Assignment

April 9, 2023

1 Name: Shailja Kant Tiwari

2 Entry No.: 2021PHS7218

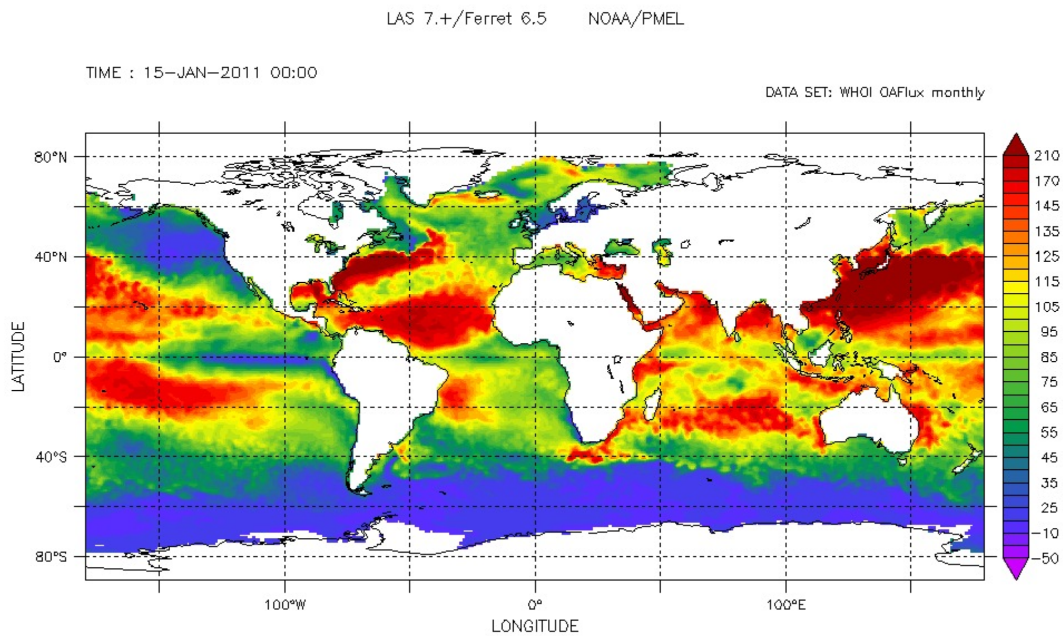
2.1 imports

[1]:
```
import pandas as pd
import matplotlib.pyplot as plt
```

2.2 Q 1. Use the data Source 1 provided above. Generate spatial plots of Latent heat flux, Sensible heat flux, Net heat flux over the Global oceans for Winter (January month) and Summer (July month). Mark the important regions where you observe large variations and mention the reasons for these variations (e.g. ocean current and winds there, etc).

2.2.1 Surface Latent Heat Flux

Surface latent heat flux is the transfer of heat energy from the Earth's surface to the atmosphere through the process of evaporation. This process is influenced by various factors such as temperature, humidity, wind speed, and the availability of water on the surface.



monthly mean surface latent heat flux, positive upward (w/m/m)

