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/.

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/.

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。

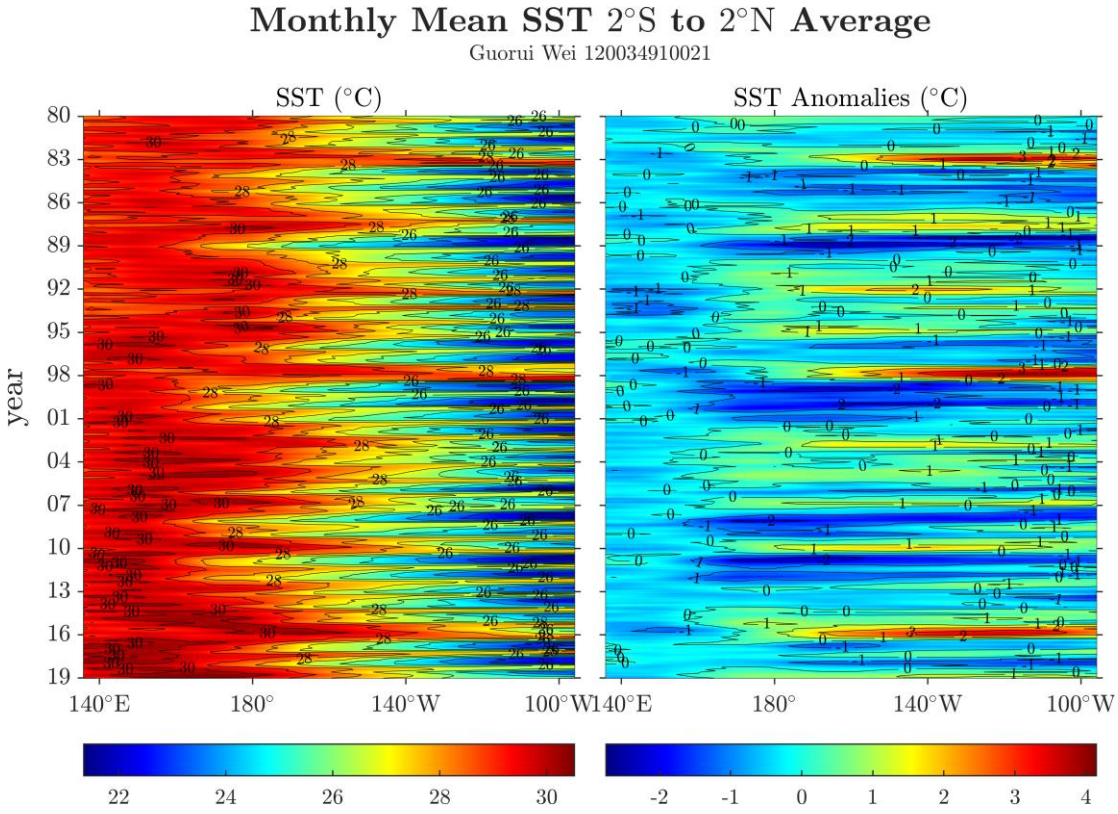

Figure 1 Monthly mean SST

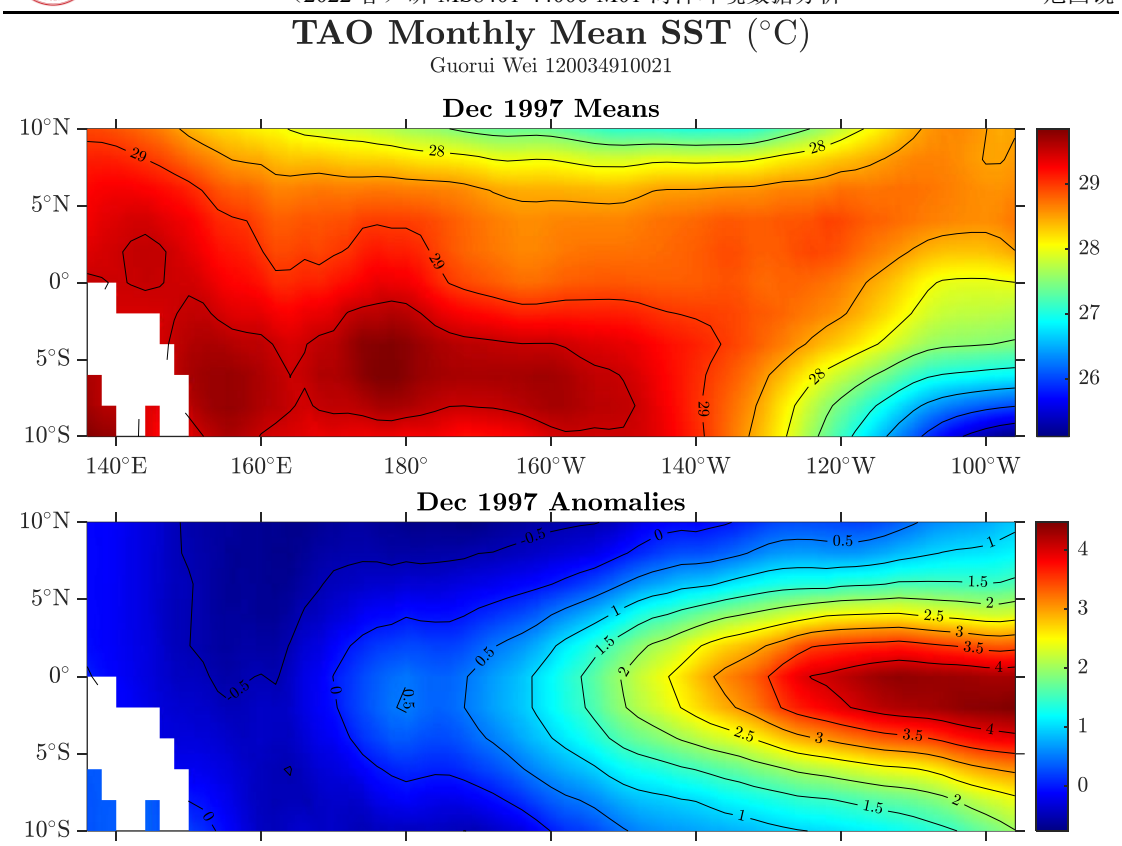

Figure 2 TAO Monthly mean SST (Dec 1997)

