Climate Change Projections: IPSL-CM6A-LR

This is code to display Multiplicative Change Factor figure.(Note: You must run climate_change_analysis_BCC & climate_change_analysis_CNRM before this)

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NOTE: Figures will be be hidden from knitted markdown.

read in daily total climate projection and historical data exported from jupyter notebook, code can be found here: https://github.com/aloha-aina/Aloha-Aina-Master

```
## Note: these data are from climate model IPSL-CM6A-LR (France)
## daily totals
ipsl_historical_tot = read.csv(here("climate_change_data", "IPSL_daily_tot","oahu_historical_1850_2014_
  rename(date = dayofyear, pcp = pr)
ipsl_ssp126_tot = read.csv(here("climate_change_data","IPSL_daily_tot","oahu_ssp126_2015_2100_total.csv
  rename(date = dayofyear, pcp = pr)
ipsl_ssp245_tot = read.csv(here("climate_change_data","IPSL_daily_tot","oahu_ssp245_2015_2100_total.csv
  rename(date = dayofyear, pcp = pr)
ipsl_ssp370_tot = read.csv(here("climate_change_data","IPSL_daily_tot","oahu_ssp370_2015_2100_total.csv
  rename(date = dayofyear, pcp = pr)
ipsl_ssp585_tot = read.csv(here("climate_change_data","IPSL_daily_tot","oahu_ssp585_2015_2100_total.csv
  rename(date = dayofyear, pcp = pr)

ipsl_historical_tot$date <- ymd(ipsl_historical_tot$date)
ipsl_ssp126_tot$date <- ymd(ipsl_ssp126_tot$date)
ipsl_ssp245_tot$date <- ymd(ipsl_ssp245_tot$date)
ipsl_ssp370_tot$date <- ymd(ipsl_ssp370_tot$date)
ipsl_ssp585_tot$date <- ymd(ipsl_ssp585_tot$date)
```

Daily total visualization

```
ipsl_daily_tot_proj <-
  ggplot() +
  geom_line(data = ipsl_historical_tot, aes(x=date, y=pcp, color= "black"), size = 0.5) +
  geom_line(data = ipsl_ssp126_tot, aes(x=date, y=pcp, color="orange"), size = 0.5) +
  geom_line(data = ipsl_ssp245_tot, aes(x=date, y=pcp, color="red"), size = 0.5) +
  geom_line(data = ipsl_ssp370_tot, aes(x=date, y=pcp, color = "blue"), size = 0.5) +
  geom_line(data = ipsl_ssp585_tot, aes(x=date, y=pcp, color = "seagreen"), size = 0.5) +
  theme_minimal() +
  scale_y_continuous(breaks=seq(0,150,10)) +
  scale_x_date(date_breaks = "20 years", date_labels = "%Y") +
  ggtitle("Oahu, HI Daily Total Precipitation, IPSL-CM6A-LR: 1850-2100") +
```

```
    labs(x = "Year",
        y = "Precipitation (in)") +
    scale_color_manual(values = c("black", "orange", "red", "blue", "seagreen", "purple"),
                        labels = c("historical" , "spp126", "ssp245", "ssp370", "ssp585")) +
    theme(legend.title=element_blank())+
        theme(legend.position="bottom")

ipsl_daily_tot_proj
```

