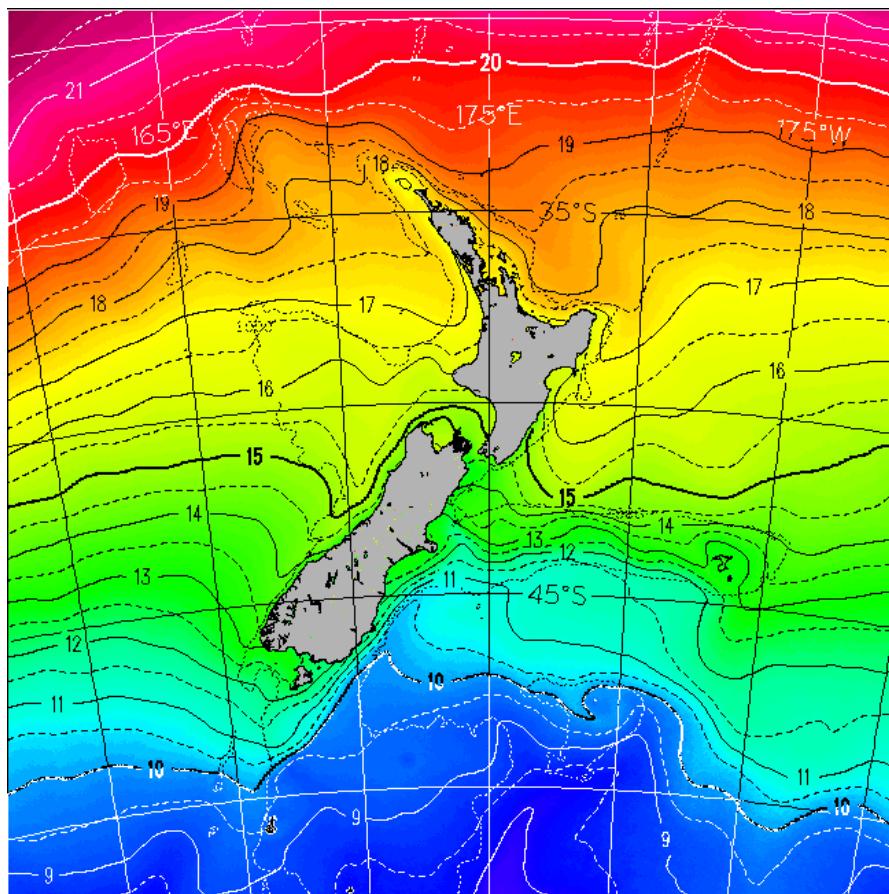


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Sea Surface Temperature Data and Analysis for the 2015 Synthesis Report

For Ministry for the Environment

Reference: 0361-01-RFQ



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Quality Assurance Statement		
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18

Executive Summary

This report provides an analysis of the trends in sea surface temperatures (SST) over the New Zealand region during the 20 year period 1993 to 2012 inclusive.

The long term annual mean is derived from 240 monthly mean SST analyses, which in turn is used to specify the year to year anomalies in SST, both as mapped spatial values at 1 km resolution, and aggregated by Tasman Sea, Sub-Tropical and Sub Antarctic Waters water masses. For reference the aggregated mean SST anomaly over the whole New Zealand region (approximately $2,600 \times 2,600$ km 2) is also indicated.

While there was a significant increase in mean annual SST from 1993 to 1999, SSTs in all but Sub-Antarctic Waters have been close to the long term mean values since 2002. There is a significant apparent positive anomaly in the 2013 data, but this may not be real as the August data for this year are missing from the NSA. Typically August is the month in which SSTs in the New Zealand region reach minimum values.

The largest positive water mass anomaly was 0.67°C in Sub-Antarctic Waters in 1999, and the largest negative water mass anomaly was -0.56°C in Sub-Tropical Waters in 1993, reflecting the cooling impact of the Mt Pinatubo eruption of 15 June 1991.

1 Introduction

The NIWA Sea surface temperature Archive (NSA) is derived from NOAA satellite Advanced Very High Resolution Radiometer (AVHRR) data received by NIWA, and provides high spatial (approximately 1 km) and high temporal (approximately 6 hourly in cloud free locations) resolution estimates of sea surface temperatures over the New Zealand region. NSA data are available for the period January 1993 to the present day. The methods used to derive and validate the NSA are given in Uddstrom and Oien (1999), and Uddstrom (2003).

2 Method

2.1 Long Term Mean SST

The 20 year mean SST for the New Zealand region was estimated by temporally compositing 240 monthly mean 1 km resolution SSTs over a region 2600×2600 km centred on New Zealand, as indicated in Figure 2-1.

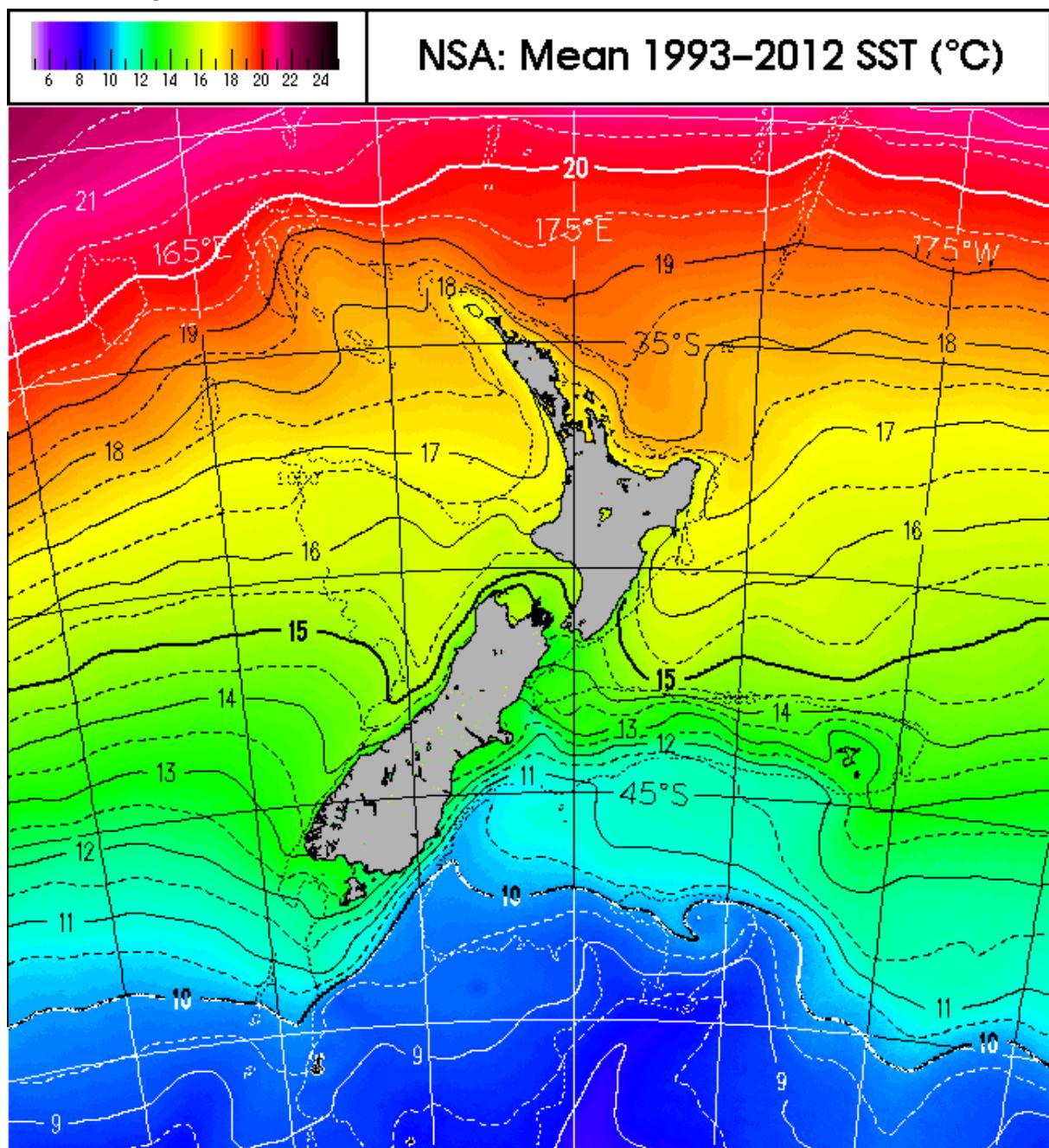


Figure 2-1: Mean sea surface temperatures in the New Zealand region for the period January 1993 to December 2012. Isotherms are indicated by solid and dashed lines, as is the 1000 m bathymetry (dashed) by dotted lines.

The mean SST over the map area is 14.656°C and the mean standard deviation of the SSTs over the map area arising from both within-year and inter-annual variability is 1.859°C .

2.2 Annual Means and Anomalies

The following figure indicates the annual mean (for each of the 20 years) and its anomaly (year minus 20 year mean) with respect to the 20 year mean indicated in Figure 2-1

