The Variability of Sea Surface Temperature in the North-East Pacific Ocean in the Period from January 1990 to December 2022

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "The Variability of Sea Surface Temperature in the North-East Pacific Ocean in the Period from January 1990 to December 2022" is based on the results of investigations carried out by me in the Marine Sciences at the School of Earth, Ocean and Atmospheric Sciences (S.E.O.A.S.), Goa University under the Supervision/ Mentor-ship of Dr. Joshua Rosario D'Mello and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "The Variability of Sea Surface Temperature in the North-East Pacific Ocean in the Period from January 1990 to December 2022" is a bonafide work carried out by Mr. SIDDHANT SITARAM BUDE under my supervision/ mentorship in partial fulfilment of the requirements for the award of the degree of Master of Science in the Discipline of Marine Sciences at the School of Earth, Ocean and Atmospheric Sciences (S.E.O.A.S.), Goa University.

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PREFACE

The Earth's oceans cover 71 % of the surface of earth and are vast reservoirs of thermal energy, playing a fundamental role in regulating the planet's climate and weather patterns. Among the key parameters influencing oceanic dynamics, sea surface temperature (SST) stands out as a critical indicator of both short-term fluctuations and long-term trends in global climate change.

Understanding the variability in SST is therefore essential for unravelling the intricate mechanisms driving climate variability and its impacts on individuals, ecosystems, economies, and societies worldwide. In the present era of climate change, with the problem of global warming, it is important to understand the variability of sea surface temperature, in various parts of the world's oceans too. This motivated me for the study on the topic "The Variability of Sea Surface Temperature in the North-East Pacific Ocean in the Period from January 1990 to December 2022" in this dissertation work.

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LIST OF ABBREVIATIONS, ACRONYMS, UNITS AND SYMBOLS

Abbreviation, Acronym, Unit or Symbol	**Expanded Form**
~	approximately
°C	degree Celsius
°C/century	degree Celsius per century
°C/decade	degree Celsius per decade
°C/year	degree Celsius per year
°E	degree East
°N	degree North
°S	degree South
°W	degree West
%	percentage
–	to
ATMS	Advanced Technology Microwave Sounder
AVHRR	Advanced Very-High-Resolution Radiometer
AWP	Atlantic Warm Pool
CO_2	Carbon dioxide
CMIP	Coupled Model Intercomparison Project
COADS	Comprehensive Ocean-Atmosphere Data Set
CSS	California Current System
CZCS	Coastal Zone Color Scanner
ECV	essential climate variable

ENSO	El Niño Southern Oscillation
ERSSTv5	Extended Reconstructed Sea Surface Temperature version 5 dataset
ESA	European Space Agency
GC	Gulf of California
GMST	global mean surface temperature
GoM	Gulf of Mexico
GOSTA	Global Ocean Surface Temperature Atlas
GSST	global sea surface temperature
INSAT	Indian National Satellite
IR	infrared
ISRO	Indian Space Research Organisation
ITCZ	Inter-Tropical Convergence Zone
JAXA	Japan Aerospace Exploration Agency
JPSS	Joint Polar Satellite System
K per decade	Kelvin per decade
MEEMD	Multi-dimensional Ensemble Empirical Mode Decomposition
MEI	Multi-variate ENSO Index
MERSI	Medium Resolution Spectral Imager
MLR	multiple linear regression
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction

NOAA	National Oceanic and Atmospheric Administration
OI	Optimum Interpolation
PDO	Pacific Decadal Oscillation
R^2	Coefficient of Determination
RCP	Representative Concentration Pathway
S-NPP	Suomi National Polar-orbiting Partnership
SCS	South China Sea
SLP	sea level pressure
SST	sea surface temperature
SVD	Singular Value Decomposition
U.S.	United States
U.S.A.	United States of America
VIIRS	Visible Infrared Imaging Radiometer Suite
WES	Wind-Evaporation-SST
W/m^2	Watts per square metre
WOA	World Ocean Atlas
WMO	World Meteorological Organization

ABSTRACT

"The Variability of Sea Surface Temperature in the North-East Pacific Ocean in the Period from January 1990 to December 2022" is the topic of study of this dissertation work. The data used in this study is from the HadISST data set. The parameter downloaded is sea surface temperature, whose data is monthly. The downloaded spatial resolution of 1 degree by 1 degree. The PyFerret software of Pacific Marine Environmental Laboratory (PMEL) of National Oceanic and Atmospheric Administration (NOAA) is used in Linux Ubuntu operating system. The maps in the study area of the north-east Pacific Ocean (Equator to 40 °N, 170 °W to 77 °W) are averaged in the period from January 1990 to December 2022 for the SST parameter. Monthly averages and seasonal averages are also mapped. Similarly, slopes of trendlines are also mapped. Besides the above, basin-averaged values of SST and their trendlines are plotted, and the basin-averaged SST values and the slopes of trendlines are also computed. The SST values show a basin-average of 24.943 °C for the entire period. The warmest month is September with a value of 26.430 °C, while the coolest month is February with a value of 23.455 °C. Seasonally, the warmest season is Boreal Autumn with a value of 26.266 °C, while the coolest season is Boreal Spring with a value of 23.748 °C. The slopes of trendlines show an increasing trend with a value of 0.0080 °C/year, for the entire study period. The month of August show the highest trendline value of 0.0088 °C/year, while January and March show lowest trendline values of 0.0038 °C/year. The trendlines show highest values in Boreal Autumn season (0.0074 °C/year) and lowest values in the Boreal Winter season (0.0041 °C/year).

Keywords- Average, north-east Pacific Ocean, Sea Surface Temperature, Trends, Variability.s

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The vast expanse of Earth's oceans, covering 71 % of its surface, basically influences climate, ecosystems, and the hydrologic cycle. Oceans are essential for life and regulating global climate, oceans serve as a crucial nutrient sink and store heat and carbon dioxide (CO_2). They formed gradually over billions of years ago. (Costanza, 1999).

With the ocean covering 71 % of Earth's surface, scientists closely monitor sea surface temperature (SST) to decipher the intricate relationship between the ocean and Earth's atmosphere. SST data is vital for understanding the global climate system and plays a crucial role in weather prediction, atmospheric model simulations, and the study of marine ecosystems (https://oceanservice.noaa.gov/facts/sea-surface-temperature).

Oceans act as a boundary for sea surface temperature, absorbing a vast majority of solar radiation. Additionally, the ocean contributes 85% of atmospheric water vapor and exchanges various important gases. Moreover, it serves as a major source of atmospheric aerosols, impacting cloud formation and climate dynamics. (Bigg et al., 2003).

SST or the Ocean Surface Temperature, represents the temperature of the uppermost layer of seawater up-to few milli-meters (https://ecowatch.nmeoaa.gov/thematic/sea-surface-temperature).

Typically, it encompasses the region ranging from 1 milli-meter to 20 meters beneath the sea surface (https://en.wikipedia.org/wiki/Sea_surface_temperature#:~:text).

The measurement of Sea Surface Temperature (SST) has evolved significantly over time. Prior to the 1980s, manual methods such as using thermometers on shorelines, ships, and buoys were common, but they had limitations. Since the 1980s, satellite observations, particularly instruments like Moderate Resolution Imaging Spectroradiometer (MODIS), have revolutionized SST data collection by providing comprehensive coverage of the world's oceans using infrared and microwave radiation. Modern methods include ship injection temperature, hull-mounted thermistors on ships, and thermistors on drifting and moored buoys, which estimate bulk SST. Infrared satellite data focus on the "skin layer" of the ocean surface, approximately 10 micro-meters deep, ensuring accuracy and reliability through validation with in-situ measurements. Complementary data sources such as ocean floats and buoys further contribute to understanding oceanic temperatures (Emery et al., 2001; https://podaac.jpl.nasa.gov/SeaSurfaceTemperature).

Achieving higher accuracy in SST measurements, particularly for climate research purposes, requires a thorough understanding of various procedural and instrumental factors, such as diurnal thermocline effects, skin effect, and spatial variability of SST, as well as advancements in in-situ measurements and atmospheric correction techniques. Comparisons between satellite and ground-based data sets may provide valuable insights for improving measurement accuracy (Jones et al., 1984).

SST is the longest and most widely measured parameter in the ocean. SSTs interface between the ocean and the overlying atmosphere. SSTs control the exchange of heat and gases between the atmosphere and ocean (Emery, 2015).

SST is a strong indicator of productivity, pollution, and global climate change (Fingas, 2019).

SST is a critical climate indicator essential for monitoring, detecting, and predicting climate changes. Satellite-based SST measurements are invaluable, as satellites cover the Earth's surface regularly, providing a unique global dataset (Barbosa et al., 2009).

When SST is measured from space, the depth measured is determined by the frequency used by the satellite instrument. For instance, infrared instruments measure a shallow depth of approximately 20 micro-meters, while microwave radiometers penetrate deeper, measuring to a depth of a few milli-meters (https://coastwatch.gitbook.io/satellite-course/lectures/sea-surface-temperature).

SST measurements, especially those derived from satellite-based infrared imaging, are essential for understanding and monitoring various environmental processes, including marine productivity, pollution dynamics, and the complex mechanisms driving global climate change. These measurements provide valuable insights into the state and dynamics of the ocean, supporting scientific research, resource management efforts, and informed climate policy formulation (Azmi et al., 2015).

According to Jang et al., (2019) Sea Surface Temperature (SST) is the most crucial parameter for studying various oceanic and atmospheric processes, both spatially and temporally. It is monitored through high-quality in-situ measurements and satellite observations, which are essential for understanding and predicting oceanic and atmospheric phenomena. Satellite-observed SST databases are widely utilized for studying SST fronts, mesoscale eddy dynamics, ocean surface currents, air-sea interaction, and their impacts on climate change. These databases also serve as input data for atmospheric and oceanic

circulation models.

Satellite SST measurements are particularly significant because they capture the temperature of the ocean's ultra-thin surface layer, approximately 10 millimetres thick. This layer is vital as it directly interacts with the atmosphere, exerting a profound influence on various atmospheric phenomena (O'Carroll et al., 2019).

Sea surface temperature (SST) serves as a foundational element in comprehending, monitoring, and forecasting the intricate interplay of heat, momentum, and gases between the ocean and the atmosphere. At the ocean-atmosphere interface, SST holds substantial societal implications, shaping large-scale phenomena like ocean gyres and atmospheric circulation cells, which in turn influence weather and climate patterns. Additionally, SST impacts local-scale phenomena such as the generation of sea breezes and convective clouds, underscoring its pivotal role in understanding and predicting weather systems and climate dynamics (Robinson et al., 2012).

Sea Surface Temperatures (SSTs) are influenced by a combination of atmospheric and oceanic processes. Atmospheric factors such as wind speed, air temperature, cloud cover, and humidity affect the exchange of energy between the ocean and the atmosphere, directly impacting SST. Additionally, oceanic processes including heat transport by currents, vertical mixing driven by wind and thermohaline circulation, and the depth of the oceanic boundary layer play crucial roles in redistributing heat and influencing SST (Deser et al., 2010).

The primary mechanism through which the ocean interacts with the atmosphere is via heat and moisture exchanges. These processes play a significant role in shaping extreme weather events, such as hurricanes or torrential rains, which are projected to become more frequent and intense according to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Therefore, understanding sea surface temperature (SST) patterns and trends is crucial for investigating interactions and feedback with the atmosphere, climate drivers like El Niño, and marine biodiversity, particularly in understanding predicted future climate scenarios. Satellites measure skin and sub-skin temperature at the sea surface in a thin layer at depths of 10 µm and 1 mm (Pastor, 2021).

Measuring SST is particularly useful for forecasting the onset of extreme weather events such as the El Niño and the La Niña cycles. During an El Niño cycle, warmer-than-normal temperatures are observed in the Pacific Ocean near the equator. During a La Niña cycle, the same region experiences cooler-than-average ocean temperatures. These cycles affect ocean circulation, global weather patterns, and marine ecosystems as a result of changes in pressure and wind speed occurring over multiple years (Bjerknes, 1966).

In the Pacific Ocean, El Niño and La Niña disrupt normal conditions, impacting the coast of the United States of America (U.S.A.). El Niño brings warmer, dryer weather to the northern United States (U.S.) and Canada but increased flooding to the Gulf Coast and Southeast. It disrupts marine ecosystems, reducing upwelling and affecting fish populations. La Niña causes drought in the southern U.S. and heavy rains in the Pacific Northwest and Canada. It enhances marine life off the coast. These events occur irregularly every two to seven years, lasting from months to years.

(https://oceanservice.noaa.gov/facts/ninonina.html#:~:text=La%20Ni%C3%B1a%20causes%20the%20jet,contain%20more%20nutrients%20than%20usual)

Sea surface temperature (SST) is a critical indicator of oceanic conditions, influencing global climate dynamics by modulating heat transfer and moisture fluxes between the ocean and atmosphere. SST anomalies have far-reaching effects beyond the ocean, impacting terrestrial climate and ecological processes. They can exacerbate extreme weather events, affect agricultural productivity, and influence carbon absorption by terrestrial ecosystems. The El Niño Southern Oscillation (ENSO), driven by SST variations in the Pacific Ocean, is a prominent example of how SST influences global climate patterns, with El Niño and La Niña phases causing widespread climatic anomalies (Kumar et al., 2024).

Satellite measurements are widely utilized to generate detailed maps of Sea Surface Temperature (SST) across various spatial scales, ranging from regional to global. Regional SST maps are valuable for applications in fisheries management and the study of ocean circulation and frontal features, while global maps are essential for climate monitoring, input into atmospheric models, and as a diagnostic tool for oceanographic models (Wick et al., 2002).

The current array of satellites provides global Sea Surface Temperature (SST) measurements with accuracies that meet the requirements for a wide range of scientific, operational, and climate-related purposes (O'Carroll et al., 2019).

List of some notable satellites used for SST measurements:

1. **Aqua Satellite (NASA):** Carries the Moderate Resolution Imaging Spectroradiometer (MODIS) for SST measurements.

2. **Terra Satellite (NASA):** Similar to Aqua, Terra also carries MODIS for SST observations.

3. **Indian Geostationary Satellite [Indian National Satellite system (INSAT)-3D]-** Operated by Indian Space Research Organisation (ISRO), used for meteorological and weather monitoring. Additionally, it contributes to sea surface temperature (SST) measurements as part of its broader environmental monitoring capabilities.

4. **Suomi National Polar-orbiting Partnership (S-NPP):** Equipped with the Visible Infrared Imaging Radiometer Suite (VIIRS) for SST measurements.

5. **NOAA-20 [formerly Joint Polar Satellite System (JPSS)-1]:** Part of the Joint Polar Satellite System, NOAA-20 carries the Advanced Technology Microwave Sounder (ATMS) and VIIRS for SST observations.

6. **Sentinel-3A and Sentinel-3B (ESA):** These Earth Observation satellites carry the Sea and Land Surface Temperature Radiometer (SLSTR) for precise SST measurements.

7. **Copernicus Sentinel-2 [European Space Agency (ESA)]:** While primarily designed for land observations, Sentinel-2's Multi-Spectral Instrument (MSI) has been used for coastal SST measurements.

8. **Himawari-8 and Himawari-9 [Japan Aerospace Exploration Agency (JAXA)]:** Operated by the Japan Meteorological Agency, these geostationary satellites monitor SST in the Asia-Pacific region.

9. **Göktürk-1 (Turkey):** Utilizes the Turkish Space Agency's Space Observation System (Göktürk-1) for Earth observation, including SST measurements.

10. **Fengyun-3 series (China):** Carrying the Medium Resolution Spectral Imager (MERSI), these satellites provide SST observations over the Asia-Pacific region.

The oceans play a crucial role in the Earth's climate system as heat reservoirs, absorbing and storing vast amounts of heat that influence weather patterns and climate variability over both short and long timescales. Sea Surface Temperature (SST) is a key component of this system, driving energy exchange between the ocean and atmosphere and impacting atmospheric circulation patterns. Variations in SST, particularly those associated with phenomena like El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), have significant implications for global climate (Venegas et al., 2023).

Sea surface temperature (SST) trends offer crucial insights into climate change's impact on the world's oceans. Over several decades, observations reveal a consistent global warming trend in SST. This rise is attributed to both natural variability, such as El Niño-Southern Oscillation (ENSO) and anthropogenic factors like greenhouse gas emissions. Regional variations exist due to factors like ocean currents and atmospheric circulation patterns. SST trends significantly affect marine ecosystems, leading to coral bleaching, altered fish migration patterns, and ecosystem shifts (Paltridge et al., 1981).

Warm SSTs fuel tropical cyclones, while their aftermath can induce cooling effects. SST exhibits diurnal variations and is influenced by ocean currents. Coastal SSTs impact local weather patterns, with upwelling and onshore winds affecting nearby areas. SST data is essential for weather prediction and has societal implications. Overall, understanding SST patterns is vital for addressing climate-related challenges (Lawrence et al., 2004).

SST varies primarily with latitude, with the warmest waters typically located near the equator and the coldest waters located in the Arctic and Antarctic regions (https://marine.copernicus.eu/ocean-climate-portal/sea-surface-temperature).

Studies have demonstrated that sea surface temperature (SST) can impact precipitation through atmospheric teleconnections, facilitating the transport of warm and moist air from the ocean to land and consequently enhancing precipitation rates. This phenomenon has been observed in various studies such as Barron et al. (2012), L. Dong et al. (2018), Hu et al. (2021), Livezey & Smith (1999), and Zhang et al. (2010).

Sea surface temperature (SST) is recognized as an Essential Climate Variable (ECV) by the World Meteorological Organization (WMO), indicating its importance in characterizing Earth's climate. Advancements in satellite technology have provided higher-resolution data, allowing for more detailed study of SST patterns and trends. SST serves as a proxy for the ocean's energy storage, making it crucial for understanding climate change dynamics. Monitoring SST helps predict future climate scenarios and assess impacts on weather extremes, marine ecosystems, and human societies (https://gcos.wmo.int/en/essential-climate-variables/sst).

The current array of satellites provides global Sea Surface Temperature (SST) measurements with accuracies that meet the requirements for a wide range of scientific, operational, and climate-related purposes (O'Carroll et al., 2019).

Rainfall along the western coast of U.S. is influenced by coupled processes between the sea surface temperature (SST) and atmospheric circulation (Hu et al., 2021). Also, natural mid-latitude atmospheric processes control majority of its fraction of variability (Williams et al., 2015).

In the northeast Pacific sector, one of the most influential modes of interannual variability is the El Niño-Southern Oscillation (ENSO). During the warm phase of ENSO, known as El Niño, the chances of extreme precipitation events increase, particularly during winter over the southwestern United States (Zhang et al., 2010).

Understanding sea surface temperature (SST) trends is crucial for mitigating anthropogenic climate effects, despite challenges in monitoring due to technical issues and vast oceanic areas. Numerous studies have quantified SST trends over the last century using various datasets, including those from the Comprehensive Ocean-Atmosphere Data Set (COADS) and the World Ocean Atlas, as well as satellite-derived data. These studies consistently show significant global warming trends in SST over the past century, with two distinct warming periods observed. The Atlantic Ocean particularly contributes to this warming, with regional variations observed due to factors like changes in winds, ocean currents, and upwelling intensity. Coastal areas are of particular importance due to their economic and ecological significance, with warming trends impacting biological production and ecosystems (Gómez–Gesteira et al., 2008).

1.2 OBJECTIVES

- To study the average monthly, seasonal and annual variability of sea surface temperature (SST) in the north-east Pacific Ocean.
- To study the trends in monthly, seasonal and annual variability of the sea surface temperature (SST) in the north-east Pacific Ocean.

1.3 SCOPE

The study on variability in sea surface temperature (SST) in the north-east Pacific Ocean aims to comprehensively analyse SST fluctuations in the region. This includes:

1. analysing historical SST data over the last 3 decades.

2. mapping spatial distribution across the north-east Pacific Ocean.

3. Computing long-term trends of SST.

The study uses freely-available, online, monthly SST data from January 1990 to December 2022. In-situ observations are not done as part of this dissertation. The data analysed is 1 degree by 1 degree spatially and in the north-east Pacific Ocean defined as the region between (0° – 40 °N, 170 °W – 77 °W). The software used to compute and plot is PyFerret.

1.4 LITERATURE REVIEW

The twentieth century saw a notable increase of approximately 0.9 °C in annual-mean globally averaged Sea Surface Temperature (SST), with projections indicating continued warming in the future (Meehl et al., 2007).

Since 1850, SST has undergone significant fluctuations, including periods of stability and warming, particularly in the early 20th century to the 1940s, and a more recent abrupt rise since the late 1970s. Over the entire period, SST has risen by close to 0.9 °C, with a significant portion, about 0.6 °C, occurring in the last four decades. This trend is evidenced by the latest five-year average SST, which is approximately 0.2 °C higher than the reference period of 1991– 2020, underscoring a sustained warming trend (https://climate.copernicus.eu/climate-indicators/sea-surface-temperature).

Williams et al. (2017) discuss reconstructed SSTs over a period of 342 years, highlighting significant warming and cooling intervals. They report warming trends from the 1660s to 1800, followed by a cooling phase until 1840, and subsequent warming from 1860 to 2007.

A study analysed 19,276 coastal locations, covering an area exceeding 9 million km^2. Over the last three decades, ap3w4proximately 71.6 % of this area experienced significant increases in sea surface temperature (SST), at a mean rate of 0.25 ± 0.13 °C per decade. Conversely, cooling was observed in 6.8 % of the area, with an average rate of -0.11 ± 0.10 °C per decade. Higher coastal warming rates were observed between the Tropic of Cancer and the Arctic Circle, particularly in enclosed or semi-enclosed seas and areas with complex coastal morphology. Additionally, intense warming rates were observed in open coasts such as off eastern China, western

Africa, and northeaster South America. The frequency of yearly extremely hot days has significantly increased in 38.1% of the world's coastal areas, while extreme cold events have decreased in 45.8 % of the coastline. Changes in extreme temperature events are correlated with SST changes, with regions experiencing the most warming also witnessing an increase in hot events. In temperate coastal areas, seasonal warming has been occurring significantly earlier in the year, particularly in sheltered or semi-closed portions of the coast (Lima et al., 2012).

The study's findings indicate a global ocean warming trend, with certain regions experiencing exceptions such as the subpolar North Atlantic, equatorial central Pacific, and the Southern Ocean in the Pacific sector. The equatorial central Pacific underwent a transition from cooling to warming around the mid-20th century, becoming one of the fastest-warming regions in recent decades, alongside the Arctic Ocean, western-boundary current regions, and their mid-latitude extensions in both hemispheres. Significant warming during recent decades was observed in the Arctic Ocean, east of the continents in the northern hemisphere, the entire Indian Ocean, and particularly the tropical Pacific Ocean (https://www.ipcc.ch/report/ar6/wg1/chapter/chap ter-9/).

Deser et al. (2010) discusses trends in sea surface temperatures (SSTs) over the 20th century, focusing on various data sources and reconstructions. Notably, positive SST trends are observed in most regions, with magnitudes ranging from 0.4 °C to 1.6 °C per century.

ENSO and PDO are oceanic climate phenomena that affect global weather patterns. ENSO occurs every 3– 8 years with warm and cold phases impacting atmospheric circulation, while PDO represents decadal variability in North Pacific SST. Both influence weather phenomena like hurricanes and monsoons, and understanding them is crucial for climate research and forecasting (https://www.noaa.gov/weather).

Maul et al., (2007) studied the SST variability along the Pacific coast, particularly regarding El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) influences.

The paper by Valipour et al., (2021) provides an overview of the current state of global warming and climate change, focusing on the global mean surface temperature (GMST) as a key indicator. It notes that the Earth's surface temperature is currently near its highest level in the past million years, with GMST anomalies consistently increasing. The mean GMST anomalies in 2000– 2019 are 0.54 °C higher than in 1961– 1990. Additionally, the paper highlights a reduction in the standard deviation of decadal variation in GMST anomalies, attributed to changes in climate sensitivity to oscillation indices like El Niño/ Southern Oscillation (ENSO). The frequency of ENSO events has changed over time, with more occurrences in the past compared to recent years, impacting GMST anomalies significantly. This analysis underscores the complexity of global temperature trends, influenced by both natural climate oscillations and human-induced climate change.

The trend observed in the SST data for the 1982– 2006 period indicates a pattern of low-frequency variability. This trend mode is characterized by an increasing trend in SST in the western Pacific Ocean and the North Atlantic region, especially at northern latitudes and south of Greenland. Conversely, there is a decreasing trend in SST observed in the equatorial eastern and central Pacific regions during this period. This pattern suggests a systematic shift in SST distribution over the specified time frame, with notable variations in different geographical areas. The temporal evolution of global mean sea surface temperature (SST) exhibits an increasing trend, with a linear regression model estimating a rate of 0.12 ± 0.0068 °C/decade. Peaks in the SST trend coincide with major El Niño-Southern Oscillation (ENSO) warm events, notably occurring in 1982– 1983, 1986– 1987, and 1997– 1998 (Barbosa et al., 2009).

The study by Xu et al. (2021) utilized the Multi-dimensional Ensemble Empirical Mode Decomposition (MEEMD) method to analyse the long-term trend of Global Sea Surface Temperature (GSST). It found a non-uniform evolution of GSST trends across different ocean regions. In 2015, most areas showed warming, except for the western part of the northern North Atlantic, and the Southern Ocean in the Pacific sector, which exhibited initial cooling followed by warming. The strongest warming during recent decades was observed in the Arctic Ocean, eastern regions of the continents in the northern hemisphere, the entire Indian Ocean, and particularly in the tropical Pacific Ocean. The equatorial central Pacific Ocean experienced significant changes, transitioning from initial cooling to rapid warming with accelerated paces during recent decades.

This study investigated both decadal and seasonal variations in SST in the Equatorial West Pacific along coast of China Shelf Seas up to the year 2100 using CMIP5 models. The findings revealed a significant increase in both decadal and seasonal SSTs over the next century. Decadal SST is projected to rise by approximately 1.5 °C by 2090, while seasonal SST is expected to increase by about 1.03 °C to 1.95 °C by 2090. The most substantial increment is anticipated between 2030 and 2060, with stability observed from 2060 to 2090. Although the SST increase in 2030 is less significant than that in later years, the distribution of SST increases is uneven. Specific local regions, such as the east of Bohai Sea (east of Qinhuangdao), the Changjiang Estuary, and the shore of Jiangsu Province, exhibit high SST increases of up to 1.5 °C (Cane et al., 1997).

During the period under study, both the Multivariate ENSO Index (MEI) and the Oceanic Niño Index (ONI) generally mirrored the Sea Surface Temperature (SST) pattern. However, in 2014, SST experienced a rapid surge while both indices remained relatively stable. By the latter part of 2015, both SST and the indices increased in value, with the highest ONI value in November 2015 reaching 2.9 °C. This indicates a significant and prolonged warming event off the central coast of Baja California during 2014– 2015, surpassing the intensity observed during the El Niño event of 1997– 1998 (Robinson, 2016).

In 2015, the Global Sea Surface Temperature (GSST) exhibited warming trends in most regions, except for specific areas such as the western part of the northern North Atlantic, equatorial central Pacific, and Southern Ocean in the Pacific sector. The Arctic Ocean and the eastern tropical Atlantic Ocean experienced the most significant warming, while the subpolar North Atlantic Ocean consistently cooled over the entire time span (Xu et al., 2021).

The study analysed Sea Surface Temperature (SST) data from 1985 to 2002, identifying a positive long-term temperature trend of approximately 0.06 °C per year. It observed seasonal anomalies, with minimum basin-averaged SST occurring in years with winter SST minimums. A sharp increase in SSTs was noted after 1993. While most anomalies were related to El Niño events, winter SST anomalies correlated better with East Atlantic-West Russia atmospheric patterns than with North Atlantic Oscillation indices. Additionally, a longer-term analysis from 1957 to 2002 showed a small negative trend in blended field and satellite winter SSTs (Ginzburg et al., 2007).

The criteria for declaring an El Niño event typically involve sustained increases in sea surface temperatures (SSTs) above a certain threshold over a specified period. Traditionally, the threshold is defined as 0.5 degrees Celsius above the long-term average SSTs for a consecutive period of five months. However, exceptionally strong El Niño events, such as those in 1997-98 and 2015-16, have seen much greater temperature anomalies, with SSTs rising by more than 2.5 degrees Celsius (4.5 degrees Fahrenheit) above average. These intense El Niño events have significant impacts on global weather patterns and climate due to their heightened intensity and prolonged duration (https://earthobservatory.nas a.gov/features/ElNino?ref=blog.traqo.io#:~:text=An%20El%20Ni%C3%B1o%20is%20declared%20when%20the%20average,degrees%20Celsius%20%284.5%20degrees%20Fahrenheit%29%20above%20the%20average).

The analysis covers sea surface temperature anomalies (SSTA) from 1981 to 2018 compared to the mean SST during 1982 to 2010. Global mean area-weighted SST trends are 0.09 ± 0.006 K per decade (excluding perennial sea-ice regions) and 0.11 ± 0.008 K per decade (including these regions). Positive trends are widespread, except in the Southern Ocean south of about 50 °S, which cooled or remained stable before warming in the last decade. Strongest warming trends are observed near the Arctic sea-ice boundary, in the Mediterranean, Black Sea, and along the northern edge of the Northern Hemisphere western boundary currents. Notable warm anomalies persist in the Northeast Pacific and off the North and East Pacific coasts (Bulgin et al., 2020).

The trends in global sea surface temperature (SST) from 1949 to 2006 show relatively stable SST until the mid-1970s, followed by a steady increase of about 0.4

°C by 2006. This warming trend is observed across most ocean basins, with the Indian Ocean showing the largest increase. Contributions to the global SST rise come primarily from the Atlantic, western Pacific, and Indian Oceans. Major El Niño-Southern Oscillation (ENSO) events, particularly in the Pacific Ocean, are evident in the data, with the 1997-98 event leading to the largest global anomaly. However, subsequent cooler years balance out the overall trend. Overall, the passage highlights long-term SST changes and the influence of ENSO events on global temperatures (Large et al., 2012).

The analysis of the Extended Reconstructed Sea Surface Temperature version 5 dataset (ERSSTv5) using Multi-dimensional Ensemble Empirical Mode Decomposition (MEEMD) method to analyse reveals significant warming trends across the Pacific Ocean. While some areas, like the equatorial central Pacific, initially experienced cooling trends, recent decades have seen rapid warming in this region. Hotspots of warming include the eastern tropical Pacific, the Arctic Ocean, and regions east of the northern hemisphere continents. Long-term trends show a three-band structure of warming, with subtropical regions warming first, followed by subpolar regions. Understanding these trends is crucial for predicting and mitigating the impacts of climate change in the Pacific Ocean (Xu et al., 2021).

The analysis of observational Sea Surface Temperature (SST) data aimed to identify trends in the equatorial Pacific SST gradient over the past century. A new analysis method revealed that while global warming trends were prevalent, cooling trends emerged in specific regions, particularly the eastern equatorial Pacific. The analysis across three datasets showed a strengthened gradient over the 20th century. The trend in the gradient, measured in degrees Celsius per century with 95 %

confidence limits, was +0.66 ± 0.14 for the new analysis method, +0.11 ± 0.15 for GOSTA, and +0.28 ± 0.14 for COADS. These findings align with predictions for strong atmospheric coupling over the enhanced eastern warming of greenhouse models (Cane et al., 1997).

ENSO, the El Niño-Southern Oscillation, is a natural climate phenomenon characterized by variations in sea surface temperatures and atmospheric pressure in the tropical Pacific Ocean. Two main theories, the Delayed Oscillator Theory and the Stochastic Forcing Theory, have emerged to explain its dynamics. Both theories involve positive and negative feedback mechanisms between the atmosphere and ocean, leading to the growth and decay of ENSO events. The dominant positive feedback is the Bjerknes feedback, where westerly wind anomalies in the western and central equatorial Pacific generate positive sea surface temperature anomalies in the eastern Pacific, further reinforcing westerly wind anomalies. The dominant negative feedback involves the dynamical adjustment of the equatorial Pacific thermocline to the overlying wind field, eventually leading to the demise of an event. These theories have contributed to advancements in predicting ENSO events, enabling the routine issuance of ENSO forecasts (Deser et al., 2010).

The decomposition of monthly sea surface temperature (SST) variability in the tropical Pacific Ocean from 1950 to 2010 reveals three key patterns. The first pattern aligns closely with the canonical El Niño-Southern Oscillation (ENSO) pattern, while the second pattern is influenced solely by linear trends across the region. A third pattern, known as ENSO Modoki, is also identified but its linear trend is small and dataset-dependent. Trends in the equatorial zonal SST gradient between the Niño-4 and Niño-3 regions reflect aspects of ENSO Modoki, but they lack significant negative trends, particularly during boreal wintertime months. The presence of positive SST trends across the equatorial Pacific Ocean suggests reevaluating the use of fixed SST anomaly thresholds to define ENSO events (L'Heureux et al., 2012).

The study by (Ginzburg et al., 2005) utilized a weekly mean Multi-Channel Sea Surface Temperature (MCSST) dataset to analyse seasonal and interannual variations in sea surface temperatures (SSTs) across four regions of the Caspian Sea and Garabogazköl (Kara-Bogaz-Gol) Bay from 1982 to 2000. The analysis revealed positive SST trends in the Middle and Southern Caspian regions, indicating an increase of approximately 0.05 °C per year and 0.10 °C per year during this period, potentially attributed to global climate warming.

The analysis of the Extended Reconstructed Sea Surface Temperature version 5 dataset (ERSSTv5) reveals significant warming trends across the Pacific Ocean. While some areas, like the equatorial central Pacific, initially experienced cooling trends, recent decades have seen rapid warming in this region. Hotspots of warming include the eastern tropical Pacific, the Arctic Ocean, and regions east of the northern hemisphere continents. Long-term trends show a three-band structure of warming, with subtropical regions warming first, followed by subpolar regions. Understanding these trends is crucial for predicting and mitigating the impacts of climate change in the Pacific Ocean.

An analysis of sea surface temperature (SST) in the Caribbean Sea from 1982 to 2012 reveals a notable warming trend, especially in the last 15 years. This warming trend is supported by SST and precipitation analyses, indicating its significance. Observations suggest a potential influence of strong ENSO episodes on the regional climate. Additionally, the Atlantic Warm Pool (AWP) has shown increased size and intensity from 1998 to 2012 during the late rainfall season, correlated with elevated SSTs and enhanced moisture transport (Glenn et al., 2015).

Between October 2013 and February 2014, a significant cooling event occurred in the Northeast Pacific Ocean, marked by a temperature decrease of 5.5 °C, the lowest since 1980. Despite weaker-than-normal heat fluxes due to entrainment, the overall cooling rate remained typical, possibly due to a thin mixed layer. Anomalies in Sea Level Pressure (SLP) led to positive temperature anomalies in the north-east Pacific Ocean during this period, reducing heat loss from the ocean to the atmosphere. This surplus heat persisted into the following summer, contributing to unusually warm temperatures in the Pacific Northwest. The exact cause of the anomalous atmospheric forcing is not specified, but Sea SST anomalies in the far western tropical Pacific, along with intrinsic atmospheric variability, likely played significant roles (Bond et al., 2015).

The analysis of monthly sea surface temperature (SST) variation from 1982 to 2019 in the Gulf of Mexico (GoM) reveals a linear warming trend with a best-fit slope of 0.158 °C per decade. This equates to an overall increase of 0.6 °C in SST across the entire GoM during the study period. The monthly temperature time series illustrates the annual SST cycle, with minimum temperatures (22– 24 °C) typically occurring around February and maximum temperatures (28– 30 °C) in August (Li et al., 2022).

