CD 732: Data Visualization
Report for Datathon-2

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1. Introduction

We are given the data of India Ocean, generated by the ocean model MOM, run by Indian National Center for Ocean Information Services, INCOIS, Hyderabad. The data values are available for the following variables at different depths ranging from 5m to 225m with an interval of 10m:

1) Salinity – It is the amount of salt dissolved in a body of water.
2) Potential Temperature – The temperature that an unsaturated parcel of dry air would have if brought adiabatically and reversibly from its initial state to a standard pressure.
3) Meridional current – Meridional currents flows from north to south, or from south to north, along the Earth's longitude lines (or meridian circles)
4) Zonal current – Zonal currents flows from east to west, or from west to east, along the Earth's latitude lines

Our main aim is to effectively visualize the above data to find interesting underlying patterns of the Indian Ocean. We would like to study the spatial and temporal patterns related to ocean phenomena. Since we have the data around the time of the Tsunami of December 2004, we will also look at the visualizations to infer the impact of the tsunami on the above mentioned variables.

2. Methods

The data is mainly visualized using *plotly* and *matplotlib*, along with some additional matplotlib packages like *basemap* to visualize the world map and *manimation* for creating a movie of the visualized variables on an increasing time step basis.

2.1. Scalar Field Visualization

We use *Isosurface* and *Surface* from *plotly.graph_objects* to generate isosurfaces and volume slices respectively. The *contourf()* function from *matplotlib* is used to generate additional depth profiles. The color mapping has been chosen to best reflect the information the data wants to portray. It varies for different variables as mentioned in the following subsections. The minimum and maximum value of the *colormaps* (for matplotlib) as well as *surfacecolor* (for plotly) have been fixed by taking the minimum and maximum value of the corresponding variable across all data files. The latitudes and longitudes have been deliberately removed in depth profiling whereas additional markings for depth variations are incorporated for better visualization.

2.1.1. Salinity.

- **Isosurface visualization:** The isosurface has been plotted for the salinity values (an example is shown in figure 1). A perceptually uniform sequential colormap (plasma) has been chosen for this plot. This happens to be the default colormap for sequential data in plotly. In the mentioned figure, depth has been clipped till 50 meters to observe the data closer to the surface.
- **Slicing (with respect to depth):** Ocean volume slice rendering is done for the salinity values (an example is shown in figure 2). This visualisation can be used to infer the variation of salinity in the Indian ocean with respect to depth (5m - 225m) of the ocean. The colormap chose for this purpose is sequential. It can be observed from the visualisation that the data becomes sparse as depth increases. It is also interesting to note that in higher latitudes, salinity increases with depth.
- **Slicing (with respect to time):** The salinity values are visualized at a constant depth (an example is shown in figure 3). The colormap chosen for this purpose is sequential. The inferences are similar to the ones drawn in the previous datathon such as salinity near the surface of the ocean appears to have increased a bit after the occurrence of the tsunami of December 2004.

2.1.2. Potential Temperature.

- **Isosurface visualization:** The isosurface has been plotted for the potential temperature values (an example is shown in figure 4). A sequential colormap