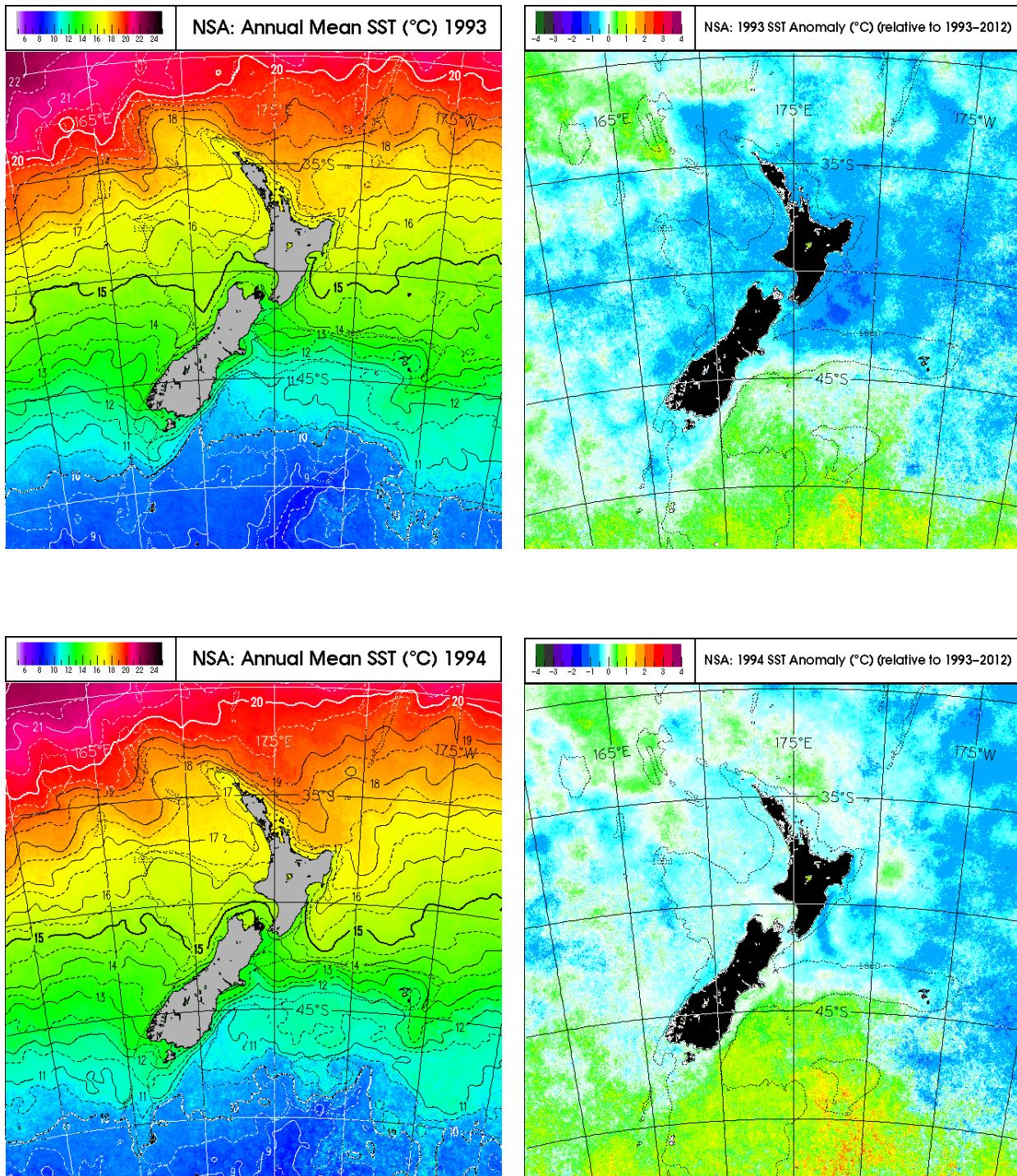
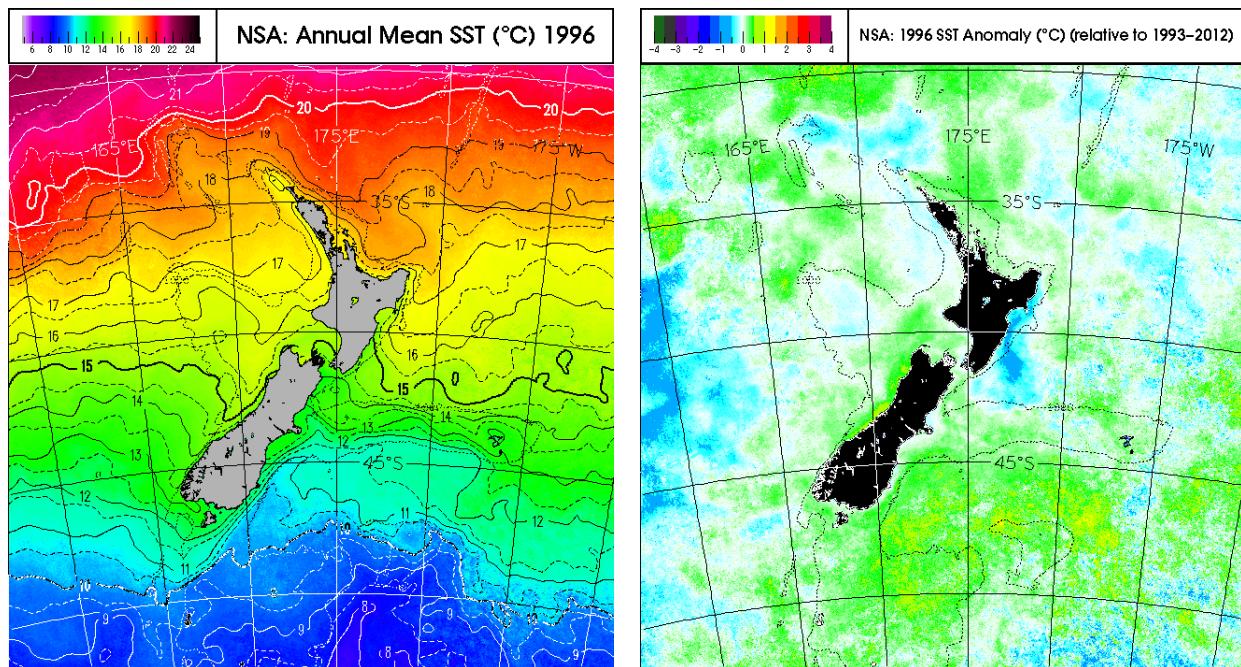
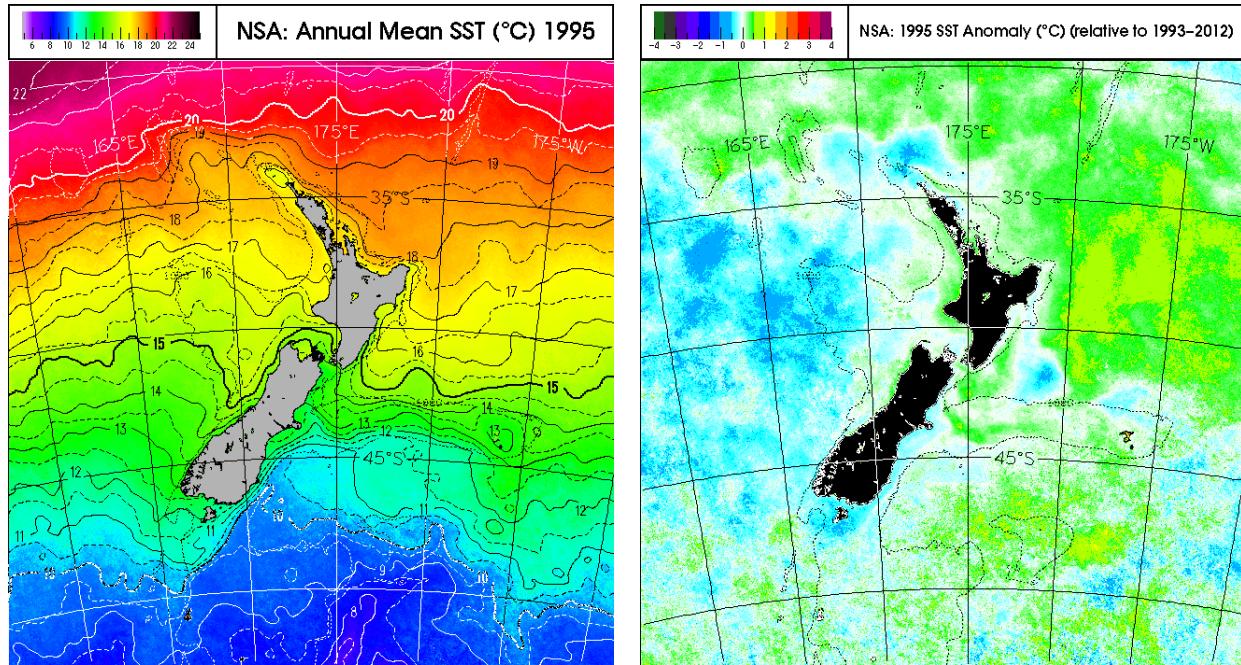
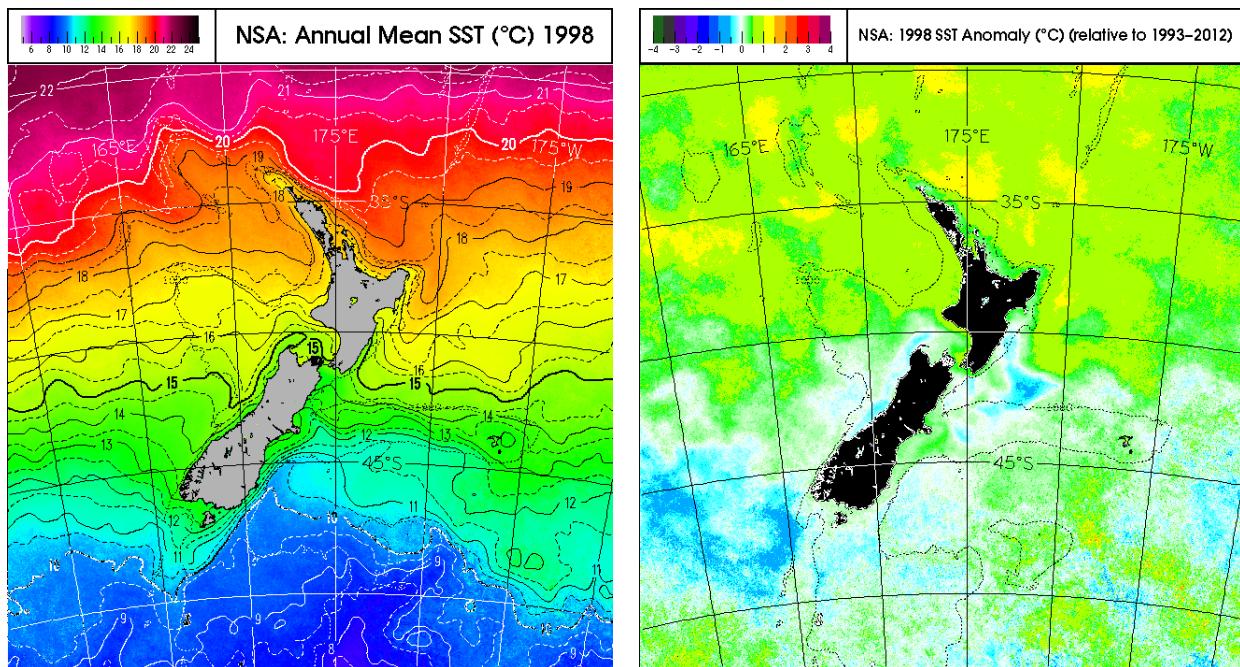
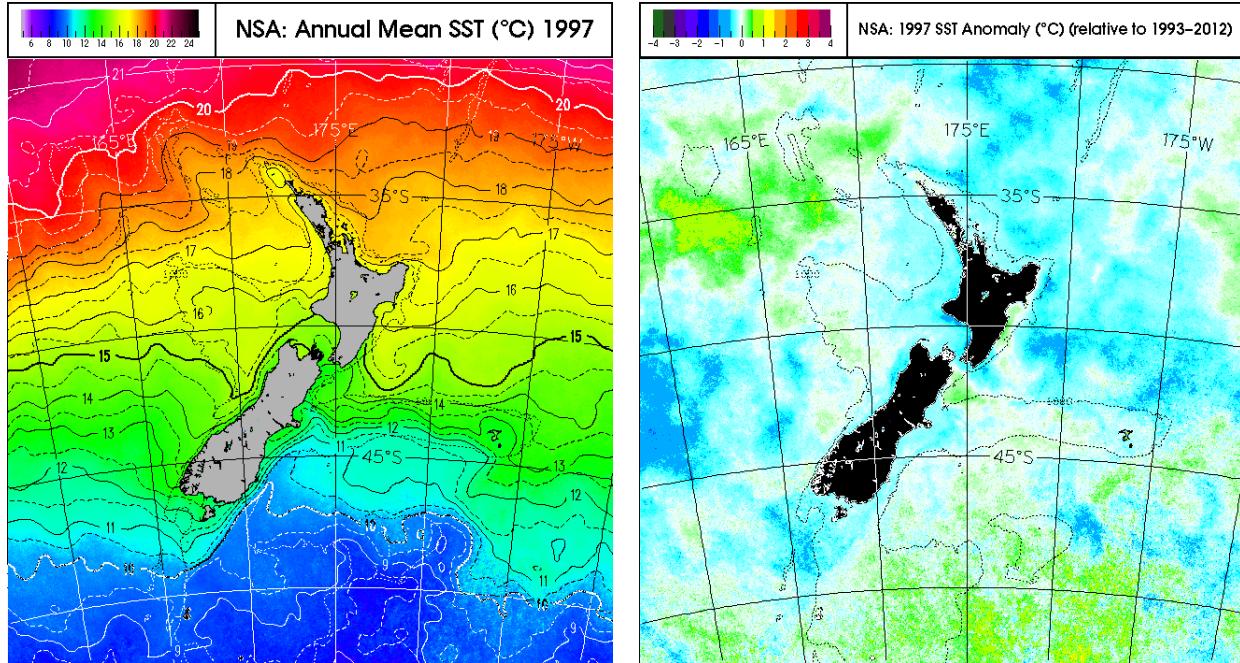
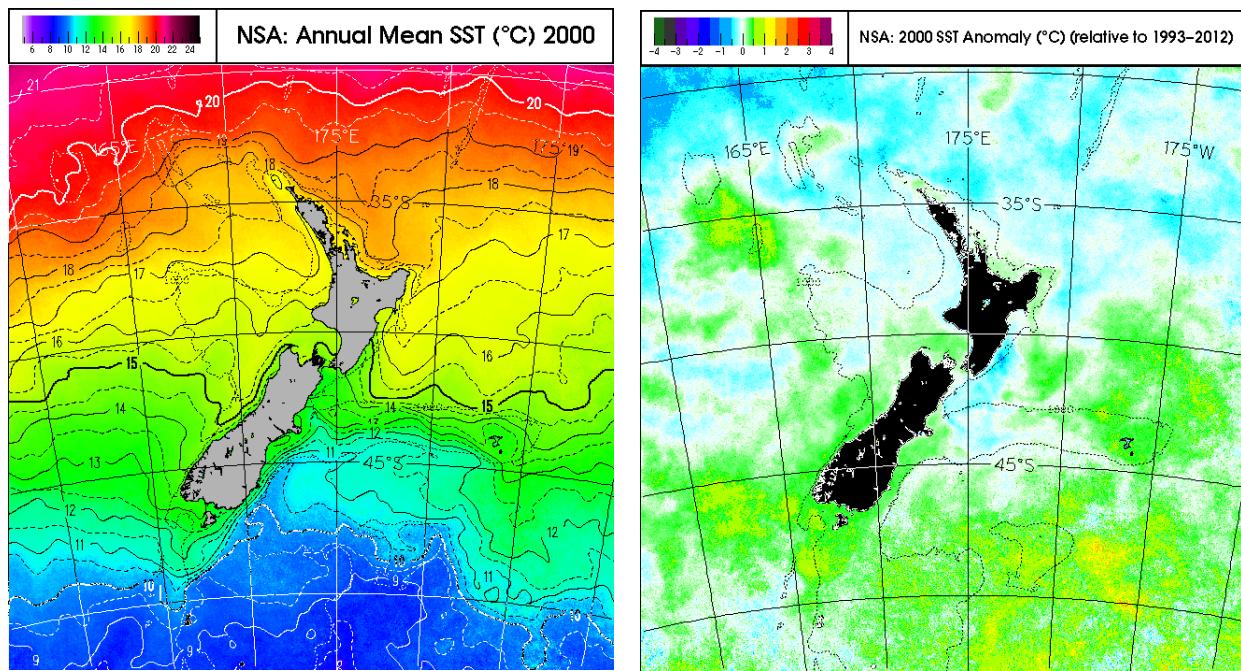
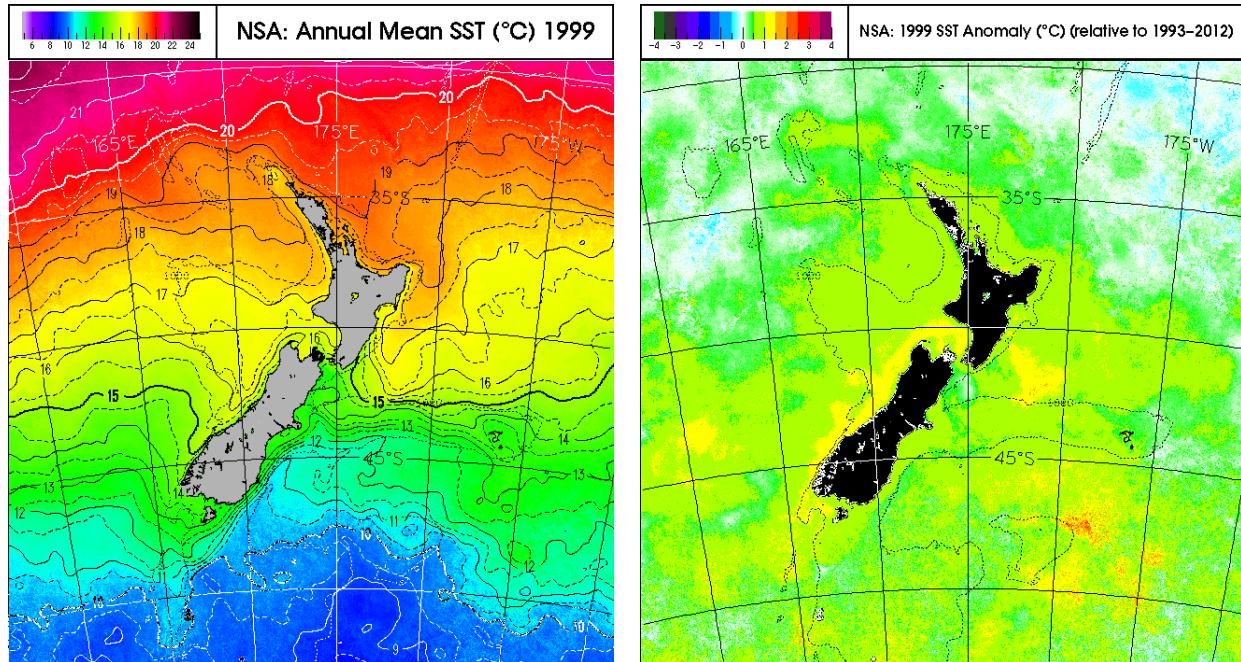
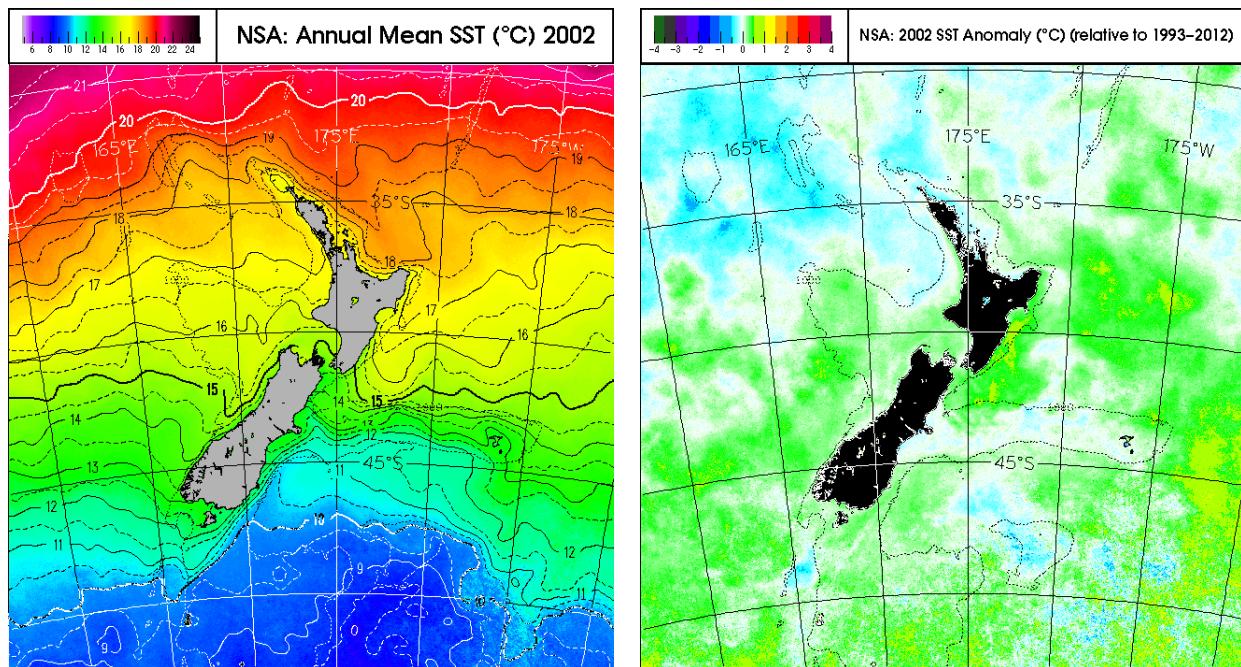
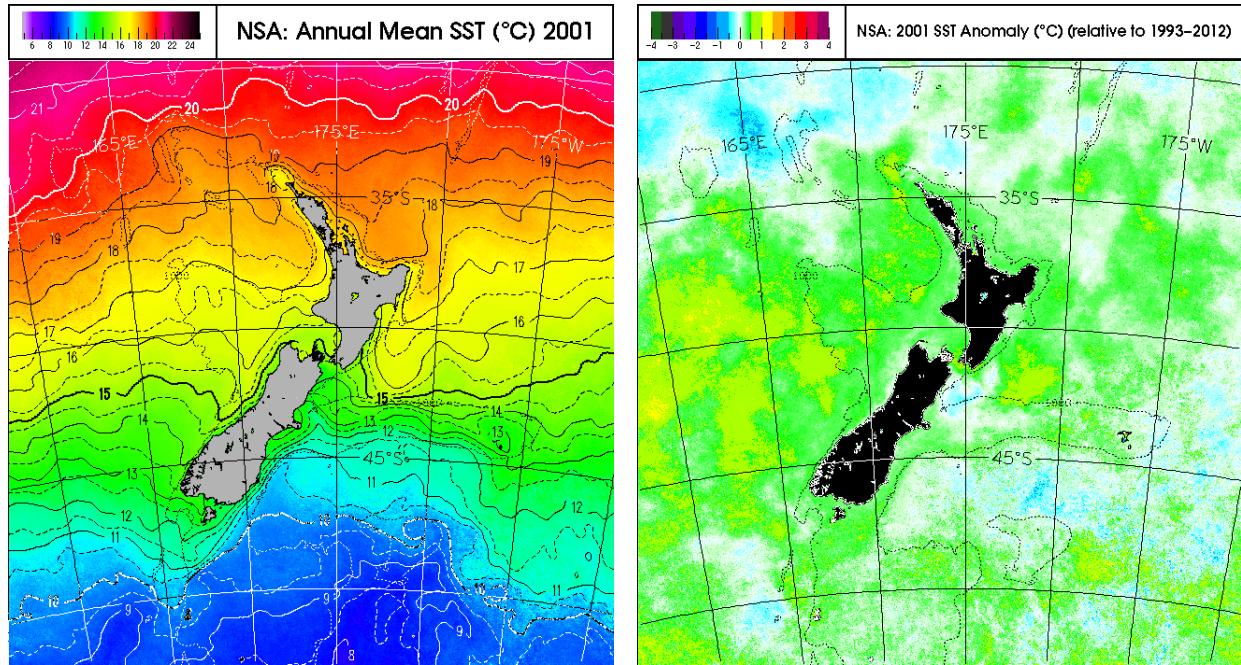


