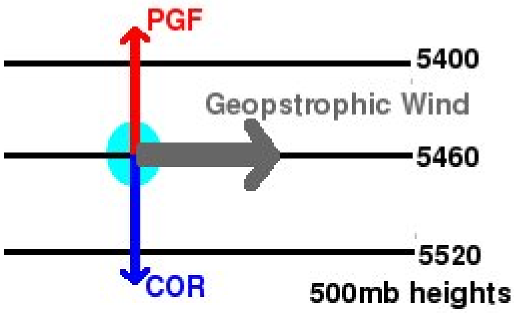
Homework 2

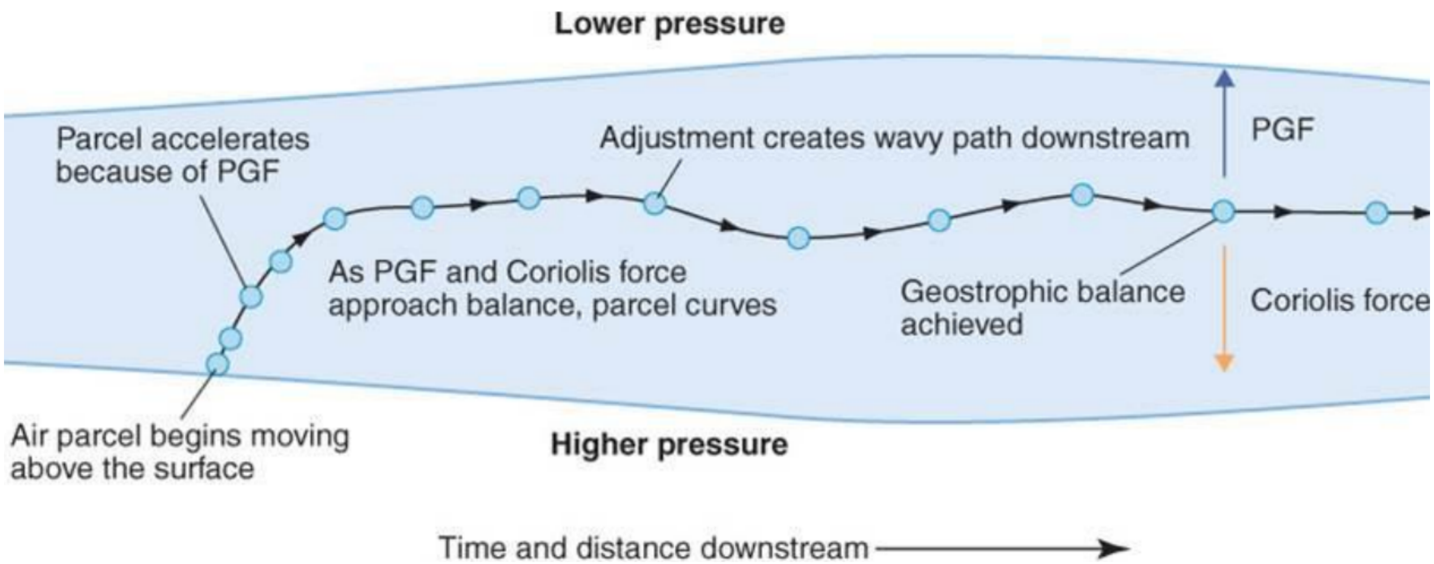
due: 10/26/2018

Part I: Visualizing Circulation Changes

1. PGF should point from high to low geopotential heights. Coriolis points to the right of the PGF, then opposite direction when they're in equilibrium.



example



geostrophic winds

2. Calculate the horizontal pressure gradient force at both points. (Give your answer in component form; assume that the y axis is parallel to the left and right edges of the map, and the x axis is parallel to the top and bottom edges).