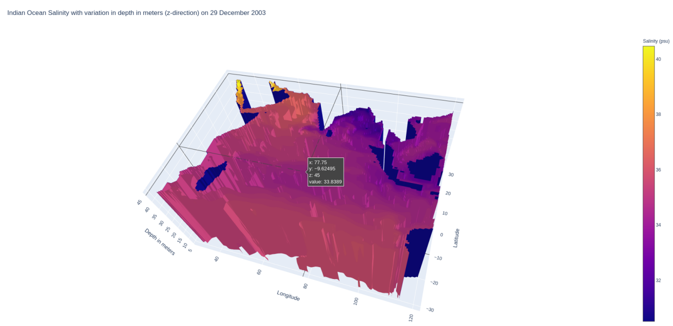

Figure 1. Indian Ocean Salinity isosurfaces

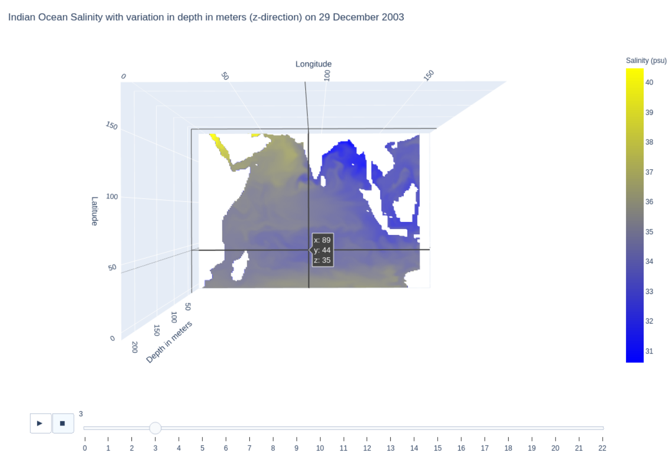

Figure 2. Indian Ocean Salinity with variation in depth

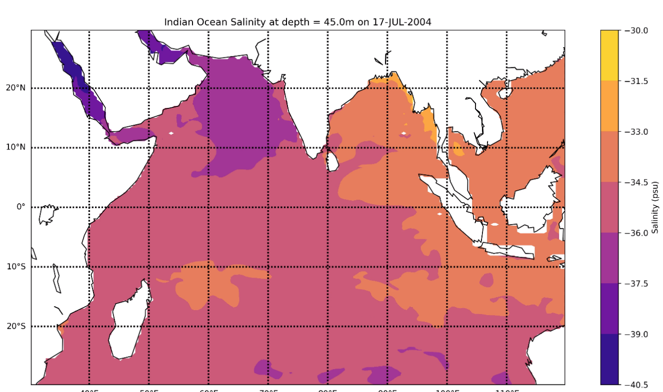

Figure 3. Indian Ocean Salinity with variation in time at a constant depth

(hot) has been chosen for this plot which emulates the blackbody radiation from an object at increasing temperatures and therefore is a good colormap to visualize temperature based data. In the mentioned figure, depth has been clipped till 50 meters to observe the data closer to the surface. An interesting observation that can be noted here is that temperature in the ocean decreases with increasing depth.