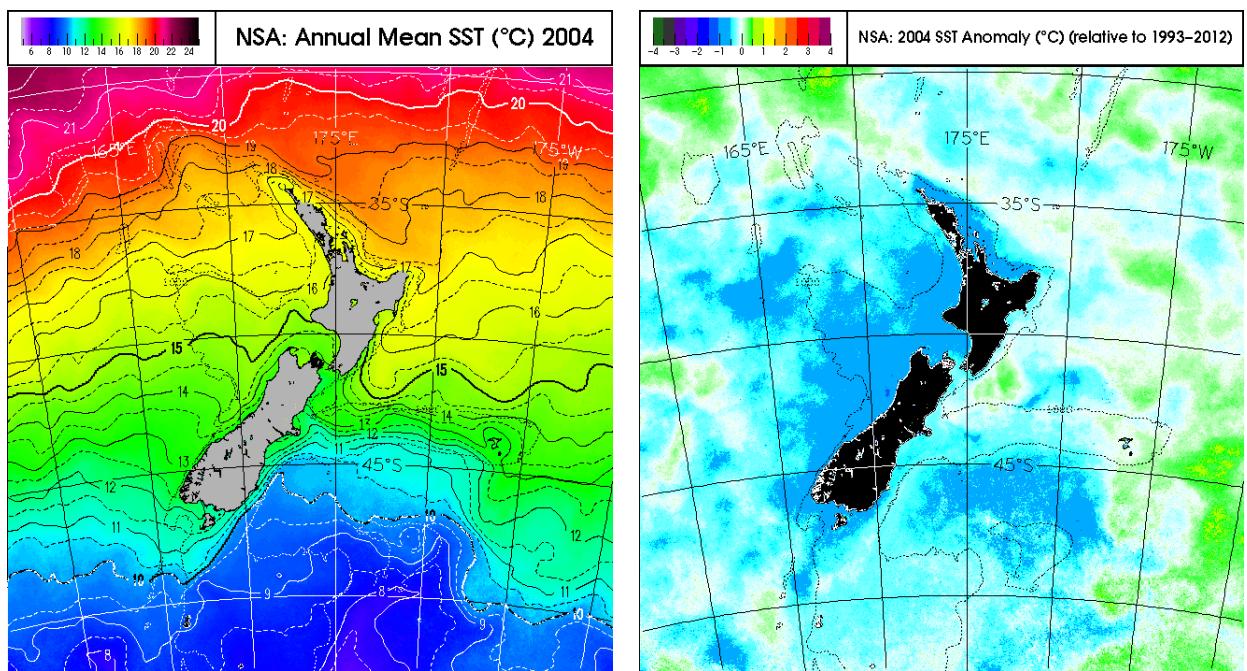
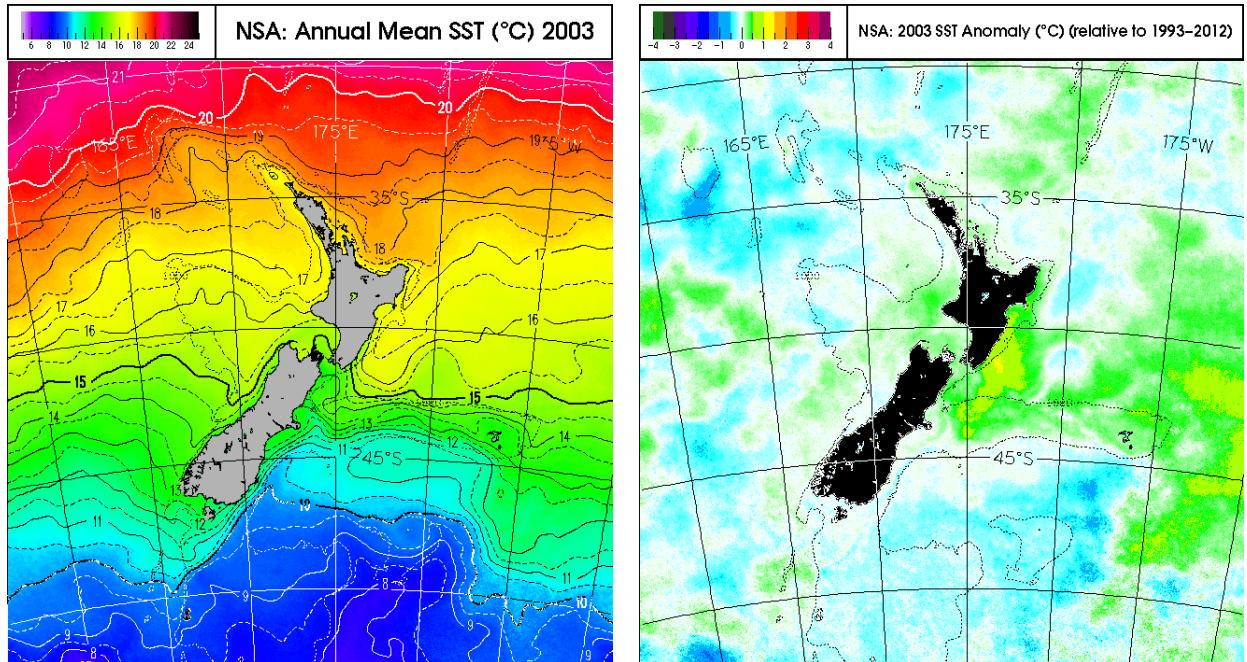
Figure 2-2: Annual SST means and anomalies relative to the 1993-2012 long term mean.