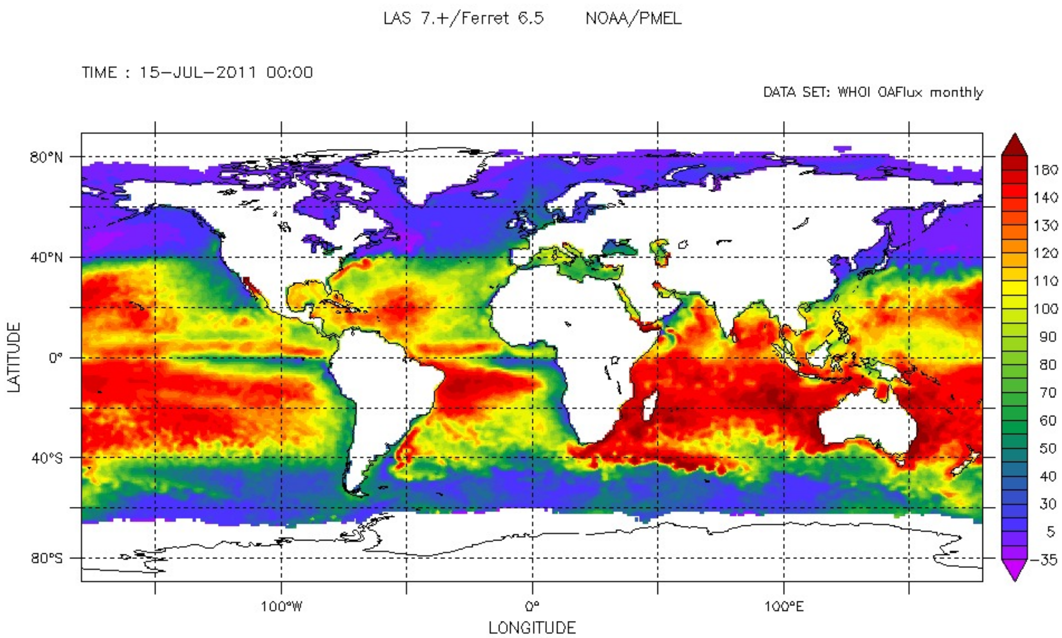
`La Niña` is a weather phenomenon characterized by cooler-than-normal sea surface temperatures in the equatorial Pacific Ocean. The phenomenon occurs when the trade winds, which blow from east to west across the Pacific, strengthen and cause an increase in upwelling of cooler subsurface water in the eastern Pacific. The upwelled water replaces the warmer surface water, leading to a cooling of the surface temperature. The cooling can have a significant impact on global weather patterns, affecting everything from rainfall patterns to temperature extremes.

`The Western Pacific` is a warm and humid region that is characterized by high rainfall and tropical cyclones. The region is influenced by the trade winds, which blow from east to west across the Pacific and converge in the Western Pacific, leading to the formation of low-pressure systems and the development of tropical cyclones. The Western Pacific is also known for its warm sea surface temperatures, which can reach up to 30°C (86°F) in some areas.

`The Eastern Pacific` is a colder and drier region that is characterized by a relatively low amount of rainfall and fewer tropical cyclones. The region is influenced by the cold waters of the `California Current`, which flows southward along the west coast of North America, and the Humboldt Current, which flows northward along the west coast of South America. These currents bring cold water from high latitudes to the Eastern Pacific, leading to a cooling of the sea surface temperature.

In the context of the monthly mean surface latent heat flux in `January 2011`, the Western Pacific likely experienced a higher value of monthly mean surface latent heat flux compared to the Eastern Pacific. This is because the Western Pacific was likely influenced by the La Niña event that occurred from `Late 2010 to 2011`, which led to stronger trade winds and a higher rate of evaporation, as explained earlier. In contrast, the Eastern Pacific was not as strongly influenced by the La Niña event, and the colder waters of the California and Humboldt currents likely contributed to a lower value of monthly mean surface latent heat flux.

So it can be seen in the plot that the value of surface latent heat flux is higher in the Western Pacific than in the Eastern Pacific. It's value is also higher in comparison to other years as there was a La Niña event in 2010-2011 which led to stronger trade winds and a higher rate of evaporation.



monthly mean surface latent heat flux, positive upward (w/m/m)

Here it can be seen that the value of surface latent heat flux is higher in Indian Ocean in comparison to Jan 2011. This is because the Indian Ocean is a warm and humid region that is characterized by high rainfall and tropical cyclones.

The difference in the monthly mean surface latent heat flux between January and July could be due to several factors, including seasonal changes in the weather patterns, ocean currents, and sea surface temperature. In general, the Indian Ocean region experiences different weather patterns during different times of the year, which can impact the rate of evaporation and surface latent heat flux. For instance, July is typically a monsoon season in many parts of the Indian Ocean, characterized by increased precipitation and higher humidity, which could lead to higher evaporation and latent heat flux.

`Monsoon winds`: Monsoon winds in the Indian Ocean are known to have a significant impact on the ocean's heat and moisture balance. During the monsoon season, the winds blow from the southwest and bring moisture to the Indian subcontinent, leading to higher evaporation rates in the ocean. These winds could have contributed to the higher surface latent heat flux in July 2011.