The study analysed sea surface temperature (SST) variations in the Gulf of Mexico using data from Coastal Zone Color Scanner (CZCS) and Advanced Very-High-Resolution Radiometer (AVHRR) images, along with supplementary SST data spanning from 1946 to 1990. It found synchronous seasonal fluctuations in SST across the Gulf, with peak temperatures typically occurring from July to September and troughs from February to March. SST variations were more pronounced in the western Gulf, with longer persistence of temperature extremes, and larger variations were observed toward the Gulf's margins (Muller-Karger et al., 1991).

CHAPTER 2: METHODOLOGY

2.1 STUDY AREA

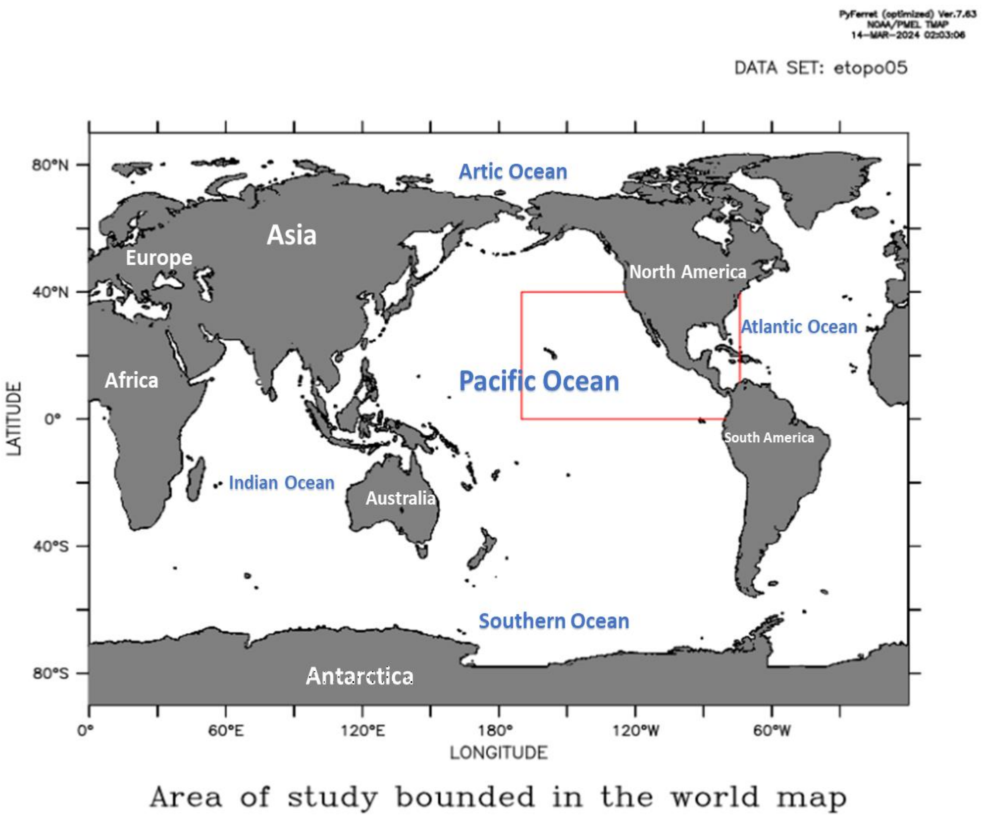


Figure 2.1 Area of Study Bounded in Red on the World Map

Continents are large landmasses on Earth, each with unique features and cultural significance. They include Africa, Antarctica, Asia, Europe, North America, Oceania, and South America. Oceans are vast bodies of saltwater that cover about 71% of the Earth's surface. The major oceans are the Pacific, Atlantic, Indian, Southern, and Arctic Oceans. Together, continents and oceans form the foundation of Earth's geography, shaping ecosystems, climates, and human societies.

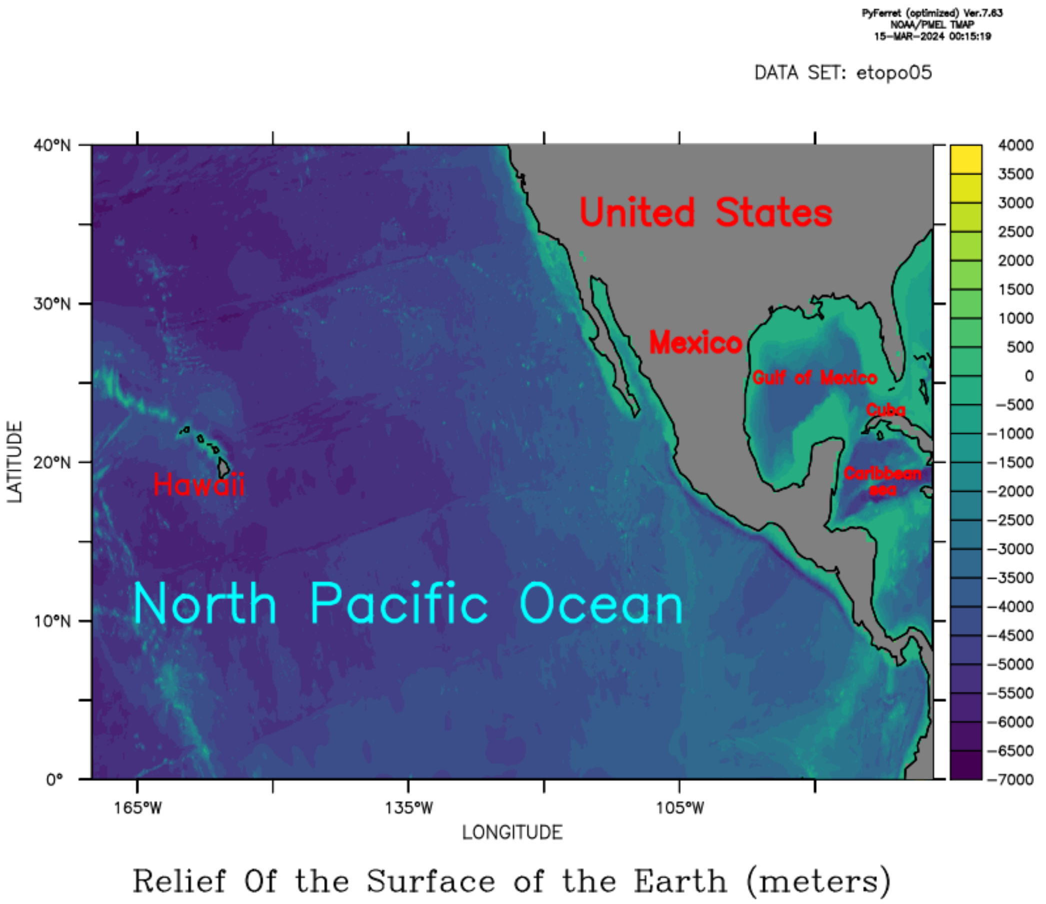


Figure 2.2 Area of study in North-East Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W)

The area of study is the region from coordinates (0 °N to 40 °N, 170 °W to 77 °W) along north-east Pacific Ocean and also in Gulf of Mexico and Caribbean Sea of Atlantic Ocean. The north-east Pacific Ocean region is characterized by the influence of several key oceanic currents, including the North Equatorial Current, California Current, Equatorial Counter Current (ECC), and the North Pacific Gyre. These currents play pivotal roles in redistributing heat, nutrients, and influencing climate patterns across the region. Additionally, the Gulf of Mexico and the Caribbean Sea, with their unique oceanic currents such as the Loop Current and the Antilles Current, contribute significantly to the regional climate and marine ecosystems.

2.2 DATA SOURCES

The dataset used is of **Average Sea Surface Temperature** from institution of Met Office Hardley Centre (Dataset ID: **erdHadISST),** downloaded on 6th December 2023 from the website of **(**https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdHadISST.html). The data is having temporal resolution of monthly and spatial resolution of 1˚x 1˚, from 90 ˚N to 90 ˚S and 180 ˚W to 180 ˚W from 1st January 1990 to 30th September 2023.

The data is provided by National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) on the Environmental Research Division's Data Access Program (ERDDAP) website.

2.3 SOFTWARE INSTALLATION AND METHODOLOGY

Ubuntu 22.04 (https://ubuntu.com/download/alternative-downloads)

Ubuntu is a widely-used open-source Linux distribution known for its user-friendly interface, stability, and extensive software ecosystem. It offers various editions, including Desktop, Server, and Core, catering to different use cases. Ubuntu releases new versions every six months, with Long-Term Support releases every two years, providing users with reliable and secure platforms for personal, server, and IoT deployments.

PyFerret (https://ferret.pmel.noaa.gov/Ferret/documentation/pyferret)

PyFerret, developed by NOAA's Pacific Marine Environmental Laboratory, is a powerful interactive data visualisation and analysis tool widely used in oceanographic and atmospheric sciences. It facilitates exploration, analysis, and visualization of large gridded datasets, including model outputs, satellite observations, and climatological data. PyFerret's capabilities include slicing, averaging, contouring, and plotting, making it adept at extracting meaningful insights from complex datasets. Notable features include efficient handling of multi-dimensional data, a flexible scripting language for automation, and both graphical and command-line interfaces for user interaction. PyFerret finds applications in research, education, and operational settings, spanning disciplines such as climate modelling, oceanography, meteorology, environmental monitoring, and data assimilation.

METHODOLOGY - The analysis was done by downloading SST data which was run on PyFerret in Ubuntu and the plotting was obtained. Further interpretation was done.

2.4 FERRET PROGRAMS

Program 2.1

Program plotting the map of study area, shown in Figure 2.2.

```
! 03 January 2024
! This program plots the study area used to study the variability and trendlines of SSTs in north-east Pacific Ocean
USE etopo05
SET REGION/X=170W:77W/Y=00N:40N
shade Rose
go fland
```

```
go land
LABEL 225 10 0 0 0.35 "@c017North Pacific Ocean"
LABEL 270 25 0 0 0.11 "@c008Gulf of Mexico"
LABEL 207 18 1 0 0.19 "@c008Hawaii"
LABEL 272 35 1 0 0.24 "@c014United States"
LABEL 262 27 1 0 0.18 "@c014Mexico"
LABEL 277.5 19 0 0 0.10 "@c008Caribbean"
LABEL 277.5 18 0 0 0.10 "@c008sea"
LABEL 280 23 1 0 0.10 "@c008Cuba"
FRAME/ File="Study Area .gif"
! sp Fprint -o "Study Area .ps" -l cps -p portrait metafile.plt
```

Program 2.2

Program plotting the averaged SSTs in the region (0 °N to 40 °N, 170 °W to 77 °W) for the entire period from 01 January 1990 to 31 December 2022, shown in Figure 3.1.1

```
! 3 January 2024
! This programme maps the Sea Surface Temperature (SST), in the North-East Pacific Ocean (00 N to 40 N, 170 W to 80W), averaged in the time period from January 1990 to December 2022.
! The maps are for the entire period, month-wise and season-wise.
! The dataset is HadISST Average Sea Surface Tempezatuze, 1°, Global, Monthly, 1870-present.
! The datafile SST_ErdHadl_90S90N180W180E_199001_202212.nc was downloaded from https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdHadISST.html on 6 December 2023.
! The dataset contains the variable sea surface temperature (SST)
! The SST data is global (90 N to 90 S, 180 W to 180 E), and 1s 1 degree by 1 degree. A stride of 1 was given when downloading this data from the website.
! The SST data is on the sea surface.
! The SST data is monthly and is downloaded in the period from January 1990 to September 2023. A stride of 1 was given when downloading this data from the website.
! The SST data is on the sea surface.

! The citation is
! Rayner, N. A., Parker, D. E., Horton, E. B., Folland, C. K., Alexander, L. V., Rowell, D. Po, Kent, E. C., Kaplan, A. (2003).
```

```
! J. Geophys.Res.Vol.108, No.D14,4407
! d.o.i.: 10.1029/2002JD002670
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!

USE SST_ErdHadl_90S90N180W180E_199001_202309.nc
        ! Dataset of SST in the period from January 1990 to September 2023
SHOW Data
KEYMARK 1
LET sst_filled = sst[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
l=1:396@fln:12]
! Map in the period from January 1990 to December 2022
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
sst_filled[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab sst_filled[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "SST (^oC) in the north-east Pacific Ocean (00^oN
to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to
December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_17_Time_Series_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_17_Time_Series_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt
```

Program 2.3

Program plotting the averaged SSTs in the region (0 °N to 40 °N, 170 °W to 77 °W) for every month-wise and season-wise from 01 January 1990 to 31 December 2022, shown in Figure 3.1.2 to 3.1.17

```
! Month-wise plots
LET SST_Jan = sst_filled[l=1:405:12]
LET SST_Feb = sst_filled[l=2:405:12]
LET SST_Mar = sst_filled[l=3:405:12]
LET SST_Apr = sst_filled[l=4:405:12]
LET SST_May = sst_filled[l=5:405:12]
```

```
LET SST_Jun = sst_filled[l=6:405:12]
LET SST_Jul = sst_filled[l=7:405:12]
LET SST_Aug = sst_filled[l=8:405:12]
LET SST_Sep = sst_filled[l=9:405:12]
LET SST_Oct = sst_filled[l=10:405:12]
LET SST_Nov = sst_filled[l=11:405:12]
LET SST_Dec = sst_filled[l=12:405:12]

! SST Map in January
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" " SST_Jan[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Jan[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "January SST (^oC) in the north-east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_01_Month_Jan_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_01_Month_Jan_00N40N170W077W_199001_202212.ps" -l cps -p portrait Metafile.plt

! SST Map in February
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" " SST_Feb[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Feb[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "February SST (^oC) in the north-east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_02_Month_Feb_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_02_Month_Feb_00N40N170W077W_199001_202212.ps" -l cps -p portrait Metafile.plt
! SST Map in March
SET MODE Metafile
```

```
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Mar[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Mar[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "March SST (^oC) in the north-east Pacific Ocean
(00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January
1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_03_Month_Mar_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_03_Month_Mar_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt

! SST Map in April
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Apr[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Apr[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "April SST (^oC) in the north-east Pacific Ocean
(00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January
1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_04_Month_Apr_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_04_Month_Apr_00N40N170W077W_199001_202212.ps" -l cps -
p portrait Metafile.plt

! SST Map in May
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_May[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_May[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "May SST (^oC) in the north-east Pacific Ocean
(00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January
1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
```

```
CANCEL MODE Metafile
FRAME/File="SST_05_Month_May_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_05_Month_May_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt

! SST Map in June
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Jun[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Jun[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "June SST (^oC) in the north-east Pacific Ocean
(00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January
1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_06_Month_Jun_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_06_Month_Jun_00N40N170W077W_199001_202212.ps" -l cps -
p portrait Metafile.plt

! SST Map in July
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Jul[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Jul[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "July SST (^oC) in the north-east Pacific Ocean
(00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January
1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_07_Month_Jul_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_07_Month_Jul_00N40N170W077W_199001_202212.ps" -l cps -
p portrait Metafile.plt
! SST Map in August
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Aug[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Aug[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
```

```
LABEL/Nouser 3.9 -0.8 0 0 0.15 "August SST (^oC) in the north-east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_08_Month_Aug_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_08_Month_Aug_00N40N170W077W_199001_202212.ps" -l cps -p portrait Metafile.plt

! SST Map in September
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" " SST_Sep[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Sep[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "September SST (^oC) in the north-east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_09_Month_Sep_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_09_Month_Sep_00N40N170W077W_199001_202212.ps" -l cps -p portrait Metafile.plt
! SST Map in October
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" " SST_Oct[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Oct[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "October SST (^oC) in the north-east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_10_Month_Oct_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_10_Month_Oct_00N40N170W077W_199001_202212.ps" -l cps -p portrait Metafile.plt
```

```
! SST Map in November
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Nov[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Nov[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "November SST (^oC) in the north-east Pacific
Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from
January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_11_Month_Nov_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_11_Month_Nov_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt


! SST Map in December
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_Dec[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_Dec[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "December SST (^oC) in the north-east Pacific
Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period from
January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_12_Month_Dec_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_12_Month_Dec_00N40N170W077W_199001_202212.ps" -l cps -
p portrait Metafile.plt

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!

! Season-wise plots
LET SST_FMA = sst_feb[l=1:33:1] * (28.25/89.25) + sst_mar[l=1:33:1] * (31/89.25)
+ sst_apr[l=1:33:1] * (30/89.25)        ! Boreal Spring Season
LET SST_MJJ = sst_may[l=1:33:1] * (31/92) + sst_jun[l=1:33:1] * (30/92) +
sst_jul[l=1:33:1] * (31/92)                    ! Boreal Summer Season
```

```
LET SST_ASO = sst_aug[l=1:33:1] * (31/92) + sst_sep[l=1:33:1] * (30/92) +
sst_oct[l=1:33:1] * (31/92)                    ! Boreal Autumn Season
LET SST_NDJ = sst_nov[l=1:32:1] * (30/92) + sst_dec[l=1:32:1] * (31/92) +
sst_jan[l=2:33:1] * (31/92)                    ! Boreal Winter Season

! SST Map in Boreal Spring Season
 SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_FMA[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_FMA[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Boreal Spring Season SST (^oC) in the<nl>north-
east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period
from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_13_Season_FMA_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_13_Season_FMA_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt

! SST Map in Boreal Summer Season
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_MJJ[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_MJJ[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Boreal Summer Season SST (^oC) in the<nl>north-
east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period
from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_14_Season_MJJ_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_14_Season_MJJ_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt

! SST Map in Boreal Autumn/ Fall Season
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_ASO[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
```

```
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_ASO[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Boreal Autumn Season SST (^oC) in the<nl>north-
east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period
from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_15_Season_ASO_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_15_Season_ASO_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt

! SST Map in Boreal Winter Season
SET MODE Metafile
SHADE/ Level=(-inf)(10 30 2.5)(inf)/ Palette=ocean_temp/ Title=" "
SST_NDJ[x=170W:77W, y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
CONTOUR/ Over/ Level=(-10 40 5)(inf)/ Nolab SST_NDJ[x=170W:77W,
y=00N:40N, T="01-Jan-1990":"31-Dec-2022"@ave]
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Boreal Winter Season SST (^oC) in the<nl>north-
east Pacific Ocean (00^oN to 40^oN, 170^oW to 077^oW),<nl>averaged in the period
from January 1990 to December 2022"
GO land
USE etopo05.cdf
SHADE/ Overlay/ Palette=black/ Level=(0 9000 9000)/ Nolab rose
CANCEL MODE Metafile
FRAME/File="SST_16_Season_NDJ_00N40N170W077W_199001_202212.gif"
sp Fprint -o "SST_16_Season_NDJ_00N40N170W077W_199001_202212.ps" -l cps
-p portrait Metafile.plt
```

Program 2.4

Program plotting maps of slopes for SST trendlines in the region (0 °N to 40 °N, 170 °W to 77 °W) averaged in the period from 01 January 1990 to 31 December 2022, shown in Figures 3.2.1

```
! 23 January 2024
! This program plots the SST trendlines from January 1990 to December 2022
```

! The SST data used was downloaded from the webpage https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdHadISST.html on 7 December 2023.
! The data is of SST,from HadISST Average Sea Surface Tempezatuze, 1°, Global, Monthly, 1870-present.
! The data is from the Equator to 40 °N and 99 °E to 170 °W, downloaded every 1.0 degree

```
SET Mode verify
USE SST_ErdHadl_90S90N180W180E_199001_202309.nc
        ! Dataset of SST in the period from January 1990 to September 2023
SHOW Data
KEYMARK 1
LET sst_filled = sst[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, l=1:405@fln:12]
! Months
LET SST_Jan = sst_filled[l=1:405:12]
LET SST_Feb = sst_filled[l=2:405:12]
LET SST_Mar = sst_filled[l=3:405:12]
LET SST_Apr = sst_filled[l=4:405:12]
LET SST_May = sst_filled[l=5:405:12]
LET SST_Jun = sst_filled[l=6:405:12]
LET SST_Jul = sst_filled[l=7:405:12]
LET SST_Aug = sst_filled[l=8:405:12]
LET SST_Sep = sst_filled[l=9:405:12]
LET SST_Oct = sst_filled[l=10:405:12]
LET SST_Nov = sst_filled[l=11:405:12]
LET SST_Dec = sst_filled[l=12:405:12]

! Seasons
LET SST_FMA = sst_feb[l=1:33:1] * (28.25/89.25) + sst_mar[l=1:33:1] * (31/89.25) + sst_apr[l=1:33:1] * (30/89.25)       ! Boreal Spring Season
LET SST_MJJ = sst_may[l=1:33:1] * (31/92) + sst_jun[l=1:33:1] * (30/92) + sst_jul[l=1:33:1] * (31/92)       ! Boreal Summer Season
LET SST_ASO = sst_aug[l=1:33:1] * (31/92) + sst_sep[l=1:33:1] * (30/92) + sst_oct[l=1:33:1] * (31/92)       ! Boreal Autumn Season
LET SST_NDJ = sst_nov[l=1:32:1] * (30/92) + sst_dec[l=1:32:1] * (31/92) + sst_jan[l=2:33:1] * (31/92)       ! Boreal Winter Season

! Trendline plots
! For the entire period
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:405:1]
```

```
LET q = sst_filled[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=99E:170W, y=00N:40N, l=1:405:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel
Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W,
y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs
(^oC/year),<nl>averaged in the period from January 1990 to December
2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_00N40N099E170W_199001_202212.ps" -l cps -
p portrait metafile.plt
```

Program 2.5

Program plotting maps of slopes for SST trendlines in the region (0 °N to 40 °N, 170 °W to 77 °W) and averaged every month-wise and season-wise in the period from 01 January 1999 to 31 December 2022, shown in Figure 3.2.2 to 3.2.17

```
! Trendlines month-wise
! January
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Jan[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel
Slope_per_year
```

```
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in January,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_01_Jan_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_01_Jan_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! February
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Feb[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in February,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_02_Feb_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_02_Feb_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! March
KEYMARK 1

SET Mode metafile
```

```
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Mar[x=99E:170W, y=00N:40N, l=1:33:1]

SET GRID q
GO regresst

! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below

LET Slope_per_year = Slope*60*60*24*365.25

SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare

GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in March,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_03_March_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_03_March_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! April
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Apr[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
```

```
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in April,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_04_Apr_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_04_Apr_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! May
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_May[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in May,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_05_May_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_05_May_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! June
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Jun[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
```

```
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel
Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W,
y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in
June,<nl>averaged in the period from January 1990 to December
2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_06_Jun_00N40N099E170W_199001_202212
.gif"
sp Fprint -o
"SST_Trendline_Slope_06_Jun_00N40N099E170W_199001_202212.ps" -l cps -p
portrait metafile.plt

! July
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Jul[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel
Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W,
y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in
July,<nl>averaged in the period from January 1990 to December
2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_07_Jul_00N40N099E170W_199001_202212.
gif"
sp Fprint -o
"SST_Trendline_Slope_07_Jul_00N40N099E170W_199001_202212.ps" -l cps -p
portrait metafile.plt
! August
```

```
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Aug[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in August,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_08_Aug_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_08_Aug_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! September
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Sep[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in September,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
```

```
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_09_Sep_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_09_Sep_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! October
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Oct[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in October,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_10_Oct_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_10_Oct_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! November
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Nov[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst

! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
```

```
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in November,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_11_Nov_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_11_Nov_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! December
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_Dec[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in December,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_12_Dec_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_12_Dec_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! Season-wise plots
! SST Map in Boreal Spring Season
```

```
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_FMA[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in Boreal Spring Season,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_13_Season_FMA_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_13_Season_FMA_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

! SST Map in Boreal Summer Season
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_MJJ[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in Boreal Summer Season,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
```

```
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_14_Season_MJJ_00N40N099E170W_19900
1_202212.gif"
sp Fprint -o
"SST_Trendline_Slope_14_Season_MJJ_00N40N099E170W_199001_202212.ps" -
l cps -p portrait metafile.plt

! SST Map in Boreal Autumn Season
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_ASO[x=99E:170W, y=00N:40N, l=1:33:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel
Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W,
y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in Boreal
Autumn Season,<nl>averaged in the period from January 1990 to December
2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_15_Season_ASO_00N40N099E170W_19900
1_202212.gif"
sp Fprint -o
"SST_Trendline_Slope_15_Season_ASO_00N40N099E170W_199001_202212.ps"
-l cps -p portrait metafile.plt

! SST Map in Boreal Winter Season
KEYMARK 1
SET Mode metafile
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:32:1]
LET q = SST_NDJ[x=99E:170W, y=00N:40N, l=1:32:1]
SET GRID q
GO regresst
! The variable "slope" which is calculated by "Ferret" is in (°C/s)
! The variable "slope" is converted in units to (°C/year) by multiplying below
LET Slope_per_year = Slope*60*60*24*365.25
```

SHADE/ Level=(-inf)(-0.04 0.04 0.02)(inf)/ Palette=no_green/ Nolabel Slope_per_year
CONTOUR/ Overlay/ Level=(0)/ Nolabel Slope_per_year[x=99E:170W, y=00N:40N]
CONTOUR/ Overlay/ Level=(0 1 0.25)/ Colour=3/ Nolabel Rsquare
GO land 7
LABEL/Nouser 3.9 -0.8 0 0 0.15 "Slopes of trendlines of SSTs (^oC/year) in Boreal Winter Season,<nl>averaged in the period from January 1990 to December 2022.<nl>Coefficient of Determination (R^2) is contoured every 0.25 interval."
CANCEL MODE Metafile
FRAME/File="SST_Trendline_Slope_16_Season_NDJ_00N40N099E170W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_16_Season_NDJ_00N40N099E170W_199001_202212.ps" -l cps -p portrait metafile.plt

Program 2.6

Program plotting the Basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), for the entire time period from January 1990 to December 2022, shown in Figures 3.3.1

! 22 February 2024
! This program plots the sea surface temperature and its trendlines, basin-averaged in the region (00 N to 40 N, 170W to 77W), in the period from January 1990 to December 2022.
! The sea surface temperature data used was downloaded from the webpage https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdHadISST.html on 7 December 2023.
! The data is of SST, from HadISST Average Sea Surface Tempezatuze, 1°, Global, Monthly, 1870-present.
! The data downloaded is from January 1990 to September 2023.
SET Mode verify
USE SST_ErdHadl_90S90N180W180E_199001_202309.nc ! Dataset of SST in the period from January 1990 to September 2023
SET REGION/ X=170W:77W/ Y=00N:40N
SHOW Data
LET sst_filled = sst[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, l=1:405@fln:12] ! Time-period from January 1990 to September 2023
! SET Mode metafile

```
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:396:1]
LET q = sst_filled[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:396:1]          ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_filled[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_filled[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/ File=SST_Trendline_Slope_basin_averaged_00N40N170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt
```

Program 2.7

Program plotting the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), for month-wise and season-wise from January 1990 to December 2022, shown in Figures 3.3.2 to 3.3.17

```
! Month-wise plots
LET SST_Jan = sst_filled[l=1:405:12]
LET SST_Feb = sst_filled[l=2:405:12]
LET SST_Mar = sst_filled[l=3:405:12]
LET SST_Apr = sst_filled[l=4:405:12]
LET SST_May = sst_filled[l=5:405:12]
LET SST_Jun = sst_filled[l=6:405:12]
LET SST_Jul = sst_filled[l=7:405:12]
LET SST_Aug = sst_filled[l=8:405:12]
LET SST_Sep = sst_filled[l=9:405:12]
LET SST_Oct = sst_filled[l=10:405:12]
LET SST_Nov = sst_filled[l=11:405:12]
LET SST_Dec = sst_filled[l=12:405:12]

! Season-wise plots
LET SST_FMA = sst_feb[l=1:33:1] * (28.25/89.25) + sst_mar[l=1:33:1] * (31/89.25)
+ sst_apr[l=1:33:1] * (30/89.25)        ! Boreal Spring Season
LET SST_MJJ = sst_may[l=1:33:1] * (31/92) + sst_jun[l=1:33:1] * (30/92) +
sst_jul[l=1:33:1] * (31/92)                        ! Boreal Summer Season
LET SST_ASO = sst_aug[l=1:33:1] * (31/92) + sst_sep[l=1:33:1] * (30/92) +
sst_oct[l=1:33:1] * (31/92)                        ! Boreal Autumn Season
LET SST_NDJ = sst_nov[l=1:32:1] * (30/92) + sst_dec[l=1:32:1] * (31/92) +
sst_jan[l=2:33:1] * (31/92)                        ! Boreal Winter Season

!!!MONTHwise
!!!!!!!!!!!! JANUARY !!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Jan[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1]                ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Jan[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Jan[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
```

```
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(00^oN-40^oN, 170^oW-77^oW) averaged in the January, in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_1_Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_1_Jan_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!FEBRUARY!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Feb[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]          ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Feb[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Feb[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]

LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the February, in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
```

```
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_2_Feb_00N40N0170W077W
_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_2_Feb_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_2_Feb00N40N170W077W_199001_20221
2.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!MARCH!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Mar[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Mar[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Mar[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
March, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_3_Mar_00N40N0170W077W
_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_3_Mar_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
```

```
sp Fprint -o "SST_Trendline_Slope_basin_averaged_3_Mar_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!APRIL!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Apr[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]          ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Apr[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Apr[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the April, in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_4_Apr_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_4_Apr_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_4_Apr_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!MAY!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
```

```
LET q = sst_May[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_May[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_May[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
May, in the period from January 1990 to<nl>December 2022 (in black). The trendline
(^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_5_May_00N40N0170W077
W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_5_May_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_5_May_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!JUNE!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Jun[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
```

```
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Jun[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Jun[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(00^oN-40^oN, 170^oW-77^oW) averaged in the June, in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_6_Jun_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_6_Jun_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_6_Jun_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!JULY!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Jul[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]   ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Jul[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
```

```
PLOT/ Title=" " sst_Jul[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]

LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the July, in the period from January 1990 to<nl>December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"

! CANCEL Mode Metafile


FRAME/ File=SST_Trendline_Slope_basin_averaged_7_Jul_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_7_Jul_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_7_Jul_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!August!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Aug[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]     ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Aug[x=170W:77W@ave, y=00N:40N@ave, l=1:396@ave], "(f7.3)")
```

```
PLOT/ Title=" " sst_Aug[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
August, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_8_Aug_00N40N0170W077W
_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_8_Aug_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_8_Aug_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt


!!!!!!!!!!!!SEPTEMBER!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Sep[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1]          ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Sep[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Sep[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
```

```
September, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_9_Sep_00N40N0170W077W
_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_9_Sep_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_9_Sep_00N40N170W077W_199001_2022
12.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!OCTOBER!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Oct[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Oct[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")
PLOT/ Title=" " sst_Oct[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.15 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
October, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
```

```
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_10_Oct_00N40N0170W077
W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_10_Oct_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_10_Oct_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!NOVEMBER!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Nov[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Nov[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")

PLOT/ Title=" " sst_Nov[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]

LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
November, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"

! CANCEL Mode Metafile
```

```
FRAME/
File=SST_Trendline_Slope_basin_averaged_11_Nov_00N40N0170W077W_19900
1_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_11_Nov_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_11_Nov_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!!DECEMBER!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = sst_Dec[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:33:1] ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(sst_Dec[x=170W:77W@ave,
y=00N:40N@ave, l=1:396@ave], "(f7.3)")

PLOT/ Title=" " sst_Dec[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-
Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in the
December, in the period from January 1990 to<nl>December 2022 (in black). The
trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File=SST_Trendline_Slope_basin_averaged_12_Dec_00N40N0170W077
W_199001_202212.gif
sp Fprint -o
"SST_Trendline_Slope_basin_averaged_12_Dec_00N40N170W077W_199001_202
212.ps" -l cps -p portrait metafile.plt _Jan_00N40N0170W077W_199001_202212.gif
```

```
sp Fprint -o "SST_Trendline_Slope_basin_averaged_12_Dec_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt


!!!!!!!!!!!!Boreal Spring Season!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_FMA[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]            ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(SST_FMA[x=170W:77W@ave, y=00N:40N@ave, l=1:33@ave], "(f7.3)")
PLOT/ Title=" " SST_FMA[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in Boreal Spring Season in the period from January 1990<nl>to December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile

FRAME/ File="SST_Trendline_Slope_basin_averaged_13_Boreal Spring Season_00N40N0170W077W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_basin_averaged_13_Boreal Spring Season_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt
_Jan_00N40N0170W077W_199001_202212.gif
sp Fprint -o "SST_Trendline_Slope_basin_averaged_13_Boreal Spring Season_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!Boreal Summer Season!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
```

```
LET q = SST_MJJ[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]        ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(SST_MJJ[x=170W:77W@ave, y=00N:40N@ave, l=1:33@ave], "(f7.3)")
PLOT/ Title=" " SST_MJJ[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.13 "Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in Boreal Summer Season in the period from January 1990<nl>to December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/File="SST_Trendline_Slope_basin_averaged_14_Boreal Summer Season_00N40N0170W077W_199001_202212.gif"

sp Fprint -o "SST_Trendline_Slope_basin_averaged_14_Boreal Summer Season_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

!!!!!!!!!!!Boreal Autumn Season!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:33:1]
LET q = SST_ASO[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, x=170W:77W, y=00N:40N, l=1:33:1]        ! Time-period from January 1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave, y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave, y=00N:40N@ave], "(f6.2)" )
```

```
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(SST_ASO[x=170W:77W@ave,
y=00N:40N@ave, l=1:33@ave], "(f7.3)")
PLOT/ Title=" " SST_ASO[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-
1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in
Boreal Autumn Season in the period from January 1990<nl>to December 2022 (in
black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x +
`Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) =
`Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile
FRAME/ File="SST_Trendline_Slope_basin_averaged_15_Boreal Autumn
Season_00N40N0170W077W_199001_202212.gif"

sp Fprint -o "SST_Trendline_Slope_basin_averaged_15_Boreal Autumn
Season_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt


!!!!!!!!!!!Boreal Winter Season!!!!!!!!!!
LET p = t[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc, gl=1:32:1]
LET q = SST_NDJ[d=SST_ErdHadl_90S90N180W180E_199001_202309.nc,
x=170W:77W, y=00N:40N, l=1:32:1]          ! Time-period from January
1990 to December 2022
SET GRID q
GO regresst
LET Slope_per_year = Slope*60*60*24*365.25
LET Slope_per_year_NE_Pacific = FLOATSTR(Slope[x=170W:77W@ave,
y=00N:40N@ave]*60*60*24*365.25, "(f9.4)" )
LET Intercept_NE_Pacific = FLOATSTR(intercep[x=170W:77W@ave,
y=00N:40N@ave], "(f6.2)" )
LET Coeff_Determination = FLOATSTR(rsquare[x=@ave, y=@ave], "(f7.3)" )
LET SST_ave_NE_Pacific = FLOATSTR(SST_NDJ[x=170W:77W@ave,
y=00N:40N@ave, l=1:32@ave], "(f7.3)")
PLOT/ Title=" " SST_NDJ[x=170W:77W@ave, y=0:40N@ave, t="01-Jan-
1990":"31-Dec-2022"]
PLOT/vs/ Over/ Line/ Title="Trendline" p, qhat[x=@ave,y=@ave]
LABEL/Nouser 3.9 -0.7 0 0 0.14 "Basin-averaged Sea Surface Temperature in the
north-east Pacific Ocean region<nl>(0^oN-40^oN, 170^oW-77^oW) averaged in
```

Boreal Winter Season in the period from January 1990<nl>to December 2022 (in black). The trendline (^oC/year) is plotted in red."
LABEL/Nouser 4 6.5 -1 0 0.14 "y = `Slope_per_year_NE_Pacific` x + `Intercept_NE_Pacific`"
LABEL/Nouser 3 6.2 -1 0 0.14 "Coefficient of Determination (R^2) = `Coeff_Determination`"
LABEL/Nouser 0 6.3 -1 0 0.14 "SST_a_v = `SST_ave_NE_Pacific` ^oC"
! CANCEL Mode Metafile

FRAME/ File="SST_Trendline_Slope_basin_averaged_16_Boreal Winter Season_00N40N0170W077W_199001_202212.gif"
sp Fprint -o "SST_Trendline_Slope_basin_averaged_16_Boreal Winter Season_00N40N170W077W_199001_202212.ps" -l cps -p portrait metafile.plt

CHAPTER 3: OBSERVATION

3.1 MAPS OF SEA SURFACE TEMPERATURE (SST) AVERAGED FROM JANUARY 1990 TO DECEMBER 2022

3.1.1 The SST Averaged for the Entire Time Period from January 1990 to December 2022

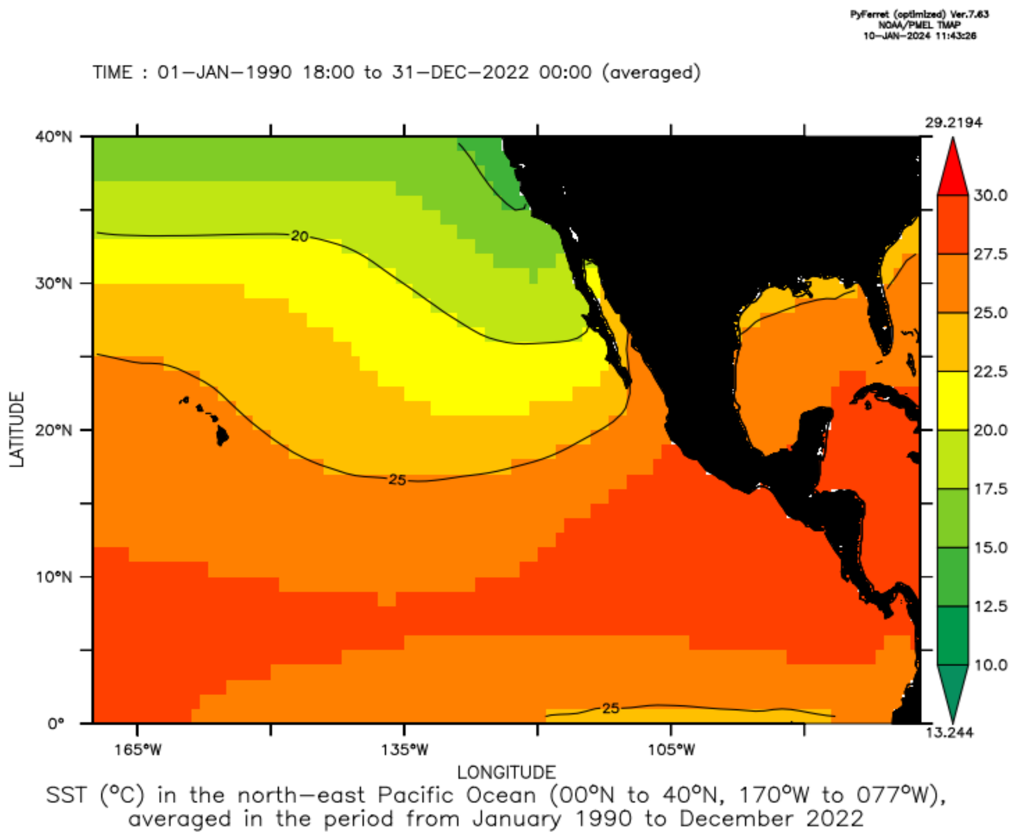


Figure 3.1.1 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged for the entire time period from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged in the time period from January 1990 to December 2022, is shown in Figure 3.1.1. The highest SST is 29.22 °C and the lowest SST value is 13.24 °C. The SSTs show a range of 15.98 ˚C.

