Transformation of 2° into 5° grids for global SST trend analyse

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Abstract

Using the COADS MSTG product for Sea Surface Temperature (SST) trend evaluation, a method to improve the data coverage is presented. It consists of two steps: 2° x 2° data are first interpolated spatially taking into account the scale of SST features and then successively transformed into 5° x 2° bands and 5° x 5° fields. Maps of the improved data coverage show the method's efficiency. Some results, including newly derived SST reference charts are presented.

1. Introduction

Investigations of global climate trends call for base periods as comprehensive as possible. Climate stations over land are far from being evenly distributed but they are at least geographically fixed, bearing individual and thus correctable biases. Obtaining a satisfying data base is much harder to achieve over the oceans where a conglomerate of many ship reports is assembled and then transformed into a grid of some sort, whereupon individual ship biases are not recognizable anymore. Data coverage is well near the preferred shipping lanes but it is very poor or nil in remote ocean areas. Starting out with COADS monthly statistics trimmed (MSTG) group data a method is presented to turn the inherent 2° x 2° grid into a 5° x 5° grid, losing some spatial resolution but gaining a more evenly distributed data set. With the exception of sharp gradient areas (Gulf stream and Kuroshio regions) mean global Sea Surface Temperature (SST) mainly exhibits features that can be represented by a 5° grid. For future evaluations there is a need to compare the results with other sea surface temperature trend pattern studies like those done by Bunker (1980). Paltridge and Woodruff (1981), Iwasaka et al. (1987), or Wolter (1987) which used 5° or even 10° resolution.

2. Long term means from 2° COADS data

Temporal means over a certain period need continuous time series. Taking COADS data as they are frequent breaks in the individual gridpoints' series can be found. As Hsuing and Newell (1983) already pointed out, shipping routes change periodically, for example seasonally. Therefore it is not probable that the same gridpoint contains sufficient data in all months. To overcome this problem a two step procedure is performed leading to 5° x5° data, where areas are better represented and gaps are not filled arbitrarily but according to their field behavior.

3. The interpolation/transformation method

3.1 Interpolation

3.1.1 Conditions

Interpolation is carried out only in the COADS 2° data and not in the 5° which are derived subsequently. The global distribution of SST also accounts for maximum interpolation distances of 10° In zonal and V In meridional direction, otherwise leading to fields represented by too few and too distant data. Furthermore two opposing values are needed for Interpolation. This restriction disables extrapolation, e.g. from offshore gridpoints towards the coastal waters.

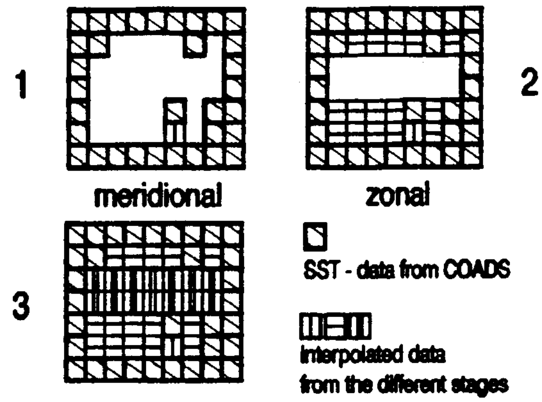

Figure 1. Interpolation of missing 2° fields in three stages.

3.1.2 The interpolation step

Interpolation takes place in three cycles (Fig. 1). Using the bounds mentioned in 3.1.1 this step is carried out meridionally, then zonally and then again meridionally. Remaining gaps are treated as missing values. Figure 2 shows the improved data base for January 1971. Note that in some areas all gaps are filled with interpolated data after this step.