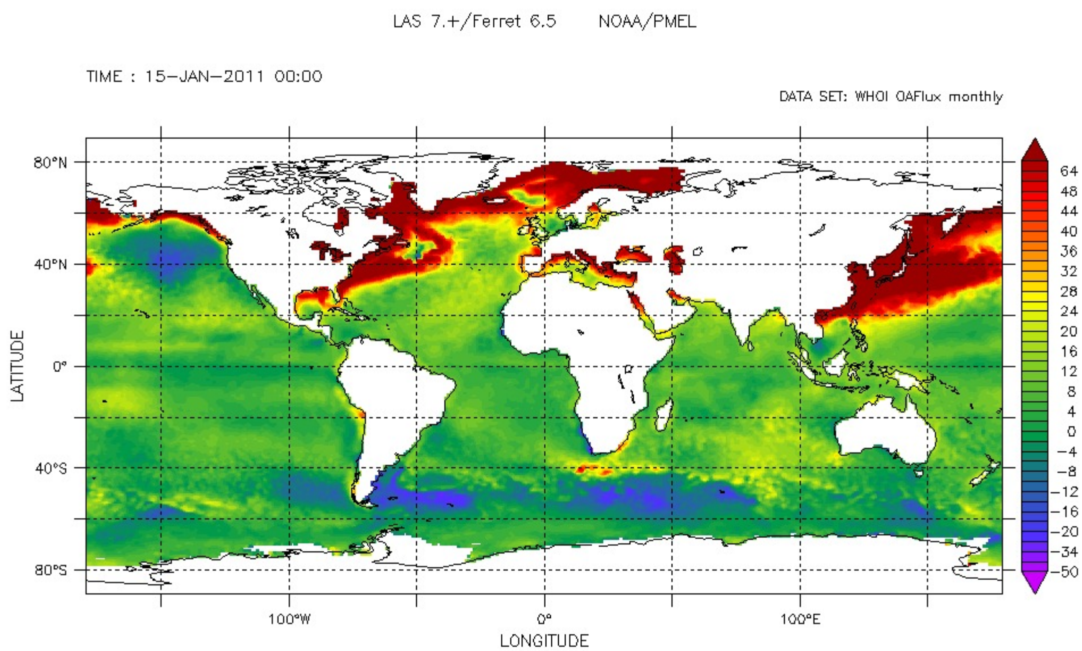
`Ocean currents`: The Indian Ocean has several ocean currents that transport heat and moisture across the ocean. The Somali Current, for instance, flows along the eastern coast of Africa, and the Agulhas Current flows along the western coast of Australia. These currents could have brought warmer water to the Indian Ocean in July 2011, leading to a higher surface latent heat flux.

`Land-sea temperature contrast`: In the Indian Ocean region, the temperature difference between land and sea can also influence the surface latent heat flux. During the monsoon season, land surfaces tend to heat up more than the ocean, leading to higher evaporation rates and latent heat flux.

`La Nina event`: As mentioned earlier, the La-Nina event from late 2010 to early 2012 could have influenced the monthly mean surface latent heat flux in the Indian Ocean in July 2011. La Nina events tend to bring cooler sea surface temperatures to the equatorial Pacific, leading to changes in global weather patterns and the ocean's heat balance.

