



# 第 1 次作业

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**摘 要:** 本文使用的程序和文档发布于 [https://grwei.github.io/SJTU\\_2021-2022-2\\_MS8401/](https://grwei.github.io/SJTU_2021-2022-2_MS8401/).

**关键词:** 词 1, 词 2

## Homework 1

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**Abstract:** The programs and documents used in this article are published at [https://grwei.github.io/SJTU\\_2021-2022-2\\_MS8401/](https://grwei.github.io/SJTU_2021-2022-2_MS8401/).

**Keywords:** keyword 1, keyword 2



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## 1 Due Date: 2022-04-30

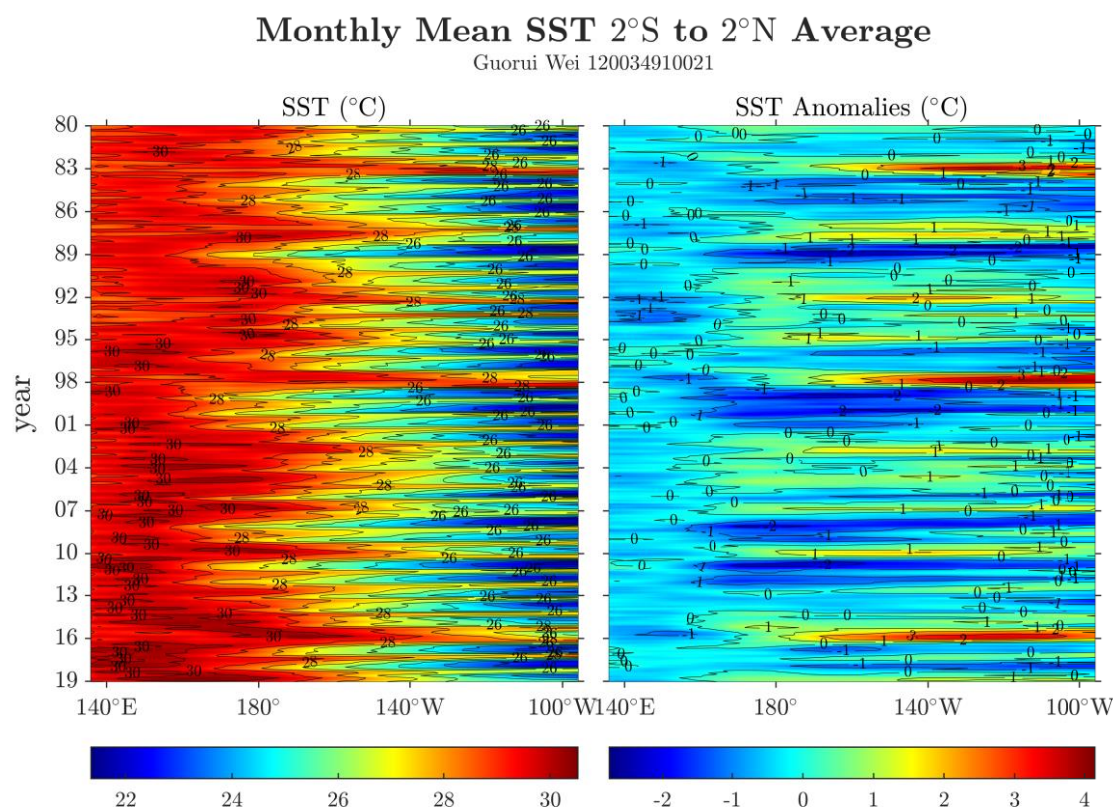
从 **Figure 1** 左子图（南北纬 2 度间纬向平均的月平均 SST）可见东太平洋 SST 存在年际振荡。对这 SST，先剔除线性变化趋势（代表长期气候变率）、再分别按月取算术平均得“气候态”（代表年内季节性周期变化）、最后用总 SST 减去线性趋势和气候态得 SST 异常值（代表年际 SST 异常如 ENSO，并叠加了难以分辨的高频变率（噪声））示于 **Figure 1** 右子图；图中东太平洋年际 SST 振荡清晰可见，还可见 SST 异常值的极性未必交替变化。