3.2 Transformation

3.2.1 Conditions

Since both resolutions (2° and 5°) do not match exactly only four complete 2° fields can be used directly to produce a 5° field. Another four are shared between two 5° fields and one is shared between four fields. In the transformation step interpolated data are treated as “real” but a record is kept on their distribution. Nevertheless, conversion into 5° fields is carried out only if one third or less of the participating fields is interpolated, otherwise they are marked as missing (X in Fig. 4). bands, containing an interpolated value (T_i)for each divided field. The 5° x 5° field contains a divided 5° x 2° band whose value (S_i) is treated likewise. Fig. 4 shows the improved data content in the 5° domain.

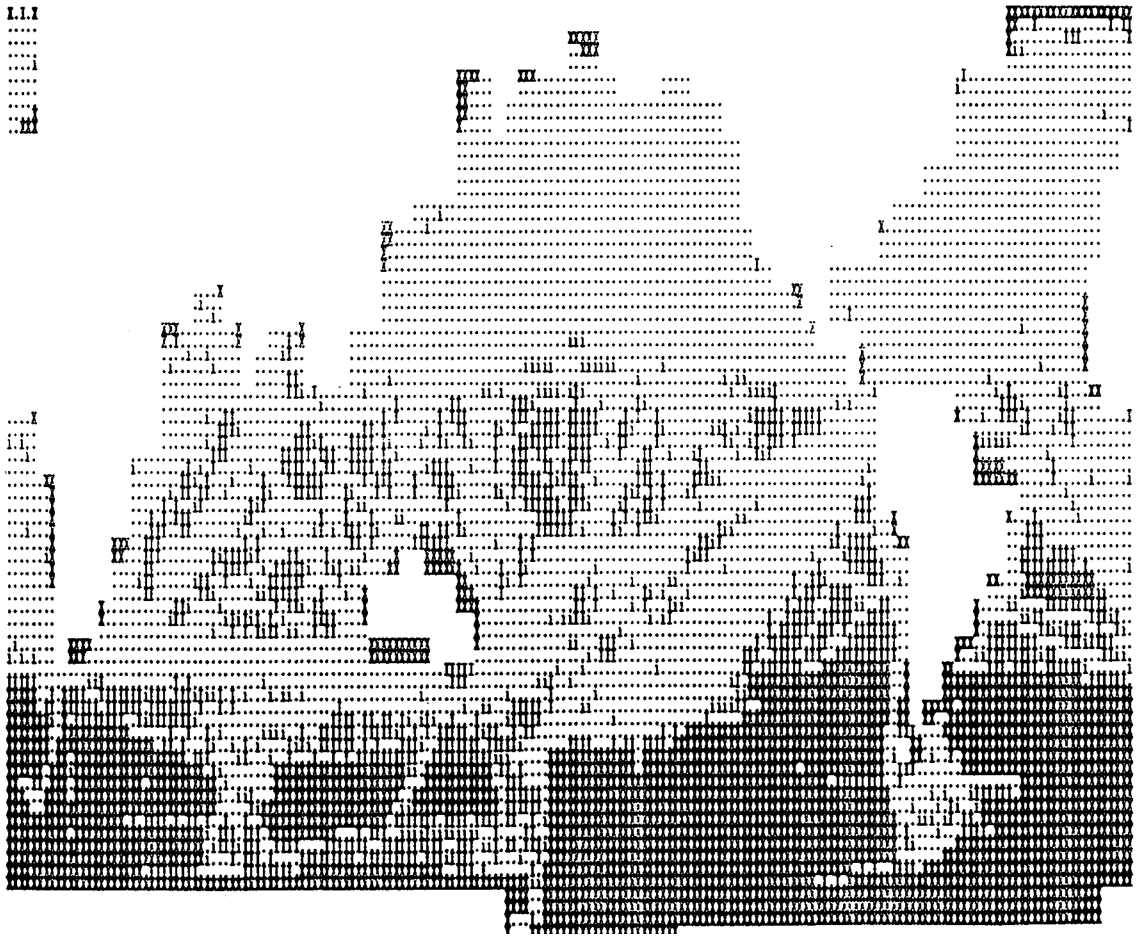

Figure 2. Data coverage for January 1971 after interpolation procedure. (.) denotes COADS data, (i) meridionally interpolated (l), zonally interpolated, and (x) missing.