2.2.2 Surface Sensible Heat Flux

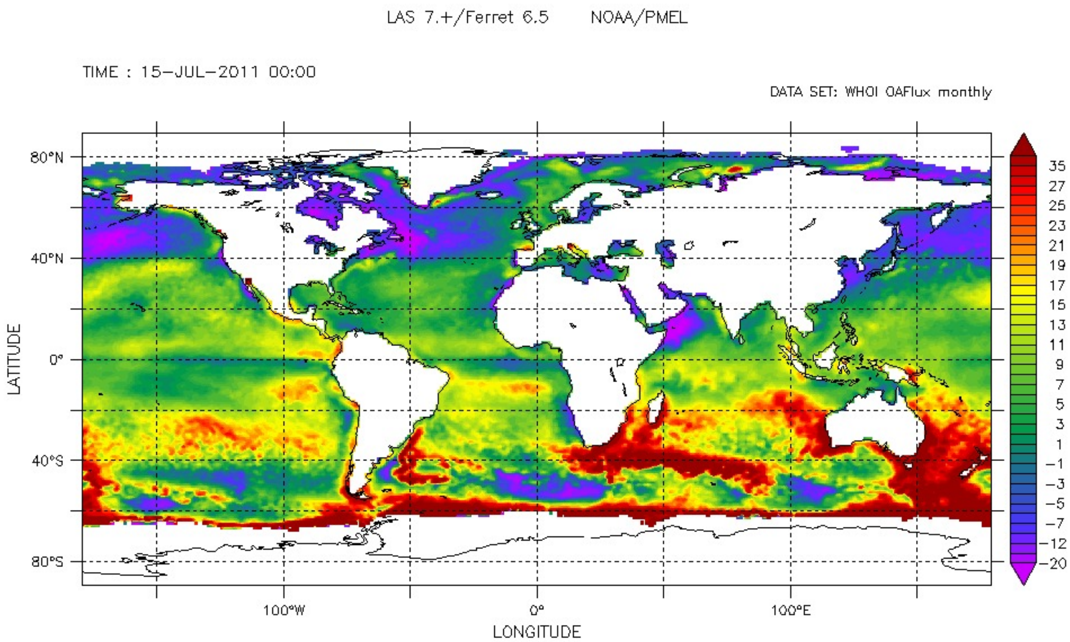
`Surface sensible heat flux` refers to the transfer of heat energy from the Earth's surface to the atmosphere due to differences in temperature between the two. The magnitude of the surface sensible heat flux depends on several factors, including air temperature, wind speed, surface roughness, and surface temperature.



monthly mean surface sensible heat flux, positive upward (w/m/m)

As in the month of January, in `Northern Hemishpere near shores`, there is winter season and hence the temperature is low. SO the air above the ocean is also cold and hence the tempperature difference between the air and the ocean is high. So there will be heat transfer from the ocean to the air and hence the value of surface sensible heat flux will be high. and in the `Southern Hemisphere near shores`, there is summer season and hence the temperature is high. So the air above the ocean is also hot and hence the temperature difference between the air and the ocean is low. So there will be less heat transfer between the ocean and the air and hence the value of surface sensible heat flux will be low.

`In the mid ocean`, the temperature is high and hence the air above the ocean is also hot. So the temperature difference between the air and the ocean is low. So there will be less heat transfer between the ocean and the air and hence the value of surface sensible heat flux will be low.



monthly mean surface sensible heat flux, positive upward (w/m/m)

In the month of July, in `Southern Hemisphere near shores`, there is summer season and hence the temperature is high. SO the air above the ocean is also hot and hence the tempperature difference between the air and the ocean is high. So there will be heat transfer from the ocean to the air and hence the value of surface sensible heat flux will be high. and in the `Northern Hemisphere near shores`, there is winter season and hence the temperature is low. So the air above the ocean is also cold and hence the temperature difference between the air and the ocean is low. So there will be less heat transfer between the ocean and the air and hence the value of surface sensible heat flux will be low.

In the mid ocean, the temperature is low and hence the air above the ocean is also cold. So the temperature difference between the air and the ocean is low. So there will be less heat transfer between the ocean and the air and hence the value of surface sensible heat flux will be low.