**Figure 2** 展示了历史上的一次强 El Nino 事件（Dec 1997），可见东太平洋海表温度异常升高，正异常值最高超过  $4^{\circ}\text{C}$ （下子图）。当时，常年的东太平洋海表冷池几乎消失（上子图）。

**Figure 3** 展示了历史上的一次强 La Nina 事件（Dec 1998），可见中东部太平洋 SST 异常偏低超  $2.5^{\circ}\text{C}$ ，东太平洋海表冷池发展极盛。

比较 **Figure 2** 和 **Figure 3**，有如下观察：（1）SST 最大变率中心位于东太平洋；（2）El Nino 和 La Nina 是非对称的，表现为前者的 SST 正异常中心较后者偏东，且绝对值有时更大。

上述观察可被 **Figure 4** 和 **Figure 5** 印证。从 **Figure 4** 可清楚观察到位于东太平洋的 SST 异常值的方差的高值中心。**Figure 5** 表明 SST 异常值的偏斜度在东太平洋为正，而在中太平洋为负，这可以被 El Nino 事件的 SST 正异常通常中心比 La Nina 事件的 SST 负一场中心更偏东的事实解释。

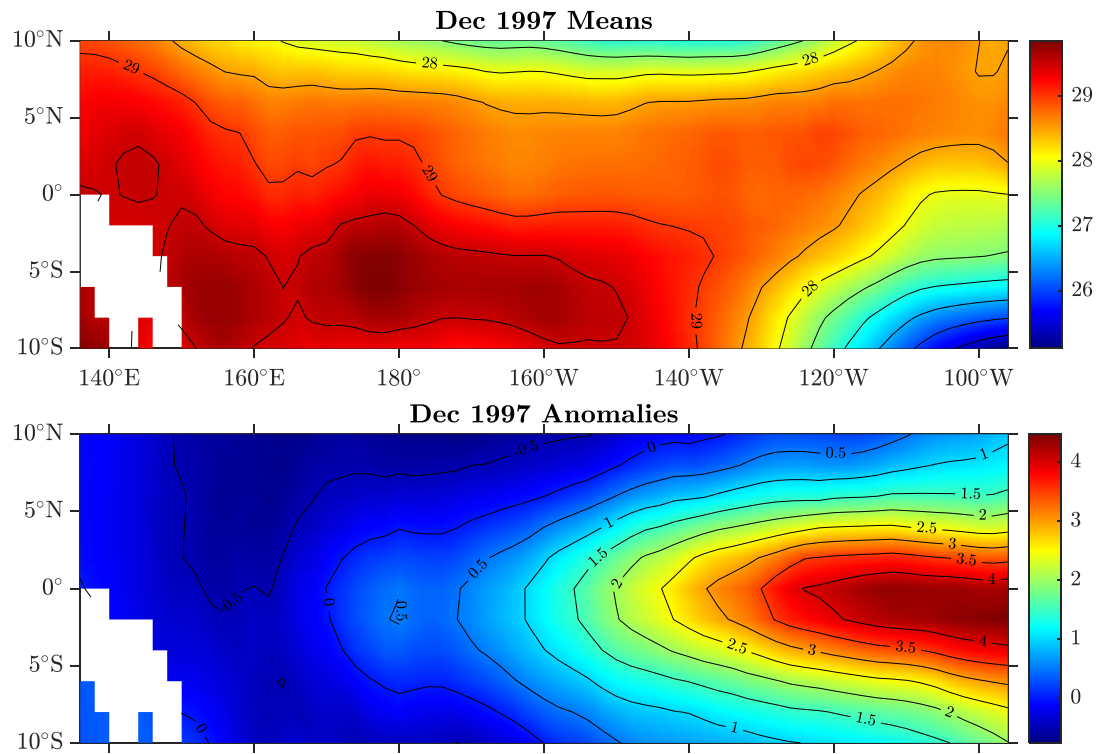


**Figure 1** Monthly mean SST



## TAO Monthly Mean SST ( $^{\circ}\text{C}$ )

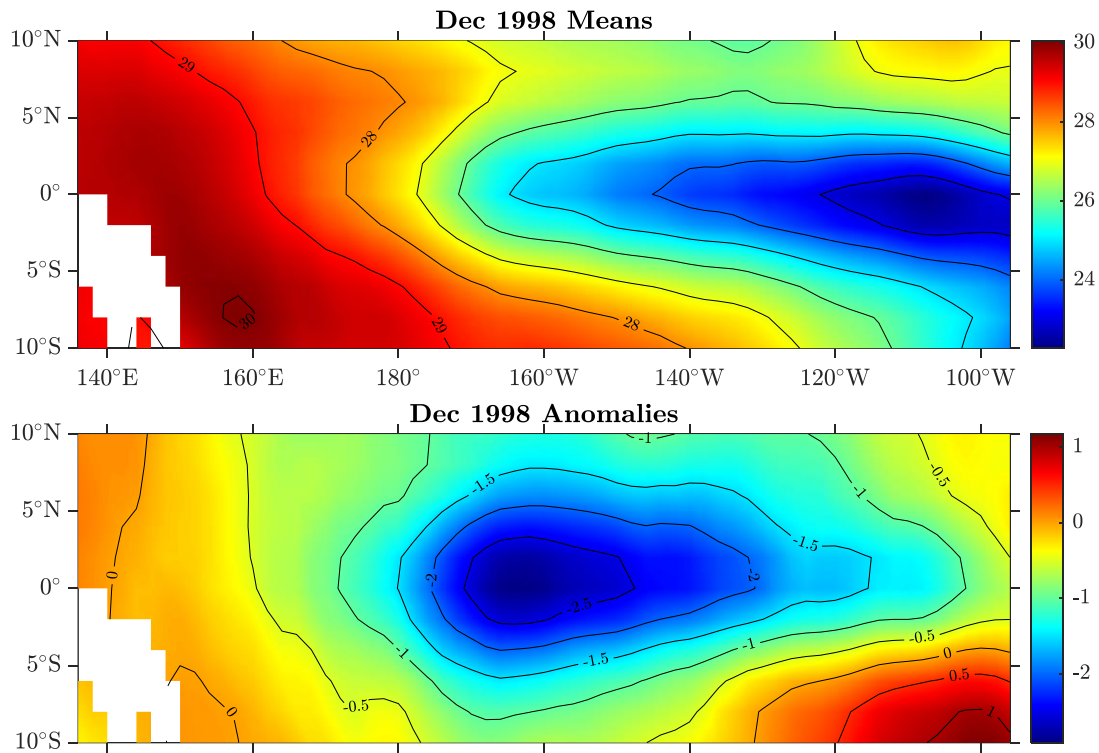
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**Figure 2** TAO Monthly mean SST (Dec 1997)

## TAO Monthly Mean SST ( $^{\circ}\text{C}$ )

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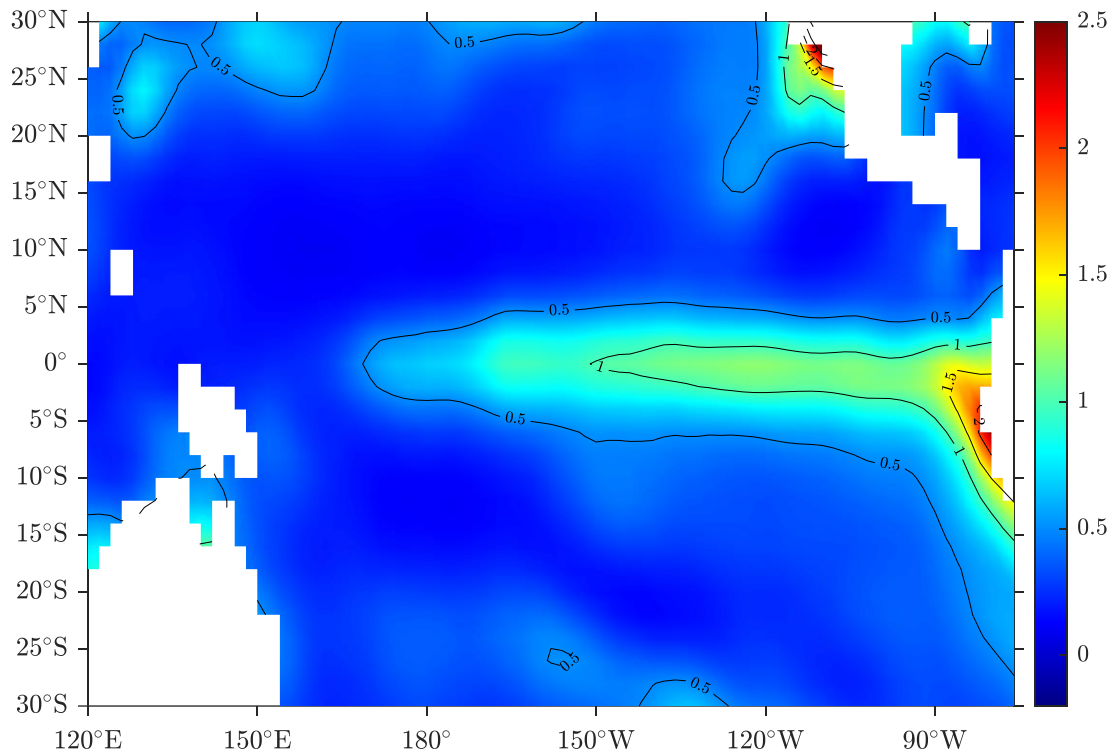