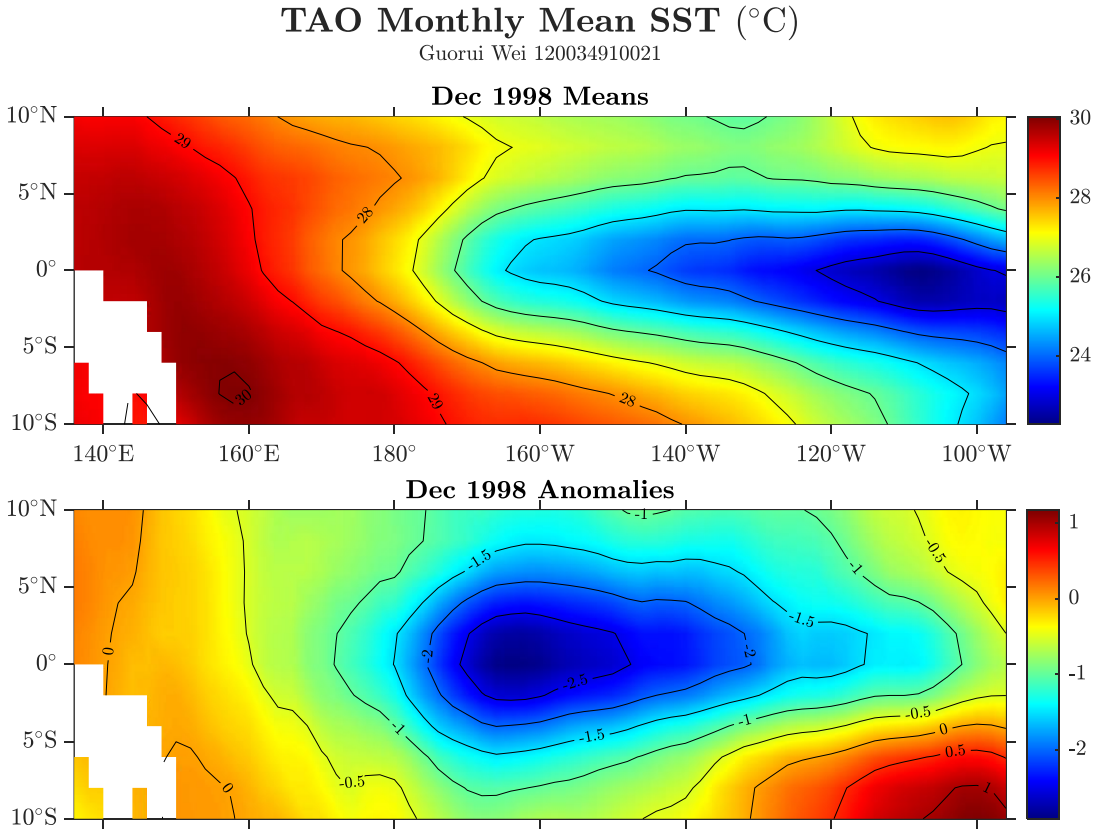

Figure 3 TAO Monthly mean SST (Dec 1998)

Fig.4(a) Variance

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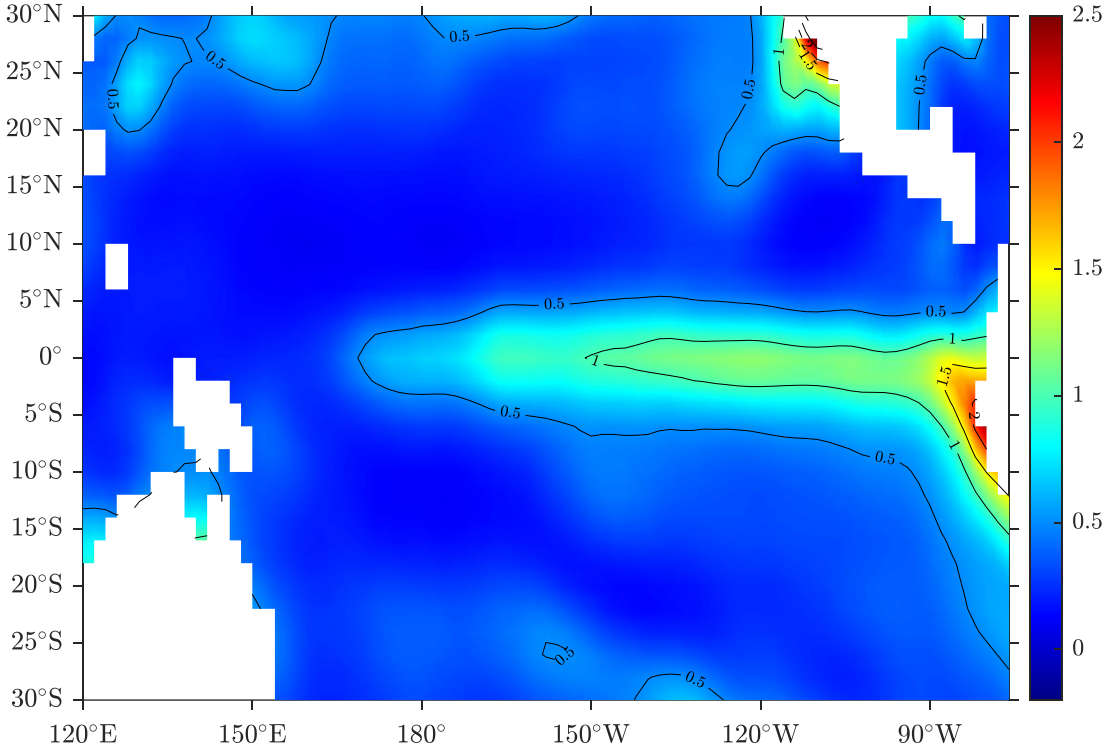