$PGF = -\frac{1}{\rho}\frac{\Delta P}{\Delta x}$ pressure gradient force

$\Delta P = -\rho g \Delta z$ hydrostatic balance

$PGF = g\frac{\Delta z}{\Delta x}$ substitute the change in pressure

note: numbers will be slightly different depending on what distances and changes in geopotential were used.

```
# A
delz = 5520-5700 #m
delx = 500 #km
PGFa = -9.8*delz/500/1000

# B
delzb = 5764-5700 #m
delxb = 500 #km
PGFb = -9.8*delzb/500/1000

delya = 5640-5700 #m
delyb = 5580-5700 #m
PGFay = -9.8*delya/500/1000
PGFby = -9.8*delyb/250/1000
```

point	PGF_x	PGF_y
A	0.003528	0.001176
B	-0.0012544	0.004704

3. Calculate the wind (both u and v components) that is required to give a Coriolis force that exactly balances the pressure gradient forces you computed in question #2. (Hint: The latitude at point A is 48N and at point B is 39N)

$$f = 2\omega sin(\theta)$$

where theta is the latitude.

Meridional (north-south)

$$-fv = PGF_x$$

$$v = -\frac{PGF_x}{2\omega sin(\theta)}$$

Zonal (east-west)

$$fu = PGF_y$$

$$u = \frac{PGF_y}{2\omega sin(\theta)}$$

```
# A
omega2 = 0.000146 #rad/s
sina = sin(48*pi/180) #rad
va = -PGFa/(omega2*sina)
ua = PGFay/(omega2*sina)

# B
sinb=sin(39*pi/180)
vb = -PGFb/(omega2*sinb)
ub = PGFby/(omega2*sinb)
```

point	v	u

point	v	u
A	-32.5163854	10.8387951
B	13.6524749	51.1967808

Part II: Air Crossing the Sierras

Now imagine that westerly winds (winds TOWARD THE EAST) are blowing across the Sierras. On the west side of the mountain range, a weather station indicates a temperature of 10C, a dew point temperature of 5C, and a surface pressure of 1000mb. Assume that the parcel is lifted adiabatically to the top of the mountain, where the pressure is 800mb, and that all moisture then precipitates out. The parcel then returns to its original pressure of 1000mb on the other side of the mountain range. Assume that the dry adiabatic lapse rate is 9.8 K/km and the moist adiabatic lapse rate is 6 K/km.

1. What is the relative humidity of the parcel at the surface?

$RH = e^*(T_d)/e^*(T_a)$

```
Ta = 283 #K ( 10C + 273 )
T_dew = 278 #K ( 6C + 273 )
e = 6.112*exp(17.67*(T_dew-273.15)/(T_dew-29.65))
es = 6.112*exp(17.67*(Ta-273.15)/(Ta-29.65))
RH = e/es
RH
```

```
## [1] 0.7104073
```

2. What is the temperature of the parcel when it reaches the top of the mountain range?

$\Delta Z = -\frac{\Delta P}{\rho g}$

$\Delta T = ALR * \Delta z = -ALR \frac{\Delta P}{\rho g}$

```
rho = 1.225 #kg/m^3
g = 9.8 # m/s^2
delP = -200 # mb
ALR = 6 # K/km using moist lapse rate once temp has cooled to dewpoint temp

ztop = (200)*100/g/rho # solve for top of mountain elevation using given pressures, assu
ming z at ground is 0

z_moist = (Ta-T_dew)/9.8*1000 # elevation where dew point is reached

delT = ALR*(ztop-z_moist)/1000

Tmountain = T_dew-delT
Tmountain
```

```
## [1] 271.0654
```

3. What is the temperature of the parcel when it reaches the other side?

```
rho = 1.225 #kg/m^3
g = 9.8 # m/s^2
delP = -200 # mb
ALR = 9.8 # K/km using dry lapse rate because all moisture precipitated out

delT = ALR*ztop/1000

temp_eastside = delT + Tmountain # K
temp_eastside
```

```
## [1] 287.3919
```

4. How does the value in question #3 compare to the initial temperature of the parcel? Explain the physical reasons for the differences.

The temperature is warmer on the other side of the mountain than where it started. This is because the air parcel no longer contains moisture, as the latent heat on the windward side converted to sensible heat after condensing and forming clouds and precipitation.