**Figure 3** TAO Monthly mean SST (Dec 1998)



**Fig.4(a) Variance**

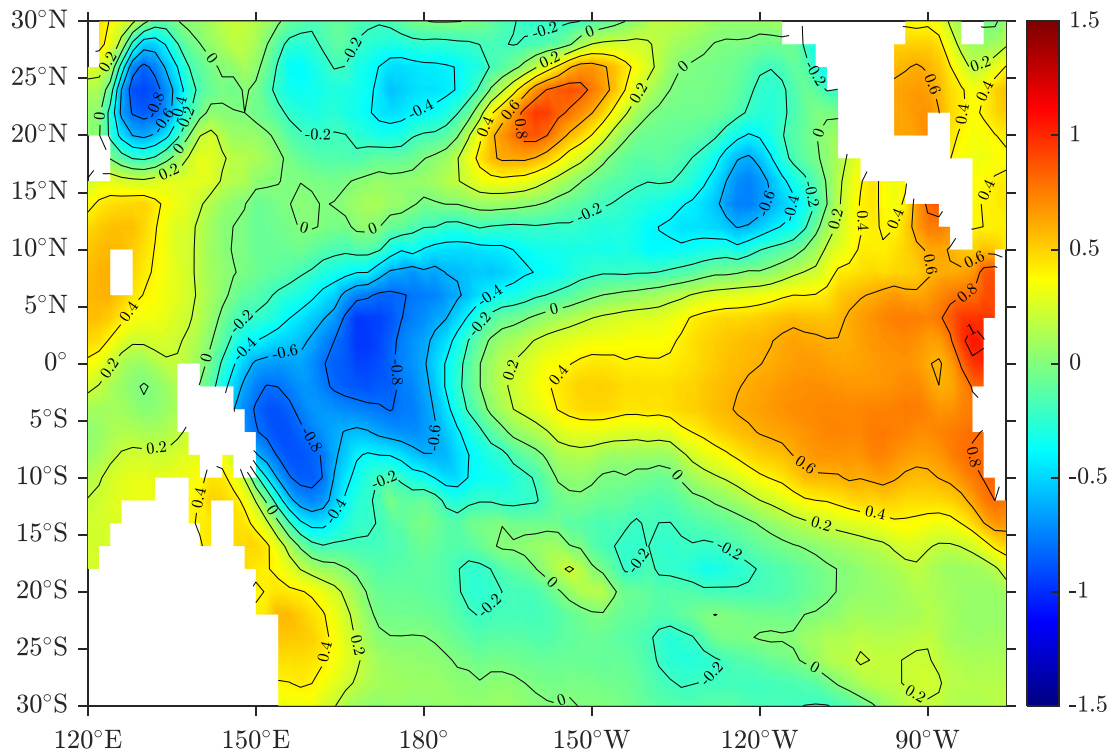
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**Figure 4** Variance of monthly-mean SST anomalies

**Fig.4(b) Skewness**

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**Figure 5** Skewness of monthly-mean SST anomalies





## References





## 附录A 本文使用的 MATLAB 程序源代码

本文使用的程序和文档发布于 [https://grwei.github.io/SJTU\\_2021-2022-2-MS8402/](https://grwei.github.io/SJTU_2021-2022-2-MS8402/).