daily totals by month

```
# add seperate columns for year, month and day
ipsl_historical_tot <- ipsl_historical_tot %>%
  mutate(year = year(date)) %>%
  mutate(month = month(date)) %>%
  mutate(day = day(date))

ipsl_ssp126_tot <- ipsl_ssp126_tot %>%
  mutate(year = year(date)) %>%
  mutate(month = month(date)) %>%
  mutate(day = day(date))

ipsl_ssp245_tot <- ipsl_ssp245_tot %>%
  mutate(year = year(date)) %>%
  mutate(month = month(date)) %>%
  mutate(day = day(date))

ipsl_ssp370_tot <- ipsl_ssp370_tot %>%
  mutate(year = year(date)) %>%
  mutate(month = month(date)) %>%
  mutate(day = day(date))

ipsl_ssp585_tot <- ipsl_ssp585_tot  %>%
  mutate(year = year(date)) %>%
  mutate(month = month(date)) %>%
  mutate(day = day(date))


# group by yearly sum of pcp
ipsl_historical_tot_yearly <- ipsl_historical_tot %>%
  group_by(year) %>%
  mutate(sum = sum(pcp)) %>%
  select(year, sum) %>%
  distinct()

ipsl_historical_tot_yearly$year <- as.numeric(ipsl_historical_tot_yearly$year)


# group by yearly sum of pcp
ipsl_ssp126_tot_yearly <- ipsl_ssp126_tot %>%
  group_by(year) %>%
  mutate(sum = sum(pcp)) %>%
  select(year, sum) %>%
```

```r
  distinct()

ipsl_ssp126_tot_yearly$year <- as.numeric(ipsl_ssp126_tot_yearly$year)

# group by yearly sum of pcp
ipsl_ssp245_tot_yearly <- ipsl_ssp245_tot %>%
  group_by(year) %>%
  mutate(sum = sum(pcp)) %>%
  select(year, sum) %>%
  distinct()

ipsl_ssp245_tot_yearly$year <- as.numeric(ipsl_ssp245_tot_yearly$year)

# group by yearly sum of pcp
ipsl_ssp370_tot_yearly <- ipsl_ssp370_tot %>%
  group_by(year) %>%
  mutate(sum = sum(pcp)) %>%
  select(year, sum) %>%
  distinct()

ipsl_ssp370_tot_yearly$year <- as.numeric(ipsl_ssp370_tot_yearly$year)

# group by yearly sum of pcp
ipsl_ssp585_tot_yearly <- ipsl_ssp585_tot %>%
  group_by(year) %>%
  mutate(sum = sum(pcp)) %>%
  select(year, sum) %>%
  distinct()

ipsl_ssp585_tot_yearly$year <- as.numeric(ipsl_ssp585_tot_yearly$year)

# group by month (and associated year) sum of pcp
ipsl_historical_tot_monthly <- ipsl_historical_tot %>%
  group_by(month,year) %>%
  mutate(sum = sum(pcp)) %>%
  select(month, year, sum) %>%
  distinct()

ipsl_historical_tot_monthly$date <- format(as.Date(paste(ipsl_historical_tot_monthly$year, ipsl_historic

ipsl_historical_tot_monthly$date <- my(ipsl_historical_tot_monthly$date)

# group by month (and associated year) sum of pcp
ipsl_ssp126_tot_monthly <- ipsl_ssp126_tot %>%
  group_by(month,year) %>%
  mutate(sum = sum(pcp)) %>%
  select(month, year, sum) %>%
  distinct()

ipsl_ssp126_tot_monthly$date <- format(as.Date(paste(ipsl_ssp126_tot_monthly$year, ipsl_ssp126_tot_montl

ipsl_ssp126_tot_monthly$date <- my(ipsl_ssp126_tot_monthly$date)
```

```r
# group by month (and associated year) sum of pcp
ipsl_ssp245_tot_monthly <- ipsl_ssp245_tot %>%
  group_by(month,year) %>%
  mutate(sum = sum(pcp)) %>%
  select(month, year, sum) %>%
  distinct()

ipsl_ssp245_tot_monthly$date <- format(as.Date(paste(ipsl_ssp245_tot_monthly$year, ipsl_ssp245_tot_montl

ipsl_ssp245_tot_monthly$date <- my(ipsl_ssp245_tot_monthly$date)

# group by yearly sum of daily avg pcp
ipsl_ssp370_tot_monthly <- ipsl_ssp370_tot %>%
  group_by(month,year) %>%
  mutate(sum = sum(pcp)) %>%
  select(month, year, sum) %>%
  distinct()

ipsl_ssp370_tot_monthly$date <- format(as.Date(paste(ipsl_ssp370_tot_monthly$year, ipsl_ssp370_tot_montl

ipsl_ssp370_tot_monthly$date <- my(ipsl_ssp370_tot_monthly$date)

# group by yearly sum of daily avg pcp
ipsl_ssp585_tot_monthly <- ipsl_ssp585_tot %>%
  group_by(month,year) %>%
  mutate(sum = sum(pcp)) %>%
  select(month, year, sum) %>%
  distinct()

ipsl_ssp585_tot_monthly$date <- format(as.Date(paste(ipsl_ssp585_tot_monthly$year, ipsl_ssp585_tot_montl

ipsl_ssp585_tot_monthly$date <- my(ipsl_ssp585_tot_monthly$date)
```