2.3 Q 2. Using the data from the link (Source 2 or 1), Plot sea surface temperature (SST) at 4 different selected locations (latitude, longitude point location) of oceans of potentially different seasonal variations for at least 1 year duration (time series plots at sea surface). Interpret your figures in terms of observed variations in SST and the processes causing these variations. Try to relate these with variations seen in heat fluxes data in Q1

[3]:
```
b1= pd.read_csv('Mid_Indian_Ocean.csv')
b2= pd.read_csv('Western_Australia.csv')
b3= pd.read_csv('Western_Indian_Ocean.csv')
b4= pd.read_csv('Western_Pacific.csv')

# convert DATETIME column to datetime
b1['DATETIME'] = pd.to_datetime(b1['DATETIME'])
```

```python
b2['DATETIME'] = pd.to_datetime(b2['DATETIME'])
b3['DATETIME'] = pd.to_datetime(b3['DATETIME'])
b4['DATETIME'] = pd.to_datetime(b4['DATETIME'])
```

[38]:
```python
def plot_sst(df, title):
    plt.figure(figsize=(20,7), dpi=150)
    plt.plot(df['DATETIME'], df['SST'])
    xticks = pd.date_range(start=b1['DATETIME'].min(), end=b1['DATETIME'].
 ↪max(), freq='MS')
    plt.xticks(xticks, xticks.strftime('%b-%Y'), rotation=45)
    plt.xlabel('Time')
    plt.ylabel('SST')
    plt.title(title)
    return plt

def plot_box(x1, x2, y1, y2, plot):
    x1 = pd.to_datetime(x1)
    x2 = pd.to_datetime(x2)

    plot.axvline(x=x1, ymax=y1, ymin=y2, color='red', linestyle='--')
    plot.axvline(x=x2, ymax=y1, ymin=y2, color='red', linestyle='--')
    return plot
```

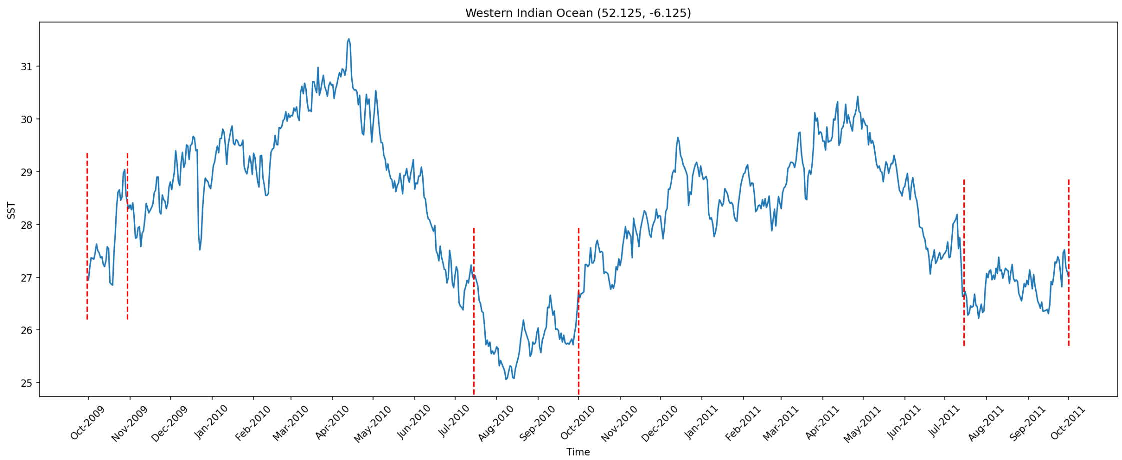
3 SST in Western Indian Ocean

[ ]:
```python
plot = plot_sst(b3, f'Western Indian Ocean {b3["LON"][0] , b3["LAT"][0]}')
# mark the start and end of the El Nino event

plot = plot_box('2009-09-30', '2009-10-30', 0.2, 0.65, plot)

plot = plot_box('2010-07-15', '2010-10-01', 0.0, 0.45, plot)

plot = plot_box('2011-07-15', '2011-10-01', 0.13, 0.58, plot)
```



`The Indian Ocean Dipole (IOD)` is an irregular fluctuation of `sea surface temperatures` in the Indian Ocean, which affects the climate and weather patterns in surrounding regions, particularly in East Africa, the Arabian Peninsula, and the Indian subcontinent. The IOD is characterized by a gradient in sea surface temperature between the eastern and western Indian Ocean.