### A.1 主程序

```
1 %% hw1.m
2 % Description: MATLAB code for Homework 1 (MS8401, 2022 Spring)
3 % Author: Guorui Wei (危国锐) (313017602@qq.com; weiguorui@sjtu.edu.cn)
4 % Student ID: 120034910021
5 % Created: 2022-04-29
6 % Last modified: 2022-04-30
7 % Toolbox: [1] [M_Map: A mapping package for
8 %           [2] [Climate Data Tools for
9 %           Matlab](https://github.com/chadagreene/CDT)
10 %% Initialize project
11
12 clc; clear; close all
13 init_env();
14
15 %% Read data
16
17 nc_path = "..\data\sst.mnmean.nc";
18 nc_info = ncinfo(nc_path);
19 sst = ncread(nc_path, 'sst'); % [deg C] sst(lon,lat,time_month)
20 sst(sst == ncreadatt(nc_path, '/sst', 'missing_value')) = NaN; % Monthly Means
    of Sea Surface Temperature (SST)
21 lon = ncread(nc_path, 'lon'); % [deg E]
22 lat = ncread(nc_path, 'lat'); % [deg N]
23 time_month = (datetime(1854,1,15) + calmonths(0:size(sst,3)-1)).';
24
25 %% Fig.1
26
27 %% Fig.1(a) SST
28
29 figure('Name', 'Fig.1')
30 t_TCL = tiledlayout(1,2, 'TileSpacing', 'tight', 'Padding', 'tight');
31
32 %
33 TF_lon_range = lon > 135 & lon < 265;
34 TF_lat_range = lat <= 2 & lat >= -2;
```





```
35 TF_time_range = datetime(1980,1,1) < time_month & time_month <
    datetime(2019,12,30);
36 SST_lat_mean =
    squeeze(mean(sst(TF_lon_range,TF_lat_range,TF_time_range),2,"omitnan"));
37 time_tick = datetime(1980,1,15) + calyears(0:3:2019-1980);
38
39 % plot
40 t_axis_SST = nexttile(t_TCL,1);
41 pcolor(t_axis_SST,lon(TF_lon_range),datenum(time_month(TF_time_range)),SST_l
    at_mean. ');
42 shading(t_axis_SST,"interp");
43 hold on
44 [C,h] =
    contour(t_axis_SST,lon(TF_lon_range),datenum(time_month(TF_time_range)),SST_
    lat_mean.',20:30,'LineWidth',0.2,'LineColor','black','ShowText','off','TextL
    ist',22:2:30);
45 hold off
46 clabel(C,h,26:2:30,"Interpreter",'latex','FontSize',6)
47 colormap(t_axis_SST,'jet')
48 % caxis(t_axis_SST,[20,30]);
49 cb = colorbar(t_axis_SST,"southoutside","TickLabelInterpreter","latex");
50 % set(cb.Label,'String',"degree Celsius",'Interpreter','latex');
51 set(t_axis_SST,"TickLabelInterpreter","latex","YTick",datenum(time_tick),"XT
    ick",140:40:260,"XTickLabel",{ '$140^{\circ}\rm{E}$', '$180^{\circ}$', '$140^{\circ}\rm{W}$', '$100^{\circ}\rm{W}$' }, "TickDir", "out", 'YDir', 'reverse');
52 datetick(t_axis_SST,'y','yy','keepticks');
53 title(t_axis_SST,"SST ($^{\circ}\rm{C}$)", 'Interpreter','latex');
54
55 %% Fig.1(b) SST anomaly
56 % y = y_0 + y_tr + y_season + y_var + y_noise
57 % [CDT/season_documentation/How this function
    works](https://www.chadagreene.com/CDT/season_documentation.html#16)
58
59 %
60 Fs = 12; % tr = trend(y,Fs) specifies a sampling rate Fs. For example, to
    obtain a trend per year from data collected at monthly resolution, set Fs
    equal to 12. This syntax assumes all values in y are equally spaced in time.
61 SST_lat_mean_tr = trend(SST_lat_mean,Fs,'dim',2,'omitnan') * 1/Fs *
    (0:size(SST_lat_mean,2)-1);
62 SST_lat_mean_climatology =
    climatology(SST_lat_mean,time_month(TF_time_range),'monthly','dim',2,'detren
    d','linear','full'); % y_climatology = y_0 + y_season
63 SST_lat_mean_var = SST_lat_mean - SST_lat_mean_tr -
    SST_lat_mean_climatology; % interannual variability (+ noise)
```