The SST values show a meridional gradient with the highest average values in the zonal band between about 5 °N and 10 °N. The SST values are lower to the north and south of this region. Along the western coast of Mexico from the states of Jalisco to Chiapas, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama and Colombia, the SSTs are above 27.5 °C. The temperatures are lesser ranging below 27.5 °C at the coast of Sinaloa in Mexico. Similar ranges of temperatures can be seen near the Equator. Decreasing SSTs are seen northwards too, from the coast of Jalisco in Mexico towards the coast of California in the United States of America (U.S.A.). A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California.

In the regions plotted, the Caribbean Sea shows temperatures above 27.5 °C. The temperatures are lesser in the Gulf of Mexico. The east coast of U.S.A. shows temperatures between 22.5 °C and 25 °C, except near Florida, where the temperatures along the coast are generally between 25 °C and 27.5 °C. Similar values can be seen along the coast Georgia and South Carolina in Atlantic Ocean.

3.1.2. The SST Averaged Month-wise from January 1990 to December 2022

a. *January:*

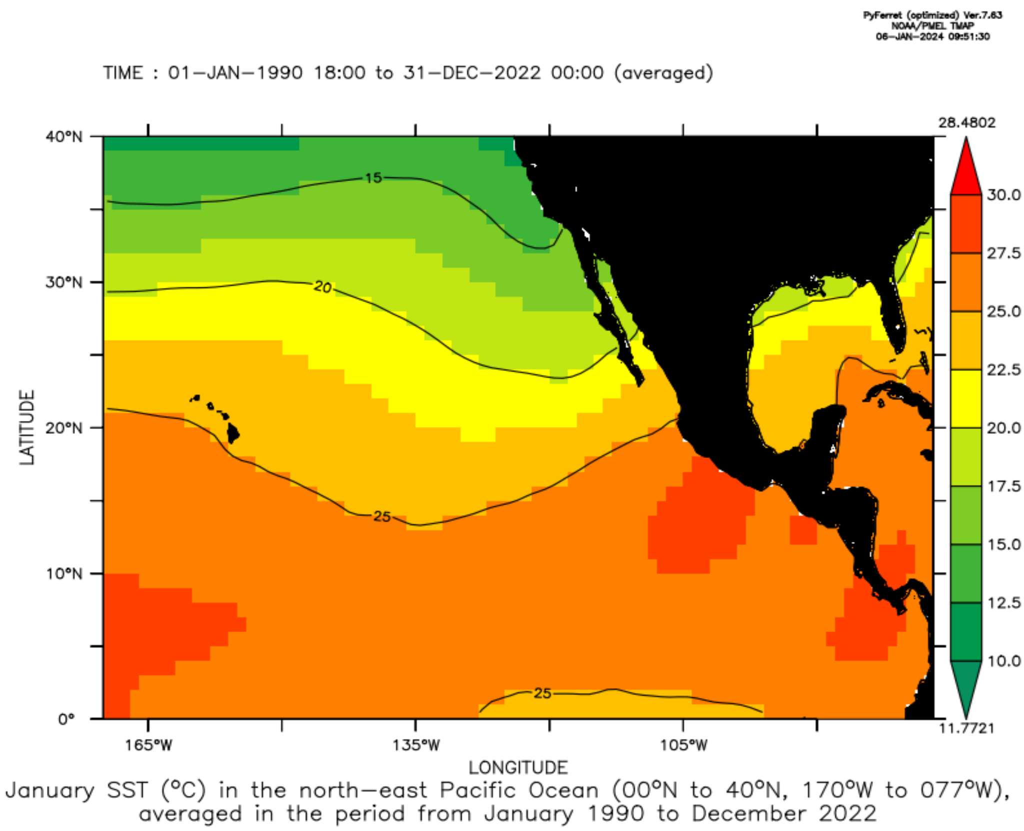


Figure-3.1.2 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every January from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0°N to 40°N, 170°W to 77°W), averaged every January, from January 1990 to December 2022, is shown in Figure 3.1.2. The highest value of SST is 28.48 °C and the lowest SST value is 11.77 °C. The SSTs show a range of 16.71 °C.

The highest average values of SST, i.e. above 27.5 °C, can be seen from the Equator to 10 °N at around 170 °W longitude, and also along the coast of Mexico from the state Colima to Puerto Escondido in Oaxaca in Mexico. Such values are seen even at the western coast of Guatemala and from Costa Rica to Panama. The SSTs values ranging from 25 °C to 27.5 °C, are seen meridionally from the Equator to around 21 °N and in the zonal band from 170 °W to the coast of Central America. A zonal band of SSTs can be seen on the coast of Mexico in Nayarit ranging from 22.5 °C to 25 °C and extending westward into the Pacific Ocean. Similar ranges of temperatures can be seen near the Equator centred at around 115°W. SSTs in the various ranges from 22.5 °C to 15 °C extend zonally westward into the Pacific Ocean, from the Pacific Coast of North America and Central America. The least SST values below 12.5 °C are seen near the west coast of California at around 40 °N and also between 170 °W to around 145 °W longitudes, at 40 °N latitude. A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California.

In the regions plotted, the Caribbean Sea shows temperatures above 25 °C, with SST extending 27.5 °C near the coast of Costa Rica and Panama. The temperatures are lesser in the Gulf of Mexico, with SSTs below 25 °C generally. The SSTs along the coast of Florida range from 17.5 °C to 25 °C. Most of the remaining part east coast of U.S.A. shows temperatures lesser than 20 °C.

b. *February:*

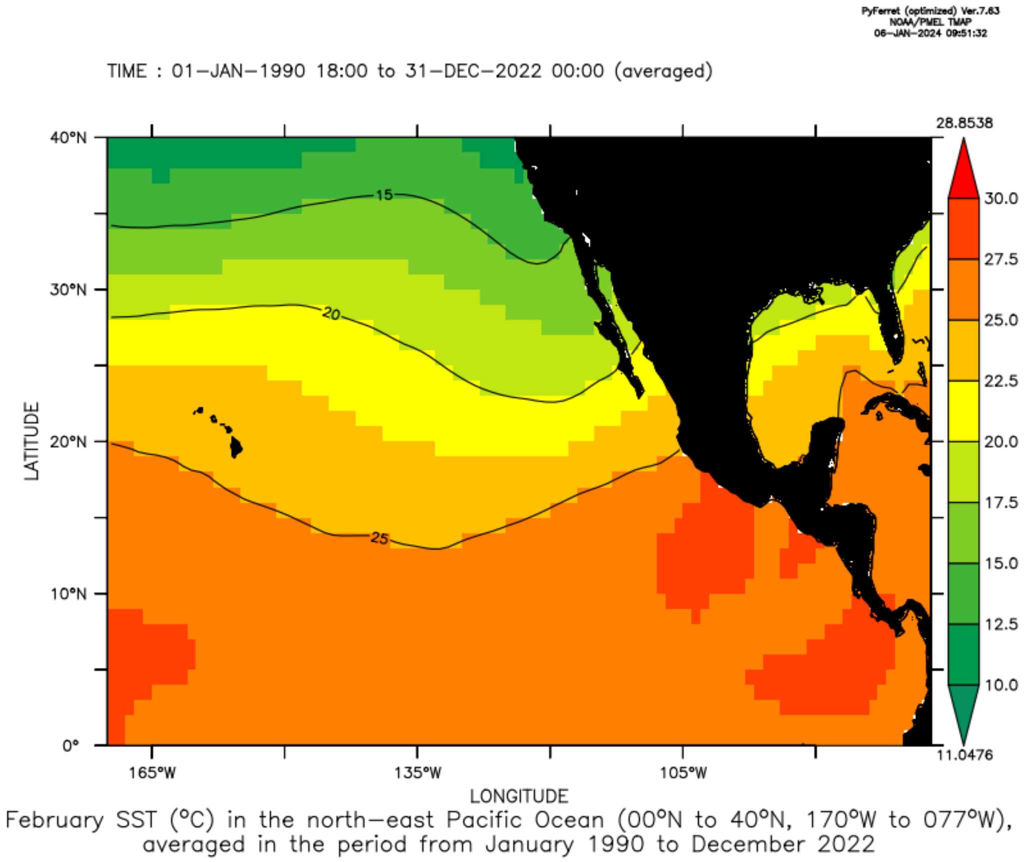


Figure-3.1.3 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every February from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0°N to 40°N, 170°W to 77 °W), averaged every February, from January 1990 to December 2022, is shown in Figure 3.1.3. The highest SST is 28.85 °C and the lowest SST value is 11.05°C. The SSTs show a range of 17.8 °C.

The highest average values of SST, i.e. above 27.5 °C, can be seen from the Equator to 10°N at around 170 °W longitude, and also along the coast of Colima to Oaxaca in Mexico. Similar values are also seen along the western coast of Guatemala to El Salvador and also even at the western coast of Costa Rica to Panama. The SSTs values ranging between 25 °C to 27.5 °C, are seen meridionally from Equator to around 20 °N and in the zonal band from 170 °W to coast of Central America. A zonal band of SSTs ranging between 22.5 °C to 25 °C can be seen from the coast near Mazatlán in Sinaloa to Jalisco, both states in Mexico. This range of SSTs extend zonally across the Pacific Ocean, and is also seen along the Hawai‘i Islands of the Pacific Ocean. The coast of north-west Sinaloa in Mexico at the mouth of Gulf of California and also the southern parts of Baja California Sur show SSTs ranging between 20 °C to 22.5 °C, and these SSTs also extend zonally westward in the Pacific Ocean. The coast of Baja California and north Baja California Sur and also the northern parts of the Gulf of California, shows averaged SSTs ranging from 15 °C to 20 °C. These SSTs zonally extend westward in the Pacific Ocean. The coastal waters near Los Angeles in California shows averaged SSTs ranging from 12.5 °C to 15 °C and extending westward in the Pacific Ocean. The coast waters near Fort Bragg in California and the region near the coordinates (39 °N, 162 °W) have the least SSTs values, i.e. below 12.5 °C.

In the regions plotted, the Caribbean Sea shows temperatures above 25 °C, with SSTs extending 27.5 °C near the coast of Panama. The temperatures are lesser in the Gulf of Mexico. The east coast of U.S.A. shows temperatures below 20 °C, except along parts of southern Florida and southern Texas.

c.*March*

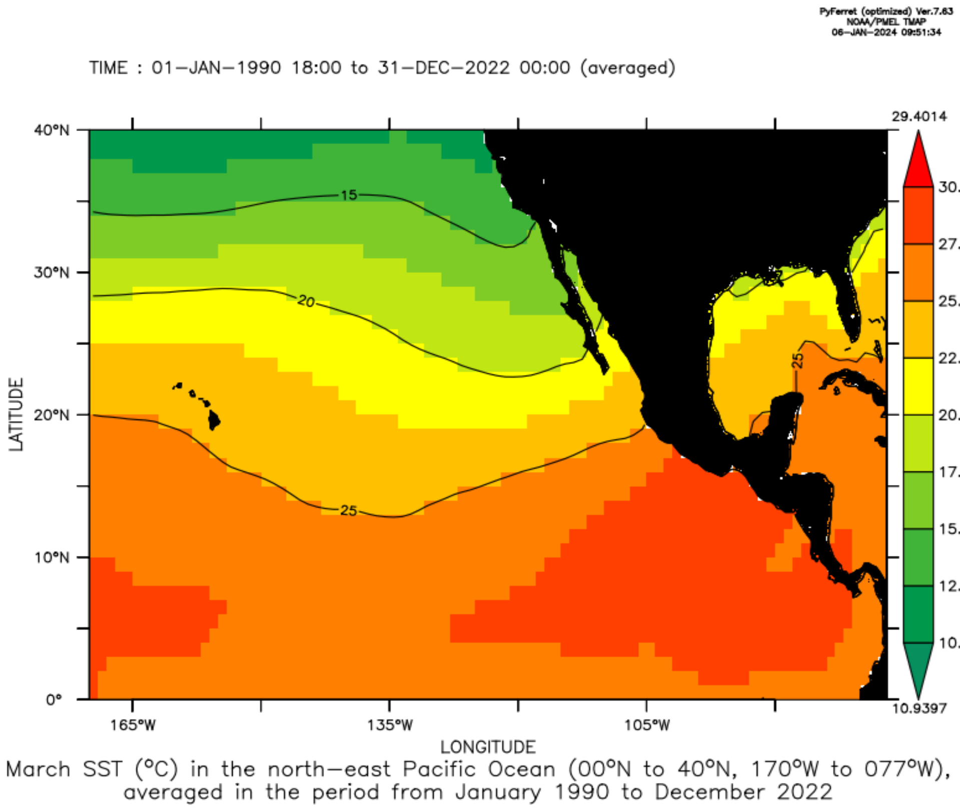


Figure 3.1.4 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every March from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0°N to 40°N, 170°W to 77 °W), averaged every March from January 1990 to December 2022, is shown in Figure 3.1.4 The highest SST is 29.40 °C and the lowest SST value is 10.94°C. The SSTs show a range of 18.46 °C.

The highest average values of SSTs, i.e. above 27.5 °C can be seen from the Equator to 10° N at 170 ° W. Similar values of SST are also along the coast of Mexico from the state Colima to Chiapas and extending southwards along the western coast of Guatemala to El Salvador. Another region of these temperature range are seen extending from Costa Rica to Panama. This region extends westward in the Pacific Ocean, tapering at around (5 °N, 127 °W). The SSTs values ranging from 25 °C and above, are seen extending meridionally from the Equator to around 20 °N at around 170 °W and extending zonally eastwards to the coast of Central America. The coast from El Salvador to Nicaragua show SSTs in the range from 25 °C to 27 °C. A zonal band of SSTs ranging between 22.5 °C to 25 °C can be seen along the coast of Mexico from Sinaloa to Nayarit and extending westward in the Pacific Ocean, passing through the coastal waters of the Hawai‘i Islands. Decreasing SSTs are seen northwards, the southernmost parts of the Baja California Sur show SSTs ranging from 20 °C to 22.5 °C and these extend zonally westward in the Pacific Ocean. The coast of Baja California and north Baja California Sur shows SSTs average values ranging from 15 °C to 20 °C and these too extend westward in the Pacific Ocean. The coastal waters near Los Angeles in California in U.S.A. shows averaged SSTs ranging from 12.5 °C to 15 °C. The coastal waters near Fort Bragg in California has the least SSTs values seen, i.e. below 12.5 °C. The waters with SSTs below 15 °C extend zonally westward from the west coast of North America to the Pacific Ocean.

The isotherms in March reach the southern-most positions generally, as compared to other months.

In the regions plotted, the Caribbean Sea shows SSTs above 25 °C from the Yucatán Peninsula in Mexico to Colombia, with SSTs extending 27.5 °C from the Caribbean coast of Costa Rica to Panama. The temperatures are mostly lower in the Gulf of Mexico as compared to the plotted region of the Caribbean Sea. The SSTs along the east coast of U.S.A. are lesser than 20 °C, except near parts of the coasts of Florida, Louisiana and southern Texas.

d. *April*

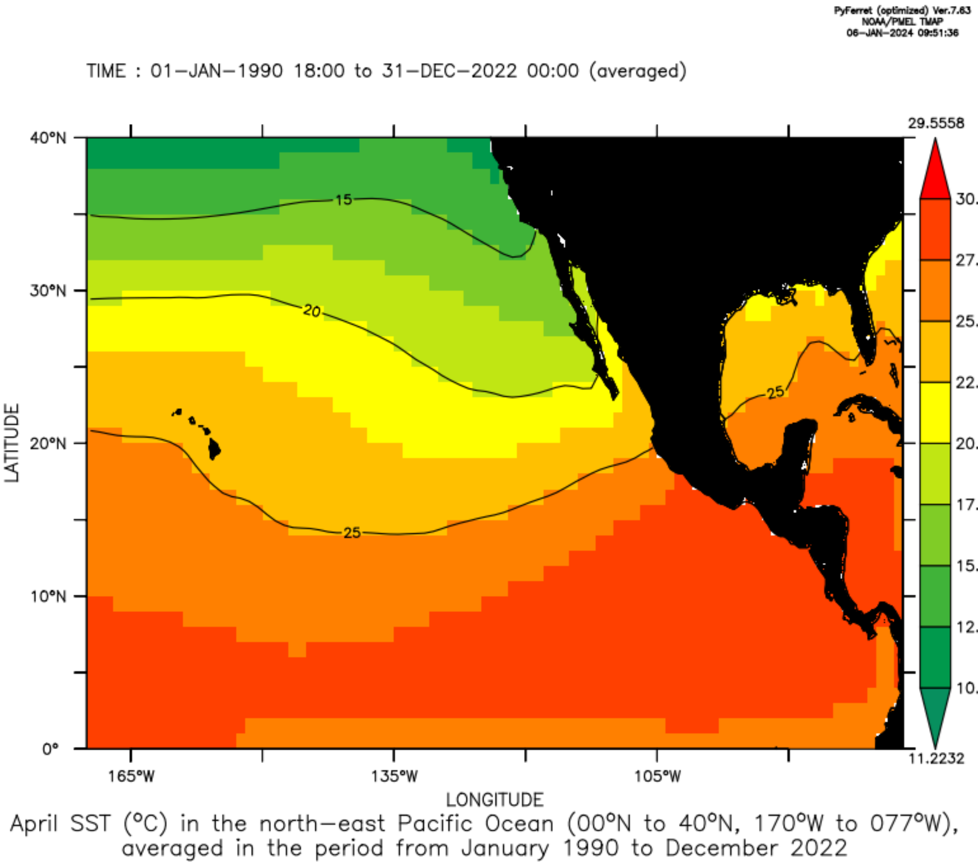


Figure 3.1.5 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every April from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every April from January 1990 to December 2022, is shown in Figure 3.1.5. The highest SST is 29.56 °C and the lowest SST value is 11.22 °C. The SSTs show a range of 18.34 °C.

The highest average values of SSTs, i.e. above 27.5 °C can be seen from the Equator to 10 °N at around 170 °W longitude, and its extends zonally eastward to the coast of Central America from the state Guerrero to Chiapas in Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and to the Gulf of Panama in Panama, and along the Pacific coast of Colombia. The SSTs ranging between 25 °C to 27.5 °C can be seen along coast of Jalisco to Colima in Mexico and extending westward in the Pacific Ocean. A similar range of SST are seen along the Equator from coast of Colombia and Ecuador, and some parts of Panama too, zonally towards the west in the equatorial Pacific Ocean till around 155 °W longitude. A zonal band of SSTs ranging between 22.5 °C to 25 °C can be seen along the coast of Mexico in south Sinaloa, Nayarit and Jalisco and extending zonally westward in the Pacific Ocean across the Hawaiʻi Islands. Decreasing SSTs are seen northwards, the southernmost part of the Baja California Sur shows SSTs ranging from 20 °C to 22.5 °C and these SSTs are seen zonally westward in the Pacific Ocean. The coast of Baja California and north Baja California Sur shows SSTs average values ranging from 15 °C to 20 °C. The coast near Los Angeles in California shows averaged SSTs ranging from 12.5 °C to 15 °C. Further north along the coast of California near Fort Bragg and the region around coordinates (40 °N, 160 °W) the least SSTs values, i.e. below 12.5 °C, are seen. A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California, with SSTs around 17.5 °C in the northern regions of the Gulf of California and increasing to around below 25 °C in the southern regions.

In the regions plotted, the Caribbean Sea shows temperatures above 27.5 °C along Caribbean coasts from Colombia to Belize and also near western Jamaica. The northern part of Caribbean Sea and the southern parts of the Gulf of Mexico, including waters from Veracruz in Mexico towards Cuba, southern Florida and Bahamas, show SSTs ranging from 25 °C to 27.5 °C. The remaining regions of the east coast of U.S.A., have SSTs along the coast ranging between 20 °C to 25 °C.

e. *May*

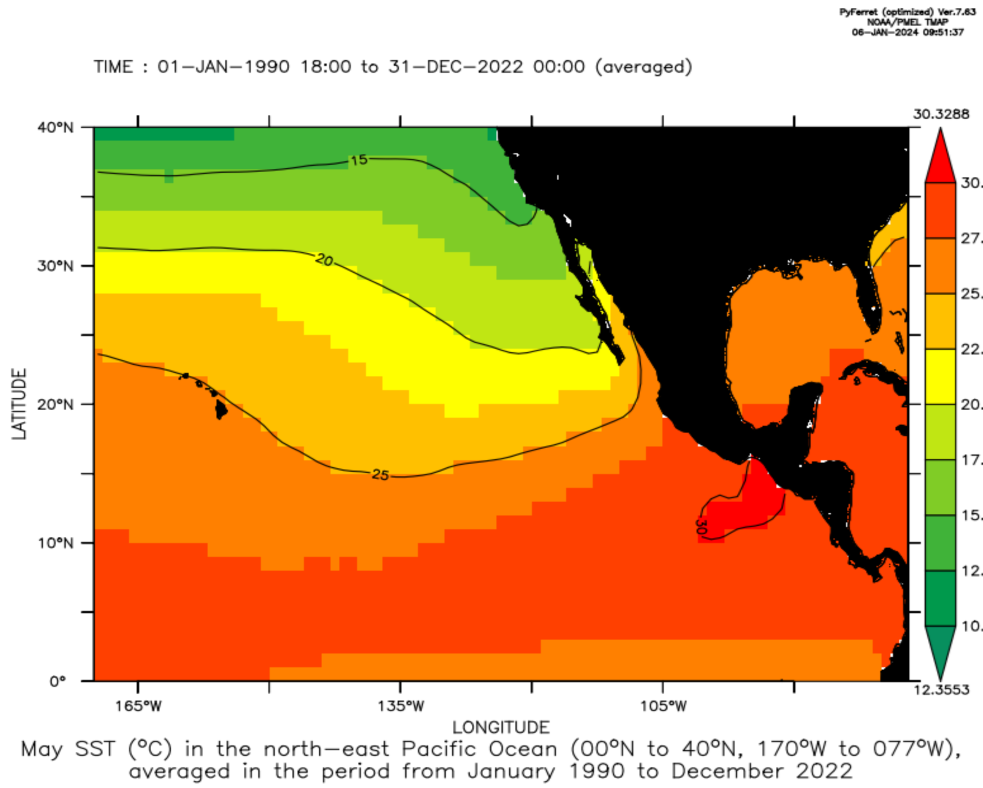


Figure 3.1.6 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every May from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every May from January 1990 to December 2022, is shown in Figure 3.1.6. The highest SST is 30.33 °C and the lowest SST value is 12.36 °C. The SSTs show a range of 17.97 °C.

The highest average values of SSTs, i.e. above 30 °C, can be seen along coast from Salina Cruz in Oaxaca to Chiapas in Mexico and further south along till the western coast of Guatemala. The SST values ranging between 27.5 °C to 30 °C are seen from the Equator to 11 °N around 170 °W longitude, extending zonally eastwards to the coast of Central America, covering the entire coast from the state of Colima to

Oaxaca in Mexico and the further south from Guatemala to the Esmeraldas in Ecuador. The SST values ranging between 25 °C to 27.5 °C are seen along the coast of Sinaloa, Nayarit, Jalisco and Colima in Mexico and extending westward in the Pacific Ocean. A similar range of SSTs are seen from coast of Ecuador to 150 °W along the Equator. The SSTs are ranging between 20 °C to 25 °C around the southern coast of Baja California Sur and extend westward in the Pacific Ocean. The SSTs ranging between 15 °C to 20 °C are seen along the coast from Baja California Sur, Baja California to the coastal waters near Los Angeles in California in U.S.A. These SSTs are seen in waters extending zonally westward in the Pacific Ocean, till at-least 170 °W. The SSTs ranging between 12.5 °C to 15 °C, are seen from the coast near Los Angeles in California to 39 °N latitude, just south of Fort Bragg. The waters having this SST range extend westward into the Pacific Ocean. The coastal water near Fort Bragg in California and also in the region between around 170 °W to 155 °W, at 40 °N latitude, show SST values below 12.5 °C. A decreasing gradient in the SSTs is seen from south to north in the Gulf of California, ranging between 17.5 °C to 27.5 °C.

In the regions plotted, the Caribbean Sea shows temperatures ranging 27.5 °C to 30 °C. In the Gulf of Mexico, parts of the Bay of Campeche and the waters to the north-west of Havana in Cuba show temperatures above 27 °C. The waters in the rest of the Gulf of Mexico are in the range between 25 °C to 27.5 °C. Such waters are also seen along the east coast of Florida and near The Bahamas. The coast of north-east Florida, Georgia, South Carolina and North Carolina states in U.S.A., show SSTs ranging between 22.5 °C to 25 °C.

f. *June:*

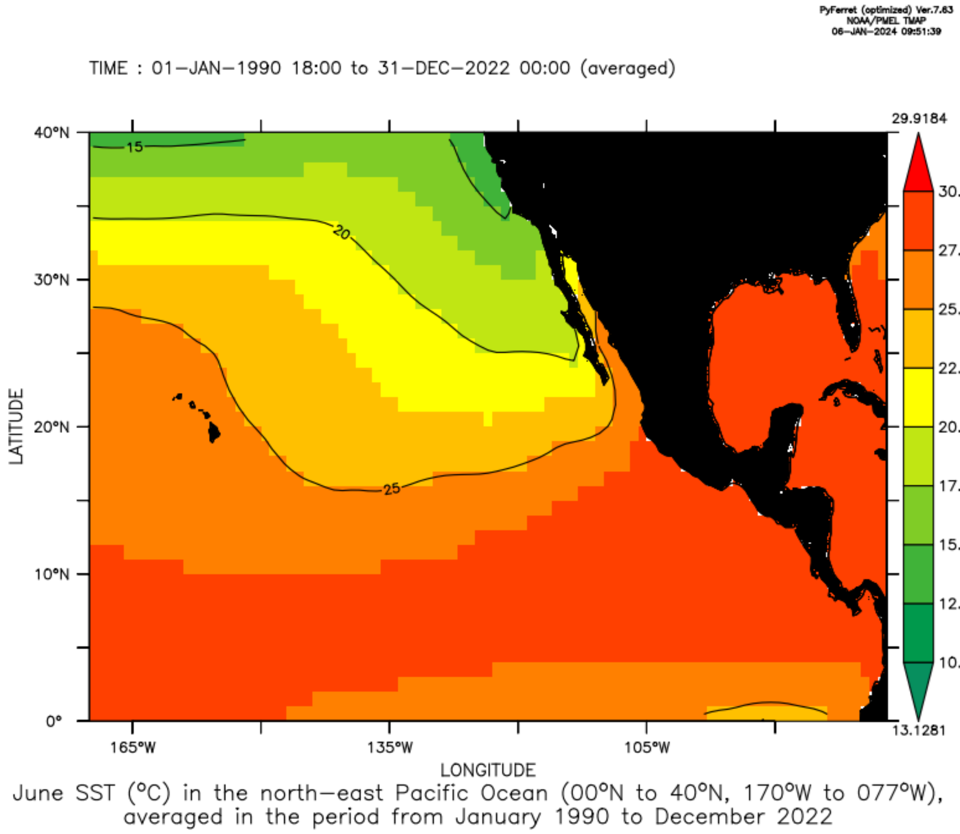


Figure 3.1.7 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every June, in the period from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every June, in the period from January 1990 to December 2022, is shown in Figure 3.1.7. The highest SST is 29.92 °C and the lowest SST value is 13.13 °C. The SSTs show a range of 16.79 °C.

The highest average values of SSTs, i.e. above 27.5 °C, can be seen from the Equator to 12 °N near170 °W longitude. These SSTs extend zonally to the coast of Central America, extending southward along the coast from the state of Jalisco to Chiapas in Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama to the west coast of Colombia. The SSTs ranging between 25 °C to 27.5 °C can be seen along coast from Sonora, southwards towards Sinaloa and Nayarit in Mexico and the waters in this SST range also extends westward in the Pacific Ocean, covering the waters around Hawaiʻi Islands. Similar range of SST are seen along the Equator from coast of Colombia and Ecuador, westward to around 145 °W in the equatorial north Pacific Ocean. A band of SSTs ranging between 20 °C to 25 °C can be seen around in the northern parts of the Gulf of California, along the coasts of Sonora, Baja California and Baja California Sur. The waters from the west coast of Baja California Sur and to its west in the Pacific Ocean, also show the above-mentioned temperature range. A patch of similar range of SST values can be seen along the Equator centred around 90 °W longitude. The SSTs values are ranging between 15 °C to 20 °C along the coast from Baja California Sur to the waters slightly to the north-west of Los Angeles in California. These SSTs in this range show a zonal band extending westward in the Pacific Ocean. The coastal waters of Fort Bragg in California have the lowest range of SST values, i.e. below 15 °C. This same range of SST values are also seen in the Pacific Ocean at 40 °N latitude, in the zonal range from around 170 °W to around 152 °W. A decreasing gradient in the SSTs are seen from south to north in the Gulf of California and also in the north Pacific Ocean region mapped.

Almost the entire plotted region of the Caribbean Sea, Gulf of Mexico and the Atlantic Ocean shows temperatures above 27.5 °C, except along the coast from north-east Florida to North Carolina, where the SST ranges between 25 °C to 27.5 °C.

g. *July:*

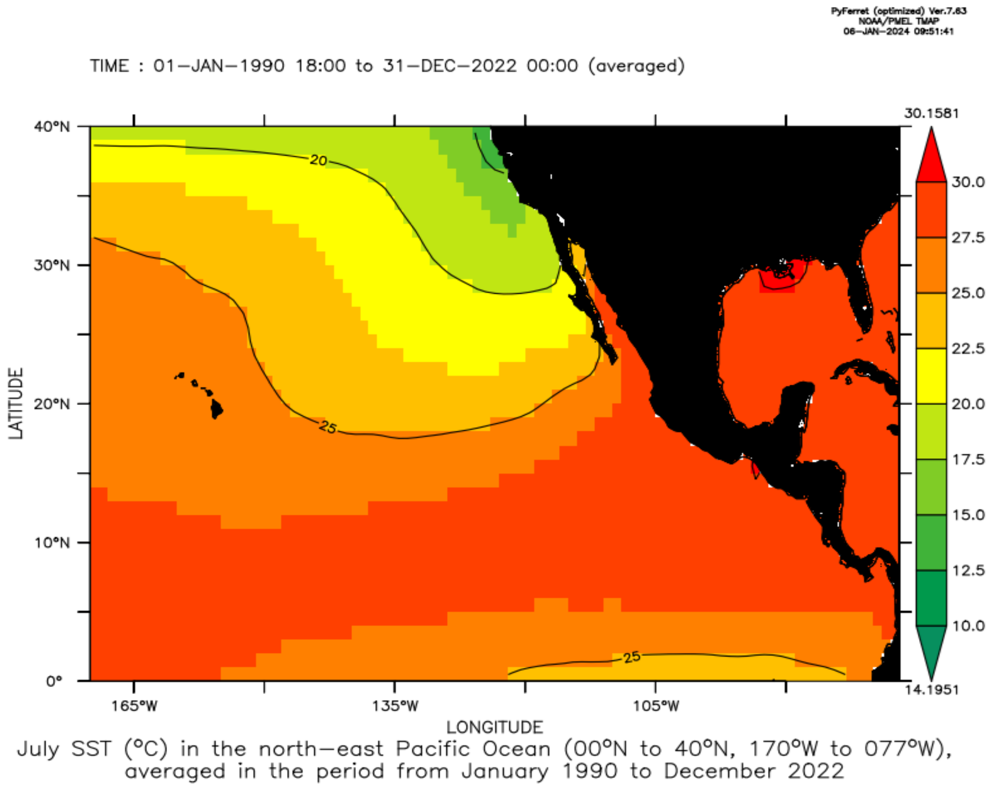


Figure 3.1.8 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every July, in the period from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every July, in the period from January 1990 to December 2022, is shown in Figure 3.1.8. The highest SST is 30.16 °C and the lowest SST value is 14.20 °C. The SSTs show a range of 15.96 °C.

