第 1 次作业

危国锐 120034910021
（上海交通大学海洋学院，上海 200030）

摘 要： 本文使用的程序和文档发布于 https://grwei.github.io/SJTU_2021-2022-2_MS8401/.

关键词： 词 1，词 2

Homework 1

Guorui Wei 120034910021
(*School of Oceanography*, *Shanghai Jiao Tong University*, *Shanghai* 200030, *China*)

Abstract: The programs and documents used in this article are published at https://grwei.github.io/SJTU_2021-2022-2_MS8401/.

Keywords: keyword 1, keyword 2

目 录

摘要 ..... **i**
Abstract ..... **i**
1 Due Date: 2022-04-30 ..... **1**
References **4**
附录 A 本文使用的 MATLAB 程序源代码 **5**
A.1 主程序 5
A.2 子程序 12

1 Due Date: 2022-04-30

从 **Figure 1** 左子图（南北纬 2 度间经向平均的月平均 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℃（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℃，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样为正，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。

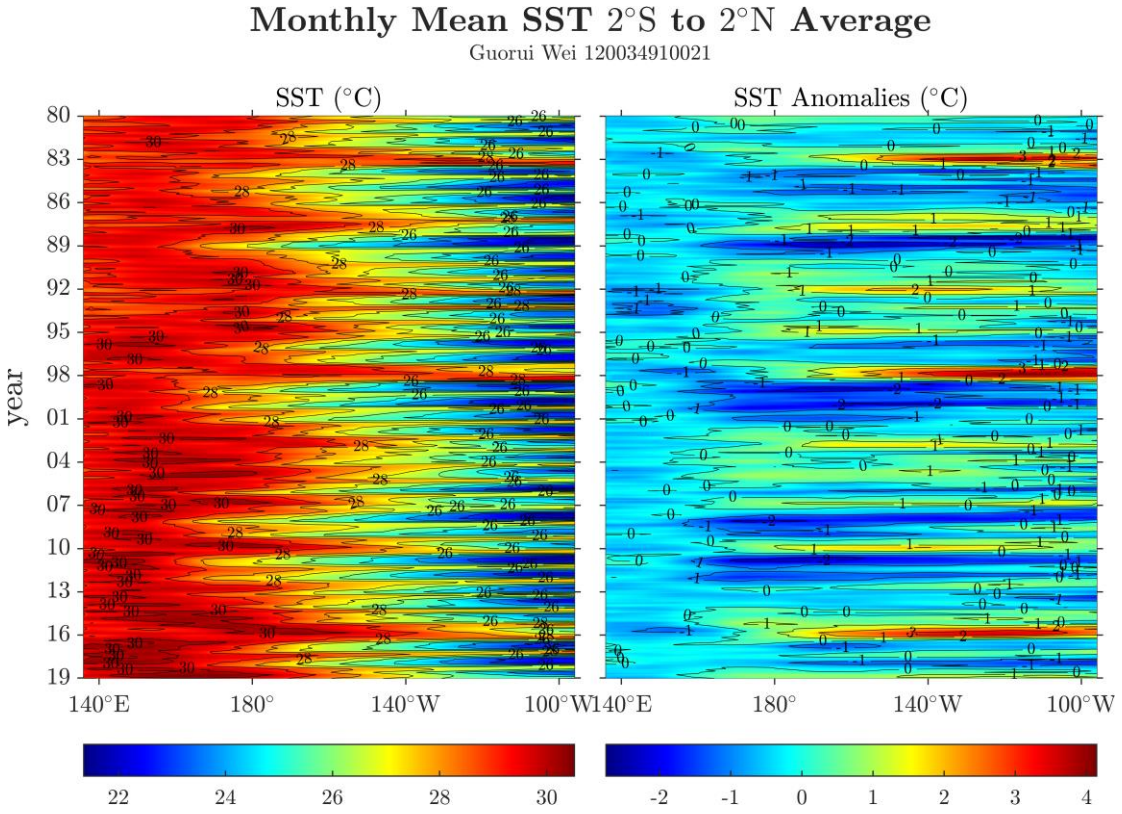

Figure 1 Monthly mean SST

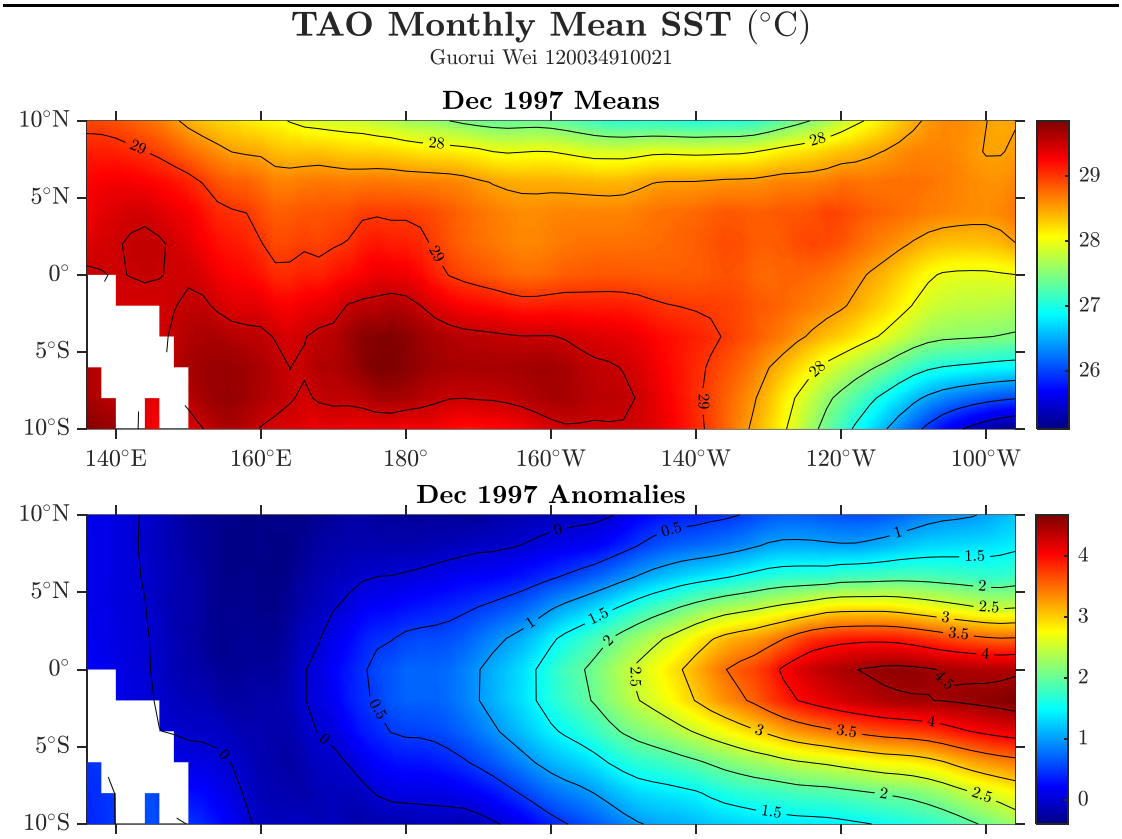

Figure 2 TAO Monthly mean SST (Dec 1997)