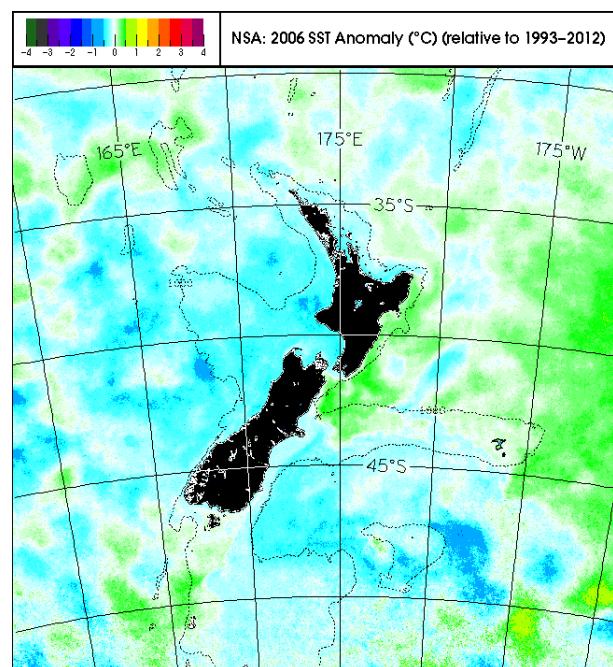
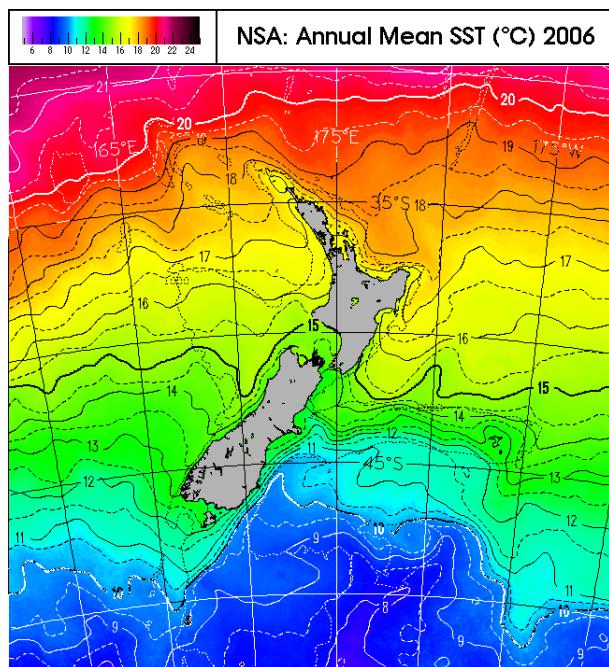
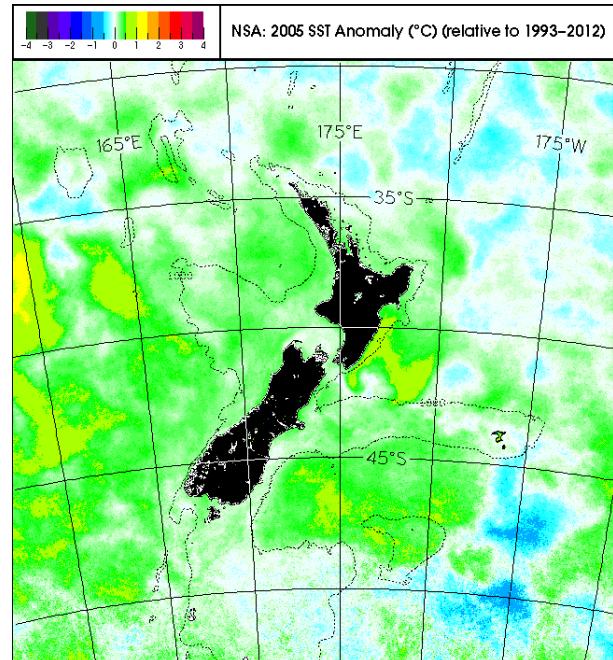
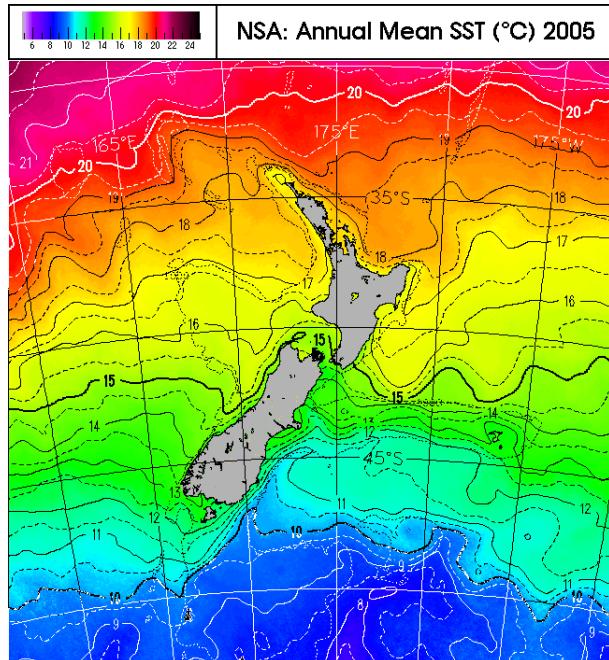