The highest average SSTs value patch, i.e. above 30 °C can be seen off the coast of Chiapas in Mexico. The SST values ranging from 27.5 °C to 30 °C are seen from Equator to 14 °N at 170 °W longitude, extending westward zonally to the coasts of Baja California Sur and also Sonora in the Gulf of California in the north till Colombia in the south, with the exception of the small part of the coast near Chiapas.

SSTs in the range from 25 °C to 27.5 °C are seen along the southern coast of Baja California Sur in Mexico, in the north-central parts of the Gulf of California and along the coasts from Colombia to Ecuador. SSTs in this range also extend westward from the southern part of Baja California Sur to the Pacific Ocean, covering the waters around the Hawai‘i Islands. Similarly, there is another zonal band of these SSTs in most of the equatorial waters from coast of Colombia and Ecuador to around 155 °W longitude. The SSTs along the west coast of Baja California and Baja California Sur range between 20 °C to 25 °C and extend westward into the Pacific Ocean. Similar SST values, i.e. 22.5 °C to 25 °C, are also seen at the Equator, between around 120 °W to around 85 °W. The SSTs are ranging 15 °C to 20 °C are seen along the coast from the waters to the north of near Monterrey Bay in California in U.S.A. to Baja California. This range of SSTs extend westward into the Pacific Ocean. The lowest temperature below 15 °C can be seen along the coast to the north of Monterrey Bay in California in U.S.A.

The entire Atlantic Ocean, including the Caribbean Sea and the Gulf of Mexico shows SSTs above 27.5 °C. The waters around the region near the mouths of the Mississippi River Delta even exceed 30 °C.

h. *August*:

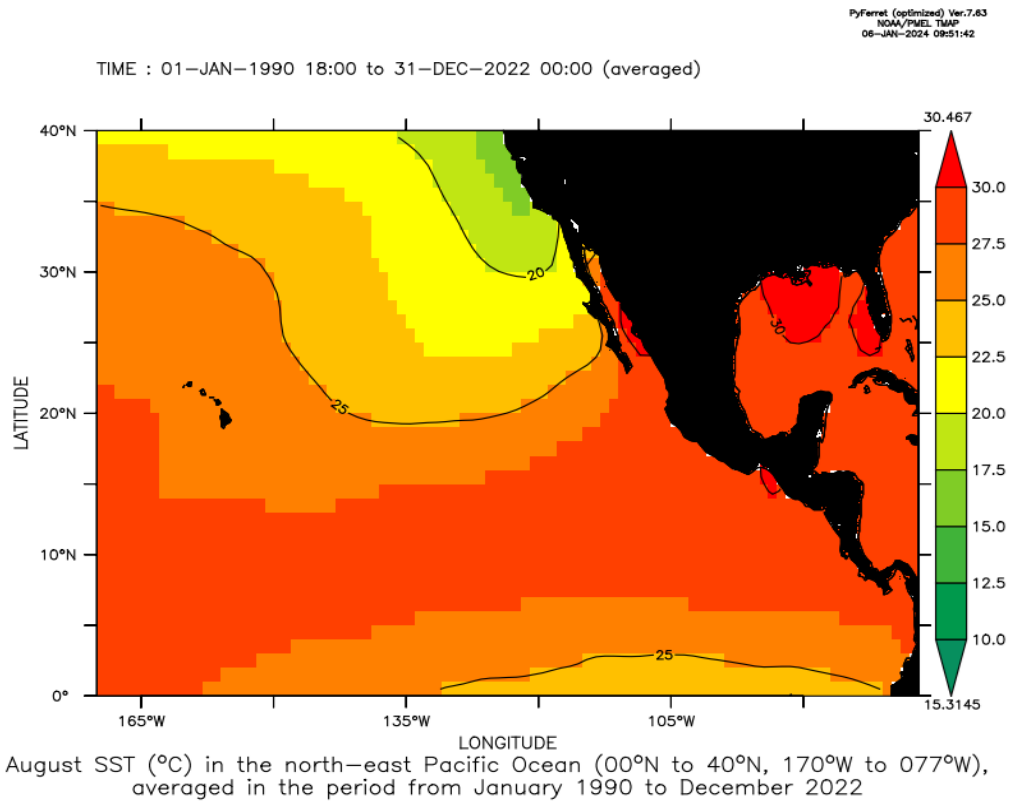


Figure 3.1.9 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every August, in the period from January 1990 to December 2022

The maps of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every August, in the period from January 1990 to December 2022, is shown in Figure 3.1.9. The highest SST is 30.47 °C and the lowest SST value is 15.32 °C. The SSTs show a range of 15.15 °C.

The highest average SSTs value, i.e. above 30 °C can be seen in Gulf of California along the coast of Sonora and Sinaloa. Such SSTs are also seen along the coast of Chiapas in Mexico. The SST values ranging from 27.5 °C to 30 °C are seen from Equator to 22 °N along 170 °W longitude. The waters with this SST range extend zonally eastward to the Baja California Sur, and then into parts of the Gulf of

California and extending southwards along the coast till Colombia, with the exception of the parts of the coasts of Sinaloa, Sonora and Chiapas mentioned earlier. Lower SSTs are seen along the coast of Baja California Sur in Mexico ranging between 25 °C to 27.5 °C and extending westward in the Pacific Ocean, including the waters around Hawai‘i Islands. Similar range of SSTs can be seen along the coast of Colombia and Ecuador, and extending zonally to around 155 °W longitude in the equatorial north Pacific Ocean. The northernmost waters in the Gulf of California also show a range of SSTs between 22.5 °C to 27.5 °C. The SSTs are ranging between 20 °C to 25 °C are seen from the coast of Baja California Sur to the waters near Los Angeles in California in U.S.A. This range of SSTs is also seen extending westward into the Pacific Ocean. Another SST patch in the same range can be seen in the equatorial water of the north Pacific, extending from around 130 °W to around 80 °W. The waters of the coast from Los Angeles in California toward the Santa Barbara County in California shows SSTs ranging between 17.5 °C to 20 °C. The lowest temperature below 17.5 °C can be seen along the further northwards along the coast of California in U.S.A.

The entire plotted Atlantic Ocean shows SSTs greater than 27.5 °C. However, the waters around the mouths of the Mississippi River Delta and the west coast of Florida shows even higher SST of greater than 30 °C.

i. *September*:

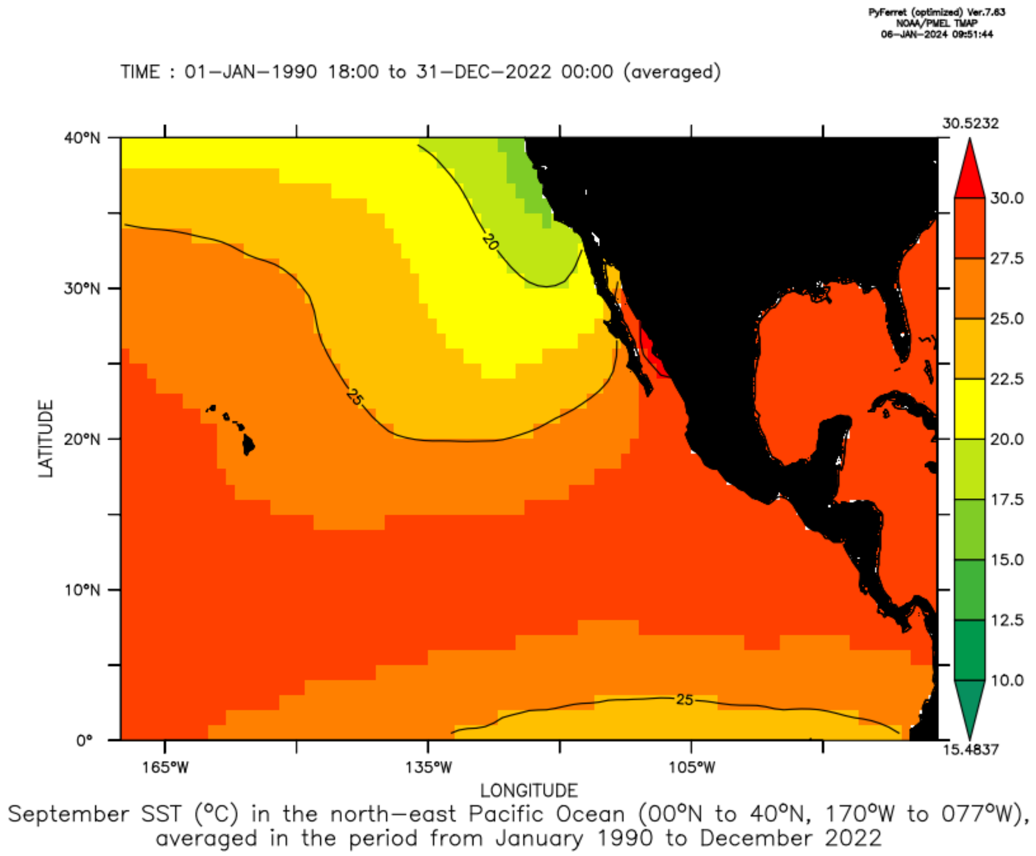


Figure 3.1.10 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every September, in the period from January 1990 to December 2022

The map of the SSTs in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged for every September in the period from January 1990 to December 2022, is shown in Figure 3.1.10. The highest SST is 30.52 °C and the lowest SST value is 15.48 °C. The SSTs show a range of 15.04 °C.

The highest average SSTs value, i.e. above 30 °C can be seen in Gulf of California along the coast of Sonora and Sinaloa in Mexico and along eastern coastal waters of Baja California Sur. The SSTs value ranging between 27.5 °C to 30 °C are seen from Equator to 26 °N along 170 °W longitude. The waters in this SST range extends zonally in the Gulf of California along the coasts of Baja California Sur and Sonora of Mexico towards the coastal waters of Colombia. The SSTs are ranging 25 °C to 27.5 °C along the western coast of Baja California Sur in Mexico and further extend westward in the Pacific Ocean around the Hawai‘i. A similar range of SSTs can be seen zonally westward along Equatorial region from coast of Colombia and Ecuador to 160 °W longitude. The SSTs ranging between 20 °C to 25 °C can be seen along the western coasts of Baja California and northern Baja California Sur. These SST range further extend westward in the Pacific Ocean. These SST range, i.e. below 25 °C, can also be seen in the Equatorial region from 81 °W to 133 °W. The coast from Santa Barbara to San Diego in California shows SSTs ranging value between 17.5 °C to 20 °C and extend westward in the Pacific Ocean. The lowest temperature, i.e. below 17.5 °C can be seen along the coast of Fort Bragg to Vandenberg Space Force Base in California in U.S.A.

The entire plotted regions in the Atlantic Ocean show similar averaged SSTs ranging between 27.5 °C to 30 °C, i.e. similar values are also seen in Gulf of Mexico, Caribbean Sea and also along coast of Georgia, South Carolina and North Carolina.

j. *October*:

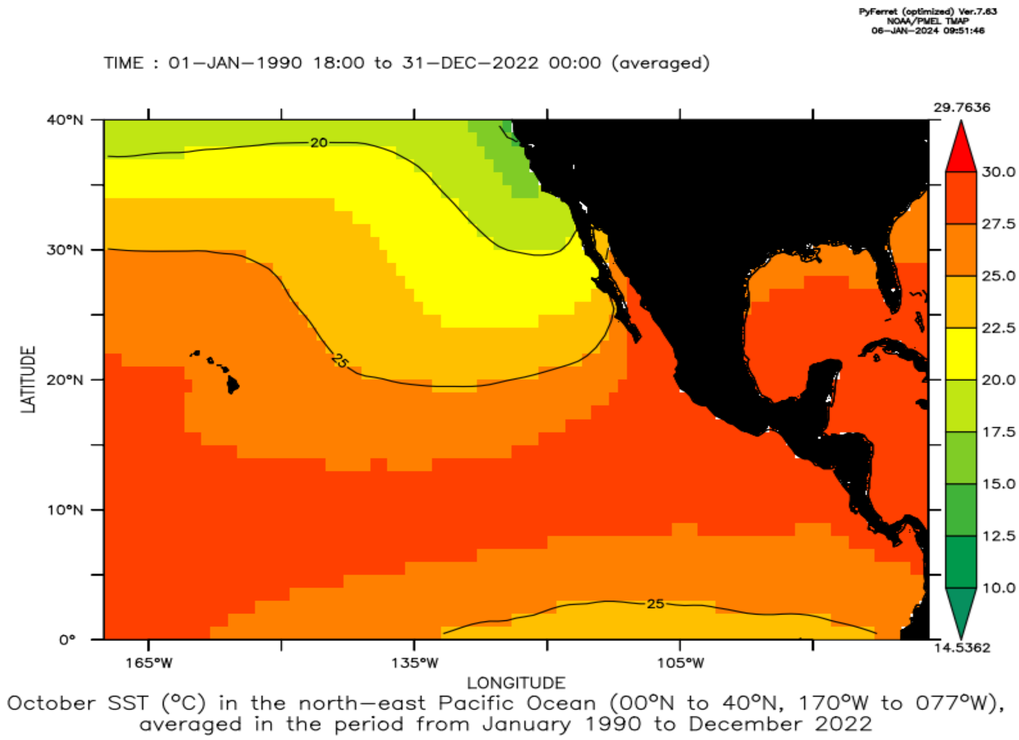


Figure 3.1.11 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every October in the period from January 1990 to December 2022

The map of the SSTs in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every October in the period from January 1990 to December 2022, is shown in Figure 3.1.11. The highest SST is 29.76 °C and the lowest SST value is 14.54 °C. The SSTs show a range of 15.22 °C.

The highest average values of SST, i.e. above 27.5 °C can be seen from the Equator to 22 ° N around 170 °W longitude. These SST values range extend zonally eastward to the coast of North America, extending from the Gulf of California in Sonora in Mexico to coastal waters of Colombia. The southern parts of Baja California Sur also show this SST range. The SSTs ranging between 25 °C to 27.5 °C can be seen along in the central part of Gulf of California and also along south-west coast of Baja

California Sur. These values are further extending westward across the Hawai‘i Islands in the Pacific Ocean. A similar range of SST are seen along the equatorial region extending from the coast of Colombia and Ecuador. The coast of Baja California and northern Baja California Sur shows SST average values ranging between 20 °C to 25 °C and further extending westward in the Pacific Ocean. A similar SST value patch, i.e. ranging from 22.5 °C to 25 °C can be seen along Equator extending zonally from around 130 °W to around 85 °W. The SST values are ranging between 17.5 °C to 20 °C along the coast of Santa Barbara in California to Ensenada in Baja California. These SST values range extend westward in the Pacific Ocean. The values of SST range between 15 °C to 17.5 °C along the coast from San Francisco to the coast near Concepcion in California. The coast to the north of San Francisco to the Cape Mendocino region in California has the least SSTs values, i.e. below 15 °C. A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California.

In the regions plotted in the Atlantic Ocean, the Caribbean Sea shows temperatures ranging 27.5 °C to 30 °C. Similar values are seen in the southern parts of the Gulf of Mexico, along the east coast of Mexico from Tamaulipas, Veracruz, Tabasco, Campeche, Yucatán and Quintana Roo, and further south in Belize, Guatemala, Honduras, Nicaragua, Costa Rica and Panama. The southern parts off the coast of Florida also generally show SSTs in the above-mentioned range. The coast of Texas, Louisiana, Mississippi, Alabama, north Florida show SSTs ranging between 25 °C to 27.5 °C. A similar value range are also seen along coast Georgia, North Carolina and South Carolina in Atlantic Ocean.

k. *November:*

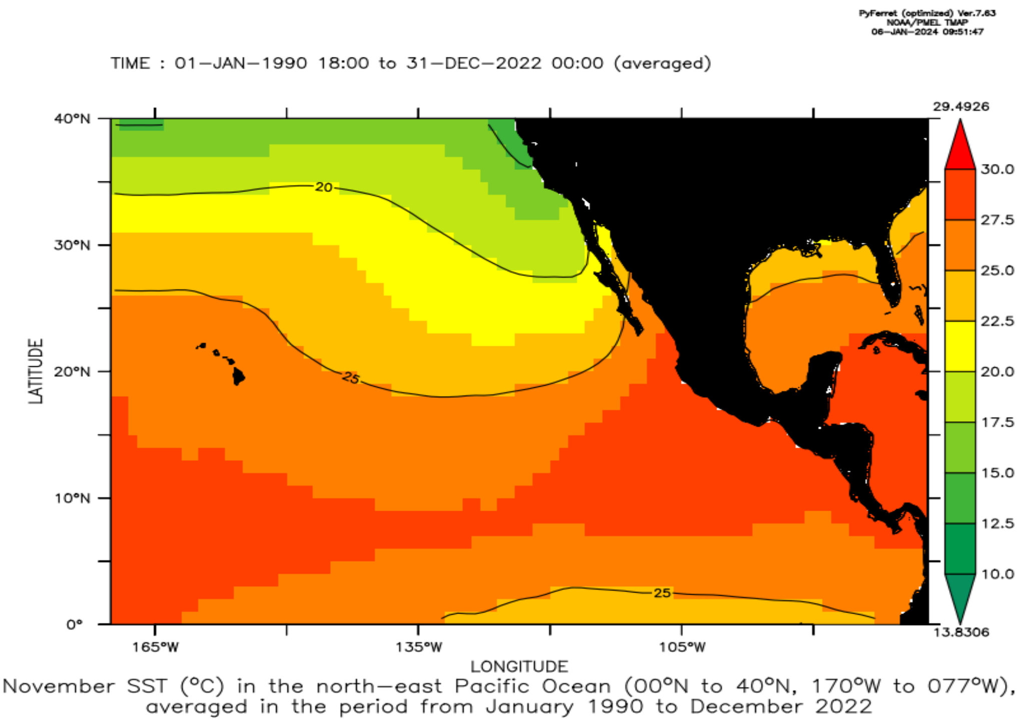


Figure 3.1.12 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every November in the period from January 1990 to December 2022

The map of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every November in the period from January 1990 to December 2022, is shown in Figure 3.1.12. The highest SST is 29.49 °C and the lowest SST value is 13.83 °C. The SSTs show a range of 15.66 °C.

The highest average values of SSTs, i.e. above 27.5 °C can be seen in shape of hourglass from the Equator to 18 °N along 170 °W longitude. These SST range values extend zonally to the coast of North America, from Sinaloa to Chiapas in Mexico and further southwards to Colombia. The SST values ranging between 25 °C to 27.5 °C can be seen near the mouth of Gulf of Mexico along southern coast of Baja California

Sur and coast from Sonora to Sinaloa in Mexico. This SST range values extend westward in the Pacific Ocean around the Hawai'i Islands. A similar range of SST is seen along the equatorial region from the coast of Colombia and Ecuador arching towards the west in the equatorial Pacific Ocean till 163 °W. The coast of Baja California and north Baja California Sur shows values ranging from 20 °C to 25 °C. The values in this range of SSTs extend westward in the Pacific Ocean. SSTs ranging from 22.5 °C to 25 °C can be seen along Equator from around 81 °W to 163 °W. The coast from a little south of Monterey Bay in California to the northern regions of Baja California shows averaged SST ranging from 15 °C to 20 °C and this SST range is seen extending westward in the Pacific Ocean. The coast from Monterey Bay in California northward past San Francisco, Fort Bragg towards the Cape Mendocino region has the least SST values, with SSTs in the range between 12.5 °C to 15 °C. This range of SST values can also can be seen at around 40 °N near around 165 °W longitude. A decreasing gradient in the SSTs, ranging from about 27.5 °C to 20 °C, are also seen from south to north in the Gulf of California.

In the regions plotted in the Atlantic Ocean, the Caribbean Sea shows temperatures ranging 27.5 °C to 30 °C. The SST values are ranging between 25 °C to 27.5 °C along the eastern coast of Mexico from Quintana Roo, Yucatán, Campeche, Tabasco, Veracruz to Tamaulipas and also along the southern coast of Florida. The coast from the north-eastern part of Tamaulipas in Mexico to the states of Texas, Louisiana, Mississippi, Alabama and northern Florida in U.S.A. show SSTs below 25 °C, with the SSTs to the east of the mouths of the Mississippi River Delta, near Louisiana, Mississippi and Alabama, being below 22.5 °C. SSTs ranging between 22.5 °C and 25 °C are also seen along coast from north-eastern Florida, Georgia, North Carolina to South Carolina in Atlantic Ocean.

l. *December:*

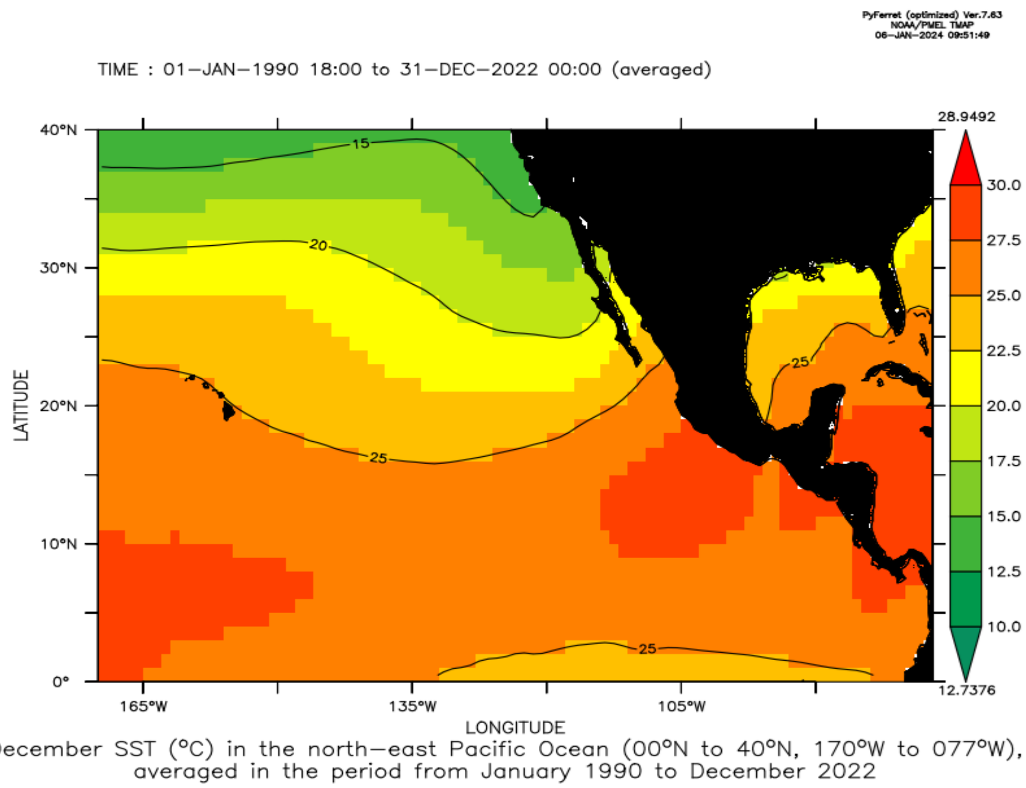


Figure 3.1.13 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every December in the period from January 1990 to December 2022

The map of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every December in the period from January 1990 to December 2022, is shown in Figure 3.1.13. The highest SST is 28.95 °C and the lowest SST value is 12.74 °C. The SSTs show a range of 16.21 °C.

The highest average values of SST, i.e. above 27.5 °C can be seen from the Equator to 11° N at around 170 ° W longitude. A similarly SST ranging region also can be seen in 3 areas along the western coast of North America., i.e. on the coast of Colima to Oaxaca in Mexico. Further from Chiapas in Mexico to Nicaragua and from Costa Rica to Colombia. The SST values ranging between 25 °C to 27.5 °C, are seen meridionally extending from 11 °N to 23 °N at 170 °W longitude. They zonally extend to the coast of North America, covering the remaining region of the coast from Sinaloa in Mexico to Ecuador. The Hawai'i Islands in the Pacific Ocean are near the isotherm of 25 °C. The SST values are ranging between 20 °C to 25 °C can be seen in the waters of Gulf of California from coast of Sonora to Sinaloa in Mexico and also along most of the coast of Baja California Sur and the south-east coast of Baja California. This range of SST values extend westward in the Pacific Ocean. SSTs ranging between 22.5 °C to 25 °C are seen in the equatorial North Pacific between around 84 °W to around 133 °W. The coast from the north-western Baja California Sur to Santa Barbara in California shows SST average values ranging from 15 °C to 20 °C and extending zonally westward in the Pacific Ocean. The coast from Concepción towards Cape Mendocino in California in U.S.A. shows averaged SSTs ranging from 12.5 °C to 15 °C. These values of SST extend westward in the Pacific Ocean. A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California, with SSTs ranging between 25 °C to 17.5 °C.

In the regions plotted in the Atlantic Ocean, the Caribbean Sea shows temperatures above 27.5 °C along the coast from Colombia to Quintana Roo in Mexico, except along parts of the coast of Belize where the SST ranges between 25 °C to 27.5 °C. The SST values ranging above 27.5 °C are seen in the southern regions of the Caribbean Sea, and northwards up to around 20 °N, near the Cayman Islands, Cabo Cruz in southern Cuba and besides also Jamaica. The northern part of Caribbean Sea to the south of Cuba, Nueva Gerona in Cuba to the coast of Quintana Roo in Mexico show SSTs ranging from 25 °C to 27.5 °C. Similar range of values are seen in the southern parts of the Gulf of Mexico, including the coastal waters from Quintana Roo to Veracruz in Mexico and also the southern tip of Florida and The Bahamas. The east coast of Mexico, from Veracruz to Tamaulipas and into southern Texas in U.S.A., shows temperatures ranging between 22.5 °C to 25 °C. The SSTs are in the range from 20 °C to 22.5 °C from the coast of Texas to just north of Tampa Bay in Florida in U.S.A, except near the coastal waters to the west, and also to east, of the mouth of the Mississippi River Delta, where the SSTs are between 17.5 °C to 20 °C. The SSTs range between 20 °C to 22.5 °C, also from the coast of north-east Florida, Georgia, North Carolina to South Carolina.

The SST Averaged Season-wise from January 1990 to December 2022

a. *Boreal Spring Season:*

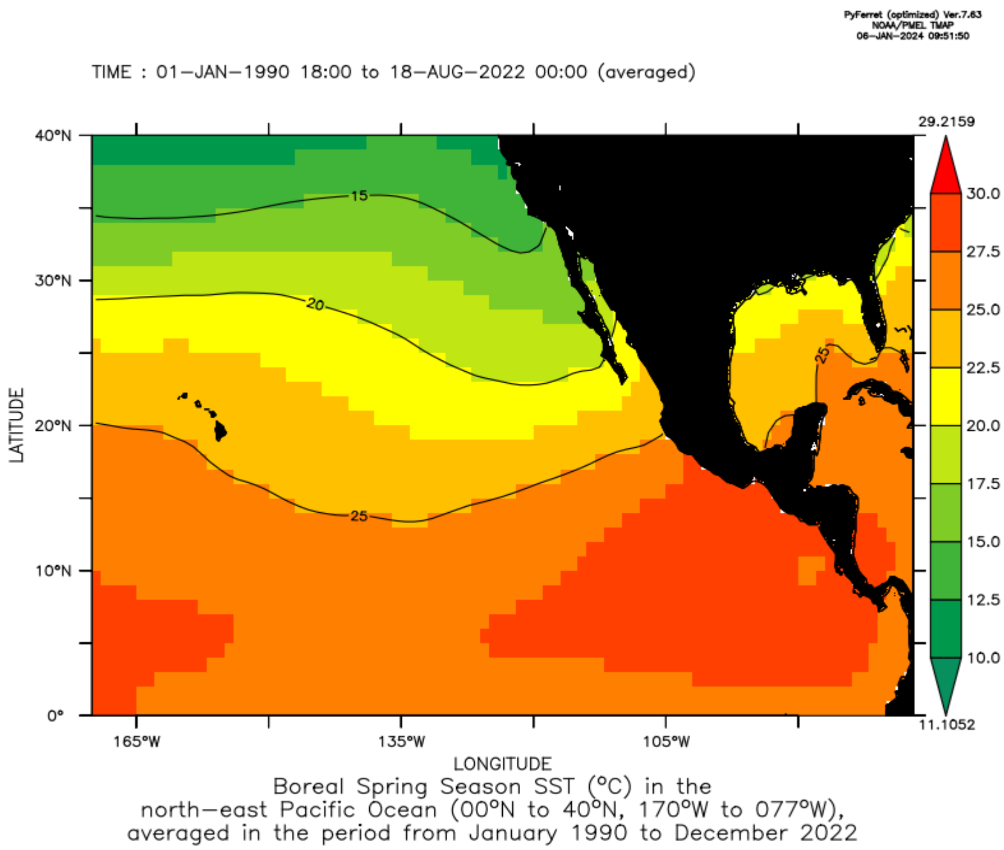


Figure 3.1.14 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Autumn Season from January 1990 to December 2022

The map of the SSTs in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Spring Season from January 1990 to December 2022, is shown in Figure 3.1.14. The highest SST is 29.22 °C and the lowest SST value is 11.11 °C. The SSTs show a range of 18.11 °C.

The highest average values of SST, i.e. above 27.5 °C, can be seen from the Equator to 10° N at around 170 ° W. A similar range of SSTs are also along the coast of Mexico from the state of Michoacán and extending southwards to Panama. This region extends westward in the Pacific Ocean, tapering at around (6 °N, 125 °W). The SST values ranging from 25 °C to 27.5 °C, are seen extending meridionally from the 10 °N to around 20 °N at around 170 °W longitude and extending zonally eastwards to the coast of the American landmass. SSTs in this range are found in the coastal waters from Colima to Michoacán in Mexico and also from Panama to Ecuador. The waters off Costa Rica show a small patch of SSTs in the same range from 25 °C to 27.5 °C. A zonal band of SSTs ranging between 20 °C to 25 °C can be seen along the coast of Mexico from Jalisco to Sonora. This SST range extends westward passing along the southern coast of Baja California Sur into the Pacific Ocean and also include the waters around the Hawai‘i Islands. Lower SSTs are seen northwards. The coast from central Baja California Sur to near Los Angeles in California in U.S.A. shows SST average values ranging from 15 °C to 20 °C. These too extend westward in the Pacific Ocean. The coastal waters from further north from near Los Angeles in California, Concepcion, Monterrey Bay, San Francisco to The Gulf of the Farallones all in California in U.S.A. shows averaged SSTs ranging from 12.5 °C to 15 °C. This range of SST values also extend zonally westward into the Pacific Ocean. The waters further north of The Gulf of the Farallones, passing Fort Bragg towards the Cape Mendocino region in California in U.S.A., have the least SSTs values seen, i.e. below

12.5 °C. Another patch of SSTs with a similar range are seen near 40 °N, between 170 °W to 140 °W in the Pacific Ocean.

In the regions plotted, the Caribbean Sea shows temperatures above 25 °C, with SST above 27.5 °C along the Caribbean coast from Panama to Nicaragua. The temperatures are lower in the Gulf of Mexico, with temperatures decreasing from 27.5 in its southern regions to above 17.5 °C to the west and east of the mouths of the Mississippi River Delta. The averaged SSTs decrease northward in the range between 25 °C to 17.5 °C along the Atlantic coast of Florida, Georgia, North Carolina and South Carolina.

b. *Boreal Summer Season:*

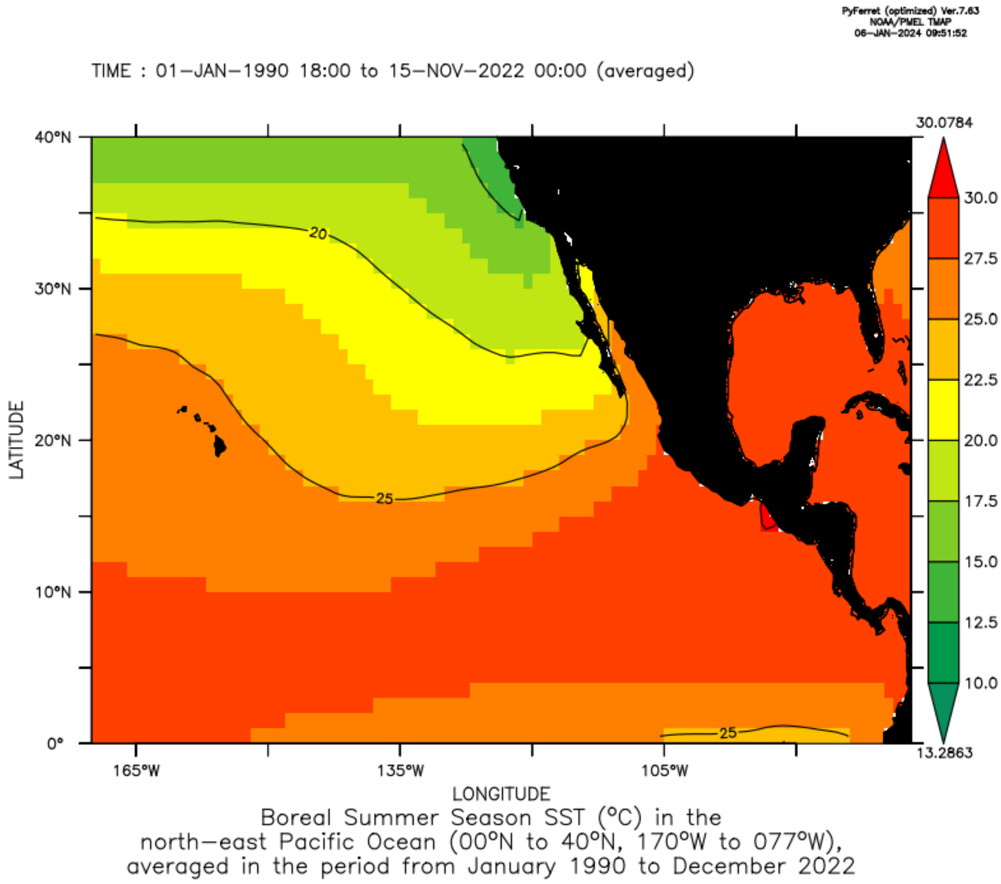


Figure 3.1.15 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season from January 1990 to December 2022

The map of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 70 °W), averaged every Boreal Summer Season from January 1990 to December 2022, is shown in Figure 3.1.15. The highest SST is 30.08 °C and the lowest SST value is 13.29 °C. The SSTs show a range of 16.79 °C.