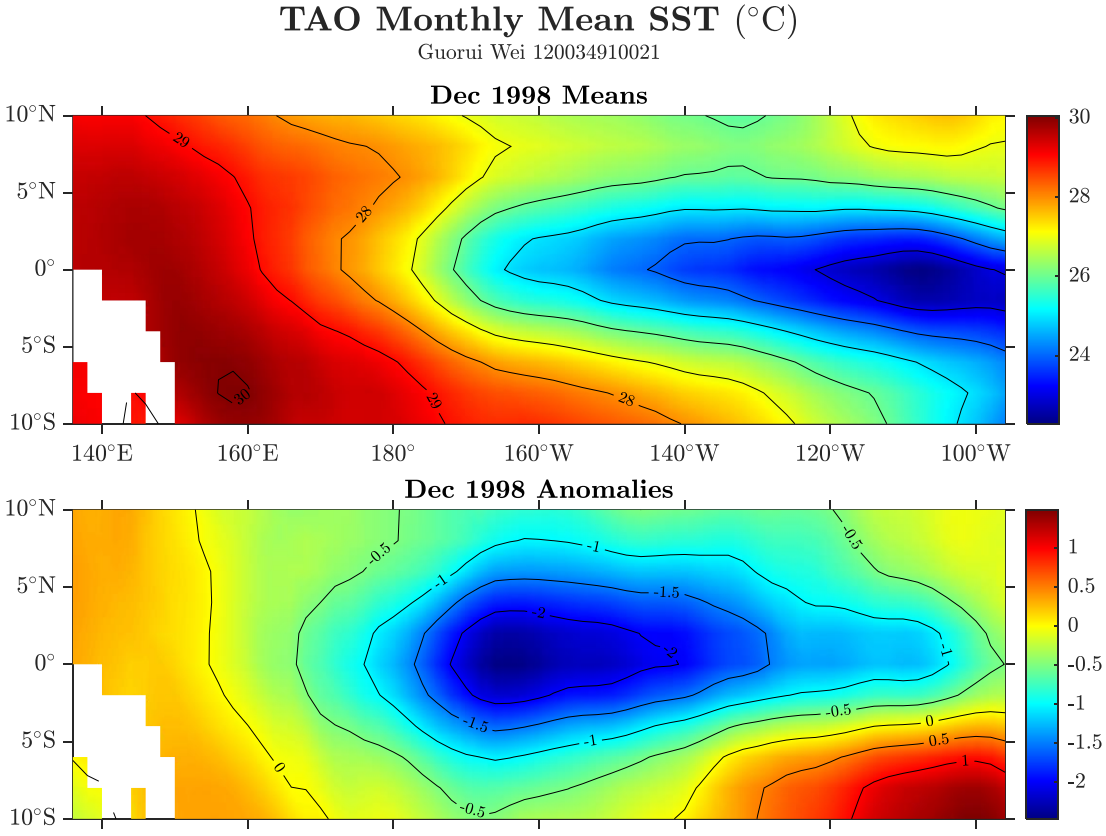

Figure 3 TAO Monthly mean SST (Dec 1998)