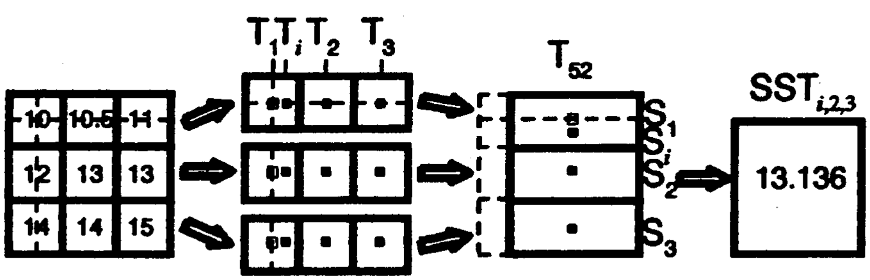

Figure 3. Conversion of 2° x 2° into 5° x 5° fields, interpolated value $T_1 = T_1 + \frac{1}{4}(T_2 - T_1)$, 5° x 2° band: $T_{52} = \frac{2T_3 + 2T_2 + 2T_1}{5} = S_n(n = 1\ldots3)$, S_1=10.625, S_i=11.181, S_2=12.850, S_3=14,400, $SST_{1,2,3}$=13.136 bands, containing an interpolated value (T_i) for each divided field.

The 5° x 5°- field contains a divided 5° x 2° - band whose value (S_i) is treated likewise. Figure 4 shows the improved data content in the 5° domain.

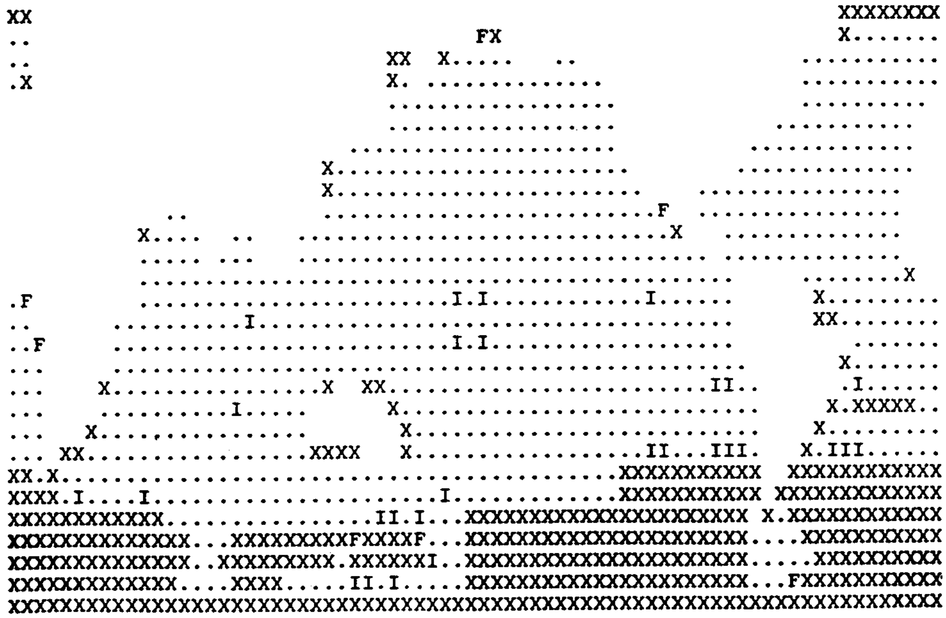

Figure 4. Data coverage January 1971(.) denotes at least 80% data, (l) the same, but less than one observation was used, (0) 60-80% data, (F) the same, but less than one observation was used, and (X) less than 60% data.