```
64
65 % plot
66 t_axis_SST_anomaly = nexttile(t_TCL,2);
67 pcolor(t_axis_SST_anomaly,lon(TF_lon_range),datenum(time_month(TF_time_range
)),SST_lat_mean_var. ');
68 shading(t_axis_SST_anomaly,"interp");
69 hold on
70 [C,h] =
    contour(t_axis_SST_anomaly,lon(TF_lon_range),datenum(time_month(TF_time_rang
e)),SST_lat_mean_var. ',-
    3:3,'LineWidth',0.2,'LineColor','black','ShowText','off');
71 hold off
72 clabel(C,h,"Interpreter",'latex','FontSize',6)
73 colormap(t_axis_SST_anomaly,'jet')
74 cb =
    colorbar(t_axis_SST_anomaly,"southoutside","TickLabelInterpreter","latex");
75 set(t_axis_SST_anomaly,"TickLabelInterpreter","latex","YTick",datenum(time_t
ick),"YTickLabel",{},{}, "XTick",140:40:260,"XTickLabel",{ '$140^{\circ}\rm{E}$',
'$180^{\circ}$', '$140^{\circ}\rm{W}$', '$100^{\circ}\rm{W}$' }, "TickDir", "out"
, 'YDir', 'reverse');
76 datetick(t_axis_SST_anomaly, 'y', 'yy', 'keepticks');
77 set(t_axis_SST_anomaly, "YTickLabel", {});
78 title(t_axis_SST_anomaly, "SST Anomalies
($^{\circ}\rm{C}$)", 'Interpreter', 'latex');
79
80 %
81 ylabel(t_TCL, "year", "Interpreter", 'latex')
82 [~,t_title_s] = title(t_TCL, "\bf Monthly Mean SST $2^{\circ}\rm{S}$ to
$2^{\circ}\rm{N}$ Average", "Guorui Wei 120034910021", 'Interpreter', 'latex');
83 set(t_title_s, 'FontSize', 8);
84 %
85 exportgraphics(t_TCL, "..\doc\fig\hw1_Fig_1.emf", 'Resolution', 600, 'Content
Type', 'auto', 'BackgroundColor', 'none', 'Colorspace', 'rgb')
86 exportgraphics(t_TCL, "..\doc\fig\hw1_Fig_1.png", 'Resolution', 600, 'Content
Type', 'auto', 'BackgroundColor', 'none', 'Colorspace', 'rgb')
87
88 %% Fig.2 & 3
89
90 %
91 TF_lon_range = lon > 135 & lon < 265;
92 TF_lat_range = lat <= 10 & lat >= -10;
93 TF_time_range = datetime(1980,1,1) < time_month & time_month <
datetime(2019,12,30);
94 TF_time_El_nino = time_month == datetime(1997,12,15);
```



```
95 TF_time_La_nina = time_month == datetime(1998,12,15);
96
97 %%%
98
99 sst_tr_coeff = trend(sst,Fs,'dim',3,'omitnan') * 1/Fs;
100 sst_tr = zeros(size(sst));
101 for k = 1:size(sst,3)
102     sst_tr(:, :, k) = sst_tr_coeff * k;
103 end
104 sst_climatology =
    climatology(sst,time_month,'monthly','dim',3,'detrend','linear','full'); %
    y_climatology = y_0 + y_season
105 sst_var = sst - sst_tr - sst_climatology; % interannual variability (+
    noise)
106
107 % Fig.2
108 figure('Name',"Fig.2 (El_nino)")
109 t_TCL = tiledlayout(2,1,"TileSpacing","tight","Padding","tight");
110 t_TCL =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_El_nino,sst_var,sst,lon,lat,28:
    30,"Dec 1997");
111 exportgraphics(t_TCL,"..\doc\\fig\\hw1_Fig_2.emf",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
112 exportgraphics(t_TCL,"..\doc\\fig\\hw1_Fig_2.png",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
113
114 % Fig.3
115 figure('Name',"Fig.3 (La_nina)")
116 t_TCL = tiledlayout(2,1,"TileSpacing","tight","Padding","tight");
117 t_TCL =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_La_nina,sst_var,sst,lon,lat,28:
    30,"Dec 1998");
118 exportgraphics(t_TCL,"..\doc\\fig\\hw1_Fig_3.emf",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
119 exportgraphics(t_TCL,"..\doc\\fig\\hw1_Fig_3.png",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
120
121 %% Fig.4
122
123 %