Fig.4(a) Variance

Guorui Wei 120034910021

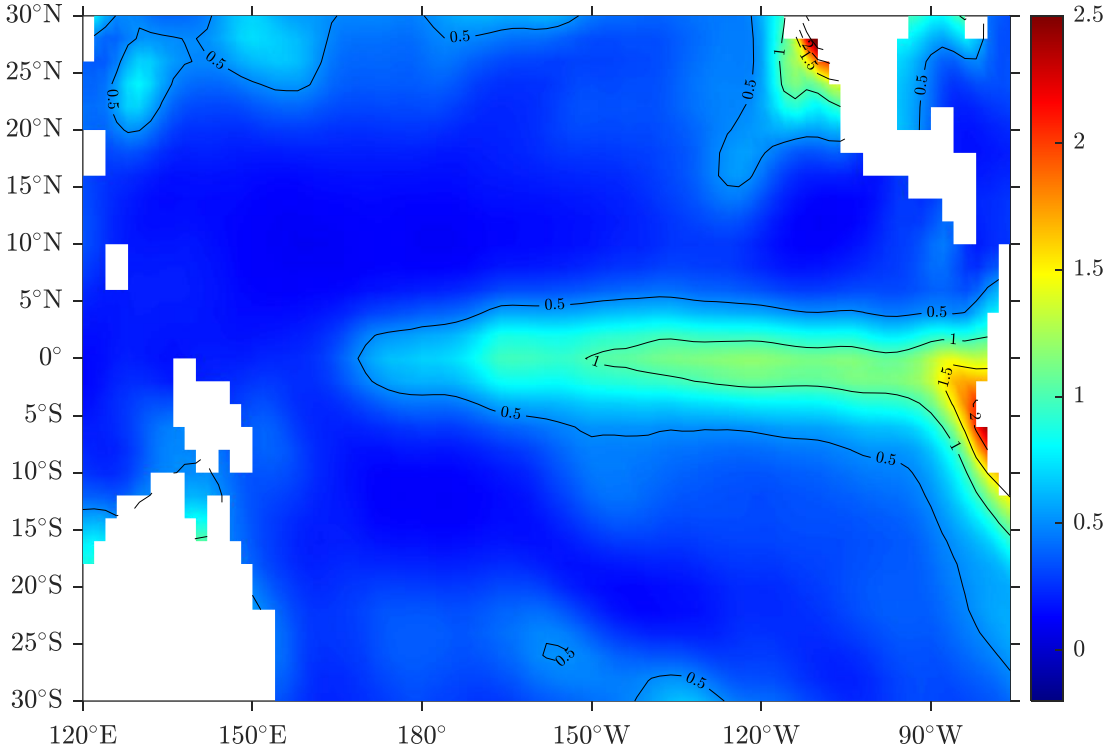

Figure 4 Variance of monthly-mean SST anomalies

Fig.4(b) Skewness

Guorui Wei 120034910021

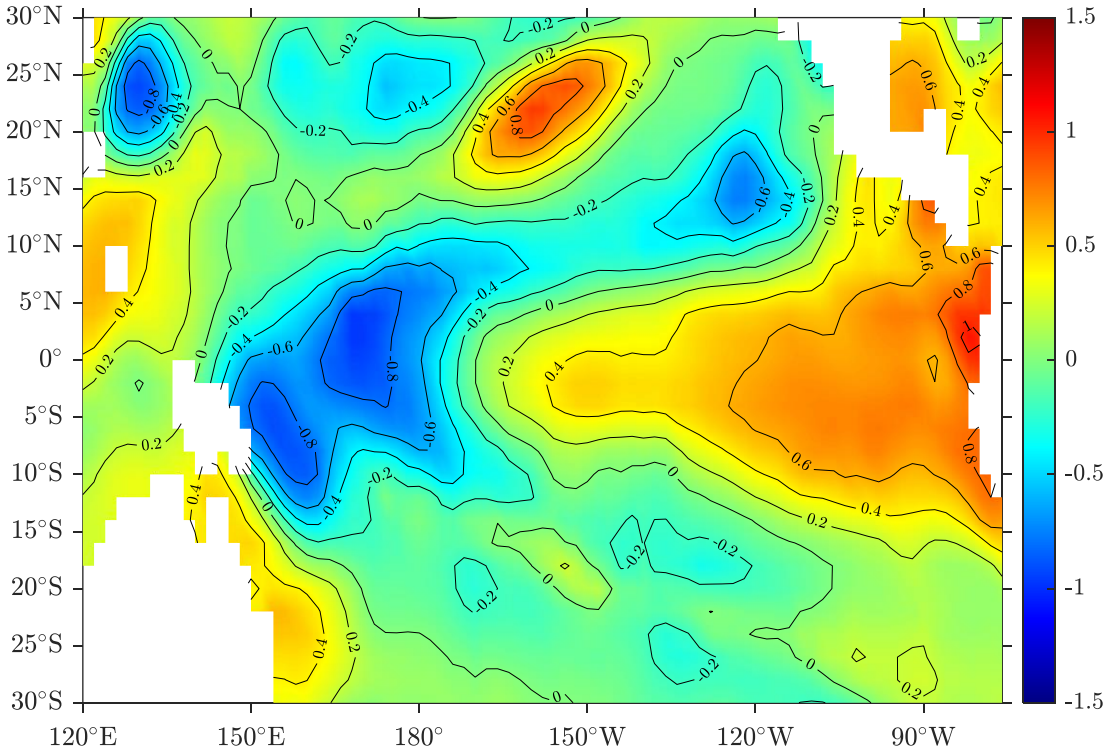

Figure 5 Skewness of monthly-mean SST anomalies

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_MS8401/.