yearly total for all ssps and historical

```r
## all three ssps
ipsl_yearly_sum_proj <-
  ggplot() +
  geom_line(data = ipsl_historical_tot_yearly, aes(x=year, y=sum, color="black"), size = 0.5) +
  geom_line(data = ipsl_ssp126_tot_yearly, aes(x=year, y=sum, color="orange"), size = 0.5) +
  geom_line(data = ipsl_ssp245_tot_yearly, aes(x=year, y=sum, color="red"), size = 0.5) +
  geom_line(data = ipsl_ssp370_tot_yearly, aes(x=year, y=sum, color = "blue"), size = 0.5) +
  geom_line(data = ipsl_ssp585_tot_yearly, aes(x=year, y=sum, color = "seagreen"), size = 0.5) +
  theme_minimal() +
  #scale_y_continuous(breaks=seq(0,450,50)) +
  scale_x_continuous(breaks=seq(1850,2100,50)) +
  # scale_x_date(date_breaks = "5 years", date_labels = "%Y") +
  ggtitle("Oahu, HI Yearly Total Precipitation, IPSL-CM6A-LR: 1850-2100") +
  scale_color_manual(values = c("black", "orange", "red", "blue", "seagreen"), labels = c("historical",
  labs(x = "Year",
       y = "Precipitation (in)") +
  geom_smooth(data = ipsl_historical_tot_yearly, aes(x=year, y=sum), method='lm', formula = y~x, color =
  geom_smooth(data = ipsl_ssp126_tot_yearly, aes(x=year, y=sum), method='lm', formula = y~x, color = "o
```

```
    geom_smooth(data = ipsl_ssp245_tot_yearly, aes(x=year, y=sum), method='lm', formula = y~x, color = "r
    geom_smooth(data = ipsl_ssp370_tot_yearly, aes(x=year, y=sum), method='lm', formula = y~x, color = "b
    geom_smooth(data = ipsl_ssp585_tot_yearly, aes(x=year, y=sum), method='lm', formula = y~x, color = "s
    theme(legend.title=element_blank())+
      theme(legend.position="bottom")

ipsl_yearly_sum_proj
```