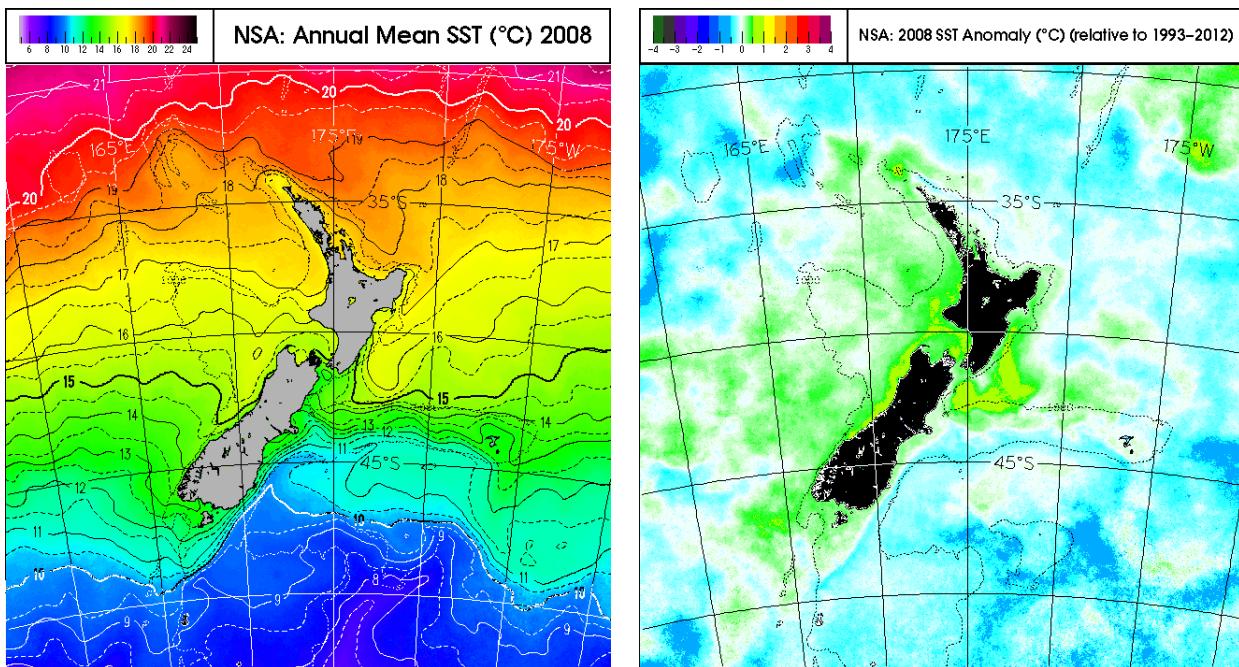
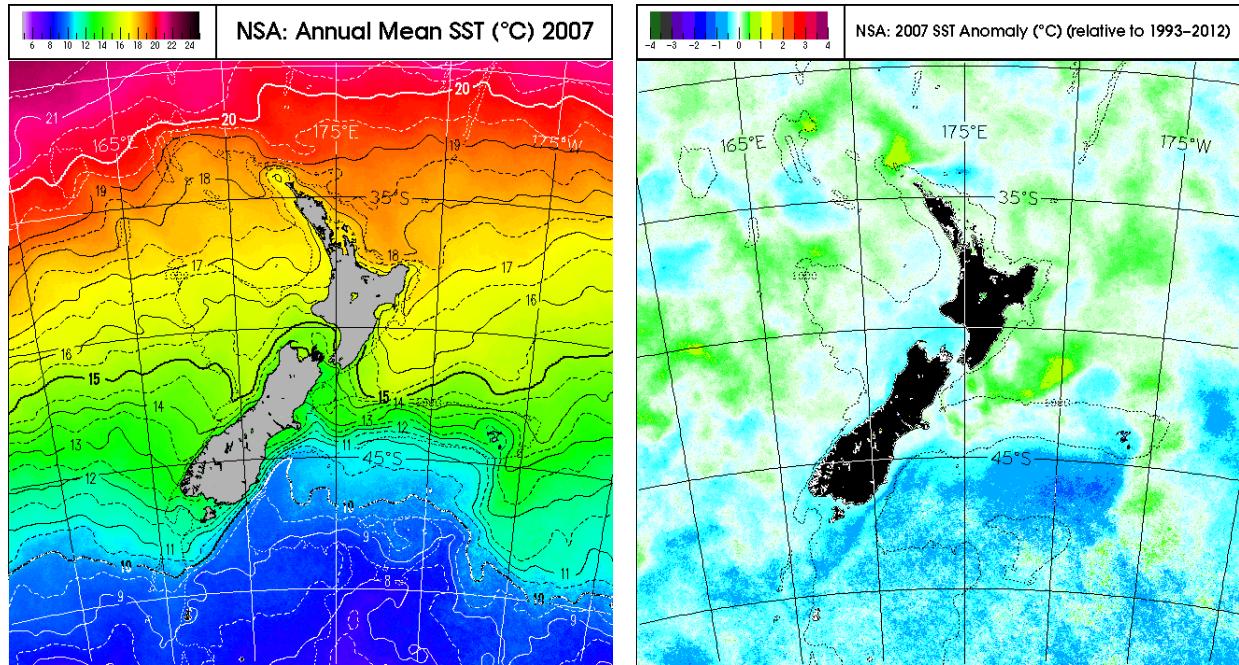