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SST base period                          Base period 1951-1970 (north.hemisphere)                                PERIOD:  1951-70
WAG 3, D.Gibletz                                  Source: COADS-Data                                             Mean (Year)
    |            Mean Longitude
    |   55  60  65  70  75  80  85  90  95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 -175 -170 -165 -160 -155
 N  |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
80__|......................................................................................................................................|
75__|......................................................................................................................................|
70__|......................................................................................................................................|
65__|......................................................................................................................................|
60__|............................................................................................................xxxxxxxxxxx.................|
55__|..........................................................................................xxxxx 3.2 .......... 4.2 4.5 4.6 4.7 4.5 4.3 ..............|
50__|..........................................................................................xxxxx 4.2 ..... 5.0 5.4 5.6 5.6 5.8 6.1 6.4 6.7 7.0 7.3 |
45__|............................................................................................ 5.9 4.9 5.5 6.3 6.4 6.7 7.1 7.3 7.7 8.0 8.3 8.6 9.0 |
40__|............................................................................................ 9.4 10.2 11.0 10.9 11.0 11.5 12.0 12.3 12.3 12.3 12.5 12.6 12.8 |
35__|...............................................................................16.6 17.4 17.7 18.0 18.0 17.8 17.6 17.6 17.5 17.3 17.3 17.0 16.9 16.9 17.0 17.1 |
30__|.........................................................................xxxxx20.3 21.8 22.2 22.3 21.9 21.7 21.6 21.4 21.2 21.0 20.8 20.7 20.6 20.5 20.6 20.6 20.5 |
25__|.........................................................................22.6 24.4 24.3 24.3 24.5 24.8 24.8 24.7 24.6 24.4 24.2 24.1 23.9 23.6 23.5 23.5 23.3 23.1 |
20__|..........26.7 26.7 ......................................................26.3 26.2 26.4 26.8 27.0 27.2 27.3 27.2 26.9 26.7 26.5 26.3 26.0 25.8 25.5 25.3 25.0 24.6 |
15__|xxxxx26.0 26.9 27.6 27.9 ..........27.9 27.9 ................26.9 27.4 27.9 27.7 28.1 28.3 28.1 28.2 28.3 28.1 27.9 27.7 27.5 27.3 27.2 26.9 26.6 26.3 25.9 25.3 |
10__|26.6 26.8 27.4 28.1 28.4 .....28.2 28.3 28.3 ...............27.8 28.3 28.3 28.4 28.7 28.7 28.5 28.5 28.6 28.5 28.4 28.3 28.1 27.9 27.6 27.5 27.2 27.1 26.8 26.7 |
 5__|26.8 27.5 28.1 28.4 28.4 28.0 28.2 28.4 28.5 28.7 28.7 28.0 28.2 28.5 28.4 28.4 28.6 28.7 28.6 28.6 28.9 29.0 29.0 29.0 28.7 28.4 28.3 28.1 28.1 28.1 27.9 27.8 |
 0__|27.4 28.1 28.5 28.6 28.4 28.4 28.3 28.4 28.5 28.9 28.9 28.4 28.5 28.6 28.8 28.6 28.8 29.0 28.9 29.0 29.2 29.1 29.0 28.9 28.6 28.5 28.3 28.1 28.0 27.9 27.7 27.5 |