5. What type of geopotential height feature is located off the western coast of California?

There is a small ridge off the coast of California, right below a large low pressure system.

6. How is the above height feature related to the changes in precipitation seen in California and western Canada?

As air moves north from high to low pressure, the coriolis force pushes it towards the east and the coast of California, going clockwise over the ridge. Likewise, counterclockwise advection around the low pressure system pushes the water vapor towards the coast where it experiences orographic uplift and increases precipitation over northern California and the pacific northwest.

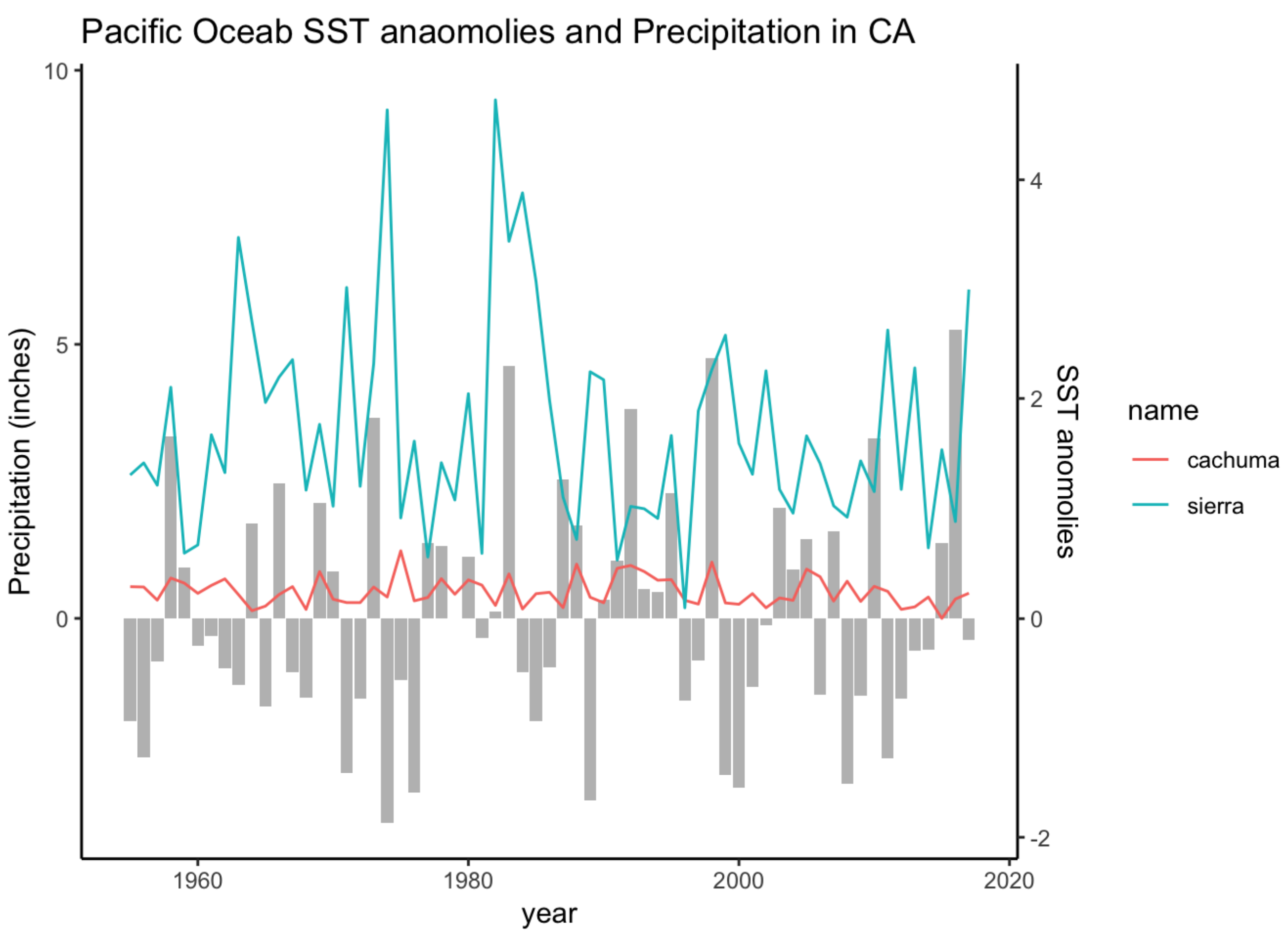
7. Why are the precipitation changes in question 6 confined so closely to the coast? Relate your answer to the analyses you did for questions #1-4.