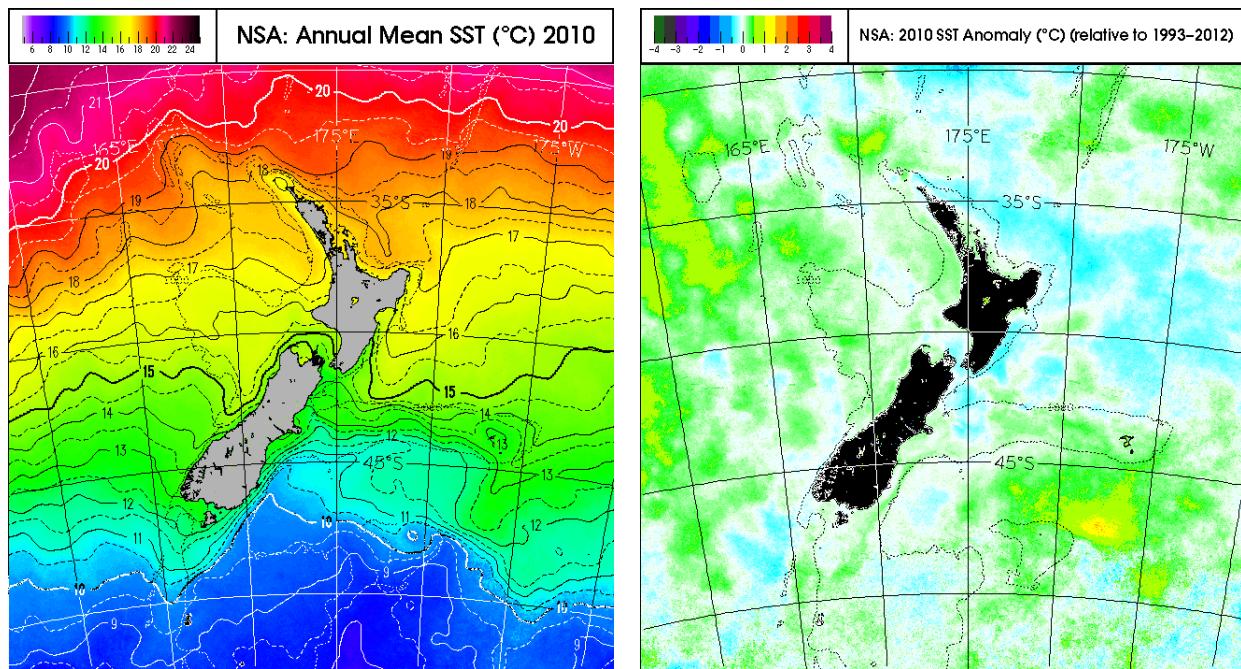
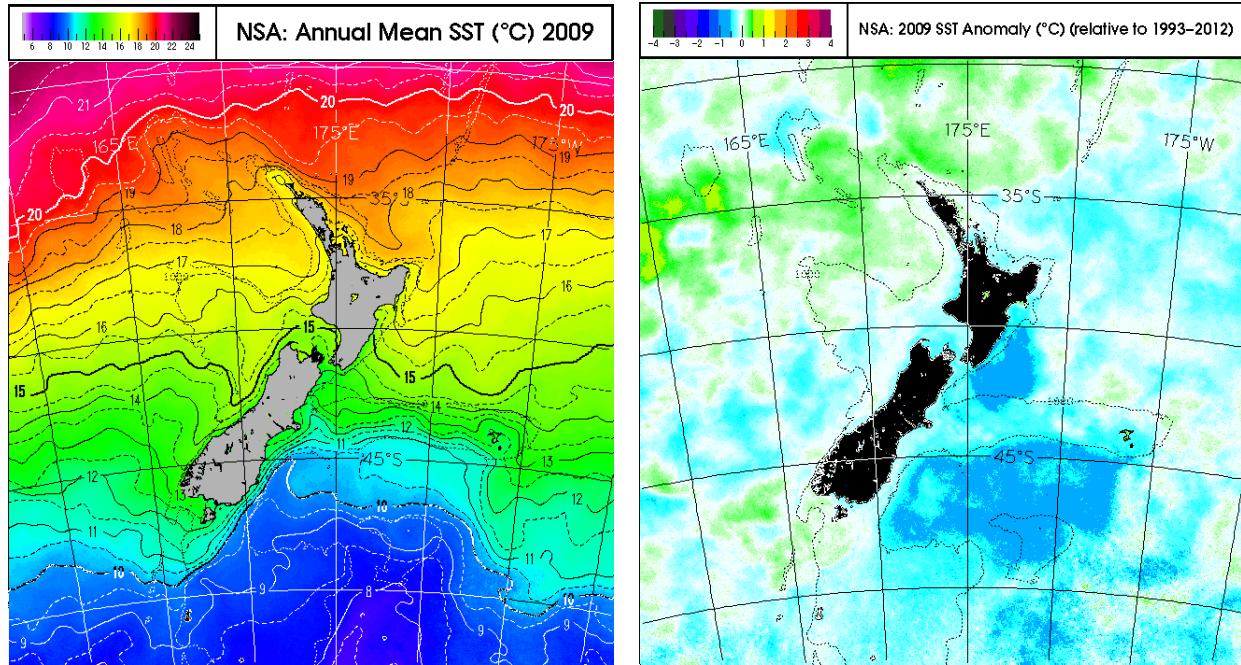


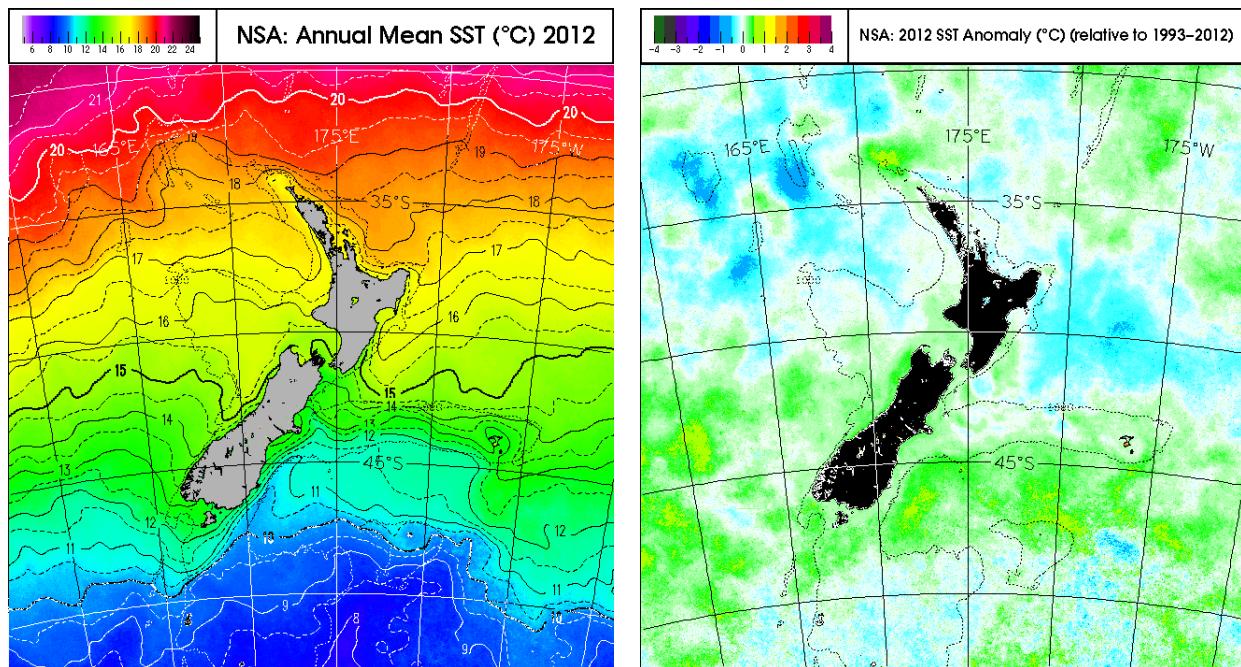
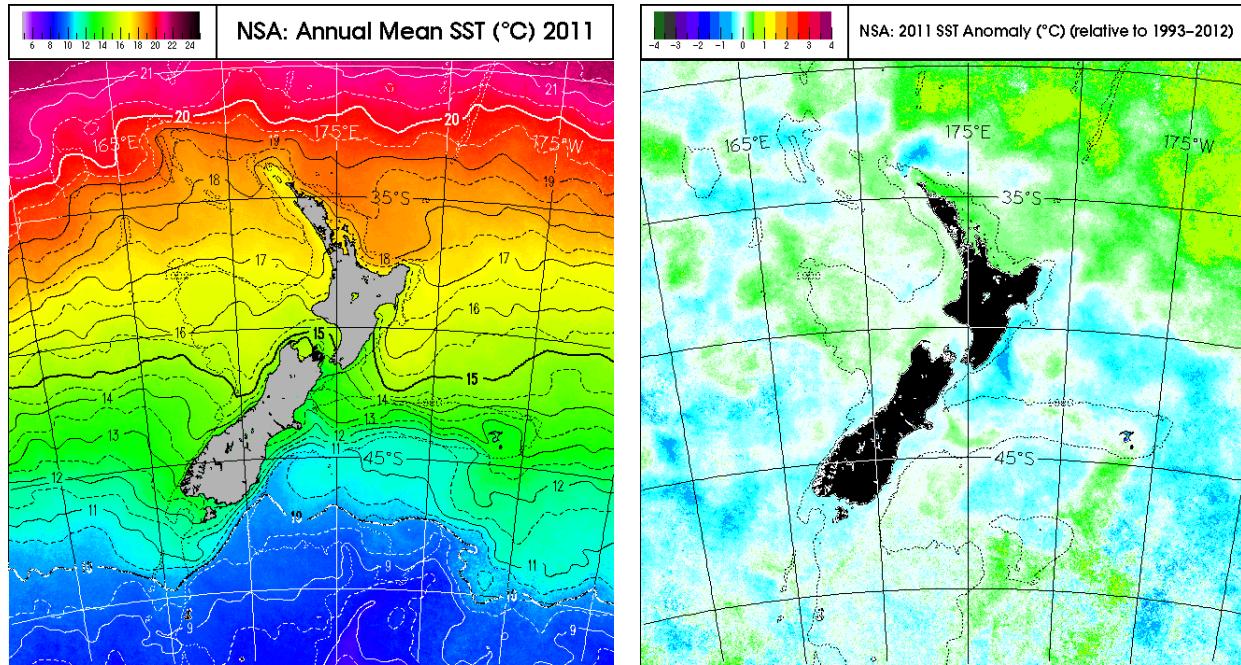


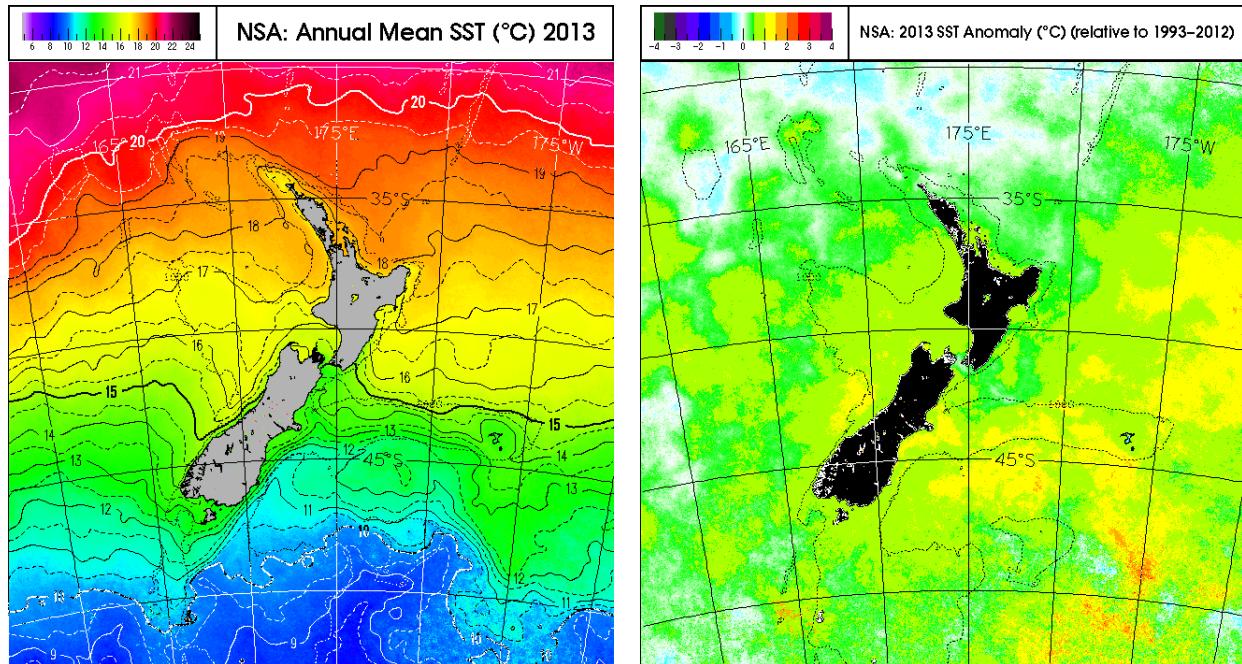












2.3 Time Series Analysis

Three areas were used to specify the spatial average of SSTs, associated approximately, with the eastern Tasman Sea, Sub Tropical Waters (STW) north of the Chatham Rise, and Sub Antarctic Waters (SAW) south of the Chatham Rise. The spatial average temperature for the whole mapped area was also calculated. The following table specifies the polygons used to describe the sub areas.