monthly totals

```
# all three ssps
ipsl_monthly_sum_proj <-
  ggplot() +
  geom_line(data = ipsl_historical_tot_monthly, aes(x=date, y=sum, color="black"), size = 0.5) +
  geom_line(data = ipsl_ssp126_tot_monthly, aes(x=date, y=sum, color="orange"), size = 0.5) +
  geom_line(data = ipsl_ssp245_tot_monthly, aes(x=date, y=sum, color="red"), size = 0.5) +
  geom_line(data = ipsl_ssp370_tot_monthly, aes(x=date, y=sum, color = "blue"), size = 0.5) +
  geom_line(data = ipsl_ssp585_tot_monthly, aes(x=date, y=sum, color = "seagreen"), size = 0.5) +
  theme_minimal() +
  scale_y_continuous(breaks=seq(0,300,50)) +
  #scale_x_continuous(breaks=seq(1850,2100,50)) +
 scale_x_date(date_breaks = "50 years", date_labels = "%Y") +
  ggtitle("Oahu, HI Monthly Total Precipitation, IPSL-CM6A-LR: 1850-2100") +
  scale_color_manual(values = c("black", "orange", "red", "blue", "seagreen"), labels = c("historical",
  labs(x = "Year",
       y = "Precipitation (in)") +
  # geom_smooth(data = bcc_historical_tot_monthly, aes(x=date, y=sum), method='lm', formula = y~x, colo
  # geom_smooth(data = bcc_ssp126_tot_monthly, aes(x=date, y=sum), method='lm', formula = y~x, color =
  # geom_smooth(data = bcc_ssp245_tot_monthly, aes(x=date, y=sum), method='lm', formula = y~x, color =
  # geom_smooth(data = bcc_ssp370_tot_monthly, aes(x=date, y=sum), method='lm', formula = y~x, color =
  # geom_smooth(data = bcc_ssp585_tot_monthly, aes(x=date, y=sum), method='lm', formula = y~x, color =
  theme(legend.title=element_blank())+
    theme(legend.position="bottom")

  # stat_regline_equation(label.y = 200) +
  # stat_cor(label.y = 190)

ipsl_monthly_sum_proj
```

separate historical total precip based on 30 yr time periods

```
ipsl_historical_tot_1984_2014 <- ipsl_historical_tot %>%
  filter(year %in% (1984:2014))

## separate projections based on 2020 to 2070
ipsl_ssp126_tot_2020_2050 <- ipsl_ssp126_tot %>%
  filter(year %in% (2020:2050))

ipsl_ssp245_tot_2020_2050 <- ipsl_ssp245_tot %>%
  filter(year %in% (2020:2050))

ipsl_ssp370_tot_2020_2050 <- ipsl_ssp370_tot %>%
```

```
  filter(year %in% (2020:2050))

ipsl_ssp585_tot_2020_2050 <- ipsl_ssp585_tot %>%
  filter(year %in% (2020:2050))

ipsl_daily_tot_period <-
  ggplot() +
   geom_line(data = ipsl_historical_tot_1984_2014, aes(x=date, y=pcp, color="black"), size = 0.5) +
  geom_line(data = ipsl_ssp126_tot_2020_2050, aes(x=date, y=pcp, color="orange"), size = 0.5) +
  geom_line(data = ipsl_ssp245_tot_2020_2050, aes(x=date, y=pcp, color="red"), size = 0.5) +
  geom_line(data = ipsl_ssp370_tot_2020_2050, aes(x=date, y=pcp, color = "blue"), size = 0.5) +
  geom_line(data = ipsl_ssp585_tot_2020_2050, aes(x=date, y=pcp, color = "seagreen"), size = 0.5) +
  theme_minimal() +
  scale_y_continuous(breaks=seq(0,100,10), limits = c(0, 100)) +
  scale_x_date(date_breaks = "3 years", date_labels = "%Y") +
  ggtitle("Oahu, HI Daily Total Precipitation, IPSL-CM6A-LR: 1984-2050") +
   labs(x = "Year",
       y = "Precipitation (in)") +
  scale_color_manual(values = c("black", "orange", "red", "blue", "seagreen"), labels = c("historical",
   theme(legend.title=element_blank())+
    theme(legend.position="bottom") +
    theme(text = element_text(size=14))

ipsl_daily_tot_period

# ggsave('ipsl_daily_tot_period.png', ipsl_daily_tot_period, width = 12, height = 8, units = "in")
```