There is a coastal mountain range and the Sierra Nevadas that cause precipitation to occur on the west side due to the orographic lifting.

Part III: ENSO Impacts on California

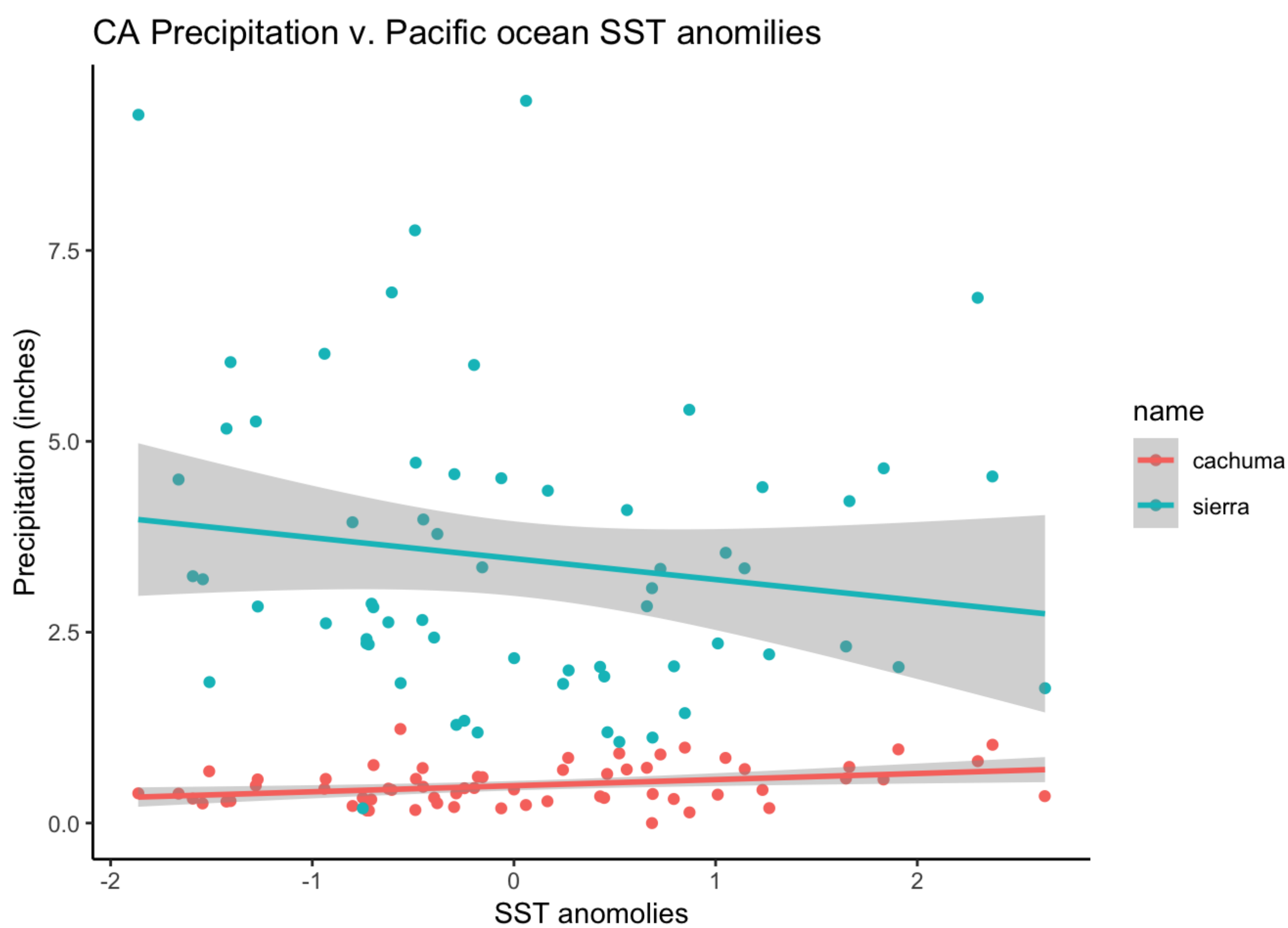
1. Make time series plots of all three variables, for a time period of your choice (which is at least 25 years in length).

```
cachuma <- read.table("/Volumes/GoogleDrive/My Drive/203_sections/LakeCachuma_MonthlyRai
nfall_DJF.txt", quote="\"", comment.char="")
colnames(cachuma) <- c("year","p")
cachuma$name <- "cachuma"

nino <- read.table("/Volumes/GoogleDrive/My Drive/203_sections/NINO34_ERSSTv3b_DJF.txt",
 quote="\"", comment.char="")
colnames(nino) <- c("year","SST_anom")


sierra <- read.table("/Volumes/GoogleDrive/My Drive/203_sections/NothernSierra8Stationpr
ecip_DJF.txt", quote="\"", comment.char="")
colnames(sierra) <- c("year","p")
sierra$name <- "sierra"

rain_plot <- as.data.frame(rbind(cachuma, sierra))

ggplot() +
  geom_col(data=nino, aes(x=year, y=SST_anom*2), fill="grey") +
  geom_line(data=rain_plot, aes(x=year, y=p, col=name)) +
  labs(y="Precipitation (inches)") +
  scale_y_continuous(sec.axis = sec_axis(~.*0.5, name = "SST anomolies")) +
  theme_classic() +
  ggtitle("Pacific Oceab SST anaomolies and Precipitation in CA")
```