124 TF_lon_range = lon > 119 & lon < 285;
125 TF_lat_range = lat <= 30 & lat >= -30;
126 %
127 sst_var_Va = var(sst_var(TF_lon_range,TF_lat_range,:),0,3,"omitnan");
```



```
128 sst_var_Sk = skewness(sst_var(TF_lon_range,TF_lat_range,:),0,3);
129
130 %% Fig.4(a)
131 figure('Name',"Fig.4(a) (variance)")
132 t_TCL = tiledlayout(1,1,"TileSpacing","tight","Padding","tight");
133 t_TCL = fig4(t_TCL,lon,lat,TF_lon_range,TF_lat_range,sst_var_Va,[-
    0.2,2.5],"\bf Fig.4(a) Variance");
134 %
135 exportgraphics(t_TCL,"..\doc\fig\hw1_Fig_4a.emf",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
136 exportgraphics(t_TCL,"..\doc\fig\hw1_Fig_4a.png",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
137
138 %% Fig.4(b)
139 figure('Name',"Fig.4(b) (skewness)")
140 t_TCL = tiledlayout(1,1,"TileSpacing","tight","Padding","tight");
141 t_TCL = fig4(t_TCL,lon,lat,TF_lon_range,TF_lat_range,sst_var_Sk,[-
    1.5,1.5],"\bf Fig.4(b) Skewness");
142 %
143 exportgraphics(t_TCL,"..\doc\fig\hw1_Fig_4b.emf",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
144 exportgraphics(t_TCL,"..\doc\fig\hw1_Fig_4b.png",'Resolution',600,'Content
    Type','auto','BackgroundColor','none','Colorspace','rgb')
145
146 %% local functions
147
148 %% Initialize environment
149
150 function [] = init_env()
151 % Initialize environment
152 %
153 % set up project directory
154 if ~isfolder("../doc/fig/")
155     mkdir ../doc/fig/
156 end
157 % configure searching path
158 mfile_fullpath = mfilename('fullpath'); % the full path and name of the
    file in which the call occurs, not including the filename extension.
159 mfile_fullpath_without_fname = mfile_fullpath(1:end-
    strlength(mfilename));
160 addpath(genpath(mfile_fullpath_without_fname + "../data"), ...
161         genpath(mfile_fullpath_without_fname + "../inc")); % adds the
    specified folders to the top of the search path for the current MATLAB®
    session.
```



```
162
163     return;
164 end
165
166 %%
167
168 function [t_TCL] =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_target,sst_var,sst,lon,lat,SST_
    contour_label_v,month_name_str,main_title_str)
169     arguments
170         t_TCL
171         TF_lon_range
172         TF_lat_range
173         TF_time_target
174         sst_var
175         sst
176         lon
177         lat
178         SST_contour_label_v = 28:30
179         month_name_str = "Dec 1997"
180         main_title_str = "\bf TAO Monthly Mean SST $({\circ} \rm{C})$"
181     end
182
183     %
184     SST_mean = sst(TF_lon_range,TF_lat_range,TF_time_target);
185     SST_var = sst_var(TF_lon_range,TF_lat_range,TF_time_target);
186
187     % plot mean SST
188     t_axis_SST = nexttile(t_TCL,1);
189     pcolor(t_axis_SST,lon(TF_lon_range),lat(TF_lat_range),SST_mean. ');
190     shading(t_axis_SST,"interp");
191     hold on
192     [C,h] =
        contour(t_axis_SST,lon(TF_lon_range),lat(TF_lat_range),SST_mean. ', 'LineWidth
        ',0.2, 'LineColor', 'black', 'ShowText', 'off');
193     hold off
194     clabel(C,h,SST_contour_label_v,"Interpreter","latex","FontSize",6)
195     colormap(t_axis_SST,'jet')
196     cb = colorbar(t_axis_SST,"eastoutside","TickLabelInterpreter","latex");
197     set(t_axis_SST,"TickLabelInterpreter","latex","YTick",-