The highest average SST values, i.e. above 30 °C, can be seen along the coast of Chiapas in Mexico and Guatemala. The SST values ranging between 27.5 °C to 30 °C are seen from the Equator to 12 °N at 170 °W longitude, and these SSTs extend zonally eastward to the coast of Jalisco in Mexico and further southwards to Colombia except around some parts along the coast of Chiapas in Mexico and Guatemala where SST range is highest. The SST values are ranging between 25 °C to 27.5 °C along the coast of Sonora to Jalisco in Mexico and also along parts of the eastern coastal waters of Baja California Sur in the Gulf of California. This range of SSTs extends westwards in the Pacific Ocean and also include the waters around the Hawai'i Islands. A similar range of SSTs can be seen also can be seen along the equatorial region from coast of Colombia and Ecuador to around 155 °W longitude. However, SSTs ranging between 22.5 °C to 25 °C are also seen along the Equator from around 84 °W to 105 °W. The west coast Baja California Sur and around its southernmost tip show SST values ranging between 20 °C to 25 °C and these too are seen extending westward in the Pacific Ocean. The SST values along the coast of Punta Prieta in Baja California Sur to northwards along coastal waters of Baja California in Mexico, Los Angeles in California to Oso Flaco in San Luis Obispo County in California in U.S.A. shows SSTs ranging between 15 °C to 20 °C. This SST range also extends zonally westwards into the Pacific Ocean. The lowest temperature, i.e. below 15 °C, can be seen along the Californian coast from Pismo Beach in San Luis Obispo Bay, past Monterey Bay, San Francisco, Fort Bragg to the Cape Mendocino region. A decreasing gradient in the SSTs are also seen from south to north in the Gulf of California, with SSTs ranging between 27.5 °C to 20 °C.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico and the Caribbean Sea shows average values of SST ranging between 27.5 °C to 30 °C everywhere. The coast along north-east Florida, Georgia, South Carolina and North Carolina in North Atlantic Ocean shows SSTs in the range from 25 °C to 27.5 °C.

c. *Boreal Autumn Season:*

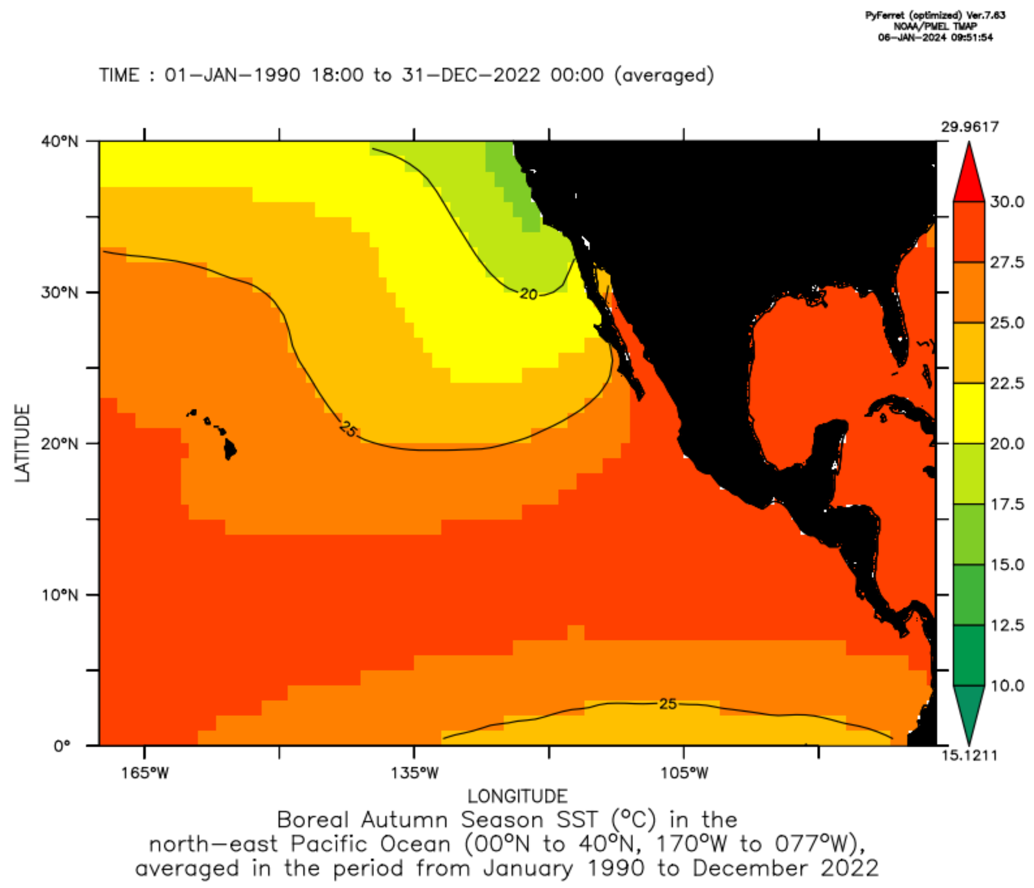


Figure 3.1.16 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Autumn Season from January 1990 to December 2022

The map of the SST in the north-east Pacific Ocean (0° N to 40 °N, 170 °W to 77 °W), averaged every Boreal Autumn Seasons from January 1990 to December 2022, is shown in Figure 3.1.16. The highest SST is 29.96 °C and the lowest SST value is 15.12 °C. The SSTs show a range of 14.84 °C.

The highest average value SSTs, i.e. above 27.5 °C, are seen from the Equator to 23 °N along 170 °W longitude. These SST extend zonally eastward to the coast of the American landmass. The coast from Sonora in Mexico to Colombia shows SSTs in this range. The waters in the southern Gulf of California, along the south-eastern coast of Baja California to past the southern tip Baja California Sur in Mexico also show the SSTs in the above-mentioned range. The SSTs are ranging between 25 °C to 27.5 °C along the western coast of Baja California Sur and arching westward into the Pacific Ocean and also surround the waters of the Hawai‘i Islands. A similar SST range can be seen along the equatorial region from coast of Colombia and Ecuador arching to around 160 °W longitude. SSTs ranging between 22.5 °C to 25 °C are seen along Equator from around 81 °W to around 133 °W longitude. The coast of Baja California and north-western Baja California Sur in Mexico shows SST ranging between 20 °C to 25 °C. This range of SST values extend westward in the Pacific Ocean. The SST values ranging between 17.5 °C to 20 °C can be seen along the coast from Ensenada in Baja California in Mexico to Oso Flaco in San Luis Obispo County in California in U.S.A. The lowest range of SSTs between 15 °C to 17.5 °C can be seen along the coast from Pismo Beach in San Luis Obispo County in California in U.S.A., past the Monterey Bay, The Gulf of the Farallones, Fort Bragg to the Cape Mendocino region, all in California in U.S.A. The Gulf of California shows an SST gradient decreasing from south to north with SSTs ranging below 30 °C to 22.5 °C.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico and the Caribbean Sea show SSTs ranging between 27.5 °C to 30 °C, over the entire plotted region. The entire plotted Atlantic Ocean region shows SSTs in the range between 27.5 °C to 30 °C, except for the waters near the coast of North Carolina in U.S.A. which show SSTs in the range between 25 °C to 27.5 °C.

d. *Boreal Winter Season:*

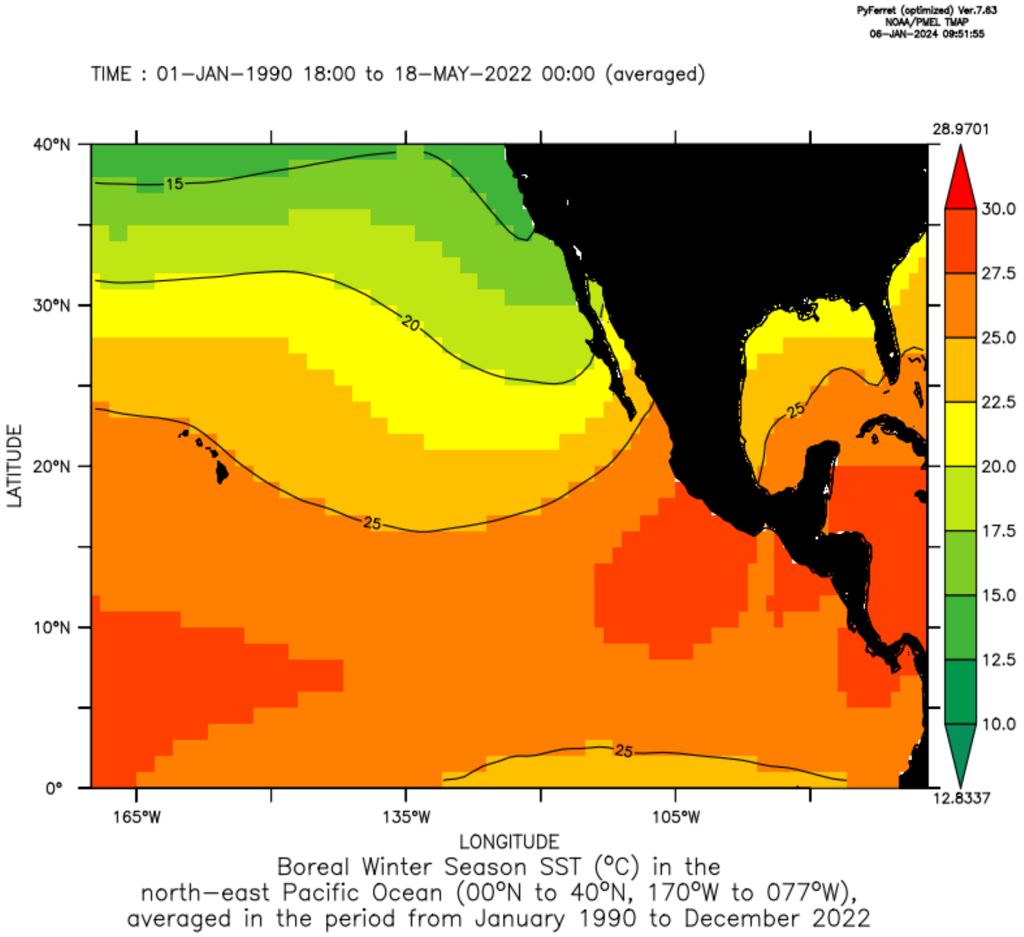


Figure 3.1.17 SST (°C) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season from January 1990 to December 2022

The map of the SST in the north-east Pacific Ocean (0 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season from January 1990 to December 2022, is shown in Figure 3.1.17. The highest SST is 28.97 °C and the lowest SST value is 12.83 °C. The SSTs show a range of 16.14 °C.

The highest average values of SSTs, i.e. above 27.5 °C, are seen from the Equator to 12° N at 170 ° W longitude and extending zonally and taper eastwards in the Pacific Ocean at around 139 °W. Similar SST values are also along three regions along the coast of North America, i.e. along the coast of Mexico from the state of Colima to Salina Cruz in Oaxaca, Chiapas in Mexico to Nicaragua and along the coast of Costa Rica to Colombia. The SST values ranging between 25 °C to 27.5 °C, are seen meridionally extending from 12 °N to 24 °N at 170 °W longitude. They zonally extend to the coast of the American landmass, covering the remaining region of the coast from Sinaloa in Mexico to Ecuador. The Hawai'i Islands have waters with SSTs close to the 25 °C isotherm. SSTs ranging between 22.5 °C to 25 °C can be seen in the equatorial region between the longitudes from around 86 °W to 133 °W. A zonal band of SSTs ranging between 20 °C to 25 °C can be seen along the eastern coast of Baja California and along nearly the entire coast of Baja California Sur. This SST range is also seen in Gulf of California along the western coast of Sonora and Sinaloa in Mexico. This SST range extend westward in the Pacific Ocean. The coast from Punta Prieta in Baja California Sur in Mexico to Oso Flaco in San Luis Obispo County in California in U.S.A. shows SSTs ranging between 15 °C to 20 °C. The values in this SST range value extend westward into the Pacific Ocean. The coast from the San Luis Obispo County, past San Francisco, Fort Bragg to the Cape Mendocino region in California in U.S.A. has the least SST values ranging between 12.5 °C to 15 °C. A decreasing gradient in the SSTs is also seen from the south to the north in the Gulf of California. The SSTs range between 27.5 °C to 17.5 °C.

In the regions plotted in the Atlantic Ocean, the Caribbean Sea shows temperatures above 27.5 °C along the coast from Colombia to Quintana Roo in Mexico, except along parts of the coast of Belize, Guatemala and Honduras, where the SST ranges between 25 °C to 27.5 °C. The SST values ranging above 27.5 °C are seen in the southern regions of the Caribbean Sea, and northwards up to around 20 °N, near the Cayman Islands, Cabo Cruz in southern Cuba and besides also Jamaica. The northern part of Caribbean Sea to the south of Cuba, Nueva Gerona in Cuba to the coast of Quintana Roo in Mexico show SSTs ranging from 25 °C to 27.5 °C. Similar range of values are seen in the southern parts of the Gulf of Mexico, including the coastal waters from Quintana Roo to Veracruz in Mexico and also the southern tip of Florida and The Bahamas. The east coast of Mexico, from Veracruz to Tamaulipas and to the coast of extremely southern Texas in U.S.A., shows temperatures ranging between 22.5 °C to 25 °C. This range of SSTs is also seen along parts of the south-western coast of Florida and also along parts of its eastern coast. The SSTs are in the range from 20 °C to 22.5 °C are seen from the coast of Texas, Louisiana, Mississippi, Alabama to the north-western coast of Florida in U.S.A. The SSTs also range between 20 °C to 22.5 °C, along the coast from north-east Florida, Georgia, South Carolina to North Carolina.

3.2 MAPS OF SLOPES FOR SEA SURFACE TEMPERATURE (SST) TRENDLINES AVERAGED FROM JANUARY 1990 TO DECEMBER 2022

3.2.1 The map of slopes for SST trendlines averaged for the Entire Time Period from January 1990 to December 2022

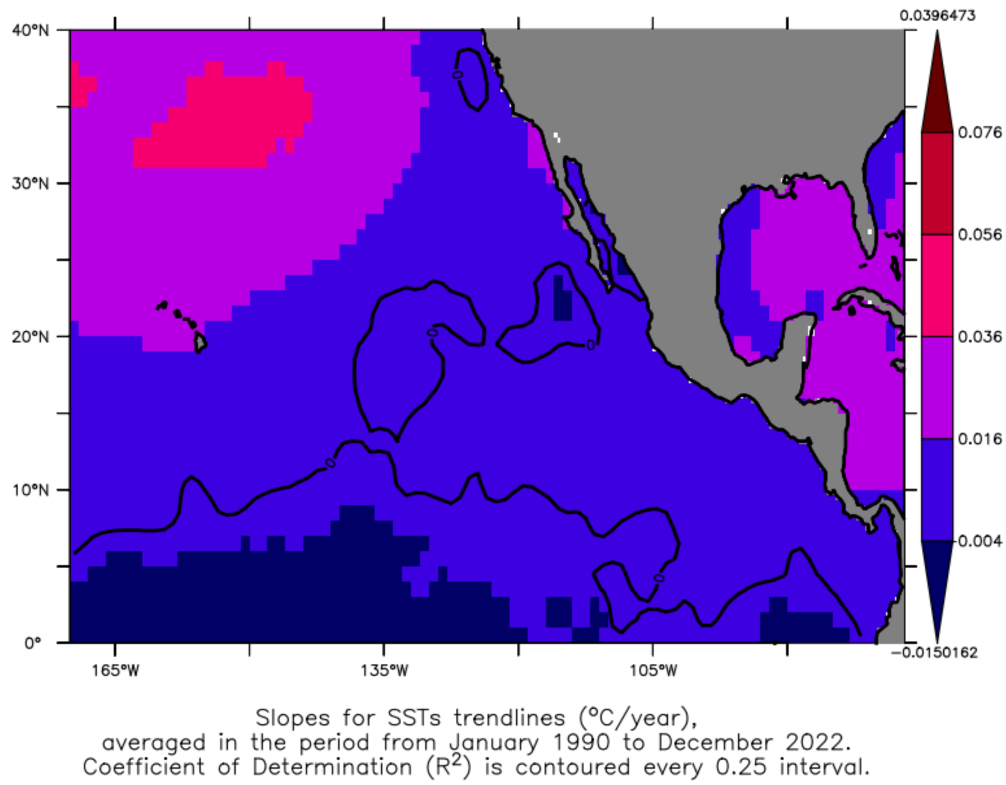


Figure 3.2.1 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged for the entire time period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged in the entire time period from

January 1990 to December 2022 is shown in Figure 3.2.1. The slopes for SSTs trendline are ranging from -0.015 °C/year to 0.040 °C/year.

The highest positive values of slope of SSTs trendline i.e. above 0.036 °C are seen along the deep waters of Pacific Ocean centred around 35 °N and 115 °W, similarly a patch also can be seen around 35 ° N to 38 °N and 170 °W longitude. The lowest negative value of slope of SSTs trendlines i.e. below 0.004 °C are seen in waters along Gulf of California and south-westward from coast of Baja California Sur. A similar range of values also can be seen in the Equatorial region along off coast waters of Ecuador centred around 90 °N longitude and further extending westward from around 110 °W till 170 °W. Most of the Pacific Ocean shows positive trends.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico's eastern waters along the coast of U.SA show values of SSTs trendline a bit lower i.e. below 0.016 °C where-else western waters show higher values of SSTs trendlines i.e. above 0.016 °C. This value is also seen around the waters of Cuba and The Bahamas. A similar range is also seen in majority regions of Caribbean Sea except around the coast of Panama and Santa Cruz del Sur in Cuba where it is ranging below 0.016 °C. Ranges below 0.016 °C are also seen north-western coast of Florida, Georgia, South Carolina and North Carolina.

3.2.1 The Maps of slopes for SST Trendlines Averaged Month-wise from January 1990 to December 2022

a. *January*

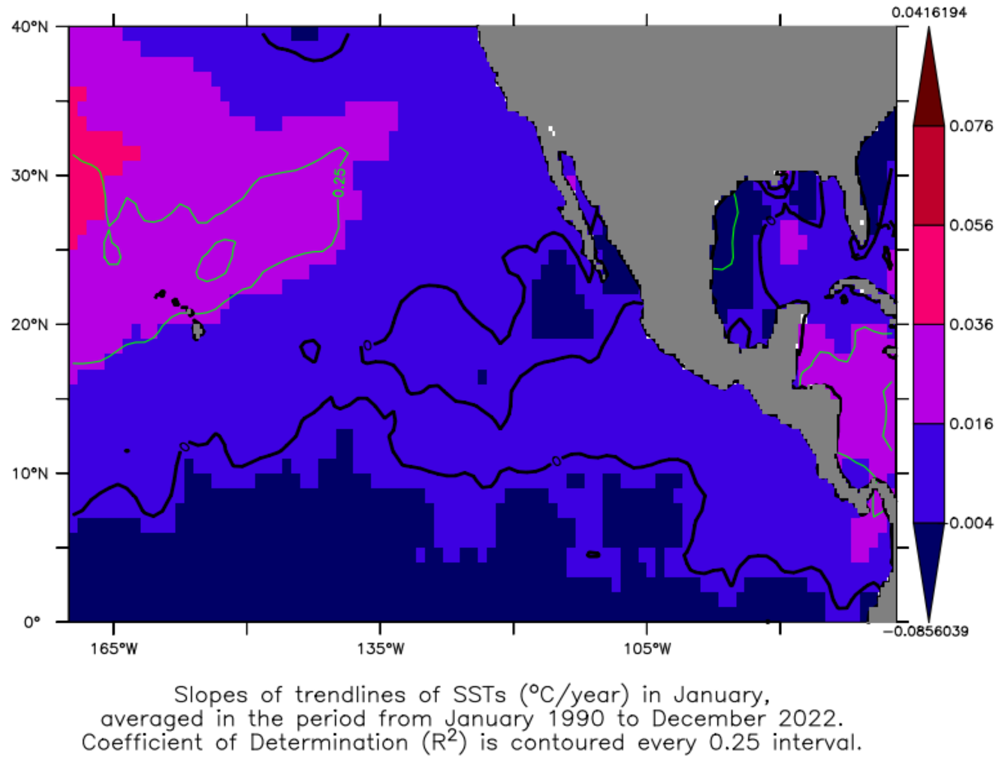


Figure 3.2.2 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every January in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every January in the period from January 1990 to December are shown in Figure 3.2.2. The slopes for SSTs trendline are ranging from -0.086 °C/year to 0.041 °C/year.

The highest positive values in slope of trendlines of SSTs i.e. above 0.036 °C can be around the waters at 170 °W longitude from 25 °N to 36°. The lowest negative value of slope of trendlines of SSTs trendlines are seen in the mouth region of Gulf of California and westward from the coastal waters off Baja California Sur. A similar range of values also can be seen in the Equatorial region along coastal waters of Ecuador and extending westward in the Pacific Ocean till 170 °W. A similar range of SST trendline is also seen centred at 40 °N and 137 °W. Most of the part of Equatorial Pacific Ocean shows positive trends. The Coefficient of Determination (R^2) values are above 0.25 in the deep waters centred around the coordinates at (23 °N, 158 °W).

In the regions plotted in the Atlantic Ocean, in the Gulf of Mexico, the east coast of Mexico along with Texas and Louisianna of U.S show lowest SSTs trendline ranging between -0.86 °C/year to 0.004 °C/year. A similar range is also seen around the coasts of Alabama and southern-east extension of Florida to Georgia, South Carolina and North Carolina. Most part of the Caribbean Sea shows SSTs trendlines ranging between 0.016 °C to 0.036 °C except the coats of Costa Rica and Panama where the ranging is below 0.016 °C. The Coefficient of Determination (R^2) value is above 0.25 along east coast of U.S.A in Gulf of Mexico and in majority region of the Caribbean Sea.

b. *February*

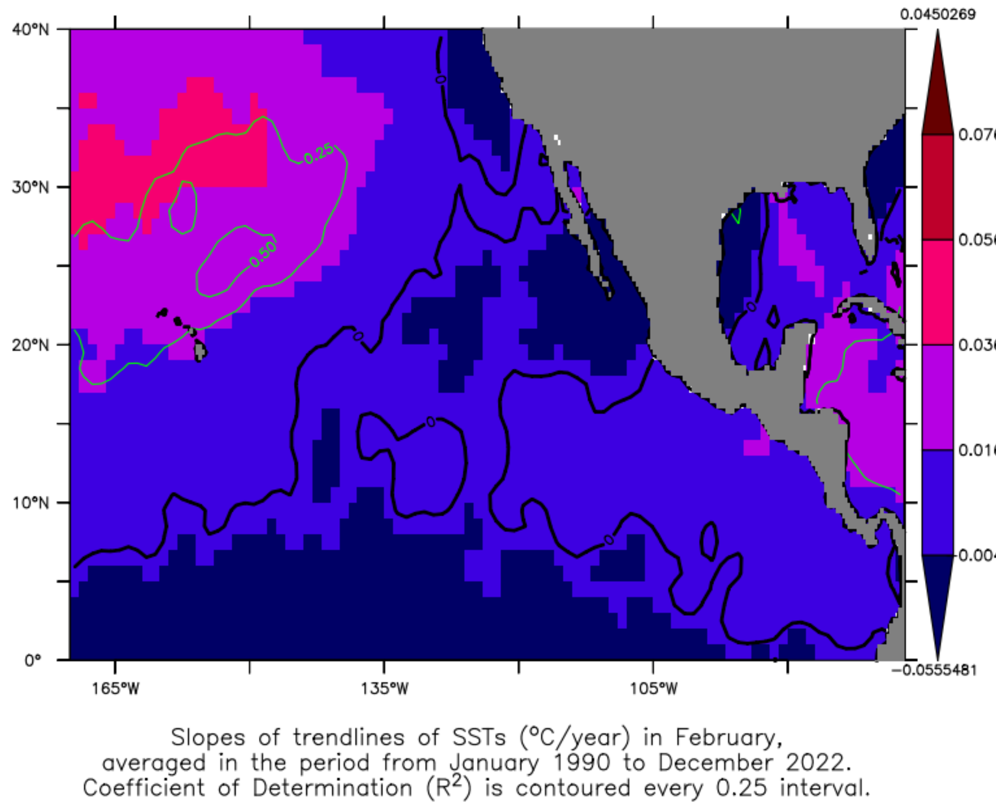


Figure 3.2.3. Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every February in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every February in the period from January 1990 to December 2022 is shown in Figure 3.2.3. The slopes for SSTs trendline are ranging from -0.056 °C/year to 0.046 °C/year.

The highest positive values of slope of trendline of SSTs i.e. above 0.036 °C are seen in the waters of Pacific Ocean around the region 26 °N to 36 °N latitude and 140 °W to 170 °W longitude. The lowest negative value of slope of trendlines of SSTs are seen along the coastal waters of California in U.S and coastal waters around on east-west of Baja California Sur. A similar range of values also can be seen in the Equatorial region extending from 88 °W to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 in the deep waters centred around the coordinates at (23 °N, 158 °W)

In the regions plotted in the Atlantic Ocean, in the Gulf of Mexico, the east coast of Mexico in Tamaulipas and Veracruz along with Texas and Louisianna of U.S show lowest values of slopes of trendline of SSTs ranging between -0.056 °C to 0.004 °C. A similar range is also seen around the north-eastern coasts of Florida, Georgia, South Carolina and North Carolina. Most part of the Caribbean Sea shows SSTs trendlines ranging between 0.016 °C/year to 0.036 °C/year.

The Coefficient of Determination (R^2) values are above 0.25 around the coast of Texas and in most region of Caribbean Sea.

c. *March*

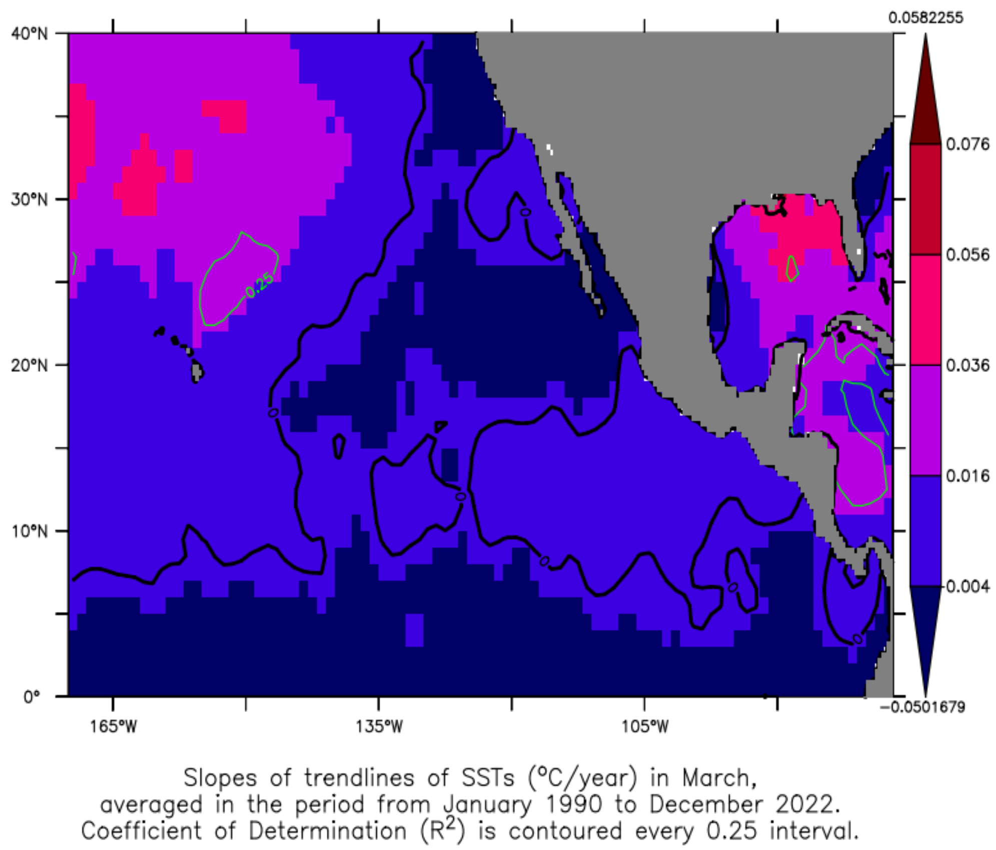


Figure 3.2.4 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every March in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every March in the period from January 1990 to December 2022 is shown in Figure 3.2.4. The slopes for SSTs trendline are ranging from -0.050 °C/year to 0.058 °C/year.

The highest positive values of slope of trendlines of SSTs i.e. above 0.036 can be seen in patches in the waters of Pacific Ocean between the region 29°N to 37 °N latitude and 150°W to 170 °W longitude. The lowest negative value of slope of trendlines of SSTs are seen along the coastal waters of California in U.S. This range slope of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from Sonora to Nayarit and extending south-westward in the Pacific till 145 °W. A similar range of values also can be seen in the Equatorial region extending westward along coast of Ecuador to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 can be seen in a patch centred around the coordinates at (25 °N, 150 °W).

In the regions plotted in the Atlantic Ocean, in the Gulf of Mexico, the highest SST range can be seen along the Mississippi River Delta to the western coast of Florida. The east coast of Mexico in Tamaulipas and Veracruz show lowest SSTs trendline ranging between -0.056 °C/year to 0.004 °C/year. A similar range is also seen around the north-western coast of Florida, Georgia, South Carolina and North Carolina. Most part of the Caribbean Sea shows SSTs trendlines ranging between 0.016 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are above 0.25 can be seen in the centre of Gulf of Mexico and majority region of Caribbean Sea.

d. *April*

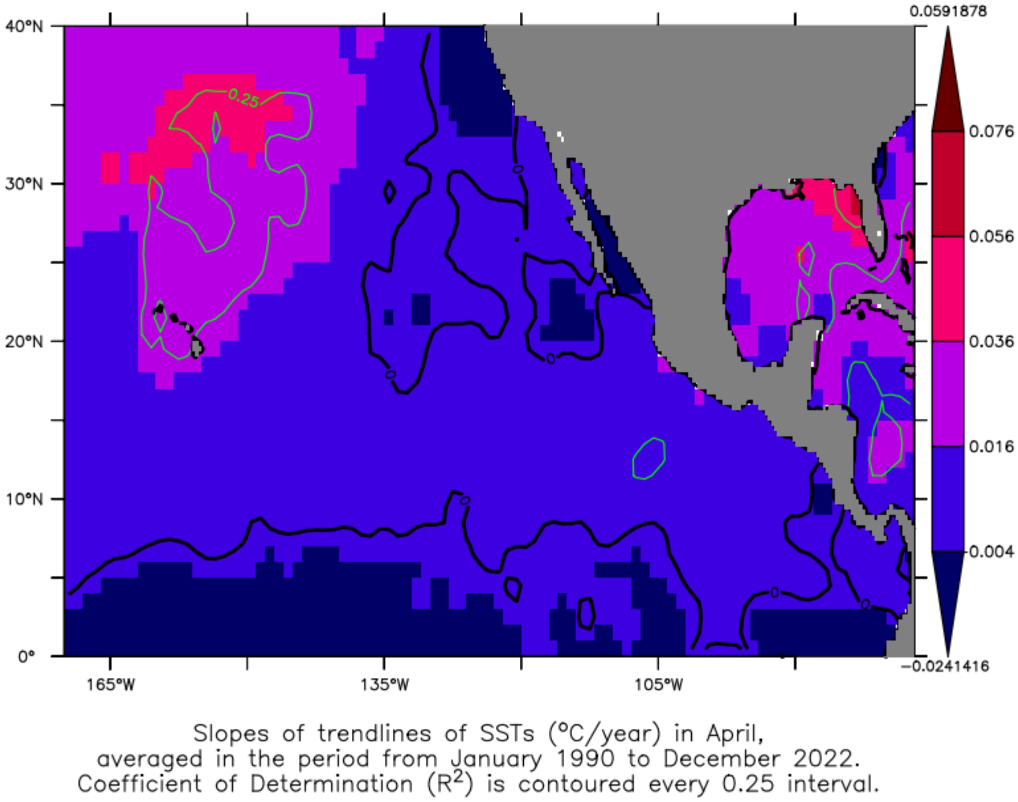


Figure 3.2.5. Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every April in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every April in the period from January 1990 to December 2022 is shown in Figure 3.2.5. The slopes for SSTs trendline are ranging from -0.024 °C/year to 0.060 °C/year.

The highest positive values of slope of trendlines of SSTs i.e. above 0.036 °C can be seen in the waters of Pacific Ocean between the region 30°N to 37 °N latitude and 148°W to 166 °W longitude. The lowest negative value of slope of trendline of SSTs are seen along the coastal waters of California in U.S. This range slope of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from Sonora to Sinaloa. Many similar ranging small patches can be seen westward in the Pacific centred at (21 °N, 119 °W) and around (21 °N, 134° W) and also along the coast of Costa Rica. This similar range of values also can be seen in the Equatorial region extending westward in big patches from coast of Ecuador to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 can be seen in deep above the Hawai'i Island and at the coordinate around (11°N, 105 °W)

In the regions plotted in the Atlantic Ocean, in the Gulf of Mexico, the highest slopes of trendlines of SSTs is seen along west coast of Florida i.e. ranging above 0.056 °C and a patch can be seen around (25 °N,90 °W) centred in the Gulf of Mexico. A similar range also can be seen along the coast of The Bahamas. Most part of the Gulf of Mexico shows SSTs trendlines ranging between 0.016 °C/year to 0.036 °C/year. The Caribbean Sea shows ranging between 0.016 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are above 0.25 are seen in patches in Gulf of Mexico and in Caribbean Sea

e. *May*

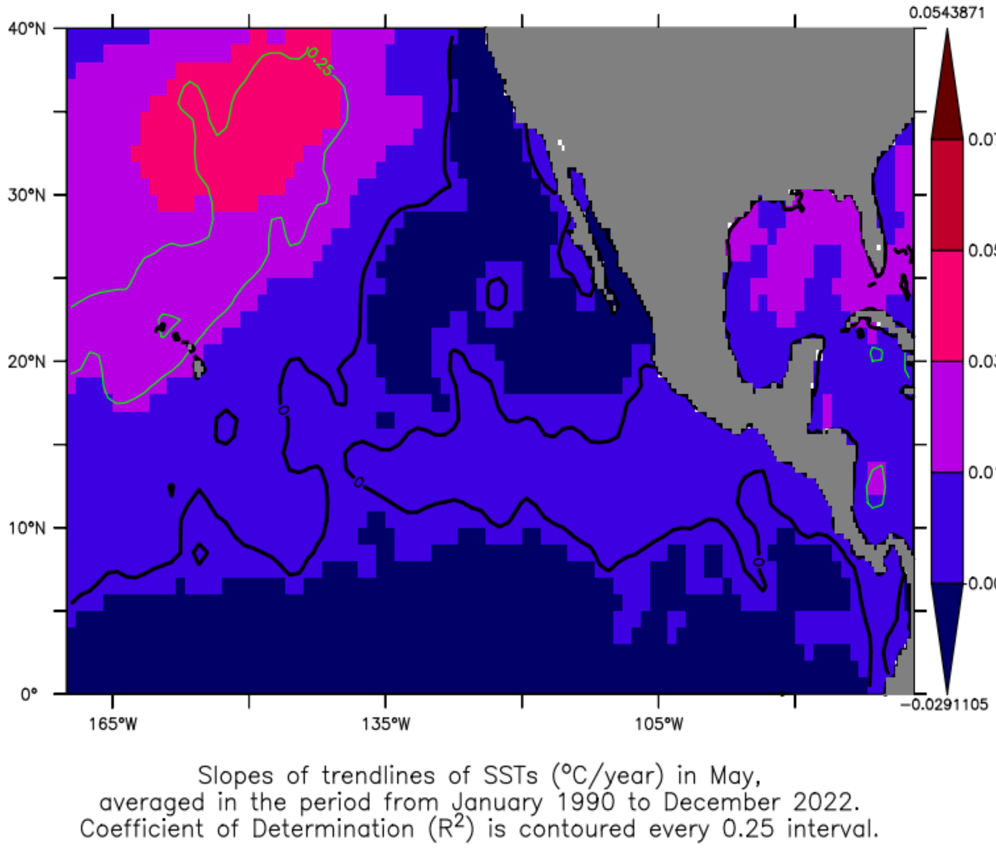


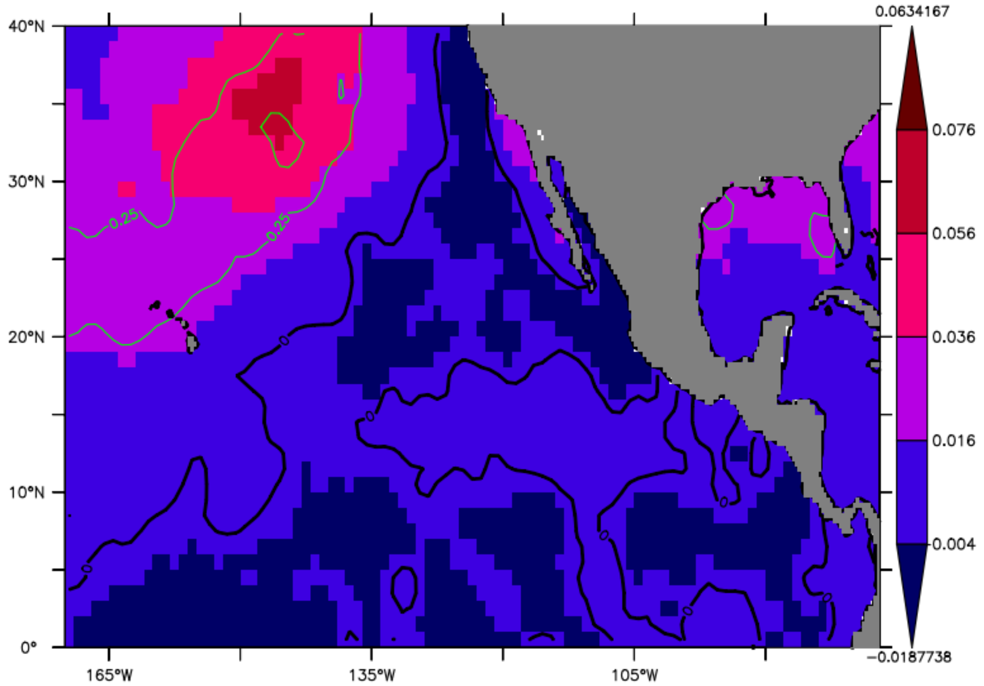
Figure 3.2.6 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every May in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every May in the period from January 1990 to December 2022 is shown in Figure 3.2.6. The slopes for SSTs trendline are ranging from -0.030 °C/year to 0.054 °C/year

The highest positive values of slope of trendline of SSTs i.e. above 0.036 °C can be seen in the waters of Pacific Ocean between the region 29 °N to 40 °N latitude and 138°W to 163 °W longitude. The lowest negative value of slope of SSTs are seen along the coastal waters of California in U.S. and extending southward. This range values of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from Sonora to Nayarit. This similar range of values also can be seen in the Equatorial region extending westward just away from the coast of Ecuador at 81 °W to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 in the region around the north of Hawai'i Islands.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico shows the slopes of trendlines of SSTs ranging between 0.004 °C/year to 0.036 °C/year. The majority of Caribbean Sea shows ranging between 0.004 °C/year to 0.016 °C/year. The Coefficient of Determination (R^2) values are above 0.25 near the Cuba and Nicaragua.

f. *June*



Slopes of trendlines of SSTs (°C/year) in June,
averaged in the period from January 1990 to December 2022.
Coefficient of Determination (R^2) is contoured every 0.25 interval.