    |  -145 -140 -135 -130 -125 -120 -115 -110 -105 -100  -95  -90  -85  -80  -75  -70  -65  -60  -55  -50  -45  -40  -35  -30  -25  -20  -15  -10   -5    0    5
 N  |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
80__|......................................................................................................................................|........
75__|......................................................................................................................................|........
70__|......................................................................................................................................|..SST...N
65__|.....................................................................................xxxxxxxxxxxxxxxxxxxxxxx 4.4 4.3 4.9 6.4 7.7 8.0 | 5.97   6
60__|.................................................................................................... 6.4 7.3 8.3 8.8 9.2 9.1 8.6 8.6 9.2 8.8 | 8.42  10
55__| 7.9 8.7 ............................................................ 4.8 5.3 6.1 7.4 8.7 9.9 10.8 11.0 11.2 10.6 9.6 9.7 9.5 | 7.33  22
50__| 7.7 8.4 9.3 10.1 ..................................................... 3.3 7.2 9.3 9.6 10.5 11.5 12.3 12.6 12.6 11.8 10.9 10.7 xxxxx| 8.26  27
45__| 9.4 10.0 10.6 11.3 11.7 ................................................ 5.3 6.6 12.3 14.4 14.4 14.5 14.5 14.4 14.2 13.9 ..............| 9.61  28
40__|13.1 13.4 13.6 13.9 13.3 .......................................12.4 14.0 13.4 14.6 17.9 17.8 17.5 17.0 16.7 16.3 15.9 ....................|13.50  29
35__|17.1 17.0 16.8 16.2 15.0 ..............................18.9 21.4 22.0 21.7 21.4 21.0 20.6 20.2 19.7 19.2 18.9 18.6 18.1 ......................|18.27  34
30__|20.3 19.8 19.2 18.3 17.2 16.0 ....................25.2 23.7 23.2 23.1 23.0 22.8 22.6 22.3 22.0 21.7 21.3 20.7 20.0 19.5 ......................|21.13  37
25__|22.6 21.8 20.9 20.1 19.4 18.8 18.6 .............25.1 25.8 25.5 26.1 25.4 25.2 25.0 24.9 24.6 24.3 23.9 23.5 22.9 22.4 21.7 20.8 ..........................|23.47  41
20__|23.8 23.2 22.5 22.0 21.5 21.5 21.8 23.1 25.9 ..........26.5 27.1 27.5 27.3 27.1 26.9 26.5 26.2 25.9 25.5 25.0 24.6 24.1 23.5 22.5 20.5 ..........................|25.29  45
15__|25.0 24.7 24.4 24.2 24.3 24.7 25.3 26.4 27.3 xxxxx...............28.1 28.1 27.9 27.7 27.4 27.1 26.7 26.2 25.8 25.3 24.8 24.4 23.6 23.0 ..........................|26.61  49
10__|26.6 26.4 26.4 26.4 26.6 26.9 27.3 27.7 28.2 28.6 28.5 28.5 .....28.1 27.8 27.2 27.5 27.6 27.7 27.4 27.1 26.6 26.3 26.0 25.7 25.6 25.3 ..........................|27.52  54
 5__|27.7 27.5 27.5 27.4 27.3 27.3 27.3 27.4 27.6 27.7 27.8 27.6 27.7 28.0 ..........................27.8 27.7 27.5 27.3 27.2 26.9 27.1 27.4 xxxxx.....................|28.00  54
 0__|27.2 27.0 26.9 26.5 26.2 26.0 25.8 25.6 25.5 25.6 25.9 26.1 26.2 26.5 ..............................27.8 27.6 27.5 27.3 27.1 27.1 26.9 27.0 27.0 27.2 27.4 27.4 |27.69  58
LEGEND: SST=Sea Surface Temperature      N=Number of boxes
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5a