historical 50 year period graph

```
ipsl_daily_tot_period_hist <-
  ggplot() +
  geom_line(data = ipsl_historical_tot_1984_2014, aes(x=date, y=pcp, color="black"), size = 0.5) +
  theme_minimal() +
  scale_y_continuous(breaks=seq(0,50,10)) +
  scale_x_date(date_breaks = "3.5 years", date_labels = "%Y") +
  ggtitle("Oahu, HI Daily Total Precipitation, IPSL-CM6A-LR, historical: 1984-2014 ") +
   labs(x = "Year",
       y = "Precipitation (in)") +
  scale_color_manual(values = c("black"), labels = c("historical")) +
 theme(legend.title=element_blank()) +
    theme(legend.position="bottom")

ipsl_daily_tot_period_hist
```

ratio of daily total precipitation in the future vs. historical periods

```
## merge the data frames together
ipsl_daily_tot_prec_merge1 <- ipsl_ssp126_tot_2020_2050 %>% right_join(ipsl_ssp245_tot_2020_2050, by =
ipsl_daily_tot_prec_merge2 <- ipsl_daily_tot_prec_merge1 %>%  right_join(ipsl_ssp370_tot_2020_2050, by =
ipsl_daily_tot_prec_merge_fin <- ipsl_daily_tot_prec_merge2 %>% right_join(ipsl_ssp585_tot_2020_2050,by
  select(date, year.x, month.x, day.x, pcp.x, pcp.y, pcp.x.x, pcp.y.y) %>%
  rename(year = year.x,
        month = month.x,
```

```
        day = day.x,
        ssp126_pcp=pcp.x,
        ssp245_pcp=pcp.y,
        ssp370_pcp = pcp.x.x ,
        ssp585_pcp = pcp.y.y )

ipsl_historical_tot_1984_2014_rename <- ipsl_historical_tot_1984_2014 %>%
  rename(hist_date = date,
        hist_pcp = pcp,
        hist_year = year,
        hist_month = month,
        hist_day = day)

ipsl_merge_his_proj <- cbind(ipsl_daily_tot_prec_merge_fin, ipsl_historical_tot_1984_2014_rename)

ipsl_ratio_df <- ipsl_merge_his_proj %>%
  mutate(ssp126_hist = ssp126_pcp/hist_pcp,
        ssp245_hist = ssp245_pcp/hist_pcp,
        ssp370_hist = ssp370_pcp/hist_pcp,
        ssp585_hist = ssp585_pcp/hist_pcp) %>%
  select(date, ssp126_hist,ssp245_hist, ssp370_hist, ssp585_hist) %>%
  pivot_longer(cols = ssp126_hist:ssp585_hist,
               names_to = c("ssp"),
               values_to = "fut_hist_ratio")
```

March 14, 2009 = Wailupe storm that we will use to do CC analysis with.

```
ipsl_merge_his_proj_filt_mar14 <- ipsl_merge_his_proj %>%
  filter(month == "3") %>%
  filter(day == "14") %>%
  group_by(month,day) %>%
  mutate(ssp126_pcp_avg = mean(ssp126_pcp),
        ssp245_pcp_avg = mean(ssp245_pcp),
        ssp370_pcp_avg = mean(ssp370_pcp),
        ssp585_pcp_avg = mean(ssp585_pcp),
        hist_pcp_avg = mean(hist_pcp)) %>%
  select(month,day,ssp126_pcp_avg,ssp245_pcp_avg,ssp370_pcp_avg, ssp585_pcp_avg, hist_pcp_avg ) %>%
  distinct()


ipsl_merge_his_proj_filt_mar14 <- ipsl_merge_his_proj_filt_mar14 %>%
  mutate(ssp126_hist = ssp126_pcp_avg/hist_pcp_avg,
        ssp245_hist = ssp245_pcp_avg/hist_pcp_avg,
        ssp370_hist = ssp370_pcp_avg/hist_pcp_avg,
        ssp585_hist = ssp585_pcp_avg/hist_pcp_avg) %>%
  select(month, day, ssp126_hist,ssp245_hist, ssp370_hist, ssp585_hist) %>%
  pivot_longer(cols = ssp126_hist:ssp585_hist,
               names_to = c("ssp"),
               values_to = "fut_hist_ratio")

proj_hist_mar14_ipsl <- ggplot(data = ipsl_merge_his_proj_filt_mar14, aes(x=ssp, y=fut_hist_ratio)) +
  geom_point(size=2) +
  theme_minimal() +
```

```r
    labs(x="Shared Socioeconomic Pathways (ssp)",
         y="Future Projection/Historical Daily Total Average Ratio (Mar 14)",
         caption = "Climate Model: IPSL-CM6A-LR") +
      theme(text = element_text(size=15)) +
    scale_x_discrete(labels=c("ssp126_hist" = "ssp 1-2.6",
                              "ssp245_hist" = "ssp 2-4.5",
                               "ssp370_hist" = "ssp 3-7.0",
                              "ssp585_hist" = "ssp 5-8.5")) +
    scale_y_continuous(limits = c(0,3.5))

proj_hist_mar14_ipsl
```

```r
# ggsave('proj_hist_mar14_ipsll.png', proj_hist_mar14_ipsl, width = 12, height = 10, units = "in")
```