A.1 主程序

```
%% hw1.m
% Description: MATLAB code for Homework 1 (MS8401, 2022 Spring)
% Author: Guorui Wei (危国锐) (313017602@qq.com; weiguorui@sjtu.edu.cn)
% Student ID: 120034910021
% Created: 2022-04-29
% Last modified: 2022-05-13
% Toolbox: [T1] [M_Map: A mapping package for Matlab](https://www.eoas.ubc.ca/~rich/map.html)
%          [T2] [Climate Data Tools for Matlab](https://github.com/chadagreene/CDT)
% Data:    [D1] [NOAA Extended Reconstructed Sea Surface Temperature (SST) V5](https://psl.noaa.gov/data/gridded/data.noaa.ersst.v5.html)

%% Initialize project

clc; clear; close all
init_env();

%% Read data

nc_path = "..\data\sst.mnmean.nc";
nc_info = ncinfo(nc_path);
sst = ncread(nc_path,'sst'); % [deg C] sst(lon,lat,time_month)
sst(sst == ncreadatt(nc_path,'/sst','missing_value')) = NaN; % Monthly Means of Sea Surface Temperature (SST)
lon = ncread(nc_path,'lon'); % [deg E]
lat = ncread(nc_path,'lat'); % [deg N]
time_month = (datetime(1854,1,15) + calmonths(0:size(sst,3)-1)).';

%% Fig.1

%%% Fig.1(a) SST

figure('Name',"Fig.1")
t_TCL = tiledlayout(1,2,"TileSpacing","tight","Padding","tight");

%
```

```
TF_lon_range = lon > 135 & lon < 265;
TF_lat_range = lat <= 2 & lat >= -2;
TF_time_range = datetime(1980,1,1) < time_month & time_month < datetime(2019,12,30);
SST_lat_mean = squeeze(mean(sst(TF_lon_range,TF_lat_range,TF_time_range),2,"omitnan"));
time_tick = datetime(1980,1,15) + calyears(0:3:2019-1980);

% plot
t_axis_SST = nexttile(t_TCL,1);
pcolor(t_axis_SST,lon(TF_lon_range),datenum(time_month(TF_time_range)),SST_lat_mean.');
shading(t_axis_SST,"interp");
hold on
[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',"TextList",22:2:30);
hold off
clabel(C,h,26:2:30,"Interpreter",'latex','FontSize',6)
colormap(t_axis_SST,'jet')
% caxis(t_axis_SST,[20,30]);
cb = colorbar(t_axis_SST,"southoutside","TickLabelInterpreter","latex");
% set(cb.Label,'String',"degree Celsius",'Interpreter','latex');
set(t_axis_SST,"TickLabelInterpreter","latex","YTick",datenum(time_tick),"XTick",140:40:260,"XTickLabel",{'$140^{\circ}\rm{E}$','$180^{\circ}$','$140^{\circ}\rm{W}$','$100^{\circ}\rm{W}$'},"TickDir","out",'YDir','reverse');
datetick(t_axis_SST,'y','yy','keepticks');
title(t_axis_SST,"SST ($^{\circ}\rm{C}$)",'Interpreter','latex');

%%% Fig.1(b) SST anomaly
% y = y_0 + y_tr + y_season + y_var + y_noise
% [CDT/season_documentation/How this function works](https://www.chadagreene.com/CDT/season_documentation.html#16)

%
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.
SST_lat_mean_tr = trend(SST_lat_mean,Fs,'dim',2,'omitnan') * 1/Fs * (0:size(SST_lat_mean,2)-1);
SST_lat_mean_climatology = climatology(SST_lat_mean,time_month(TF_time_range),'monthly','dim',2,'detrend','linear','full'); % y_climatology = y_0 + y_season
```

```
64  SST_lat_mean_var = SST_lat_mean - SST_lat_mean_tr -
    SST_lat_mean_climatology; % interannual variability (+ noise)
65
66  % plot
67  t_axis_SST_anomaly = nexttile(t_TCL,2);
68  pcolor(t_axis_SST_anomaly,lon(TF_lon_range),datenum(time_month(TF_time_range))
    ,SST_lat_mean_var.');
69  shading(t_axis_SST_anomaly,"interp");
70  hold on
71  [C,h] =
    contour(t_axis_SST_anomaly,lon(TF_lon_range),datenum(time_month(TF_time_range)
    ),SST_lat_mean_var.',-
    3:3,'LineWidth',0.2,'LineColor','black','ShowText','off');
72  hold off
73  clabel(C,h,"Interpreter",'latex','FontSize',6)
74  colormap(t_axis_SST_anomaly,'jet')
75  cb =
    colorbar(t_axis_SST_anomaly,"southoutside","TickLabelInterpreter","latex");
76  set(t_axis_SST_anomaly,"TickLabelInterpreter","latex","YTick",datenum(time_tic
    k),"YTickLabel",{},"XTick",140:40:260,"XTickLabel",{'$140^{\circ}\rm{E}$','$18
    0^{\circ}$','$140^{\circ}\rm{W}$','$100^{\circ}\rm{W}$'},"TickDir","out",'YDir
    ','reverse');
77  datetick(t_axis_SST_anomaly,'y','yy','keepticks');
78  set(t_axis_SST_anomaly,"YTickLabel",{});
79  title(t_axis_SST_anomaly,"SST Anomalies
    ($^{\circ}\rm{C}$)",'Interpreter','latex');
80
81  %