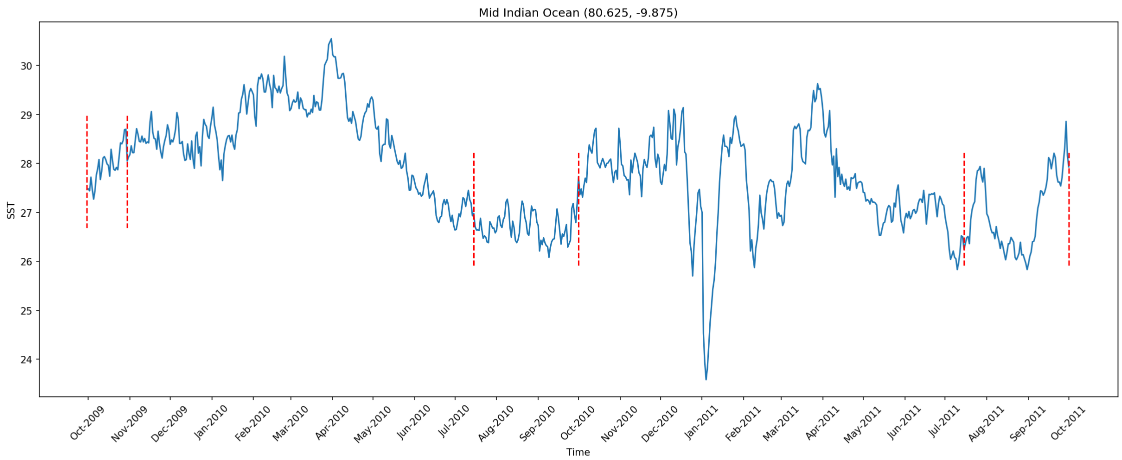
In a `positive phase` of the IOD, warmer than average sea surface temperatures occur in the western Indian Ocean, while cooler than average temperatures occur in the eastern Indian Ocean. This creates a dipole or seesaw pattern of temperature anomalies across the basin. In a `negative phase`, the pattern is reversed, with cooler temperatures in the west and warmer temperatures in the east.

As there was a Negative Indian Ocean Dipole (IOD) event in period of July-2010 to Oct-2010, the sea surface temperature in the Western Indian Ocean is lower than its value compared to that in 2009 Oct-Nov period or 2011 July-Oct period. That's why the sea surface temperature in the Western Indian Ocean was cooler than its normal value.

4 SST in Mid Indian Ocean

[69]:
```
plot = plot_sst(b1, f'Mid Indian Ocean {b1["LON"][0] , b1["LAT"][0]}');
# mark the start and end of the El Nino event

plot = plot_box('2009-09-30', '2009-10-30', 0.45, 0.75, plot)
plot = plot_box('2010-07-15', '2010-10-01', 0.35, 0.65, plot)
plot = plot_box('2011-07-15', '2011-10-01', 0.35, 0.65, plot)
```



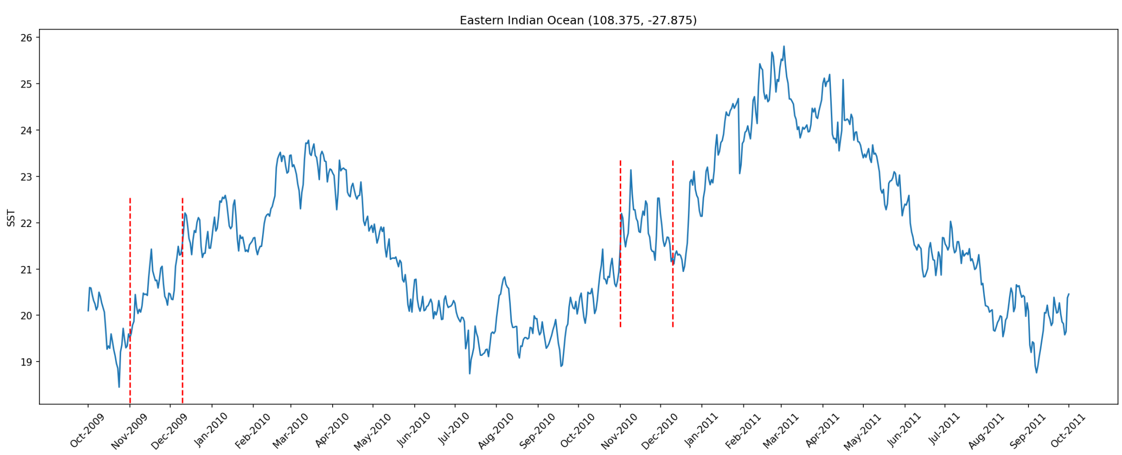
As this point is slightly towards the western Indian Ocean part. and at that time there was a Negative Indian Ocean Dipole event during `July-2010 to Oct-2010`. So we can see that because of that here it is slightly cooler in comparision to that in 2009 or 2011. But as it is in the middle of the ocean, so the temperature is not very high or low.