Figure 3.2.7 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every June in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every June in the period from January 1990 to December 2022 is shown in Figure 3.2.7. The slopes for SSTs trendline are ranging from -0.019 °C/year to 0.063 °C/year.

The highest positive values of trendline slope of SSTs, i.e. above 0.056 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (35 °N, 145 °W). The lowest negative value of slope of SSTs are seen along the coastal waters of California in U.S. This range slope of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from state Sonora to Colima. This similar range of values also can be seen in the Equatorial region in patches extending westward from coast of Costa Rica and just away from the coastal waters of Ecuador at 81 °W to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 around the coordinates at (35 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico's norther basin shows the slopes of trendlines of SSTs ranging between 0.036 °C/year to 0.016 °C/year and southern basin along with entire Caribbean Sea shows ranging between 0.004 °C/year to 0.016 °C/year. The Coefficient of Determination (R^2) values are above 0.25 in Gulf of Mexico along east coast of Texas and west Coast of Florida in the U.S.A.

g. *July*

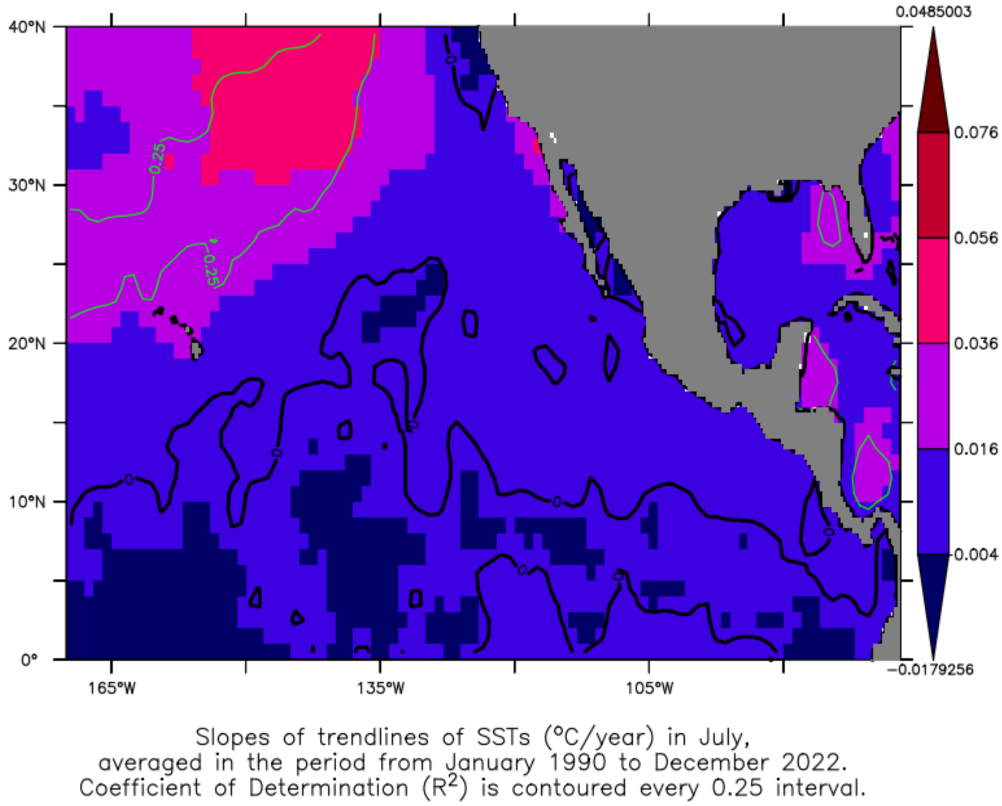


Figure 3.2.8 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every July in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every July in the period from January 1990 to December 2022 is shown is Figure 3.2.8. The slopes for SSTs trendline are ranging from -0.018 °C/year to 0.049 °C/year.

The highest positive values of trendline slope of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (35

°N, 145 °). The lowest negative value of slope of SSTs are seen along the coastal waters of San Fransico in California in U.S. This range slope of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from state Sonora to Sinaloa. This similar range of values also can be seen in the Equatorial region in patches extending westward just away from the coastal waters of Ecuador at 81 °W to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 around the coordinates at (35 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, majority region in Gulf of Mexico basin shows the slopes of trendlines of SSTs ranging between 0.004 °C/year to 0.016 °C/year where-else western coast of Florida shows values above 0.016 °C/year. The Caribbean Sea shows ranging between 0.004 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are seen above 0.25 along north-west coast of Florida in Gulf of Mexico and also in many patches in Caribbean Sea.

h. *August*

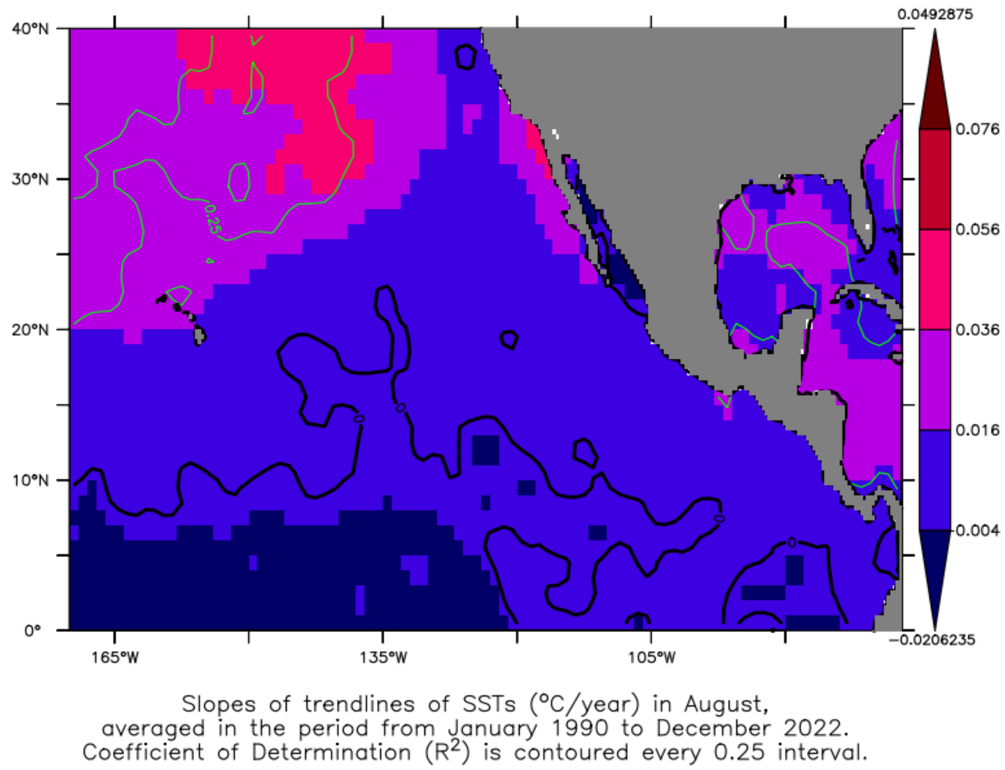


Figure 3.2.9 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every August in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every August in the period from January 1990 to December 2022 is shown in Figure 3.2.9. The slopes for SSTs trendline are ranging from -0.020 °C/year to 0.049 °C/year.

The highest positive values of slope of trendline of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (37 °N, 136 °W). A similar range also can be seen along the coast-line from San Diego to Northern most tip of Baja California. The lowest negative value of slope of trendline of SSTs are seen along the Mexican coastal waters in the Gulf of California from state Sonora to Sinaloa. A patch of similar range of values also can be seen in the Equatorial regions extending westward around 121 °W to 170 °W longitude along we small patches in the Equatorial Pacific. The Coefficient of Determination (R^2) values are above 0.25 around the coordinates at (35 °N, 150 °W).

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico basin show the slopes of trendline of SSTs ranging between 0.004 °C/year to 0.036 °C/year. The majority of Caribbean Sea shows ranging between 0.016 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are above 0.25 in most of Caribbean Sea compared to Gulf of Mexico.

i. September:

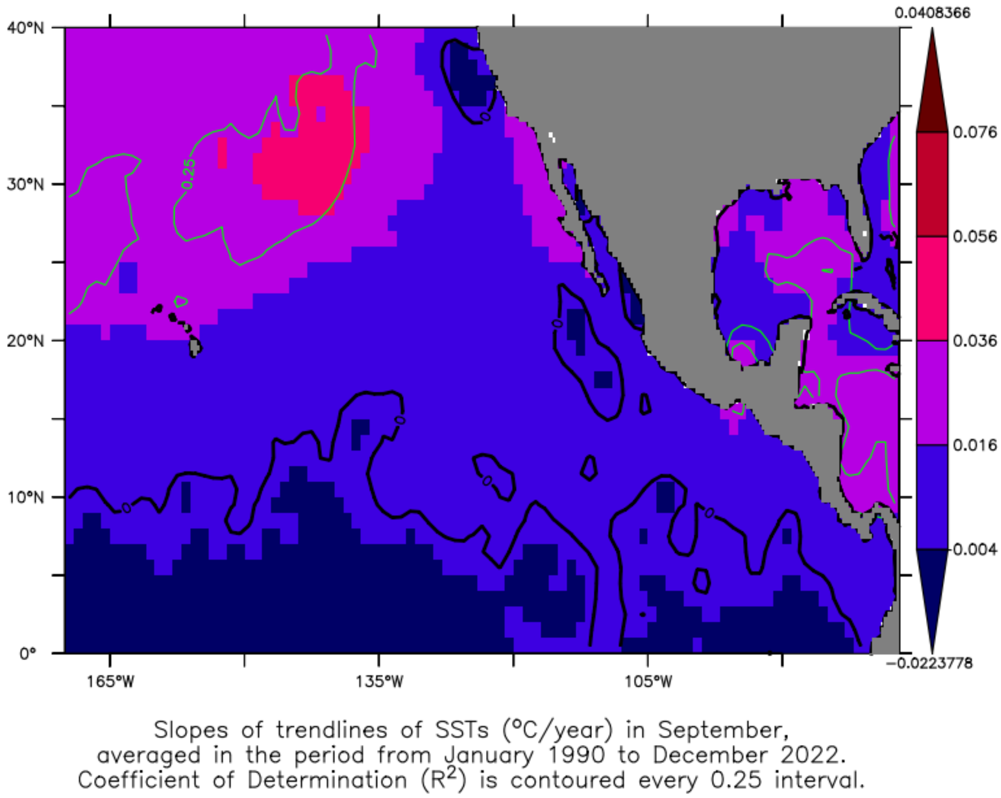


Figure 3.2.10 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every September in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every September in the period from January 1990 to December 2022 is shown in Figure 3.2.10. The slopes for SSTs trendline are ranging from -0.022 °C/year to 0.049 °C/year.

The highest positive value slope of trendline of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (32 °N, 138 °W). The lowest negative value of slope of SSTs are seen along coast of San Francisco in California followed in the waters of Gulf of California. Similar value can be also seen along the coastal waters of Nayarit. The values ranging below 0.004 (°C/year) also can be seen in the Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches around the coordinates at (30 °N, 145 °W)

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico basin show the slopes of trendline of SSTs ranging between 0.004 °C/year to 0.036 °C/year. The majority of Caribbean Sea shows ranging between 0.016 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are above 0.25 along the southern Gulf of Mexico and in half of the regions of Caribbean Sea.

j. *October:*

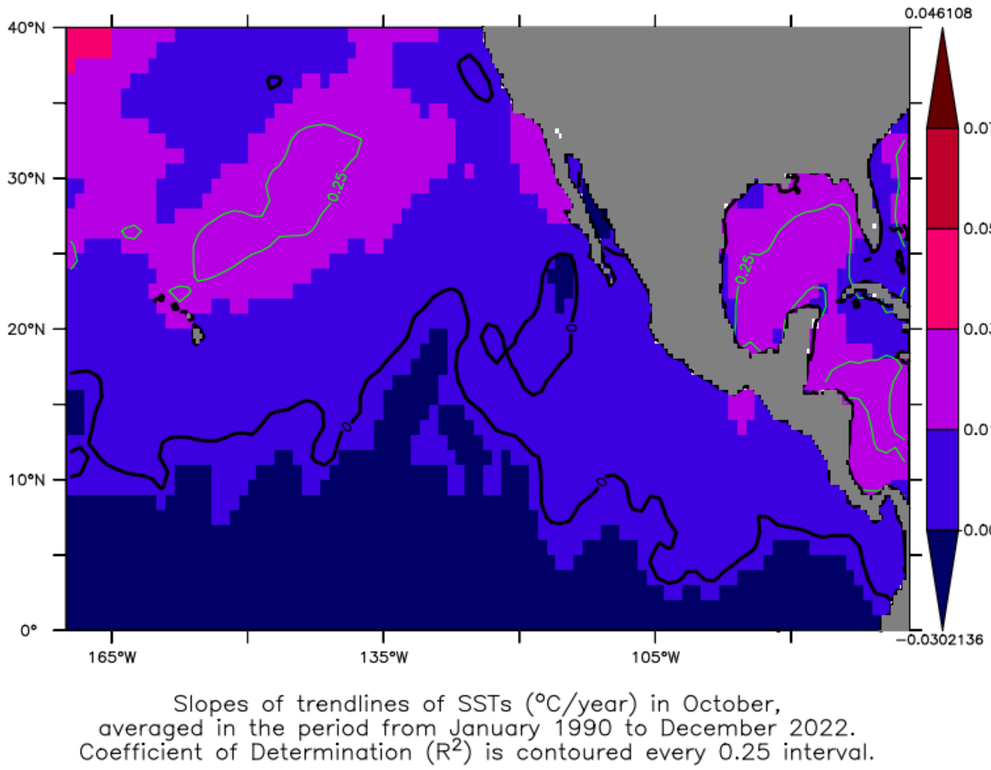


Figure 3.2.11 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every October in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every October in the period from January 1990 to December 2022 is shown in Figure 3.2.11. The slopes for SSTs trendline are ranging from -0.030 °C/year to 0.046 °C/year.

The highest positive value slope of trendline of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (40 °N, 169°W). The lowest negative value of slope of trendline of SSTs are seen along in the waters of Gulf of California and to the south-west of Baja California Sur. The values ranging below 0.004 (°C/year) are also seen in the Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches around the coordinates at (29 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, majority of the Gulf of Mexico and Caribbean Sea show the slopes of trendline of SSTs ranging between 0.016 °C/year to 0.036 °C/year except the coast around Cuba and east Florida shows slopes of trendline of SSTs ranging between 0.004 °C/year to 0.016 °C/year. The Coefficient of Determination (R^2) values are above 0.25 around south of Gulf of Mexico and southern Caribbean Sea.

k. *November:*

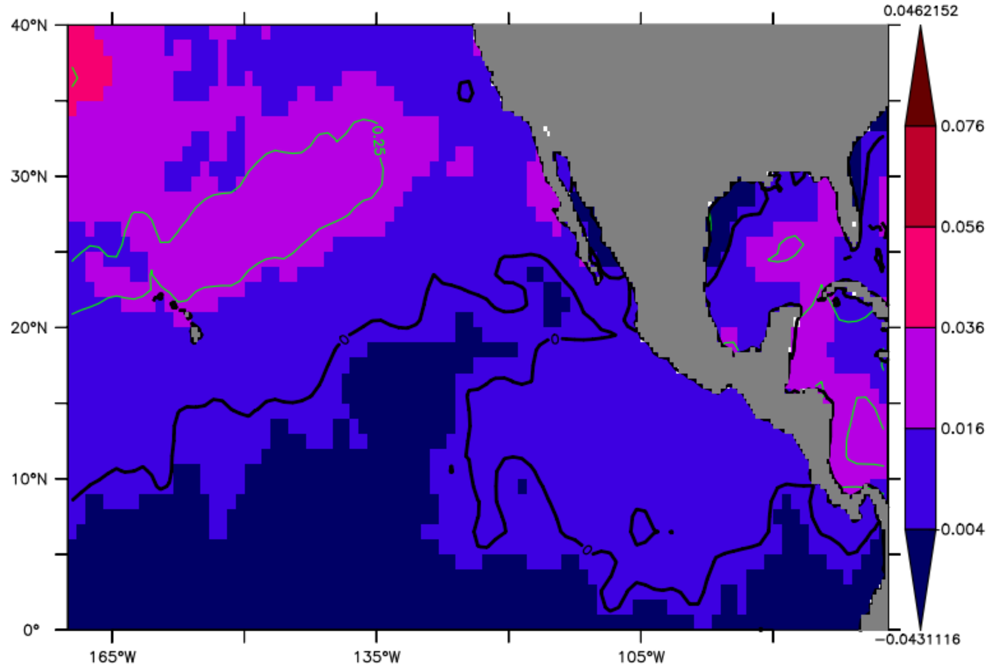


Figure 3.2.12 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every November in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every November in the period from January 1990 to December 2022 is shown in Figure 3.2.12. The slopes for SSTs trendline are ranging from -0.043 °C/year to 0.046 °C/year.

The highest positive values of slopes of trendline of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (37 °N, 169 °W). The lowest negative value slopes of trendline of SSTs are seen along in the waters of Gulf of California. The values ranging below 0.004 (°C/year) are also seen in the

Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches around the coordinates at (25 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, majority of the Gulf of Mexico and Caribbean Sea show the slopes of trendline of SSTs ranging between 0.004 °C/year to 0.036 °C/year. Except along the east coast of Texas and west Florida where the value ranges are below 0.004 °C/year. The Coefficient of Determination (R^2) values are above 0.25 in the central Gulf of Mexico and some parts in Caribbean Sea.

l. *December*

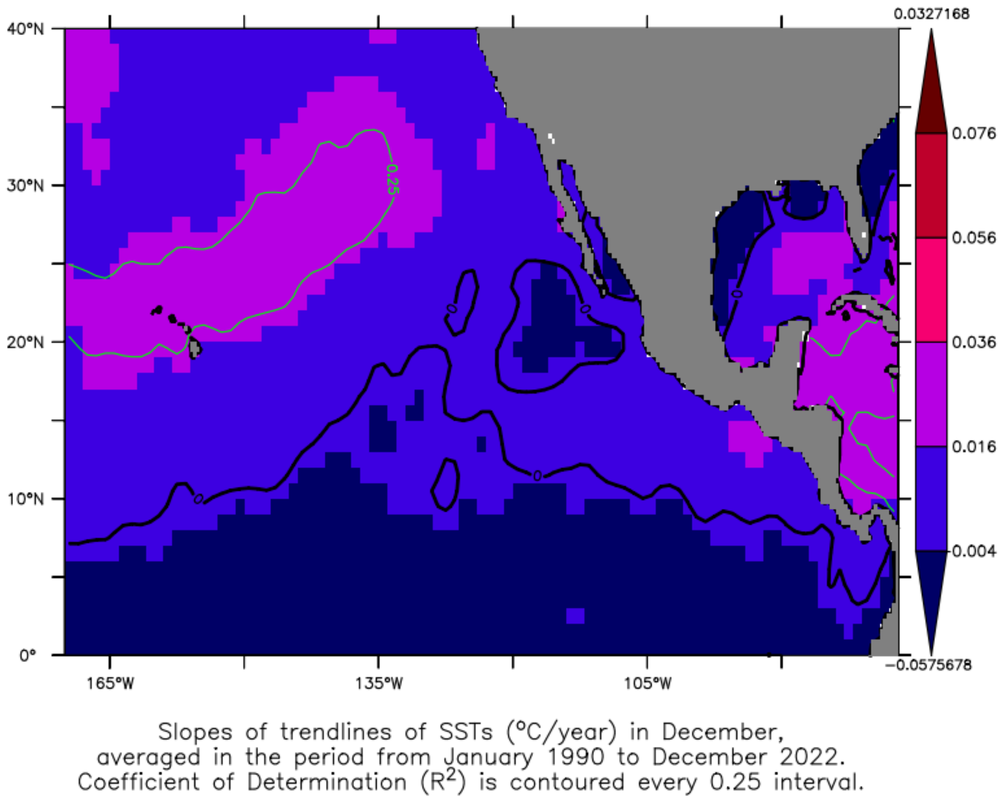


Figure 3.2.13. Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every December in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every December in the period from January 1990 to December 2022 is shown in Figure 3.2.13. The slopes for SSTs trendline are ranging from -0.058 °C/year to 0.033 °C/year.

The highest positive values of slopes of trendline of SSTs, i.e. above 0.016 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (35

°N, 150 °W). A similar value range is also seen in different small patches around coordinate at (37 °N, 169 °W) and also along the coastal waters at Baja California and Guatemala. The lowest negative value slopes of trendline of SSTs are seen along in the waters of Gulf of California and to the south Baja California Sur. The values ranging below 0.004 (°C/year) are also seen in the Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches around the coordinates at (26 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, majority of the Caribbean Sea show the slopes of trendline of SSTs ranging between 0.016 °C/year to 0.036 °C/year. In the Gulf of Mexico, east coast of Mexico and U.S and the Mississippi River Delta show values below 0.004 °C and majority region is ranging above 0.004 °C. The Coefficient of Determination (R^2) values are above 0.25 is seen along Caribbean Sea.

The Slopes of Trendline of SSTs in Boreal Spring Season from January 1990 to December 2022

a. *Boreal Spring Season:*

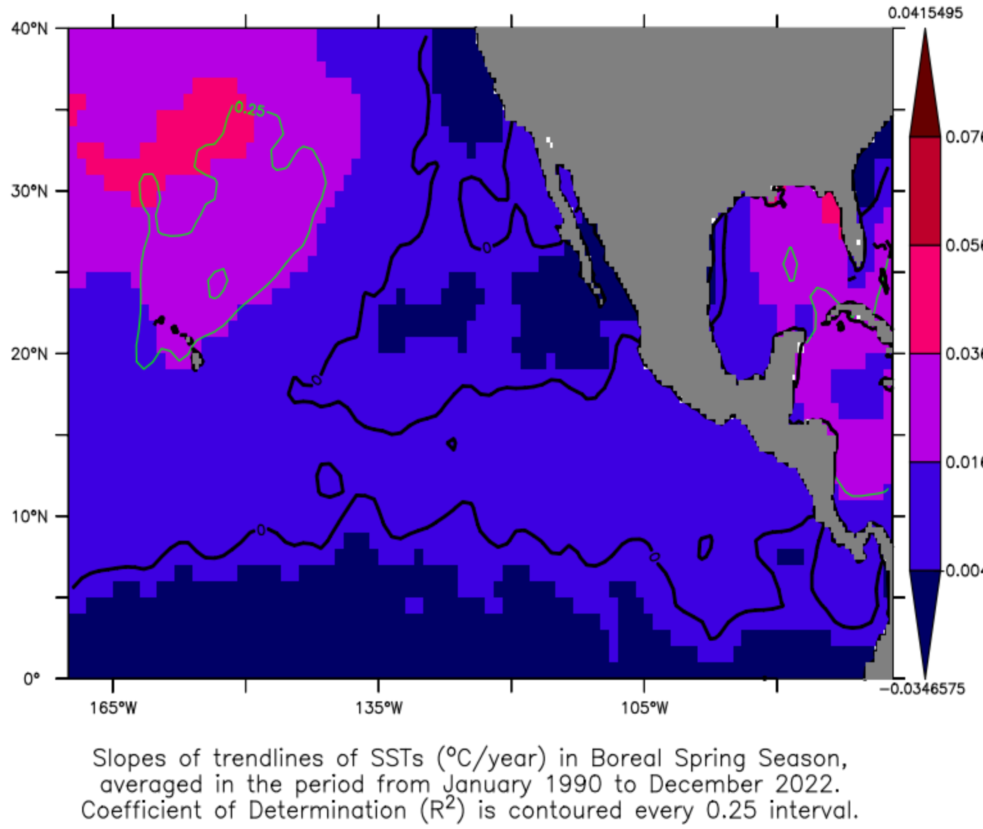


Figure 3.2.14 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Spring Season in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Spring Season in the period from January 1990 to December 2022 is shown is Figure 3.2.14. The slopes for SSTs trendline are ranging from -0.035 °C/year to 0.042 °C/year.

The highest positive values of slope of trendlines of SSTs i.e. above 0.036 °C can be seen in the waters of Pacific Ocean between the region 29 °N to 36 °N latitude and 150 °W to 170 °W longitude. The lowest negative value of slope of trendline of SSTs are seen along the coastal waters of California in U.S. This range slope of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from Sonora to Sinaloa. Many similar ranging small patches can be seen westward in the Pacific centred at (21 °N, 119 °W) and around (21 °N, 134° W) and also along the coast of Costa Rica. This similar range of values also can be seen in the Equatorial region extending westward in big patches from coast of Ecuador to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 can be seen in deep ocean above the Hawai'i Island.

In the regions plotted in the Atlantic Ocean, in the Gulf of Mexico, the highest slopes of trendlines of SSTs is seen along west coast of Florida i.e. ranging above 0.036 °C and a patch can be seen around the Mississippi River Delta. Eastern region of the Gulf of Mexico shows slopes of trendlines of SSTs lower than in westerns region and ranging between -0.035 °C/year to 0.056 °C/year. The Caribbean Sea shows ranging between 0.016 °C/year to 0.036 °C/year in most of its areas except its central part where ranges are lower. The Coefficient of Determination (R^2) values are above 0.25 are seen in patch in Gulf of Mexico and big patch around Caribbean Sea.

b. *Boreal Summer Season:*

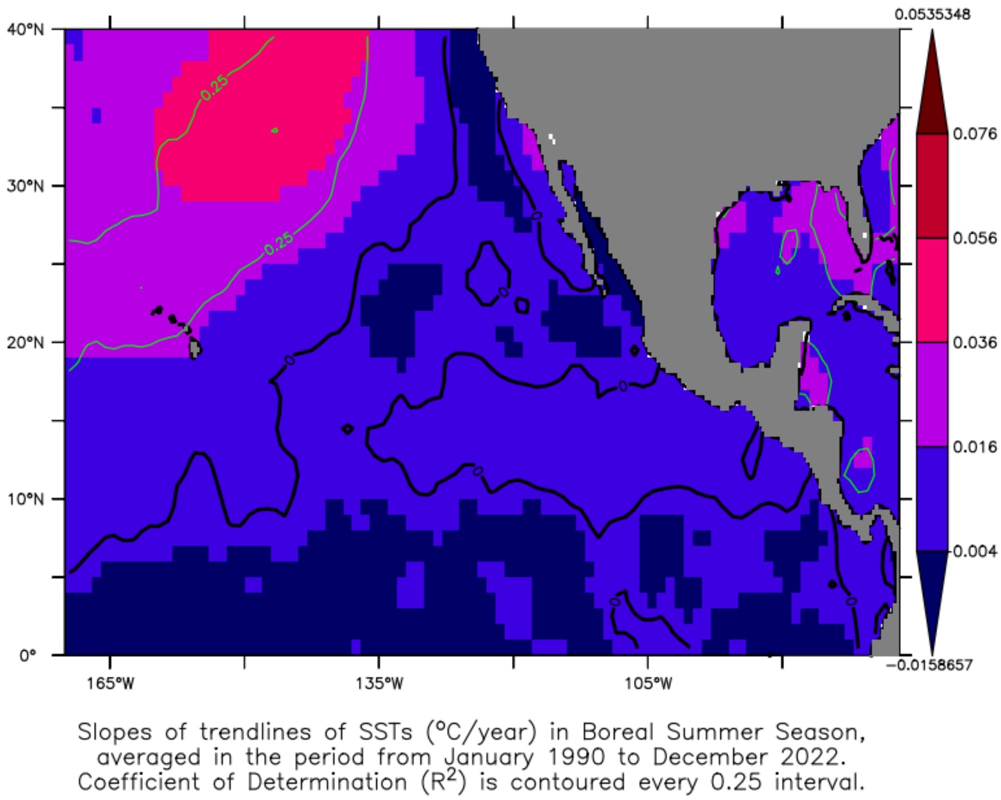


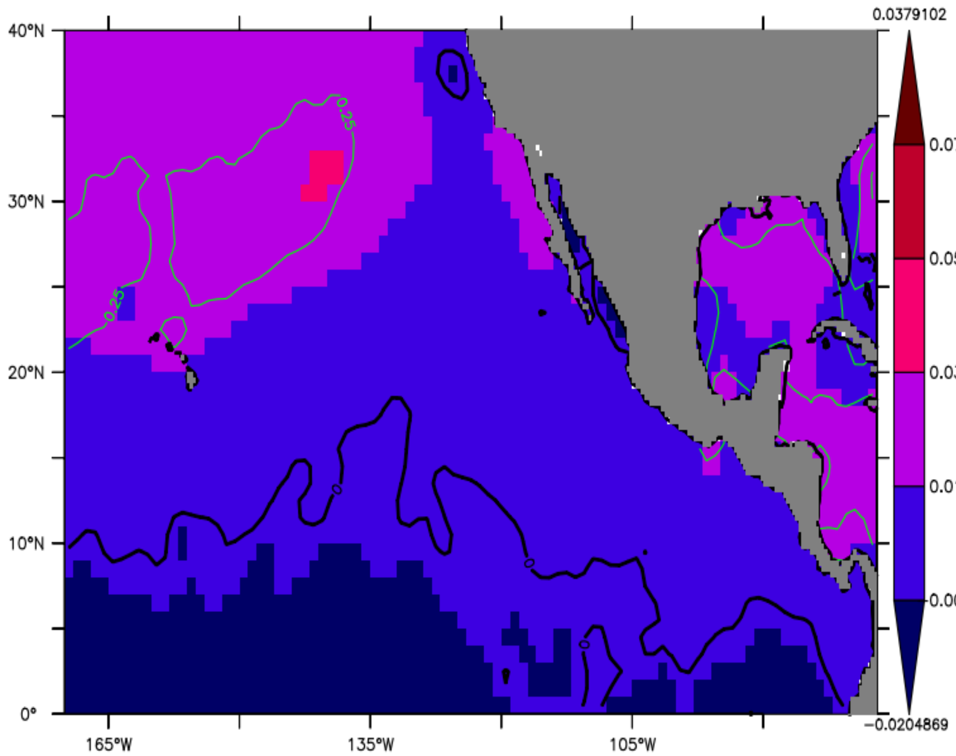
Figure 3.2.15 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season in the period from January 1990 to December 2022 is shown in Figure 3.2.15. The slopes for SSTs trendline are ranging from -0.016 °C/year to 0.054 °C/year.

The highest positive values of slope of trendline of SSTs i.e. above 0.036 °C can be seen in the waters of Pacific Ocean between the region 29 °N to 40 °N latitude and 135°W to 163 °W longitude. The lowest negative value of slope of SSTs are seen along the coastal waters of California in U.S. and extending southward. This range values of trendlines of SST also can be seen along the Mexican coastal waters in the Gulf of California from Sonora to Nayarit and in some patches to the south-west of Baja California Sur. This similar range of values also can be seen in the Equatorial region extending patchy westward just away from the coast of Ecuador and Costa Rica at 81 °W to 170 °W. The Coefficient of Determination (R^2) values are above 0.25 in the region around the north of Hawai'i Islands.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico shows the slopes of trendlines of SSTs ranging between 0.004 °C/year to 0.036 °C/year. The majority of Caribbean Sea shows ranging between 0.004 °C/year to 0.016 °C/year. The Coefficient of Determination (R^2) values are above 0.25 near the coast of Florida in Gulf of Mexico and along western region in Caribbean Sea.

c. *Boreal Autumn Season*



Slopes of trendlines of SSTs (°C/year) in Boreal Autumn Season,
averaged in the period from January 1990 to December 2022.
Coefficient of Determination (R^2) is contoured every 0.25 interval.

Figure 3.2.16 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Autumn Season in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N,170 °W to 77 °W), averaged every Boreal Autumn Season in the period from January 1990 to December 2022 is shown in Figure 3.2.16. The slopes for SSTs trendline are ranging from -0.020 °C/year to 0.038 °C/year.

The highest positive value slope of trendline of SSTs, i.e. above 0.036 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (32 °N, 137 °W). The lowest negative value of slope of SSTs are seen along coastal waters off California and also in the waters of Gulf of California to Nayarit. The values ranging below 0.004 (°C/year) also can be seen in the Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches above the Hawaiʻi Islands.