82  ylabel(t_TCL,"year","Interpreter",'latex')
83  [~,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');
84  set(t_title_s,'FontSize',8);
85  %
86  exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_1.emf",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
87  exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_1.png",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
88
89  %% Fig.2 & 3
90
91  %
92  TF_lon_range = lon > 135 & lon < 265;
93  TF_lat_range = lat <= 10 & lat >= -10;
```

```
94  TF_time_range = datetime(1980,1,1) < time_month & time_month <
    datetime(2019,12,30);
95  TF_time_El_nino = time_month == datetime(1997,12,15);
96  TF_time_La_nina = time_month == datetime(1998,12,15);
97
98  %%%
99
100 sst_tr_coeff = trend(sst,Fs,'dim',3,'omitnan') * 1/Fs;
101 sst_tr = zeros(size(sst));
102 for k = 1:size(sst,3)
103     sst_tr(:,:,k) = sst_tr_coeff * k;
104 end
105 sst_climatology =
    climatology(sst,time_month,'monthly','dim',3,'detrend','linear','full'); %
    y_climatology = y_0 + y_season
106 sst_var = deseason(detrend3(sst,'omitnan'),time_month); % interannual
    variability (+ noise)
107
108 % Fig.2
109 figure('Name',"Fig.2 (El_nino)")
110 t_TCL = tiledlayout(2,1,"TileSpacing","tight","Padding","tight");
111 t_TCL =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_El_nino,sst_var,sst,lon,lat,28:30
    ,"Dec 1997");
112 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_2.emf",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
113 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_2.png",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
114
115 % Fig.3
116 figure('Name',"Fig.3 (La_nina)")
117 t_TCL = tiledlayout(2,1,"TileSpacing","tight","Padding","tight");
118 t_TCL =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_La_nina,sst_var,sst,lon,lat,28:30
    ,"Dec 1998");
119 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_3.emf",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
120 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_3.png",'Resolution',800,'Cont
    entType','auto','BackgroundColor','none','Colorspace','rgb')
121
122 %% Fig.4
123
124 %
125 TF_lon_range = lon > 119 & lon < 285;
```

```
126 TF_lat_range = lat <= 30 & lat >= -30;
127 %
128 sst_var_Va = var(sst_var(TF_lon_range,TF_lat_range,:),0,3,"omitnan");
129 sst_var_Sk = skewness(sst_var(TF_lon_range,TF_lat_range,:),0,3);
130
131 %%% Fig.4(a)
132 figure('Name',"Fig.4(a) (variance)")
133 t_TCL = tiledlayout(1,1,"TileSpacing","tight","Padding","tight");
134 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");
135 %
136 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_4a.emf",'Resolution',800,'Con
    tentType','auto','BackgroundColor','none','Colorspace','rgb')
137 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_4a.png",'Resolution',800,'Con
    tentType','auto','BackgroundColor','none','Colorspace','rgb')
138
139 %%% Fig.4(b)
140 figure('Name',"Fig.4(b) (skewness)")
141 t_TCL = tiledlayout(1,1,"TileSpacing","tight","Padding","tight");
142 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");
143 %
144 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_4b.emf",'Resolution',800,'Con
    tentType','auto','BackgroundColor','none','Colorspace','rgb')
145 exportgraphics(t_TCL,"..\\doc\\fig\\hw1\\hw1_Fig_4b.png",'Resolution',800,'Con
    tentType','auto','BackgroundColor','none','Colorspace','rgb')
146
147 %% local functions
148
149 %% Initialize environment
150
151 function [] = init_env()
152 % Initialize environment
153 %
154     % set up project directory
155     if ~isfolder("../doc/fig/hw1")
156         mkdir ../doc/fig/hw1
157     end
158     % configure searching path
159     mfile_fullpath = mfilename('fullpath'); % the full path and name of the
    file in which the call occurs, not including the filename extension.
160     mfile_fullpath_without_fname = mfile_fullpath(1:end-strlength(mfilename));
161     addpath(genpath(mfile_fullpath_without_fname + "../data"), ...