5 SST in Eastern Indian Ocean

[70]:
```python
plot = plot_sst(b2, f'Eastern Indian Ocean {b2["LON"][0] , b2["LAT"][0]}')
# mark the start and end of the El Nino event

plot = plot_box('2009-11-01', '2009-12-10', 0.0, 0.55, plot)

plot = plot_box('2010-11-01', '2010-12-10', 0.2, 0.65, plot)
```

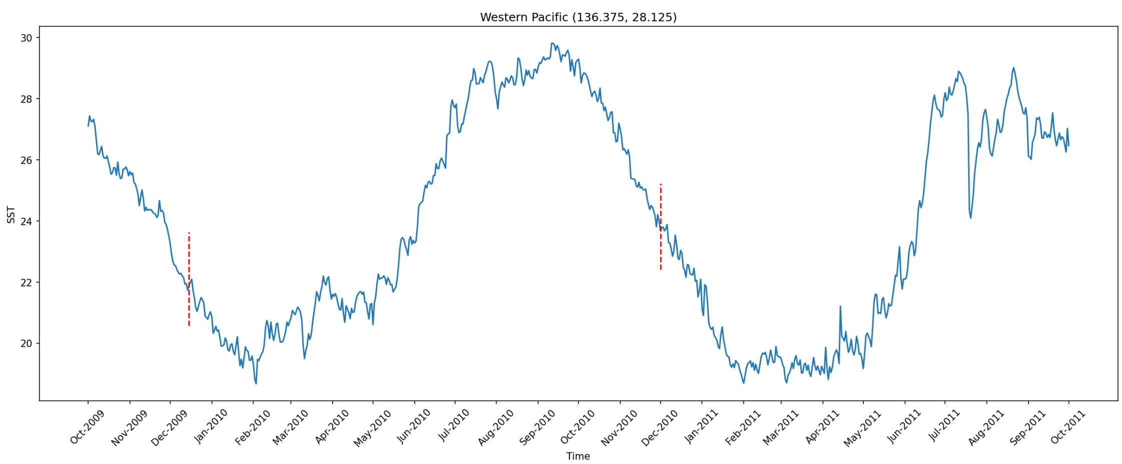


As there was a negative Indian Ocean Dipole (IOD) event in 2011, So the Eastern Indian Ocean will be warmer than its normal value as it was in 2010 December period. It can be clearly seen in the graph.

6 SST in Western Pacific

[88]:
```
plot = plot_sst(b4, f'Western Pacific {b4["LON"][0] , b4["LAT"][0]}')
# mark the location of the El Nino event

plot.axvline(pd.to_datetime('2009-12-15'), color='red', linestyle='--', ymax=0.
  ↪45, ymin=0.2)
plot.axvline(pd.to_datetime('2010-12-01'), color='red', linestyle='--', ymax=0.
  ↪58, ymin=0.35);
```