In the regions plotted in the Atlantic Ocean, the Gulf of Mexico basin show the slopes of trendline of SSTs ranging between 0.004 °C/year to 0.036 °C/year. The majority of Caribbean Sea shows ranging between 0.016 °C/year to 0.036 °C/year. The Coefficient of Determination (R^2) values are above 0.25 in most of regions of Gulf of Mexico and Caribbean Sea.

d. *Boreal Winter Season*

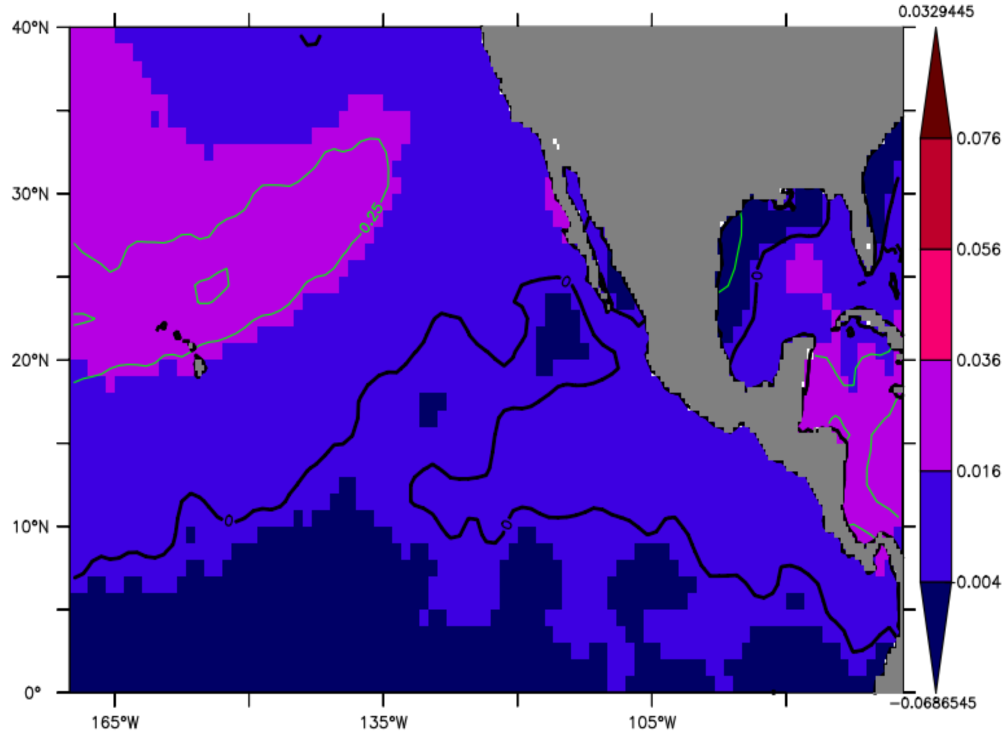


Figure 3.2.17 Map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season in the period from January 1990 to December 2022

The map of slopes of the trendlines of SSTs (°C/year) in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season in the period from January 1990 to December 2022 is shown in Figure 3.2.17. The slopes for SSTs trendline are ranging from -0.069 °C/year to 0.033 °C/year.

The highest positive values of slopes of trendline of SSTs, i.e. above 0.016 (°C/year) can be seen in the waters of Pacific Ocean centred around coordinates at (30 °N, 150 °W). A similar value range is also seen in different small patch can be seen along the coastal waters on western Baja California and Baja California Sur. The lowest negative value slopes of trendline of SSTs are seen along in the waters of Gulf of California to the south Baja California Sur. The values ranging below 0.004 (°C/year) are also seen in the Equatorial regions extending westward from coastal waters of Ecuador to 170 °W longitude. The Coefficient of Determination (R^2) values are above 0.25 in patches around the coordinates at (26 °N, 145 °W).

In the regions plotted in the Atlantic Ocean, majority of the Caribbean Sea show the slopes of trendline of SSTs ranging between 0.016 °C/year to 0.036 °C/year. In the Gulf of Mexico, east coast of Mexico and U.S and the Mississippi River Delta show values below 0.004 °C and majority region is ranging above 0.004 °C. The Coefficient of Determination (R^2) values are above 0.25 is seen at east coast of Texas in Gulf of Mexico and also along Caribbean Sea.

3.3 BASIN AVERAGED SEA SURFACE TEMPERATURE (SST)

3.3.1 Basin averaged Sea Surface Temperature for the entire period from January 1990 to December 2022

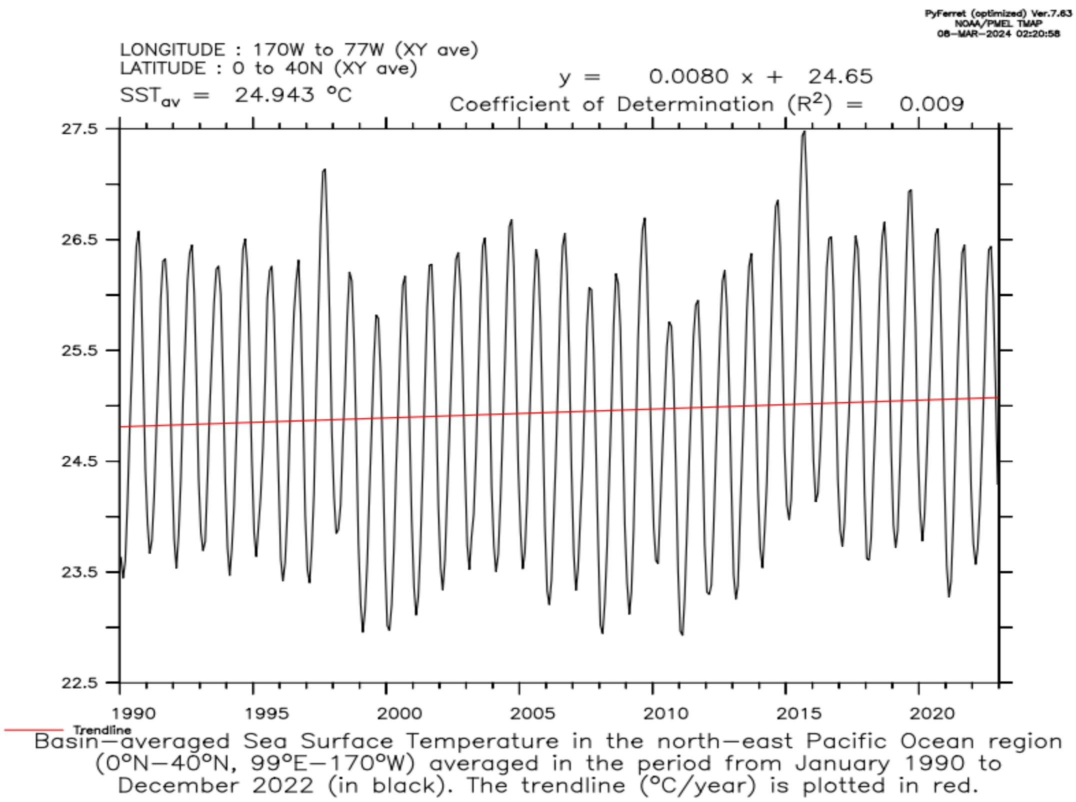


Figure 3.3.1 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged for the entire time period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged for the entire time period from January 1990 to December 2022 is shown in Figure 3.3.1. The SST ranges approximately between 22.9 °C to 27.5 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0080 °C/year. The Coefficient of Determination (R^2) has a value of 0.009. The average SST in the entire period and region gives a value of 24.943 °C.

a. *January*

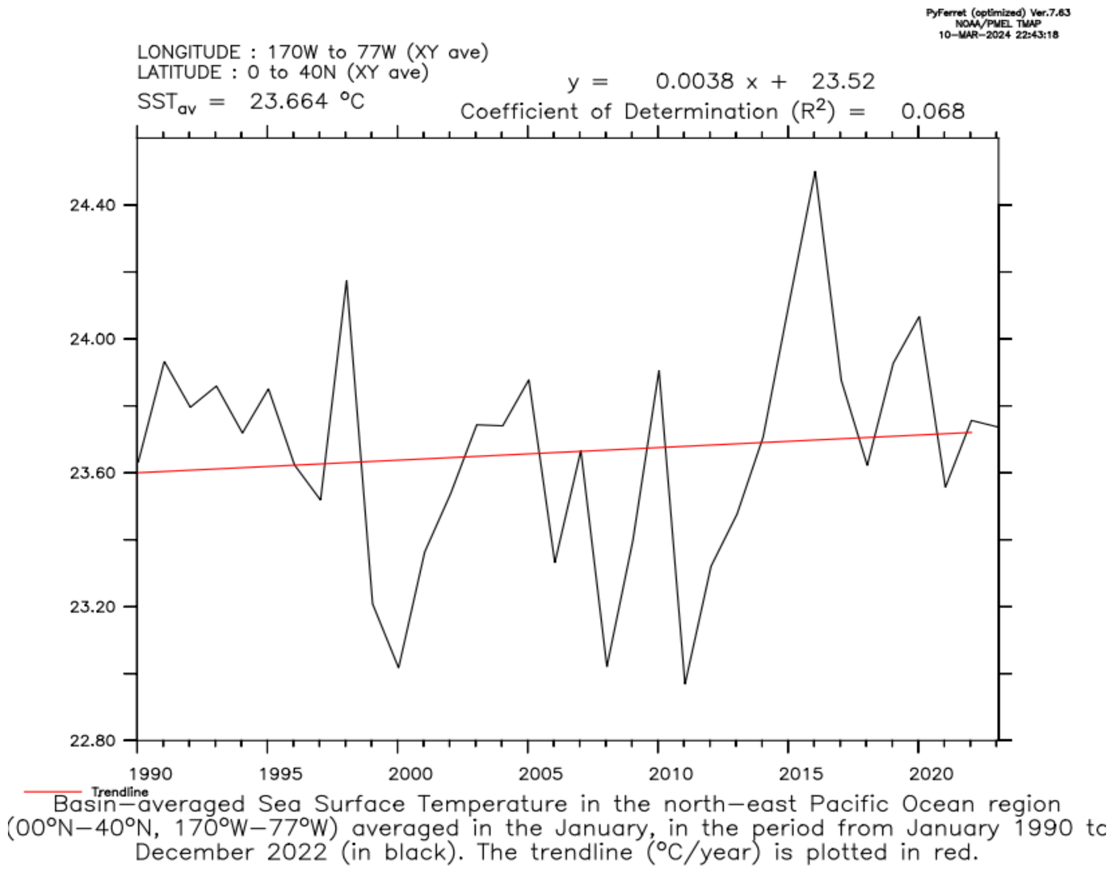


Figure 3.3.2 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every January, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every January, in the period from January 1990 to December 2022 is shown in Figure 3.3.2. The SST ranges approximately between 22.98 °C to 24.45 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0038 °C/year. The Coefficient of Determination (R^2) has a value of 0.068. The average SST in the entire period and region gives a value of 23.664 °C.

b. *February*

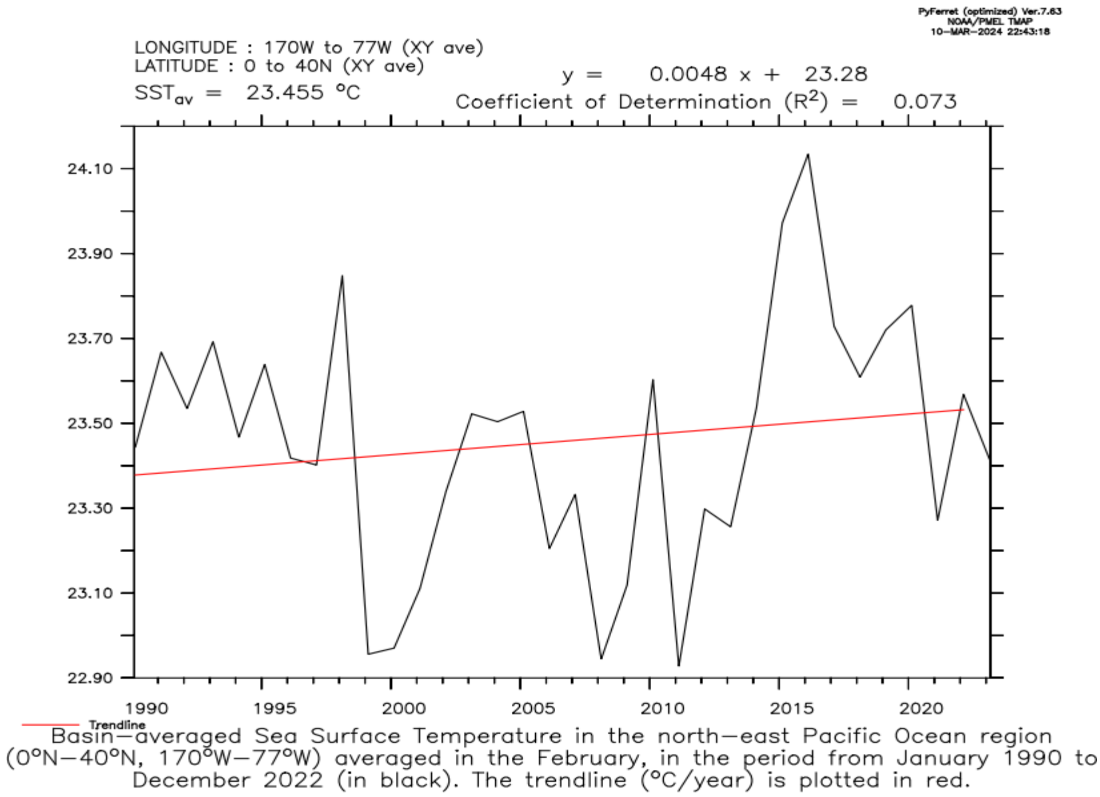


Figure 3.3.3 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every February, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every February, in the period from January 1990 to December 2022 is shown in Figure 3.3.3. The SST ranges approximately between 22.95 °C to 24.11 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0048 °C/year. The Coefficient of Determination (R^2) has a value of 0.073. The average SST in the entire period and region gives a value of 23.455 °C.

c. *March*

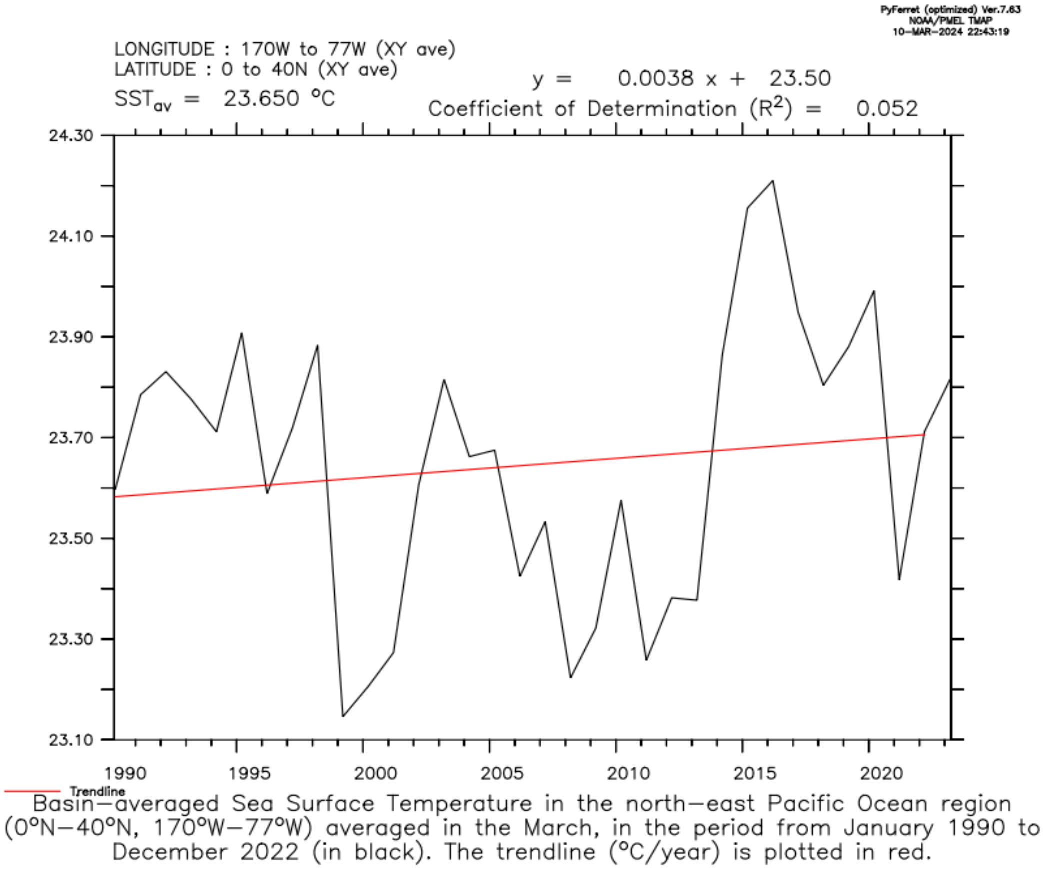


Figure 3.3.4 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every March, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every March, in the period from January 1990 to December 2022 is shown in Figure 3.3.4. The SST ranges approximately between 23.15 °C to 24.20 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0038 °C/year. The Coefficient of Determination (R^2) has a value of 0.052. The average SST in the entire period and region gives a value of 23.650 °C.

d. *April*

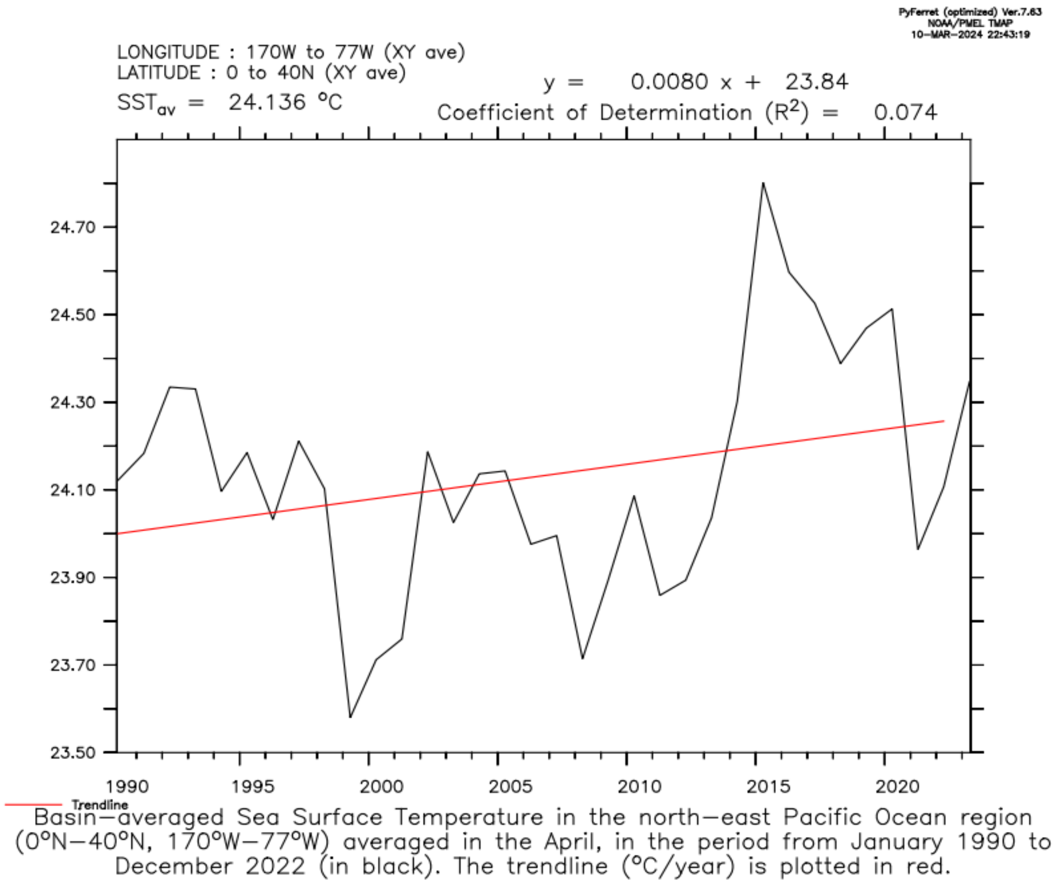


Figure 3.3.5 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every April, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every April, in the period from January 1990 to December 2022 is shown in Figure 3.3.5. The SST ranges approximately between 23.59 °C to 24.80 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0080 °C/year. The Coefficient of Determination (R^2) has a value of 0.074. The average SST in the entire period and region gives a value of 24.136 °C.

e. *May*

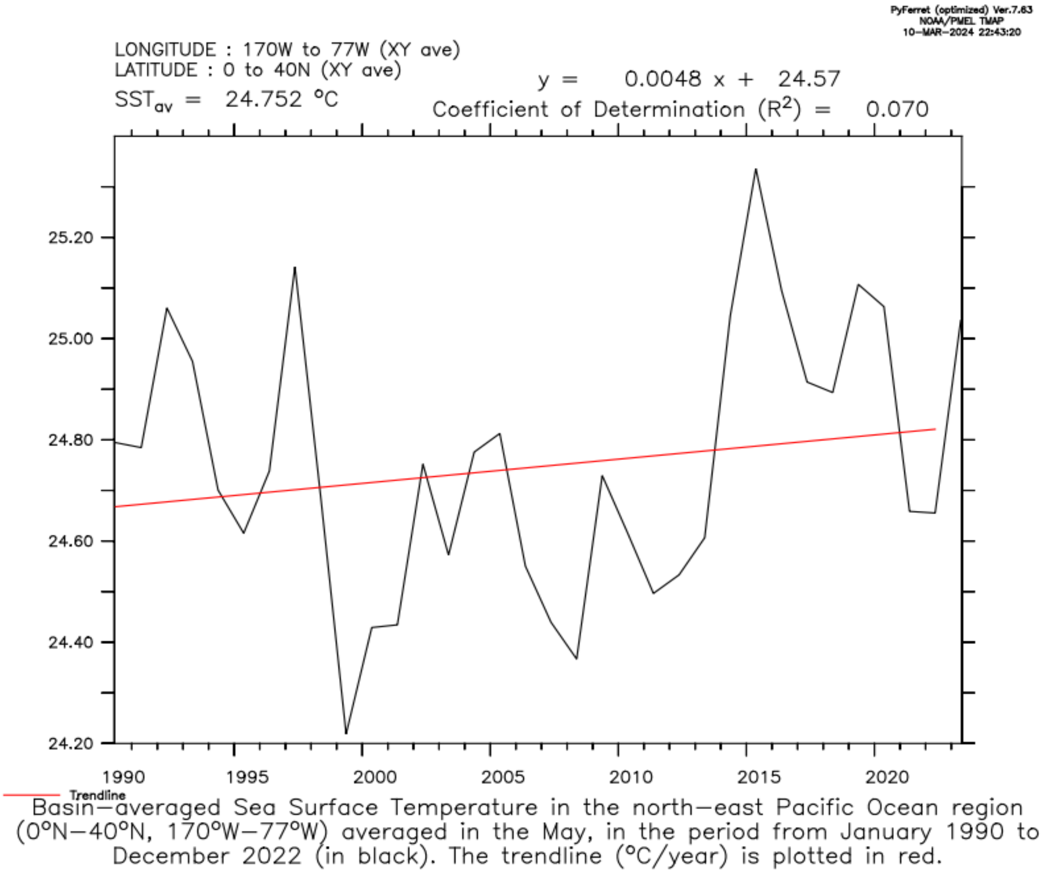


Figure 3.3.6 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every May, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every May, in the period from January 1990 to December 2022 is shown in Figure 3.3.6. The SST ranges approximately between 24.22 °C to 25.31 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0048 °C/year. The Coefficient of Determination (R^2) has a value of 0.070. The average SST in the entire period and region gives a value of 24.752 °C.

f. *June*

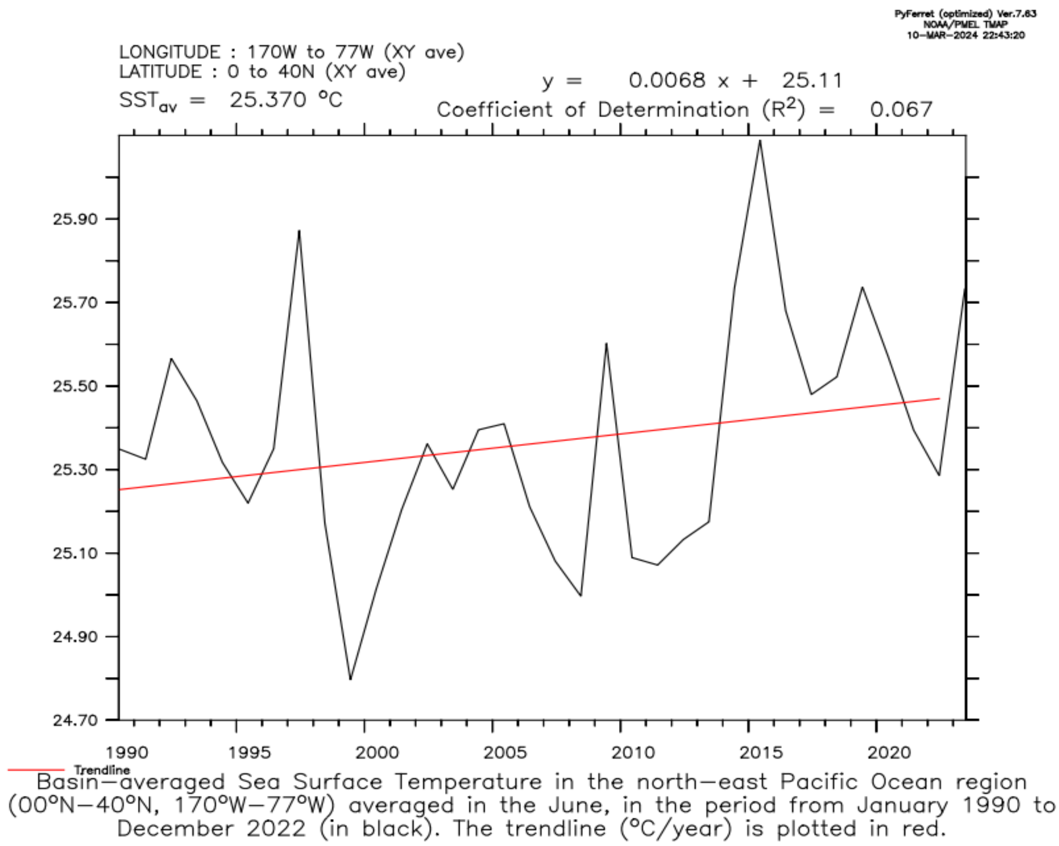


Figure 3.3.7 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every June, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every June, in the period from January 1990 to December 2022 is shown in Figure 3.3.7. The SST ranges approximately between 24.80 °C to 26.08 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0068 °C/year. The Coefficient of Determination (R^2) has a value of 0.067. The average SST in the entire period and region gives a value of 25.370 °C.

h. *July*

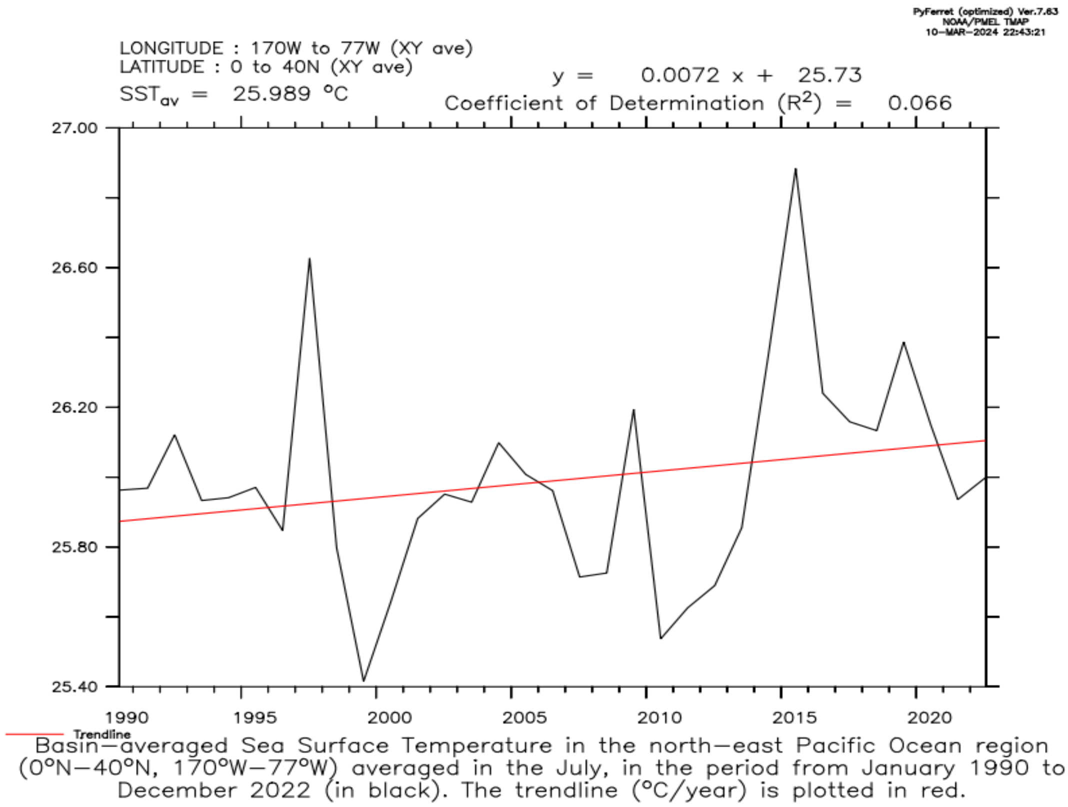


Figure 3.3.8 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every July, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged in the July, in the period from January 1990 to December 2022 is shown in Figure 3.3.8. The SST ranges approximately between 25.42 °C to 26.84 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0072 °C/year. The Coefficient of Determination (R^2) has a value of 0.066. The average SST in the entire period and region gives a value of 25.989 °C.

i. *August*

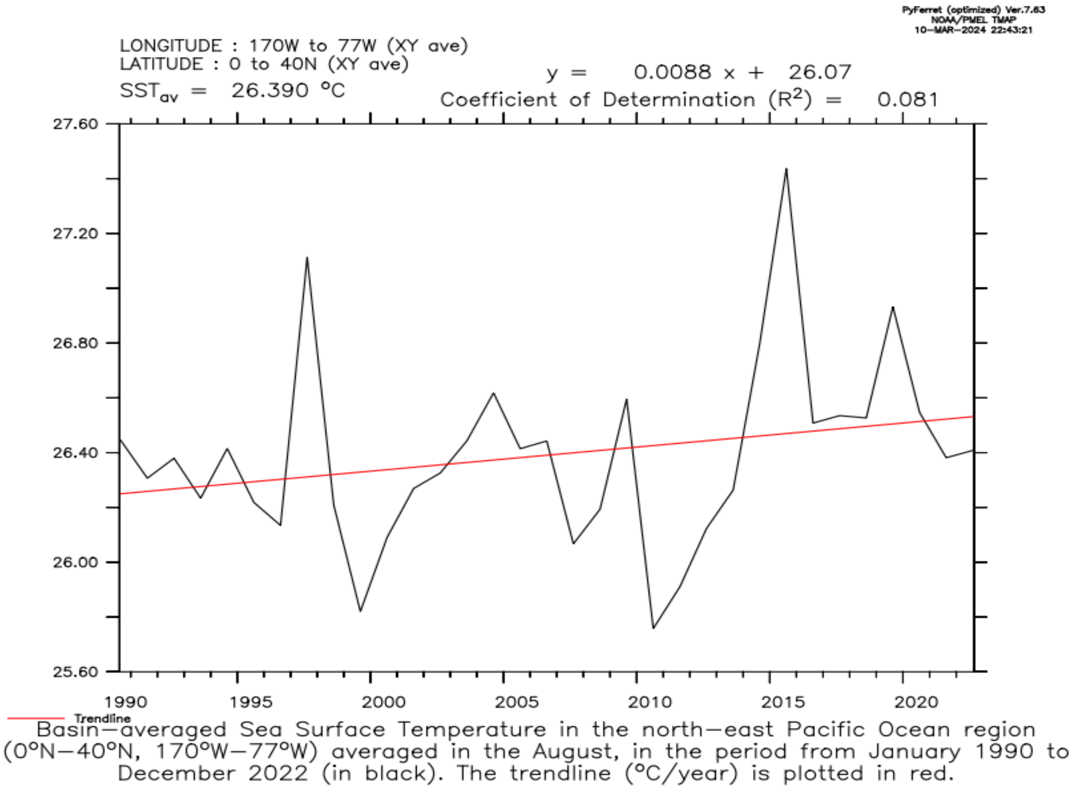


Figure 3.3.9 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every August, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every August, in the period from January 1990 to December 2022 is shown in Figure 3.3.9. The SST ranges approximately between 25.78 °C to 27.42 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0088 °C/year. The Coefficient of Determination (R^2) has a value of 0.081. The average SST in the entire period and region gives a value of 26.390 °C.

j. *September*

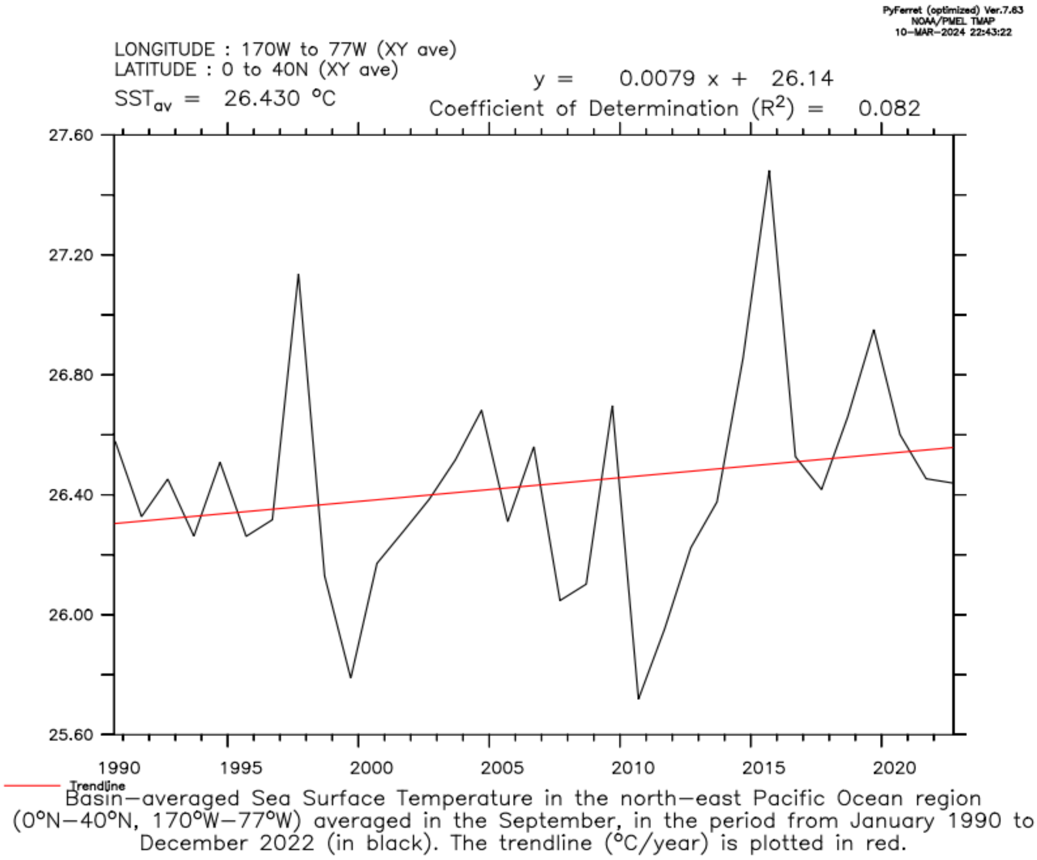
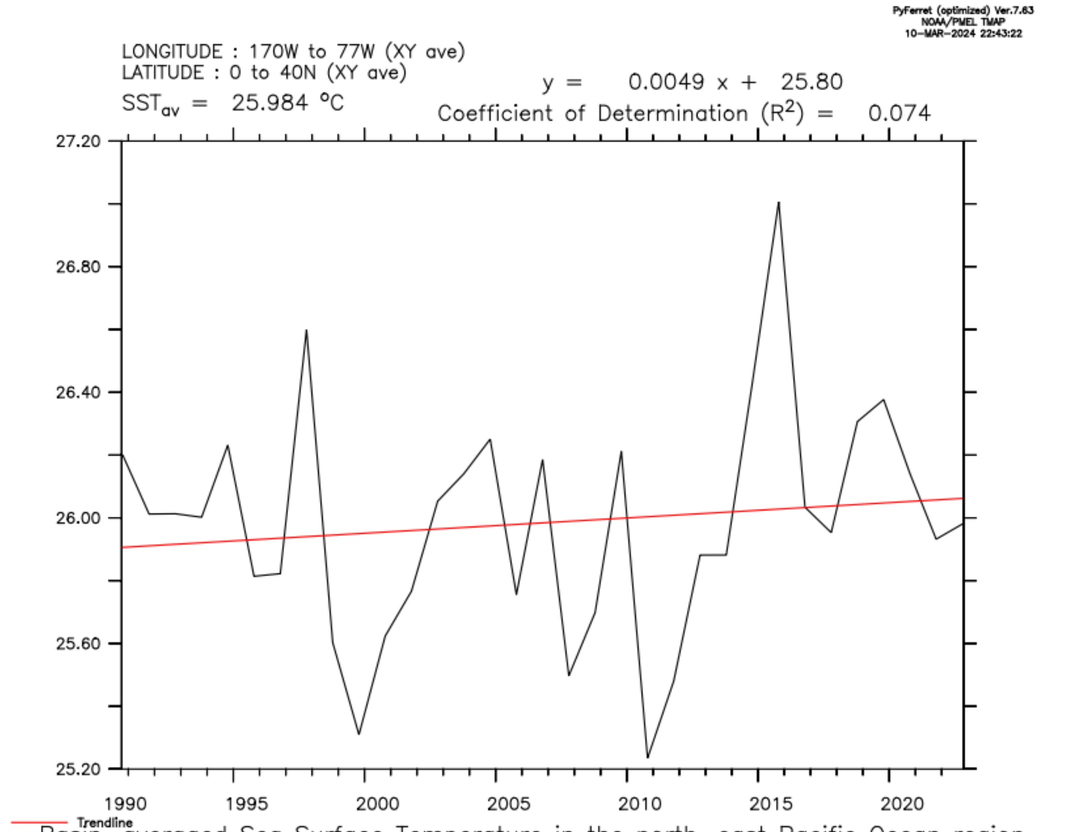


Figure 3.3.10 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every September, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged in the September, in the period from January 1990 to December 2022 is shown in Figure 3.3.10. The SST ranges approximately between 25.70 °C to 27.50 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0079 °C/year. The Coefficient of Determination (R^2) has a value of 0.082. The average SST in the entire period and region gives a value of 26.430 °C.

k. *October*



Basin–averaged Sea Surface Temperature in the north–east Pacific Ocean region (0°N–40°N, 170°W–77°W) averaged in the October, in the period from January 1990 to December 2022 (in black). The trendline (°C/year) is plotted in red.