```

```
162             genpath(mfile_fullpath_without_fname + "../inc")); % adds the
    specified folders to the top of the search path for the current MATLAB®
    session.
163
164     return;
165 end
166
167 %%
168
169 function [t_TCL] =
    fig2(t_TCL,TF_lon_range,TF_lat_range,TF_time_target,sst_var,sst,lon,lat,SST_co
    ntour_label_v,month_name_str,main_title_str)
170     arguments
171         t_TCL
172         TF_lon_range
173         TF_lat_range
174         TF_time_target
175         sst_var
176         sst
177         lon
178         lat
179         SST_contour_label_v = 28:30
180         month_name_str = "Dec 1997"
181         main_title_str = "\bf TAO Monthly Mean SST $(^{\circ} \rm{C})$"
182     end
183
184     %
185     SST_mean = sst(TF_lon_range,TF_lat_range,TF_time_target);
186     SST_var = sst_var(TF_lon_range,TF_lat_range,TF_time_target);
187
188     % plot mean SST
189     t_axis_SST = nexttile(t_TCL,1);
190     pcolor(t_axis_SST,lon(TF_lon_range),lat(TF_lat_range),SST_mean.');
191     shading(t_axis_SST,"interp");
192     hold on
193     [C,h] =
    contour(t_axis_SST,lon(TF_lon_range),lat(TF_lat_range),SST_mean.','LineWidth',
    0.2,'LineColor','black','ShowText','off');
194     hold off
195     clabel(C,h,SST_contour_label_v,"Interpreter",'latex','FontSize',6)
196     colormap(t_axis_SST,'jet')
197     cb = colorbar(t_axis_SST,"eastoutside","TickLabelInterpreter","latex");
198     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",{'$140^{\circ}\rm{E}$','$160^{\circ}\rm{E}$','$180^{\circ}$','$160^{\circ}\rm{W}$','$140^{\circ}\rm{W}$','$120^{\circ}\rm{W}$','$100^{\circ}\rm{W}$'},"TickDir","out",'YDir','normal');
    title(t_axis_SST,"\bf " + month_name_str + " Means","Interpreter","latex")

    % plot SST varibility
    t_axis_var = nexttile(t_TCL,2);
    pcolor(t_axis_var,lon(TF_lon_range),lat(TF_lat_range),SST_var.');
    shading(t_axis_var,"interp");
    hold on
    [C,h] = contour(t_axis_var,lon(TF_lon_range),lat(TF_lat_range),SST_var.','LineWidth',0.2,'LineColor','black','ShowText','off');
    hold off
    clabel(C,h,"Interpreter",'latex','FontSize',6)
    colormap(t_axis_var,'jet')
    cb = colorbar(t_axis_var,"eastoutside","TickLabelInterpreter","latex");
    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');
    title(t_axis_var,"\bf " + month_name_str + " Anomalies","Interpreter","latex")

    %
    [~,t_title_s] = title(t_TCL,main_title_str,"Guorui Wei 120034910021",'Interpreter','latex');
    set(t_title_s,'FontSize',8);
end

%%

function [t_TCL] = fig4(t_TCL,lon,lat,TF_lon_range,TF_lat_range,sst_var_Va,caxis_limits,main_title_str)
    arguments
        t_TCL
        lon
        lat
        TF_lon_range
        TF_lat_range
        sst_var_Va
        caxis_limits = [-0.5,3]
```

```
230         main_title_str = "\bf Fig.4(a) Variance"
231     end
232
233     t_axis = nexttile(t_TCL,1);
234     pcolor(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va.');
235     shading(t_axis,"interp");
236     hold on
237     [C,h] =
    contour(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va.','LineWidth',0.
    2,'LineColor','black','ShowText','off');
238     hold off
239     clabel(C,h,"Interpreter",'latex','FontSize',6)
240     caxis(t_axis,caxis_limits)
241     colormap(t_axis,'jet')
242     cb = colorbar(t_axis,"eastoutside","TickLabelInterpreter","latex");
243     set(t_axis,"TickLabelInterpreter","latex","YTick",-
    30:5:30,"YTickLabel","$"+[string(30:-
    5:5)+"^{\circ}\rm{S}","0^{\circ}",string(5:5:30)+"^{\circ}\rm{N}"]+"$","XTick"
    ,120:30:270,"XTickLabel",{'$120^{\circ}\rm{E}$','$150^{\circ}\rm{E}$','$180^{\
    circ}$','$150^{\circ}\rm{W}$','$120^{\circ}\rm{W}$','$90^{\circ}\rm{W}$'},"Tic
    kDir","out",'YDir','normal');
244     %
245     [~,t_title_s] = title(t_TCL,main_title_str,"Guorui Wei
    120034910021",'Interpreter','latex');
246     set(t_title_s,'FontSize',8);
247 end
248
```

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/.