Table 2-1: Tasman, STW and SAW analysis polygons (decimal degrees). (Southern Latitudes are indicated with a minus sign, and all longitudes are West of Greenwich).

Tasman Sea		Sub-Tropical Waters (STW)		Sub-Antarctic Waters (SAW)	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
-34.43	160.60	-29.82	172.87	-44.00	171.20
-47.25	157.50	-34.43	172.87	-47.25	167.50
-47.25	167.50	-37.05	175.00	-52.64	167.50
-41.60	172.30	-38.67	176.44	-52.52	185.00
-40.82	172.14	-41.35	175.00	-44.00	185.00
-40.55	172.70	-43.00	172.54	-44.00	171.20
-39.30	173.75	-43.00	185.00		
-39.20	175.00	-29.82	185.00		
-37.05	175.00	-29.82	172.87		
-34.43	172.80				
-34.43	160.60				

Figure 2-3 indicates the annual mean SSTs for each sub-area (Map Area, Tasman, STW, SAW) over the analysis period¹

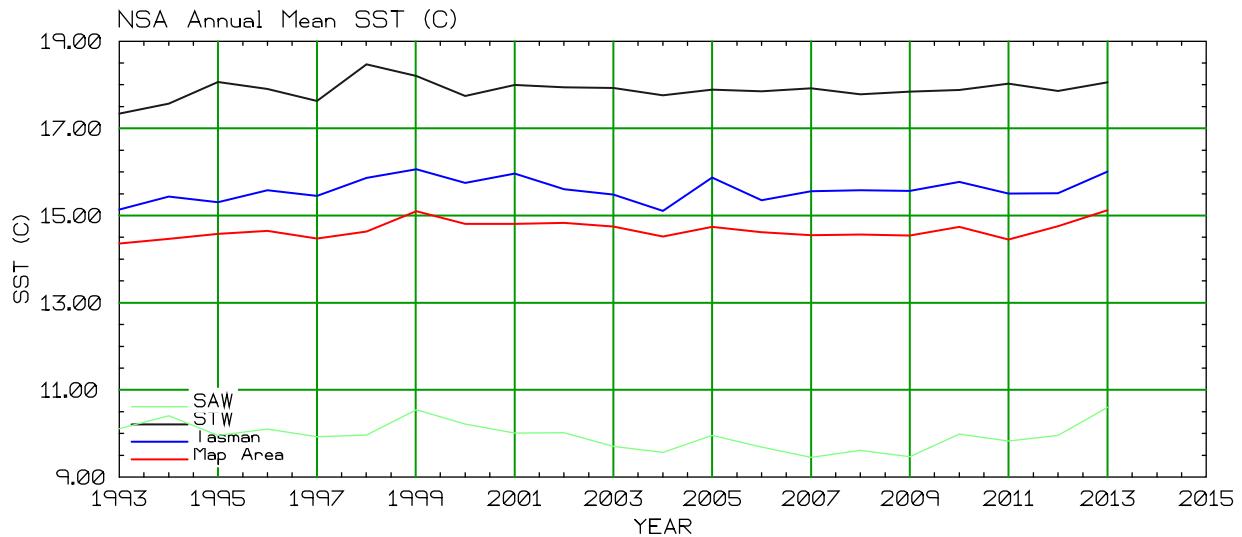


Figure 2-3: NSA Annual Mean SSTs (by water mass).

The expected standard error in the mean values lies in the range 0.001°C (for the Sub-Antarctic Waters sub-area) to 0.002°C (for the map area), indicating that all inter-annual variations are significant.

The SST anomalies (with respect to the 1993-2012, 20 year long term mean) for the same areas and period are shown in Figure 2-4²

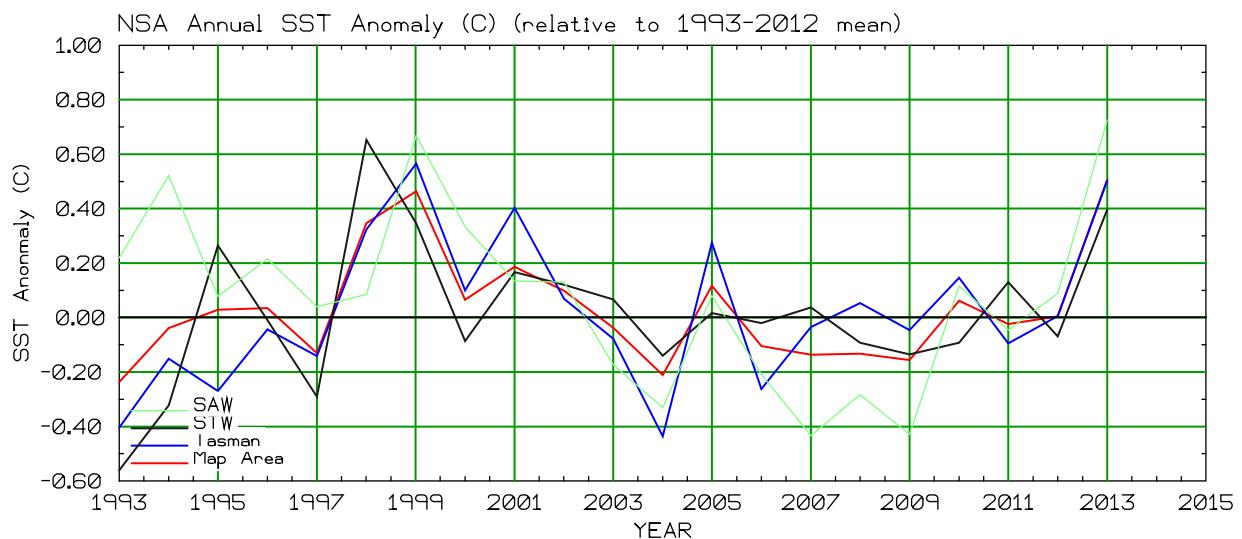


Figure 2-4: Annual SST anomalies (with respect to the long term 1993-2012 mean) for each sub area.

¹ Note: For 2013, August data, typically the month in which SSTs in the New Zealand region reach minimum values are missing from the NSA – which may be responsible for the apparently warmer SSTs in the region.

² Note: For 2013, August data, typically the month in which SSTs in the New Zealand region reach minimum values are missing from the NSA – which may be responsible for the large positive anomaly.

The expected standard error in the mean values lies in the range 0.0002°C (for the map area) to 0.0004°C (for the Sub-Antarctic Waters sub-area), indicating that all inter-annual variations are significant.

The component data for each time series is provided in Appendix A

3 Comment

While there was a significant increase in mean annual SST from 1993 to 1999, SSTs in all but Sub-Antarctic Waters have been close to the long term mean values since 2002. There is a significant apparent positive anomaly in the 2013 data, but this may not be real as the August data for this year are missing from the NSA. Typically August is the month in which SSTs in the New Zealand region reach minimum values.

The largest positive water mass anomaly was 0.67°C in Sub-Antarctic Waters in 1999, and the largest negative water mass anomaly was -0.56°C in Sub-Tropical Waters in 1993, reflecting the cooling impact of the Mt Pinatubo eruption on 15 June 1991.

4 Glossary of abbreviations and terms

AVHRR	Advanced Very High Resolution Radiometer
NOAA	National Oceanic and Atmospheric Administration (USA)
NSA	NIWA SST Archive
SAW	Sub-Antarctic Waters
SST	Sea Surface Temperature
STW	Sub-Tropical Waters

5 References

- Uddstrom, M.J. and N.A. Oien 1999: On the use of high resolution satellite data to describe the spatial and temporal variability of sea surface temperatures in the New Zealand Region. *Journal of Geophysical Research (Oceans)* **104**, C9, 20729 – 20751.
- Uddstrom, M.J., 2003: Lessons from high-resolution satellite SSTs. *Bulletin of the American Meteorological Society*, **84**(7), 896-897.

D R A F T Appendix A SST Mean and Anomaly Statistics by Year

SST Sub-Area Mean Data

The tables below indicate, for each year, the spatial mean SST, the standard deviation in the spatial mean SST, the minimum SST for the year, the maximum SST for the year, and the sample size (i.e. number of SST data used to calculate the mean and standard deviation).

Map Area

Table 5-1: Statistics of the annual mean SST over the mapped area.

Year	Mean (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	14.361	3.648	7.041	23.403	6444317
1994	14.468	3.563	6.061	24.110	6444254
1995	14.578	3.851	6.007	23.256	6444670
1996	14.649	3.787	6.765	22.579	6444554
1997	14.473	3.767	6.983	23.698	6444911
1998	14.632	3.897	6.715	23.256	6444993
1999	15.098	3.771	7.704	22.550	6444939
2000	14.811	3.764	6.908	22.844	6444677
2001	14.807	3.849	7.115	22.608	6446041
2002	14.833	3.862	7.360	22.020	6445970
2003	14.749	3.974	7.093	22.520	6446136
2004	14.519	3.925	6.826	23.109	6449116
2005	14.742	3.845	7.026	23.521	6451441
2006	14.620	3.909	7.143	24.110	6449371
2007	14.546	4.002	6.922	22.314	6449512
2008	14.563	3.929	6.877	23.698	6450169
2009	14.543	3.973	7.039	23.757	6450855
2010	14.739	3.860	7.211	22.432	6451412
2011	14.454	3.833	6.449	24.875	6450142
2012	14.756	3.840	7.368	23.374	6450272
2013	15.121	3.844	6.943	22.991	6451120

Tasman Sea

Table 5-2: Statistics of the annual mean SST over the Tasman Sea area.