merging all climate model future/historical ratios for March 14th storm (note: you will need to have run climate_change_analysis.Rmd for all climate models) to plot

```r
futhis_ratio_combine_mar14 <- merge_his_proj_filt_mar14 %>%
  rbind(bcc_merge_his_proj_filt_mar14, ipsl_merge_his_proj_filt_mar14) %>%
  mutate(model = c("CNRM"))
```

```
## Error in rbind(., bcc_merge_his_proj_filt_mar14, ipsl_merge_his_proj_filt_mar14): object 'merge_his_
```

```r
futhis_ratio_combine_mar14$model[c(5:8)] = "BCC"
```

```
## Error in futhis_ratio_combine_mar14$model[c(5:8)] = "BCC": object 'futhis_ratio_combine_mar14' not f
```

```r
futhis_ratio_combine_mar14$model[c(9:12)] = "IPSL"
```

```
## Error in futhis_ratio_combine_mar14$model[c(9:12)] = "IPSL": object 'futhis_ratio_combine_mar14' not
```

```r
cbp2 <- c("#000000", "#009E73",
          "#D55E00")

combine_ratio_plot_mar14 <- ggplot(data = futhis_ratio_combine_mar14, aes(x=ssp, y=fut_hist_ratio)) +
  geom_point(aes(color=model), size =6)+
  theme_classic() +
  labs(x="Shared Socioeconomic Pathways (SSP)",
       y="Multiplicative Change Factor (MCF)") +
  ggtitle("March 14th Wailupe Storm Event") +
    theme(text = element_text(size=22)) +
  scale_x_discrete(labels=c("ssp126_hist" = "SSP 1-2.6",
                            "ssp245_hist" = "SSP 2-4.5",
                             "ssp370_hist" = "SSP 3-7.0",
                            "ssp585_hist" = "SSP 5-8.5")) +
 scale_y_continuous(breaks=(seq(0, 3.5, .5)), limits = c(0, 3.5))  +
  guides(color=guide_legend("CMIP6 Model"))  +
    theme(legend.position="bottom") +
   scale_colour_manual(labels = c("BCC-CSM2-MR", "CNRM-ESM2-1", "IPSL-CM6A-LR"), values=cbp2) +
  theme(text=element_text(color="black"),axis.text=element_text(color="black")) +
  theme(plot.title = element_text(hjust = 0.5))
```

```
## Error in ggplot(data = futhis_ratio_combine_mar14, aes(x = ssp, y = fut_hist_ratio)): object 'futhis_
```

```
combine_ratio_plot_mar14
```

Error in eval(expr, envir, enclos): object 'combine_ratio_plot_mar14' not found

```
# ggsave('combine_ratio_plot_mar14_presentation.png', combine_ratio_plot_mar14, width = 16, height = 9,
```