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SST Anomalies                            SST-Anomalies base period 1951-1970                                     PERIOD:  1971-80
WAG 3, D.Gibletz                                  Source: COADS-Data                                             Mean (Year)
    |            Mean Longitude
    |   55  60  65  70  75  80  85  90  95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 -175 -170 -165 -160 -155
 N  |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
80__|......................................................................................................................................|
75__|......................................................................................................................................|
70__|......................................................................................................................................|
65__|......................................................................................................................................|
60__|.....................................................................................................................-0.4 -1.  ..................|
55__|........................................................................................ 0.4  0.20..........-0.13-0.29-0.26-0.30-0.09 0.00................|
50__|........................................................................................ 0.24-0.01.....-0.15-0.19-0.23-0.20-0.30-0.39-0.40-0.34-0.42-0.36|
45__|........................................................................................-0.04-0.25-0.30-0.25-0.23-0.26-0.30-0.32-0.39-0.41-0.39-0.31-0.28|
40__|........................................................................................-0.62-0.27-0.42-0.37-0.41-0.37-0.47-0.54-0.54-0.53-0.45-0.39-0.34|
35__|...............................................................................-0.07-0.48-0.59 0.03 0.15 0.02-0.18-0.38-0.30-0.32-0.49-0.44-0.49-0.41-0.30-0.22|
30__|........................................................................... 0.7  0.07-0.01 0.02-0.27-0.22-0.25-0.26-0.24-0.24-0.29-0.30-0.32-0.26-0.20-0.22-0.16-0.12|
25__|........................................................................... 0.34 0.09 0.16-0.03-0.23-0.51-0.35-0.19-0.18-0.15-0.17-0.20-0.20-0.12-0.05-0.08-0.15-0.04|
20__|..........-0.09-0.07....................................................... 0.11 0.15 0.13-0.15-0.16-0.23-0.37-0.29-0.16-0.13-0.09-0.11-0.13-0.14-0.18-0.19-0.16-0.26|
15__|xxxxx 0.10 0.09-0.06-0.10.......... 0.25 0.1 ................-0.03 0.04-0.12 0.15-0.11-0.26-0.05-0.06-0.26-0.27-0.27-0.30-0.35-0.28-0.36-0.30-0.18-0.22-0.25-0.25|
10__| 0.20 0.16 0.12-0.01-0.08..... 0.20 0.18 0.13...............-0.01-0.01 0.00 0.09-0.20-0.16-0.04-0.05-0.34-0.38-0.28-0.38-0.25-0.20-0.21-0.27-0.23-0.30-0.37-0.35|
 5__| 0.21 0.13 0.14 0.12 0.06 0.09 0.16 0.08 0.08 0.05-0.10 0.01 0.03 0.02 0.15 0.16-0.09-0.01 0.15 0.13-0.12-0.33-0.41-0.38-0.23-0.11-0.18-0.16-0.14-0.41-0.47-0.45|
 0__| 0.11 0.06 0.09 0.11 0.07 0.07 0.02 0.06 0.05 0.02-0.05 0.01 0.02 0.18 0.01 0.10-0.07-0.06 0.09 0.18 0.06-0.08-0.23-0.16-0.08-0.13-0.16-0.04-0.18-0.48-0.41-0.42|