Figure 3.3.11 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every October, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every October, in the period from January 1990 to December 2022 is shown in Figure 3.3.11. The SST ranges approximately between 25.22 °C to 27 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0049 °C/year. The Coefficient of Determination (R^2) has a value of 0.074. The average SST in the entire period and region gives a value of 25.984 °C.

l. *November*

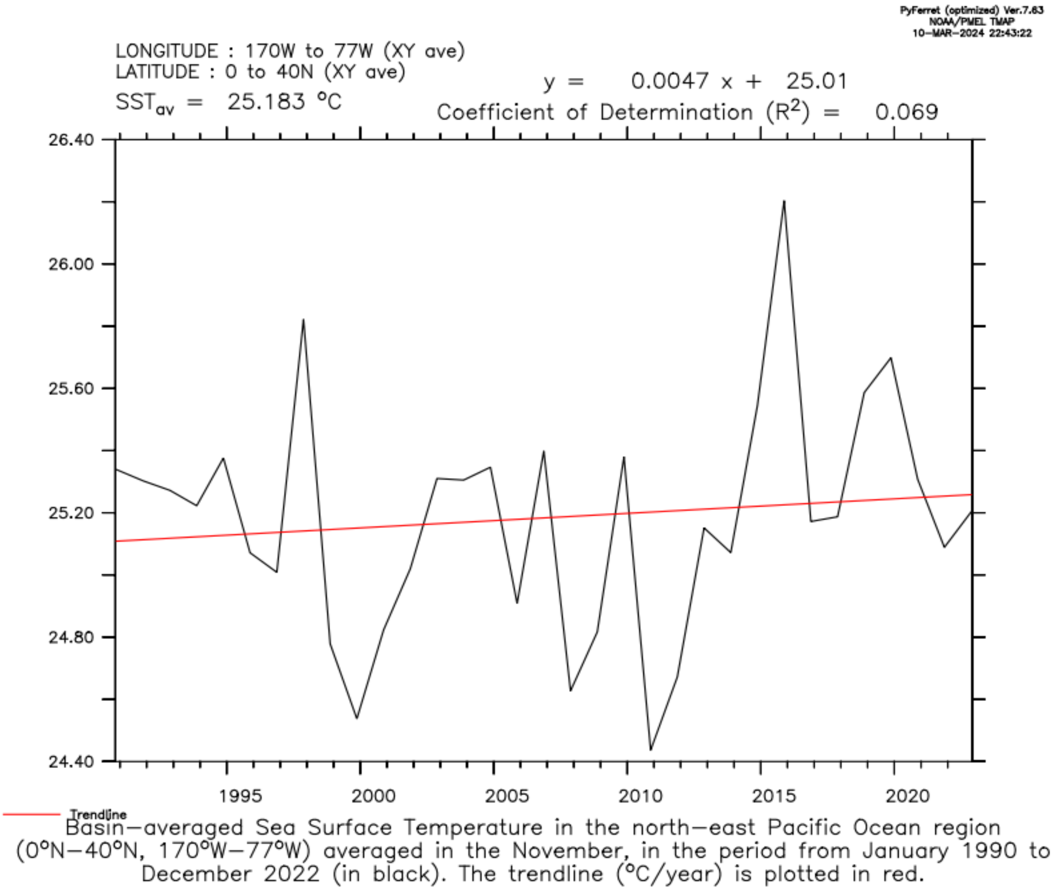


Figure 3.3.12 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every November, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged in the November, in the period from January 1990 to December 2022 is shown in Figure 3.3.12. The SST ranges approximately between 22.42 °C to 26.20 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0047 °C/year. The Coefficient of Determination (R^2) has a value of 0.069. The average SST in the entire period and region gives a value of 25.183 °C.

m. *December*

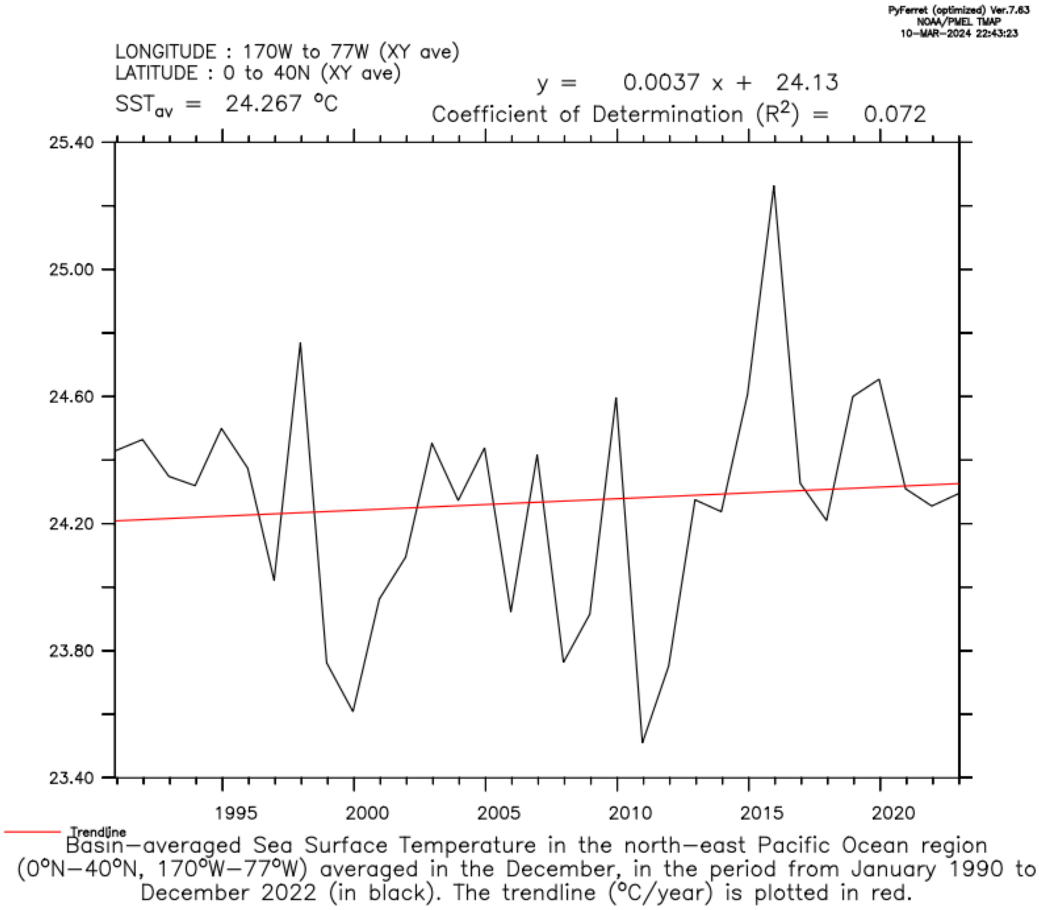


Figure 3.3.13 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every December, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged in the December, in the period from January 1990 to December 2022 is shown in Figure 3.3.13. The SST ranges approximately between 23.45 °C to 25.28 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0037 °C/year. The Coefficient of Determination (R^2) has a value of 0.072. The average SST in the entire period and region gives a value of 24.267 °C.

Slopes of Trendline of SSTs in Boreal Season's from January 1990 to December 2022

a. *Boreal Spring Season*

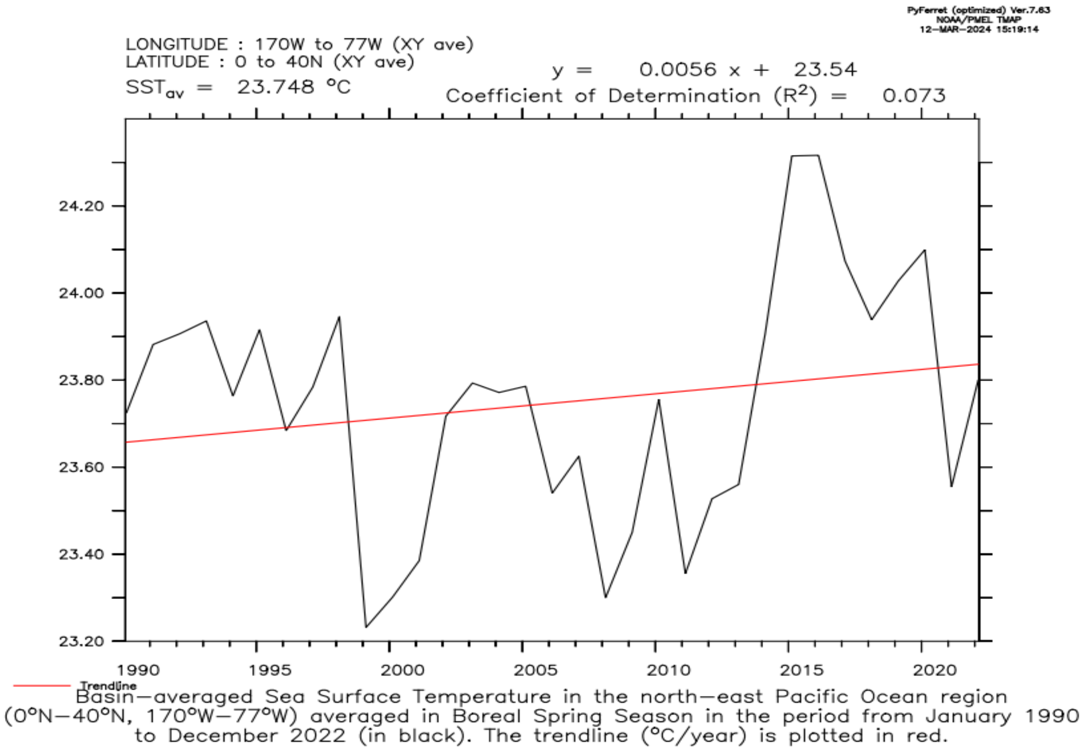


Figure 3.3.14 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Spring Season, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Spring Season, in the period from January 1990 to December 2022 is shown in Figure 3.3.14. The SST ranges approximately between 23.24 °C to 24.30 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0056 °C/year. The Coefficient of Determination (R^2) has a value of 0.073. The average SST in the entire period and region gives a value of 23.748 °C.

b. *Boreal Summer Season*

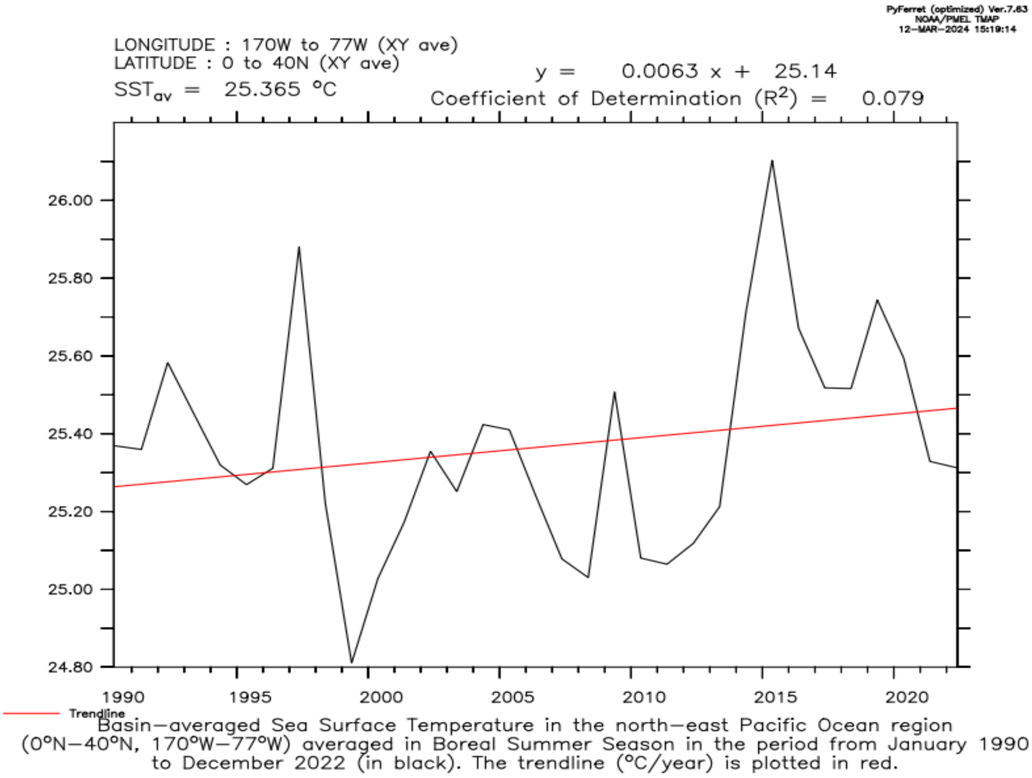


Figure 3.3.15 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season, in the period from January 1990 to December 2022 is shown in Figure 3.3.15. The SST ranges approximately between 24.82 °C to 27 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0063 °C/year. The Coefficient of Determination (R^2) has a value of 0.079. The average SST in the entire period and region gives a value of 25.365 °C.

c. *Boreal Autumn Season*

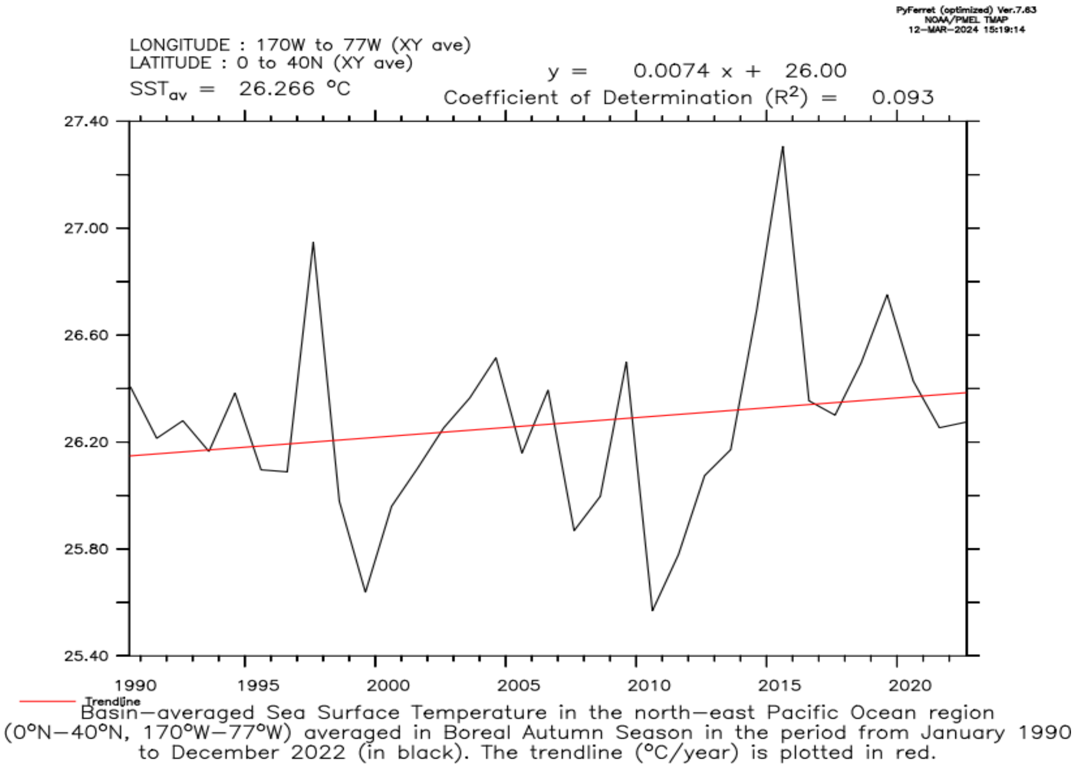


Figure 3.3.16 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Autumn Season, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Summer Season, in the period from January 1990 to December 2022 is shown in Figure 3.3.16. The SST ranges approximately between 25.58 °C to 27.30 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0074 °C/year. The Coefficient of Determination (R^2) has a value of 0.093. The average SST in the entire period and region gives a value of 26.266 °C.

d. *Boreal Winter Season*

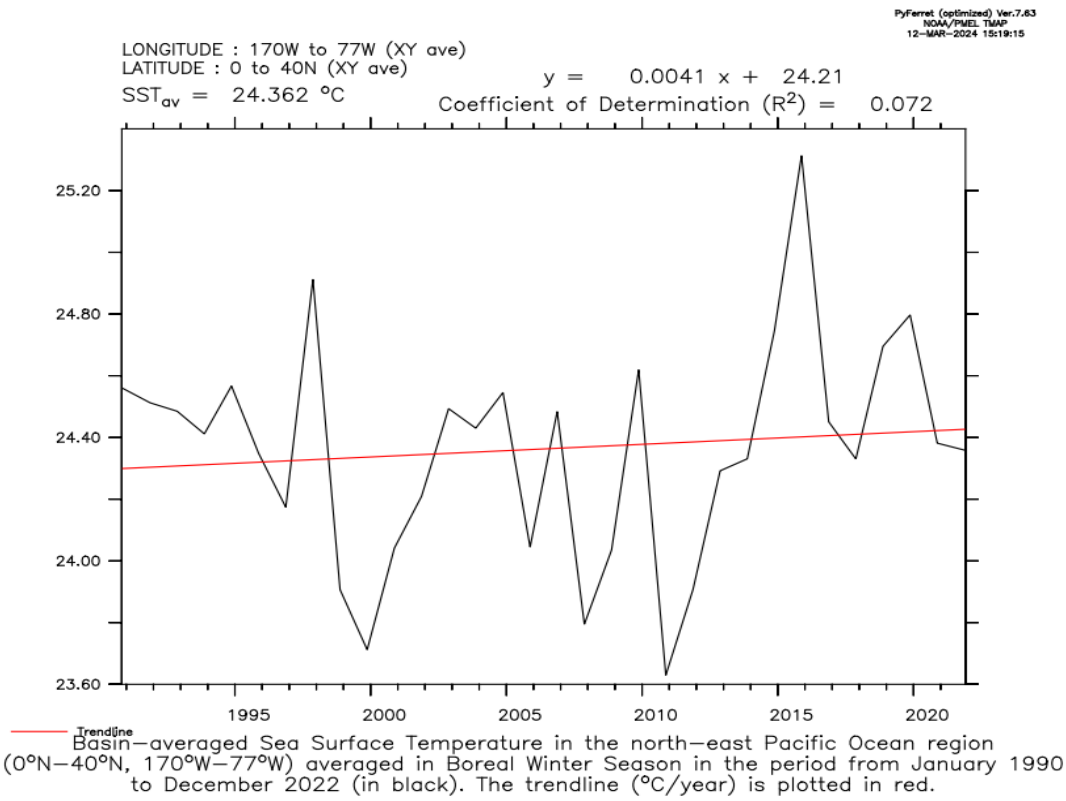


Figure 3.3.17 Basin-averaged Sea Surface Temperature in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season, in the period from January 1990 to December 2022 (in black) and trendline (°C/year) in red

The plot of the basin-averaged SST in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W), averaged every Boreal Winter Season, in the period from January 1990 to December 2022 is shown in Figure 3.3.17. The SST ranges approximately between 23.62 °C to 25.30 °C. The trendline of SSTs show an increasing trend, with increasing of 0.0041 °C/year. The Coefficient of Determination (R^2) has a value of 0.072. The average SST in the entire period and region gives a value of 24.362 °C.

CHAPTER 4: DISSCUSSION

The maps of the average sea surface temperatures (SSTs), slopes of trendlines of SSTs and the basin-averaged SSTs and their trendlines in the north-east Pacific Ocean in the period from January 1990 to December 2022 are shown in the Chapter 3. The comparisons are made for basin-averaged SSTs in the north-east Pacific Ocean region (00°N to 40°N, 170°W to 77°W) across various time scales: monthly, seasonally, and for the entire period spanning January 1990 to December 2022. This includes examining trends through slope calculations, intercepts, and coefficients of determination (R^2).

Our study, like L'Heureux et al. (2012), identified a notable meridional gradient in SSTs, with higher values typically observed around the equatorial region (5°N to 10°N) and lower values extending towards the north and south. This gradient reflects the complex interplay of oceanic and atmospheric processes influencing SST distributions in the Pacific

The spatial distribution of sea surface temperatures (SSTs) in the north-east Pacific Ocean and Gulf of Mexico aligns with patterns observed by Yin et al. (2023), with higher average values of temperatures in the Tropics, gradually decreasing poleward. In the tropical Pacific, SSTs are higher in the west and decrease eastward. This is seen in the Figure 3.1.1 in this present study. The highest SSTs are in the tropical Pacific but not at the Equator. This region is the thermal equator.

According to Xie (1998), high sea surface temperatures (SSTs), especially in the Northern Hemisphere, play a key role in maintaining the Pacific Intertropical Convergence Zone (ITCZ). This is facilitated by the Wind-Evaporation-SST (WES) feedback mechanism, where weak winds north of the equator lead to increased evaporation, further elevating SSTs and reinforcing the position of the ITCZ north of the equator. The links for the northward shift of the Inter-Tropical Convergence Zone (ITCZ) were provided by Xie (1998) at (https://iprc.soest.hawaii.edu/users/xie/ITCZ.html).

Variability in SST trends, including patches of positive and negative slopes, mirrors our own analysis across different regions. Additionally, our findings of an increasing trend in basin-averaged SSTs correspond with Yin et al. (2023) observations, indicating a warming trend over the entire time period.

The results of positive trends provided by Valipour et al. (2021) regarding the global mean sea surface temperature (GMSST) align closely with the observed trends in sea surface temperatures (SSTs) in the northeast Pacific Ocean,

The Table 4.1 shows the values of sea surface temperatures, slopes of trend-lines of sea surface temperatures, intercepts and coefficients of determination (R^2) in basin-averaged in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W) month-wise, season-wise and also for the entire period from January 1990 to December 2022. Table 4.2 shows values of least and highest sea surface temperatures and their difference based on the basin-averaged line-graph in north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W) month-wise, season-wise and also for the entire period from January 1990 to December 2022.

Table 4.1 Values of sea surface temperatures, slopes of trend-lines of sea surface temperatures, intercepts and coefficients of determination (R^2) in basin-averaged in the north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W) month-wise, season-wise and also for the entire period from January 1990 to December 2022

Time-Period / Month / Season	**Averaged Sea Surface Temperature (°C)**	**Slope of Trend-line (°C/year)**	**Intercept of Trend-line**	**Coefficient of Determination (R^2)**
January 1990 to December 2022	24.943	0.0080	24.65	0.009
January	23.664	0.0038	23.52	0.068
February	23.455	0.0048	23.28	0.073
March	23.650	0.0038	23.50	0.052
April	24.136	0.0080	23.84	0.074
May	24.752	0.0048	24.57	0.070
June	25.370	0.0068	25.11	0.067
July	25.989	0.0072	25.73	0.066
August	26.390	0.0088	26.07	0.081
September	26.430	0.0079	26.14	0.082
October	25.984	0.0049	25.80	0.074
November	25.183	0.0047	25.01	0.069
December	24.267	0.0037	24.13	0.072
Boreal Spring	23.748	0.0056	23.54	0.073
Boreal Summer	25.365	0.0063	25.14	0.079
Boreal Autumn	26.266	0.0074	26.00	0.093
Boreal Winter	24.362	0.0041	24.21	0.072

Table 4.2 Values of least and highest sea surface temperatures and their difference based on the basin-averaged line-graph in north-east Pacific Ocean region (00 °N to 40 °N, 170 °W to 77 °W) month-wise, season-wise and also for the entire period from January 1990 to December 2022

Time Period / Months / Season	Lowest Value of SST (°C)	Highest Value of SST (°C)	Difference (°C)
January 1990 to December 2022	22.90	27.50	4.60
January	22.98	24.45	1.47
February	22.94	24.11	1.17
March	23.15	24.20	1.05
April	23.59	24.80	1.21
May	24.22	25.31	1.09
June	24.80	26.08	1.28
July	25.42	26.84	1.42
August	25.78	27.42	1.64
September	25.70	27.50	1.80
October	25.22	27.00	1.78
November	24.42	26.20	1.78
December	23.50	25.28	1.78
Boreal Spring	23.24	24.30	1.06
Boreal Summer	24.82	27.00	2.18
Boreal Autumn	25.58	27.30	1.72
Boreal Winter	23.62	25.30	1.68

The investigation of month-wise trends done by Cai et al. (2001) reveals a similarity with our finding of highest value in slopes of trendline were for the month of September to November

The trendline analyses presented by Lima et al. (2012) reveal a consistent long-term trend of increasing SSTs throughout both the boreal winter and summer seasons. This trend suggests a sustained warming of the northeast Pacific Ocean. Also Gulf of Mexico is warming at rate of 0.1 to 0.2 °C per decade. The month of September has the highest SST value which also is seen in our study.

Banzon et al. (2014), report an increasing trend in basin-averaged SSTs over the entire study period, which aligns with our findings of an increasing trend in SSTs averaged for north Pacific regions. This observation strengthens the evidence of long-term warming trends in ocean temperatures, reinforcing the significance of climate change impacts on SSTs.

The discussion presented by Deser et al. (2010) delves into the spatial distribution and drivers of sea surface temperature (SST) trends across different regions. They highlight intensified warming trends observed in specific areas, such as off the east coasts of North America, as well as over the North Pacific. This observation is echoed in our study, which focuses on SST trends in the northeast Pacific Ocean and also identifies spatial variability with specific areas showing positive or negative trends.

Karnauskas et al. (2009) found highest trend in equatorial Pacific SSTs, particularly during boreal autumn and lowest trend in boreal winter. Our study found the similar outcomes, (shown in Table 4.1) i.e. during boreal autumn the trend is 0.0074 °C/year and in boreal winter it is 0.0041 °C/year.

From our figures 3.1.1 to 3.1.17 and 3.2.1 to 3.2.17 we can see that the higher SSTs are dominating in Gulf of Mexico and Caribbean Sea in Atlantic Ocean rather than in Pacific Ocean. The results of analysis by Lluch-Cota et al. (2013), on sea surface temperature (SST) trends and variability in the Pacific and Atlantic region also claims the presence of North Pacific Gyre which cools the water in north-east Pacific Ocean. We observed the absence of a significant trend in the southern part of Baja California along the California Current System (CCS) also Lluch-Cota et al. (2013) observed corresponds with our findings, indicating coherence in SST dynamics along the California margin.

There is a large increasing trend of SSTs near southern California and Baja California in August (Figure 3.2.9). Upwelling occurs along parts of the coast of North America's west coast (Bakun, 1973; https://en.wikipedia.org/wiki/California_Current). However, the reason for this increase in SST trends need more studies to find out the probable causes.

We can also see that there was a sudden rise in average SST in 1997-98 with value of 27.2 ˚C in the basin-averaged values. Schwing et al. (2002) also saw this and it is recognised as due to the ENSO event which occurred then. McPhaden et al. (1999) also observed climate event known as the 1997-98 El Niño, which is considered one of the strongest on record in the 19th century with SSTs value of 29 ˚C.

From our analysis we can see that during 2015-16 the average SSTs were highest ranging almost 27.5 ˚C this corelates to the ENSO event which was also noted by Chelle et al. (2016)

Similarly, our finding of highest average SSTs during 2015-16 aligns also with Santoso et al. (2017) with the occurrence of the 2015/2016 El Niño event. This suggests a potential correlation between the anomalously warm sea surface temperatures in the northeast Pacific Ocean and the presence of El Niño conditions during that period.

The findings from our analysis of higher SSTs during the 2015-2016 period align with the discussion provided by Su et al. (2010) and Zheng et al. (2015) regarding the formation highest SST values in the Pacific.

Our finding of exceptionally high average SSTs during 1997-98 and 2015-16 aligns with the magnitude and duration El Niño event studied by Brainard et al. (2018).

In study focused on the Gulf of Mexico (GoM) from 1982 to 2019, Li et al. (2022) reports a consistent warming trend with a best-fit slope of 0.158 °C/decade. This indicates a significant increase in sea surface temperature (SST) across the entire GoM during this period. Month-specific analysis reveals seasonal variations in warming rates, with weaker increases observed during winter months compared to summer months. Spatially, higher temperature increases are noted in coastal regions compared to offshore areas, underscoring regional differences in warming rates.

Barbosa et al. (2008) and our study indicate an upward trend in sea surface temperatures (SSTs) over the analysed periods. In Barbosa et al. (2008), the trendline for global mean SST, represented by the first two Empirical Orthogonal Function (EOF) modes, gives a value of 0.070 ± 0.0071 °C/decade. Similarly, our study demonstrates increasing trendline values in the north-east Pacific Ocean region, with slopes having a value of 0.0080 °C/year, i.e. 0.080 °C/decade, for the past 33 years.

Cane et al. (1997) reports a consistent strengthening of the gradient from 1904 to 1991 across multiple datasets. Specifically, they find trends of +0.66 ± 0.14 °C per century from their analysis, +0.11 ± 0.15 °C per century for Global Ocean Surface Temperature Atlas (GOSTA), and +0.28 ± 0.14 °C per century for Comprehensive Ocean-Atmosphere *Data* Set (COADS). By our analysis of last 33 years we obtained a value of 0.0080 °C

From Table 1 we can see the averaged SSTs in Boreal Summer, which is the hottest period in the year is having value of 25.365 °C where-else Boreal Autumn the next season is having highest SSTs value of 26.266 °C and this is due to the seasonal lag in SST. Seasonal lag in SST refers to the delay between the peak of solar radiation and the highest or lowest temperatures observed in the ocean surface. This lag occurs because water has a higher heat capacity compared to land, meaning it takes longer to heat up or cool down. During the summer months in the northern hemisphere, the sun is at its highest angle, leading to maximum solar heating. However, the highest SST typically occurs a few weeks after the summer solstice due to the time it takes for the oceans to absorb and store heat. Similarly, in winter, even though solar radiation is weaker, ocean temperatures continue to decrease for a period after the winter solstice due to the release of stored heat. This seasonal lag also can be seen for every month’s averaged SST.

CHAPTER 5: CONCLUSIONS

The basin-averaged seas surface temperature (SST) value in the north-east Pacific Ocean (00 °N to 40 °N, 170 °W to 77 °W) for the entire period of 33 years, i.e. from January 1990 to December 2022, is 24.943 °C and the slope of the trendline of the SST is 0.0080 °C/year. This indicates an increasing trend in the SST over the study region and period.

Seasonally, the Boreal Autumn has the highest SST average value of 26.266 °C. The Boreal Spring has lowest SST average value of 23.748 °C. The slopes of the trendlines of the SSTs show increasing trends in all the seasons, with highest values in the Boreal Autumn (0.0074 °C/ year) and the lowest magnitude of increasing trends in the Boreal Winter season.

Monthwise, the warmest basin-averaged SSTs are in September (26.430 °C), while the least SSTs are in February (23.455 °C). The slopes of the trendlines of SSTs show increasing trends in all the months. The largest increasing trends are in August (0.0088 °C/year), while the least increasing trends are in December (0.0037 °C/year).

From the maps of the slopes of the trendlines of SSTs in the entire study period, it is seen that there are increasing trends in the sub-tropics generally, while large parts of the tropical eastern Pacific shows decreasing trends. The largest increasing trend is in the region between (32 °N to 36 °N, 160 °W to 145 °W), with values in the range between 0.036 °C/year to 0.040 °C/year. This region shows large positive trends of SSTs from April to September, with highest trendlines in June reaching till 0.0634 °C/year.

The slopes of the trendlines of SSTs in the month of August shows largest increasing trends in the region from (30 °N to 40 °N, 160 °W to 135 °W). There is a large increasing trend of SSTs near southern California and Baja California.

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