        10:5:10,"YTickLabel",{ '$10^{\circ}\rm{S}$', '$5^{\circ}\rm{S}$', '$0^{\circ}$'
        , '$5^{\circ}\rm{N}$', '$10^{\circ}\rm{N}$' }, "XTick", 140:20:260, "XTickLabel", {
        '$140^{\circ}\rm{E}$', '$160^{\circ}\rm{E}$', '$180^{\circ}$', '$160^{\circ}\rm
```



```
{W}$', '$140^{\circ}\rm{W}$', '$120^{\circ}\rm{W}$', '$100^{\circ}\rm{W}$'}, "Ti
ckDir", "out", 'YDir', 'normal');
198     title(t_axis_SST, "\bf " + month_name_str + "
Means", "Interpreter", "latex")
199
200     % plot SST variability
201     t_axis_var = nexttile(t_TCL, 2);
202     pcolor(t_axis_var, lon(TF_lon_range), lat(TF_lat_range), SST_var. ');
203     shading(t_axis_var, "interp");
204     hold on
205     [C, h] =
contour(t_axis_var, lon(TF_lon_range), lat(TF_lat_range), SST_var. ', 'LineWidth'
, 0.2, 'LineColor', 'black', 'ShowText', 'off');
206     hold off
207     clabel(C, h, "Interpreter", 'latex', 'FontSize', 6)
208     colormap(t_axis_var, 'jet')
209     cb = colorbar(t_axis_var, "eastoutside", "TickLabelInterpreter", "latex");
210     set(t_axis_var, "TickLabelInterpreter", "latex", "YTick", -
10:5:10, "YTickLabel", {'$10^{\circ}\rm{S}$', '$5^{\circ}\rm{S}$', '$0^{\circ}$'
, '$5^{\circ}\rm{N}$', '$10^{\circ}\rm{N}$'}, "XTick", 140:20:260, "XTickLabel", {
}, "TickDir", "out", 'YDir', 'normal');
211     title(t_axis_var, "\bf " + month_name_str + "
Anomalies", "Interpreter", "latex")
212
213     %
214     [~, t_title_s] = title(t_TCL, main_title_str, "Guorui Wei
120034910021", 'Interpreter', 'latex');
215     set(t_title_s, 'FontSize', 8);
216 end
217
218 %%
219
220 function [t_TCL] =
fig4(t_TCL, lon, lat, TF_lon_range, TF_lat_range, sst_var_Va, caxis_limits, main_t
ile_str)
221     arguments
222         t_TCL
223         lon
224         lat
225         TF_lon_range
226         TF_lat_range
227         sst_var_Va
228         caxis_limits = [-0.5, 3]
229         main_title_str = "\bf Fig.4(a) Variance"
```



```
230     end
231
232     t_axis = nexttile(t_TCL,1);
233     pcolor(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va. ');
234     shading(t_axis,"interp");
235     hold on
236     [C,h] =
        contour(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va.', 'LineWidth',
        0.2, 'LineColor', 'black', 'ShowText', 'off');
237     hold off
238     clabel(C,h,"Interpreter", 'latex', 'FontSize',6)
239     caxis(t_axis,caxis_limits)
240     colormap(t_axis,'jet')
241     cb = colorbar(t_axis,"eastoutside","TickLabelInterpreter","latex");
242     set(t_axis,"TickLabelInterpreter","latex","YTick",-
        30:5:30,"YTickLabel","$"+[string(30:-
        5:5)+"^\{\circ\}\rm{S}","0^\{\circ\}",string(5:5:30)+"^\{\circ\}\rm{N}"]+"$", "XTic
        k",120:30:270,"XTickLabel",{ '$120^\{\circ\}\rm{E}$', '$150^\{\circ\}\rm{E}$', '$18
        0^\{\circ\}$', '$150^\{\circ\}\rm{W}$', '$120^\{\circ\}\rm{W}$', '$90^\{\circ\}\rm{W}$'
        }, "TickDir", "out", 'YDir', 'normal');
243     %
244     [~,t_title_s] = title(t_TCL,main_title_str,"Guorui Wei
        120034910021", 'Interpreter', 'latex');
245     set(t_title_s, 'FontSize',8);
246 end
247
```

## A.2 子程序

本文使用的程序和文档发布于 [https://grwei.github.io/SJTU\\_2021-2022-2\\_MS8401/](https://grwei.github.io/SJTU_2021-2022-2_MS8401/).