Figure 4 Variance of monthly-mean SST anomalies

Fig.4(b) Skewness

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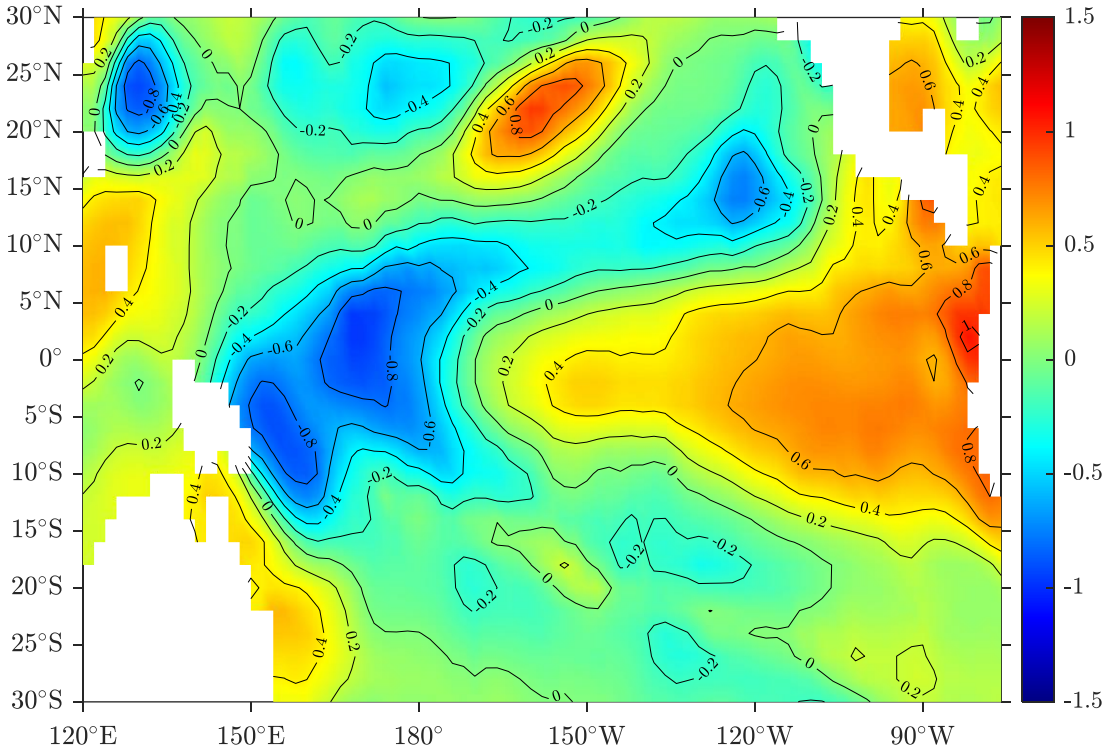

Figure 5 Skewness of monthly-mean SST anomalies

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_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: 2022-04-30
% Toolbox: [1] [M_Map: A mapping package for Matlab](https://www.eoas.ubc.ca/~rich/map.html)
%          [2] [Climate Data Tools for Matlab](https://github.com/chadagreene/CDT)

%% 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
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,'Conten
    tType','auto','BackgroundColor','none','Colorspace','rgb')
136 exportgraphics(t_TCL,"..\\doc\\fig\\hw1_Fig_4a.png",'Resolution',600,'Conten
    tType','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,'Conten
    tType','auto','BackgroundColor','none','Colorspace','rgb')
144 exportgraphics(t_TCL,"..\\doc\\fig\\hw1_Fig_4b.png",'Resolution',600,'Conten
    tType','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}$','$140^{\circ}\rm{W}$','$120^{\circ}\rm{W}$','$100^{\circ}\rm{W}$'},"TickDir","out",'YDir','normal');
198     title(t_axis_SST,"\bf " + month_name_str + " Means","Interpreter","latex")
199
200     % plot SST varibility
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_title_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"
```

```
    end

    t_axis = nexttile(t_TCL,1);
    pcolor(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va.');
    shading(t_axis,"interp");
    hold on
    [C,h] =
contour(t_axis,lon(TF_lon_range),lat(TF_lat_range),sst_var_Va.','LineWidth',
0.2,'LineColor','black','ShowText','off');
    hold off
    clabel(C,h,"Interpreter",'latex','FontSize',6)
    caxis(t_axis,caxis_limits)
    colormap(t_axis,'jet')
    cb = colorbar(t_axis,"eastoutside","TickLabelInterpreter","latex");
    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');
    %
    [~,t_title_s] = title(t_TCL,main_title_str,"Guorui Wei
120034910021",'Interpreter','latex');
    set(t_title_s,'FontSize',8);
end
```

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/.