    |  -145 -140 -135 -130 -125 -120 -115 -110 -105 -100  -95  -90  -85  -80  -75  -70  -65  -60  -55  -50  -45  -40  -35  -30  -25  -20  -15  -10   -5    0    5
 N  |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
80__|......................................................................................................................................|........
75__|......................................................................................................................................|........
70__|......................................................................................................................................|..AMO...N
65__|....................................................................................................xxxxx-1.   0.   0.  -0.4 -0.02 0.22 0.04-0.02 0.00|-0.02   9
60__|.....................................................................................................-0.71-0.50-0.47-0.58-0.63-0.51-0.33-0.21-0.15 0.  |-0.41  12
55__|-0.68-0.80...........................................................-0.5 -0.52-0.60-0.71-0.73-0.72-0.58-0.42-0.36-0.23-0.09-0.10 0.05|-0.33  23
50__|-0.30-0.36-0.45-0.42.................................................-0.07-0.70-0.76-0.59-0.51-0.39-0.39-0.32-0.28-0.01-0.03 0.16xxxxx|-0.29  28
45__|-0.24-0.18-0.20-0.31-0.34............................................-0.27-0.50-0.77-0.50-0.41-0.42-0.39-0.34-0.25-0.17...............|-0.32  28
40__|-0.24-0.12-0.07-0.18-0.66...............................-0.05-0.21-0.15-0.25-0.46-0.49-0.47-0.41-0.33-0.31-0.26....................|-0.36  29
35__|-0.15-0.09-0.07-0.10-0.22.............................. 0.48 0.17-0.16-0.18-0.23-0.27-0.29-0.32-0.29-0.26-0.29-0.40-0.34....................|-0.22  34
30__|-0.04-0.01-0.08-0.08-0.09-0.17.....................-0.37 0.02-0.05-0.13-0.19-0.17-0.15-0.10-0.13-0.16-0.21-0.20-0.23-0.29....................|-0.14  38
25__|-0.15-0.21-0.22-0.24-0.23-0.13-0.14.................... 0.02-0.16 0.13 0.05-0.02-0.08-0.13-0.11-0.13-0.11-0.10-0.09-0.02-0.03-0.10-0.22.......................|-0.11  41
20__|-0.36-0.29-0.38-0.39-0.25-0.27-0.42-0.33-0.30..........-0.08-0.03-0.04-0.04-0.10-0.11-0.09-0.08-0.07-0.12-0.11-0.17-0.29-0.36-0.25-0.37.......................|-0.17  45
15__|-0.31-0.34-0.30-0.13-0.08-0.09-0.09-0.23-0.27xxxxx...............-0.35-0.30-0.24-0.32-0.17-0.17-0.15-0.17-0.21-0.23-0.27-0.44-0.29-0.33.......................|-0.18  49
10__|-0.46-0.43-0.32-0.31-0.14-0.16-0.07-0.10-0.09-0.17-0.23-0.26.....-0.27-0.33-0.15-0.22-0.17-0.32-0.27-0.34-0.36-0.24-0.23-0.11-0.17-0.11.......................|-0.17  54
 5__|-0.43-0.35-0.40-0.18-0.10-0.16-0.14-0.06-0.10-0.13-0.28-0.26-0.06-0.24..........................-0.33-0.23-0.10-0.21-0.23-0.07-0.02-0.07xxxxx..................|-0.11  54
 0__|-0.30-0.36-0.34-0.22-0.12 0.07-0.06-0.03 0.05 0.01 0.08 0.10 0.04-0.03.............................-0.1 -0.11-0.11-0.08 0.05 0.00 0.13 0.07 0.09 0.05-0.06-0.02|-0.04  58
LEGEND: AMO=SST-Anomalies      N=Number of boxes
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5b

Figure 5.

4. The reference period 1951-70[1]

Twelve monthly mean SST charts for the period 1951-70 were constructed from 5° fields. using the transformation statistics to flag interpolated data. Only fields that contained means for each month were subsequently averaged yielding the year chart (Fig. 6a) for the Northern Hemisphere. This period coincides with a local maximum In the 20th century SST record even if the conversion from bucket to injection measurement is taken into account. The warming trend did not continue in the 70s as can be seen from SST Anomalies in Fig. 6b. Even though some areas near the equator and in the Indian Ocean exhibit further warming the overall development, generalized by the latitudinal means, is towards lower SSTs. Preliminary results for the 80s using the COADS MSTG Interim product (only monthly means and numbers of observations were available for each grid point) show that a remarkable positive SST trend is found within the tropics.

5. Conclusions

This method of smoothing a field does not claim to be perfect. Averaging over anomalies is always preferable to averaging over real data. But what kind, of anomaly is to be used for reference periods themselves? Subtracting the long-term mean of time series at each grid point of whatever resolution bears several problems: data gaps, as described in paragraph 2, occur frequently in the early years and in the time of World War I and II; since the averaging period has to be considerably longer than the reference period itself to account for low-frequency climate variations and since it has to be common to all grid points it is impossible to determine a good starting point. On the other hand, subtracting latitudinal averages of the reference period itself suffers from data gaps as well. The evaluation of global SST trends is done by comparing fields from different reference periods using latitudinal averages only as an “overlook” type of information.

Large scale (hemispheric) trend evaluation does not necessarily need very fine spatial resolutions. Data files could be more compact and easier to handle on PCs and also call for less storage power In large computers. In this case it is desirable to work with COADS data that are already gridded in 5° fields.

[1] Since 1991 the “Nordhemisphärischer Klimabericht” of the Berliner Wetterkarte has used COADS data from this time period to determine the monthly SST deviations in the Northern Hemisphere.

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