2. Make scatter plots of rainfall vs. NINO3.4 over the same time period, and calculate the correlation coefficients.

```
scatter <- cbind(rain_plot, nino$SST)
scatter$SST <- scatter$`nino$SST`

ggplot(scatter, aes(x=SST, y=p, group_by(name), col=name)) +
  geom_jitter() +
  theme_classic() +
  stat_smooth(method=lm) +
  labs(x="SST anomolies", y="Precipitation (inches)") +
  ggtitle("CA Precipitation v. Pacific ocean SST anomilies")
```




```
linmodel = scatter %>% group_by(name) %>% do(model = lm(p ~ SST, data = .))
linmodel
```

```
## Source: local data frame [2 x 2]
## Groups: <by row>
##
## # A tibble: 2 x 2
##   name    model
## * <chr>   <list>
## 1 cachuma <S3: lm>
## 2 sierra  <S3: lm>
```

```
linmodel$model
```

```
## [[1]]
##
## Call:
## lm(formula = p ~ SST, data = .)
##
## Coefficients:
## (Intercept)          SST
##     0.48971      0.07988
##
##
## [[2]]
##
## Call:
## lm(formula = p ~ SST, data = .)
##
## Coefficients:
## (Intercept)          SST
##      3.4643      -0.2743
```

3. Identify El Nino and La Nina years during this time period (the Internet is your friend here), and compare the average rainfall during El Nino and La Nina with the overall average for your time period. List the El Nino/La Nina years you used for your averaging as well.

source: https://ggweather.com/enso/oni.htm (https://ggweather.com/enso/oni.htm)

4. Discuss the results. What relationships do you see among variables? Are they the same or different than what you would expect? Describe the relationships in the context of your answers to Parts I and II. (The answer to this part should be no more than 2-3 paragraphs).

5. Write a short (1-2) paragraph description of what your results mean for water resource management in relation to climate variability. (As in assignment 1, your response should refer to the specifics of your previous answers, but no additional citations are needed.)

https://psmag.com/environment/el-nino-does-not-always-bring-the-rain (https://psmag.com/environment/el-nino-does-not-always-bring-the-rain)