Year	Mean (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	15.137	2.086	9.324	22.984	1490916
1994	15.436	2.061	9.826	22.162	1491138
1995	15.309	2.126	9.211	21.966	1490963

1996	15.583	2.203	8.941	21.814	1490861
1997	15.452	2.287	8.321	21.128	1491061
1998	15.861	2.512	8.566	22.112	1491104
1999	16.065	1.930	9.212	20.880	1491200
2000	15.750	2.058	9.336	21.293	1490979
2001	15.963	2.094	8.386	22.608	1491605
2002	15.604	1.935	8.987	21.491	1491499
2003	15.484	2.100	9.102	21.395	1491668
2004	15.108	2.120	8.500	23.109	1492128
2005	15.873	2.065	9.070	21.646	1493649
2006	15.349	2.129	9.134	24.110	1492428
2007	15.558	2.193	9.130	22.135	1492504
2008	15.581	2.034	10.254	21.701	1492859
2009	15.565	2.244	9.190	21.989	1492808
2010	15.771	2.200	10.471	20.992	1493593
2011	15.505	2.238	8.173	23.196	1492752
2012	15.516	1.945	9.503	23.374	1492871
2013	16.009	2.0898	10.519	21.491	1493117

Sub-Tropical Waters

Table 5-3: Statistics of the annual mean SST over the Sub-Tropical Waters area.

Year	Mean (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	17.338	2.083	11.943	22.544	1375991
1994	17.567	1.964	10.606	24.110	1376092
1995	18.066	1.875	11.979	23.256	1376097
1996	17.901	1.977	11.278	21.310	1376056
1997	17.632	1.906	12.017	23.698	1376117
1998	18.472	2.172	12.457	23.027	1376142
1999	18.199	1.712	12.491	22.550	1376091
2000	17.743	1.785	11.887	22.844	1376066
2001	17.994	1.812	10.444	21.842	1376444
2002	17.946	1.768	12.162	21.608	1376474
2003	17.926	1.790	11.753	22.520	1376410
2004	17.757	1.922	11.104	22.778	1377495
2005	17.891	1.816	12.419	23.521	1377596
2006	17.848	1.831	11.515	22.725	1377446
2007	17.921	1.880	10.502	22.314	1377453
2008	17.783	1.797	12.165	22.636	1377502
2009	17.845	2.094	12.001	21.755	1377767
2010	17.878	2.002	12.191	21.872	1377645
2011	18.025	2.173	11.061	24.875	1377708

2012	17.862	2.002	10.507	21.993	1377505
2013	18.0603	1.546	11.567	22.190	1377802

Sub-Antarctic Waters

Table 5-4: Statistics of the annual mean SST over the Sub-Antarctic Waters area.

Year	Mean (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	10.108	1.014	7.041	15.316	1195520
1994	10.409	1.017	6.559	18.245	1195420
1995	9.955	1.303	6.007	16.015	1195518
1996	10.101	1.334	6.805	14.803	1195575
1997	9.924	1.168	6.983	15.521	1195616
1998	9.963	1.319	6.943	18.491	1195543
1999	10.543	1.338	7.704	17.842	1195580
2000	10.215	1.214	6.908	15.539	1195574
2001	10.009	1.229	7.115	15.931	1195606
2002	10.020	1.244	7.360	16.669	1195672
2003	9.706	1.319	7.113	18.523	1195634
2004	9.565	1.262	6.826	16.393	1196077
2005	9.957	1.350	7.069	17.222	1196234
2006	9.689	1.291	7.143	18.418	1196137
2007	9.451	1.258	6.922	16.746	1196152
2008	9.613	1.357	6.877	15.755	1196205
2009	9.468	1.251	7.039	23.757	1196278
2010	9.986	1.378	7.271	16.311	1196271
2011	9.824	1.236	6.449	17.688	1196144
2012	9.960	1.386	7.368	18.436	1196215
2013	10.597	1.449	6.943	20.320	1196192

SST Sub-Area Anomaly Data

The tables below indicate, for each year, the spatial mean SST anomaly (with respect to the 1993-2012 long term mean), the standard deviation in the spatial mean SST anomaly, the minimum SST anomaly for the year, the maximum SST anomaly for the year, and the sample size (i.e. number of SST data used to calculate the mean and standard deviation).

Map Area

Table 5-5: Statistics of the annual mean SST anomaly (with respect to the 1993-2012 long term mean) over the mapped area.

Year	Mean Anomaly (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	-0.2371	0.4348	-5.1539	5.9898	6444316
1994	-0.0380	0.4736	-7.0425	6.3331	6444253
1995	0.0286	0.3226	-4.8332	6.6828	6444668
1996	0.0350	0.2649	-5.3924	5.0572	6444554
1997	-0.1304	0.2621	-7.3108	6.7031	6444911
1998	0.3464	0.4240	-5.6541	9.2703	6444991
1999	0.4638	0.3403	-5.8125	6.0100	6444939
2000	0.0658	0.3071	-5.0180	5.1272	6444677
2001	0.1859	0.2625	-6.7412	6.1755	6446041
2002	0.0982	0.2534	-5.0153	4.7166	6445969
2003	-0.0375	0.2346	-4.6434	4.7433	6446136
2004	-0.2107	0.2780	-5.8433	6.7161	6449116
2005	0.1163	0.2461	-5.3326	5.6440	6451441
2006	-0.1051	0.2265	-5.4537	7.0953	6449371
2007	-0.1368	0.2756	-6.2218	5.1806	6449511
2008	-0.1328	0.2516	-5.1315	5.8217	6450166
2009	-0.1557	0.2448	-5.7628	5.7558	6450851
2010	0.0617	0.2311	-5.0436	5.3466	6451405
2011	-0.0241	0.2827	-5.6837	7.1209	6450142
2012	0.0039	0.2297	-5.3626	8.9605	6450272
2013	0.5070	0.3269	-9.7300	9.9713	6450938

Tasman Sea

Table 5-6: Statistics of the annual mean SST anomaly (with respect to the 1993-2012 long term mean) over the Tasman Sea area.

Year	Mean Anomaly (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	-0.4041	0.2357	-5.1539	5.9898	1490916
1994	-0.1508	0.2222	-4.4446	5.6403	1491138
1995	-0.2698	0.2373	-4.7988	4.9393	1490963
1996	-0.0432	0.2395	-5.0073	5.0572	1490861
1997	-0.1408	0.2734	-5.6638	4.3582	1491061
1998	0.3230	0.4281	-5.6541	6.4757	1491104
1999	0.5660	0.3059	-5.4593	6.0100	1491200
2000	0.0994	0.2249	-4.5330	4.9656	1490979

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2001	0.4030	0.2083	-5.1202	6.1755	1491605
2002	0.0690	0.2229	-4.6954	4.7166	1491499
2003	-0.0781	0.1863	-4.6434	4.5189	1491668
2004	-0.4364	0.2233	-4.9051	6.7161	1492128
2005	0.2750	0.1948	-3.8895	5.5019	1493649
2006	-0.2625	0.1654	-4.8163	7.0953	1492428
2007	-0.0344	0.1954	-5.2565	5.1806	1492504
2008	0.0528	0.2088	-4.9897	4.9271	1492859
2009	-0.0463	0.1850	-5.7628	5.5607	1492808
2010	0.1455	0.1902	-5.0436	5.3466	1493593
2011	-0.0950	0.2061	-5.3266	6.0368	1492752
2012	0.0048	0.2262	-4.9489	5.9789	1492871
2013	0.5036	0.2313	-8.5722	5.6542	1493077

Sub-Tropical Waters

Table 5-7: Statistics of the annual mean SST anomaly (with respect to the 1993-2012 long term mean) over the Sub-Tropical Waters area.

Year	Mean Anomaly (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	-0.5610	0.2936	-4.0107	4.5913	1375991
1994	-0.3224	0.2429	-4.6045	6.3331	1376092
1995	0.2648	0.2416	-4.0762	6.6828	1376097
1996	-0.0086	0.2008	-5.0281	3.3503	1376056
1997	-0.2899	0.1659	-4.7426	6.7031	1376117
1998	0.6519	0.3442	-4.1082	6.5054	1376142
1999	0.3450	0.3495	-5.1060	4.5970	1376091
2000	-0.0863	0.2060	-4.1591	5.1272	1376066
2001	0.1670	0.1726	-5.2746	4.2972	1376444
2002	0.1206	0.1959	-5.0153	4.3967	1376474
2003	0.0669	0.2103	-4.0357	4.7433	1376410
2004	-0.1403	0.1988	-5.5431	4.9022	1377495
2005	0.0163	0.2083	-3.6927	5.6440	1377596
2006	-0.0203	0.1586	-5.4537	5.2704	1377446
2007	0.0377	0.1661	-5.3132	5.1011	1377453
2008	-0.0925	0.2300	-5.1315	5.8217	1377502
2009	-0.1352	0.2149	-4.7188	5.1248	1377767
2010	-0.0920	0.1863	-4.8884	4.8602	1377645
2011	0.1300	0.3097	-4.5996	7.1209	1377708
2012	-0.0697	0.1931	-4.4210	4.2670	1377505
2013	0.3964	0.3310	-5.1382	7.4007	1377780

Sub-Antarctic Waters

Table 5-8: Statistics of the annual mean SST anomaly (with respect to the 1993-2012 long term mean) over the Sub-Antarctic Waters area.

Year	Mean Anomaly (°C)	Standard Deviation (°C)	Minimum (°C)	Maximum (°C)	Sample Size
1993	0.2191	0.3948	-3.8331	2.6600	1195519
1994	0.5219	0.4961	-2.8859	5.3605	1195420
1995	0.0779	0.2868	-2.5851	2.9206	1195516
1996	0.2156	0.2781	-3.5398	1.9556	1195575
1997	0.0392	0.2793	-6.6548	2.5715	1195616
1998	0.0844	0.2728	-3.4392	5.9554	1195543
1999	0.6680	0.2966	-2.5036	3.7963	1195580
2000	0.3332	0.2915	-3.6842	2.3181	1195574
2001	0.1344	0.2246	-4.3612	2.7147	1195606
2002	0.1301	0.2197	-3.5613	4.0090	1195671
2003	-0.1727	0.1772	-3.4187	4.4161	1195634
2004	-0.3313	0.2251	-4.4423	2.6756	1196077
2005	0.0802	0.2678	-4.2612	4.0040	1196234
2006	-0.2081	0.1919	-3.9289	4.7330	1196137
2007	-0.4333	0.2662	-6.2218	2.7729	1196151
2008	-0.2833	0.1825	-3.1896	3.4653	1196202
2009	-0.4289	0.2137	-5.1548	5.7558	1196274
2010	0.1161	0.2407	-2.8496	4.0323	1196270
2011	-0.0460	0.1940	-3.8854	2.9377	1196144
2012	0.0880	0.2277	-3.5365	8.9605	1196215
2013	0.7251	0.3309	-4.2552	6.6354	1196192

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