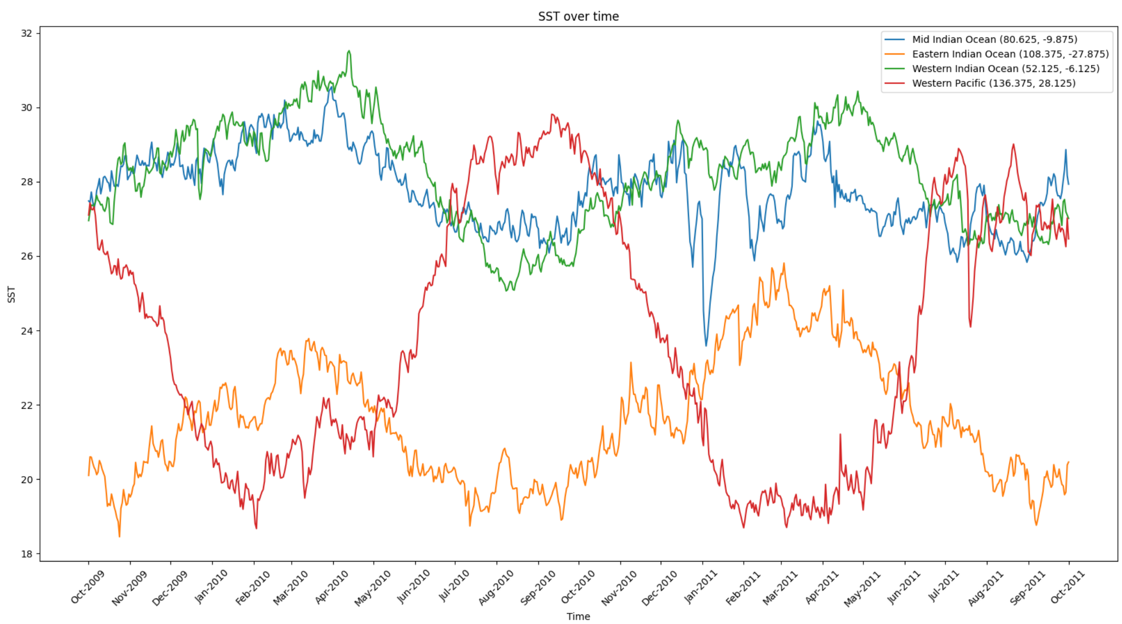
`La Niña` is a climatic phenomenon that occurs when the sea surface temperatures in the central and eastern Pacific Ocean drop below normal levels for an extended period. This event has widespread effects on weather patterns around the globe, including the Indian Ocean.

During the `La Niña event`, the sea surface temperatures in the `Western Pacific Ocean` are `hotter than normal`. This leads to a change in the ocean's heat balance, which can impact the weather patterns in the Indian Ocean. For instance, the La Niña event from late 2010 to early 2011 led to a `negative Indian Ocean Dipole event in 2011`, which caused cooler than normal sea surface temperatures in the western Indian Ocean.

7 All in one plot

[71]:
```
plt.figure(figsize=(20,10))
plt.plot(b1['DATETIME'], b1['SST'], label=f'Mid Indian Ocean {b1["LON"][0] ,␣
  ↪b1["LAT"][0]}')
plt.plot(b2['DATETIME'], b2['SST'], label=f'Eastern Indian Ocean {b2["LON"][0]␣
  ↪, b2["LAT"][0]}')
```

```python
plt.plot(b3['DATETIME'], b3['SST'], label=f'Western Indian Ocean {b3["LON"][0] , b3["LAT"][0]}')
plt.plot(b4['DATETIME'], b4['SST'], label=f'Western Pacific {b4["LON"][0]  , b4["LAT"][0]}')
plt.xlabel('Time')
plt.ylabel('SST')
# set xticks as Month-YYYY
xticks = pd.date_range(start=b1['DATETIME'].min(), end=b1['DATETIME'].max(), freq='MS')
plt.xticks(xticks, xticks.strftime('%b-%Y'), rotation=45)
plt.title('SST over time')
plt.legend()
plt.show()
```



So here we can see that `dark red` is the plot of Western Pacific and it is varying so much this is because of the trade winds which blows from Eastern Pacific to Western Pacific. It is Coldest in the month of December-January and it is warmest in the month of July-August.

`Orange color` is the plot of `Eastern Indian Ocean`. and as there was a negative Indian Ocean Dipole (IOD) event in 2011, So the Eastern Indian Ocean will be warmer than its normal value as it was in 2010 December period. It can be clearly seen in the graph.