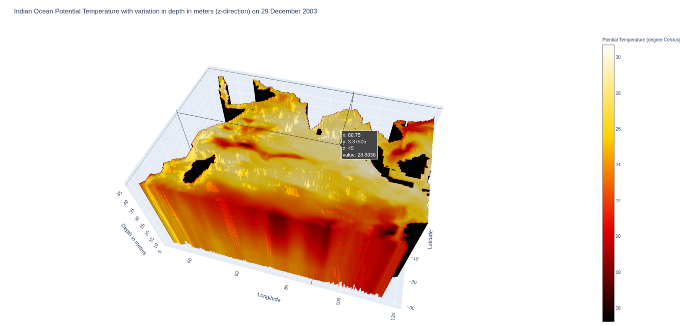

Figure 4. Indian Ocean Potential Temperature isosurfaces

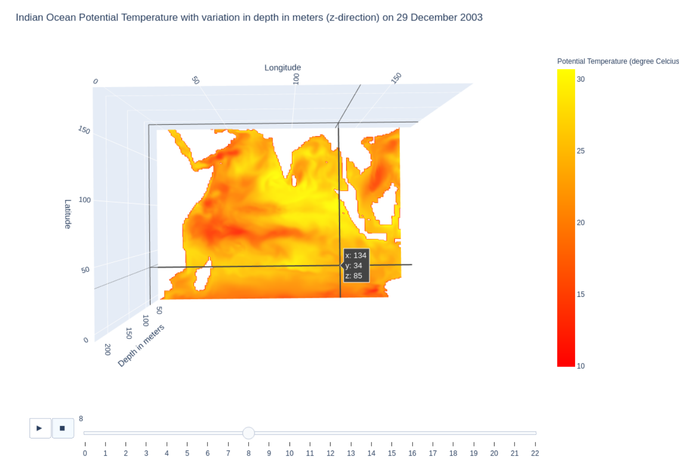

Figure 5. Indian Ocean Potential Temperature with variation in depth

- **Slicing (with respect to depth):** Ocean volume slice rendering is done for the potential temperature values (an example is shown in figure 5). This visualisation can be used to infer the variation of temperature in the Indian ocean with respect to depth (5m - 225m) of the ocean. The colormap chosen for this purpose is sequential and is suited to give a feel of temperature. It can be observed from the visualisation that the data becomes sparse as depth increases. As observed in the isosurface, temperature in the ocean decreases with increase in depth.
- **Slicing (with respect to time):** The potential temperature values are visualized at a constant depth (an example is shown in figure 6). The colormap chosen for this purpose is sequential (hot). The inferences are similar to the ones drawn in the previous datathon such as seasonalities brought about over the Indian subcontinent due to the temperature variations of the sea surface.

2.1.3. Magnitude of Currents (Zonal and Meridional).

- **Slicing (with respect to depth):** Ocean volume slice rendering is done for the magnitude of current (zonal and meridional) values (an example is shown

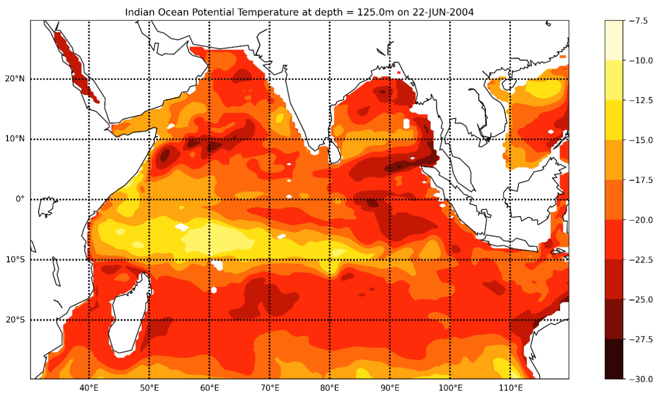

Figure 6. Indian Ocean Potential Temperature with variation in time at a constant depth

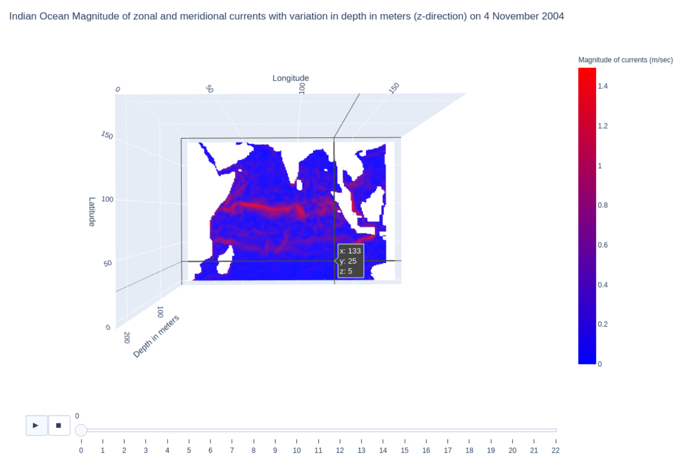

Figure 7. Indian Ocean magnitude of currents with variation in depth

in figure 7). This visualisation can be used to infer the variation of magnitude of currents in the Indian ocean with respect to depth (5m - 225m) of the ocean. The colormap chosen for this purpose is sequential and the reason behind doing so is to make the higher magnitude stand out. It can be observed from the visualisation that the data becomes sparse as depth increases. It is interesting to note that the magnitude of the currents decrease with increase in depth.

2.2. Vector Field Visualization

We use the *quiver()* function to generate the plots. The data used over here is **meridional current** and **zonal current**. After reading the values, they have been multiplied with -1 to make zonal and meridional current along x and y axis respectively. The quiver plots are plotted using – 1. keeping depth constant and varying data with time and 2. keeping time constant and varying data with depth.

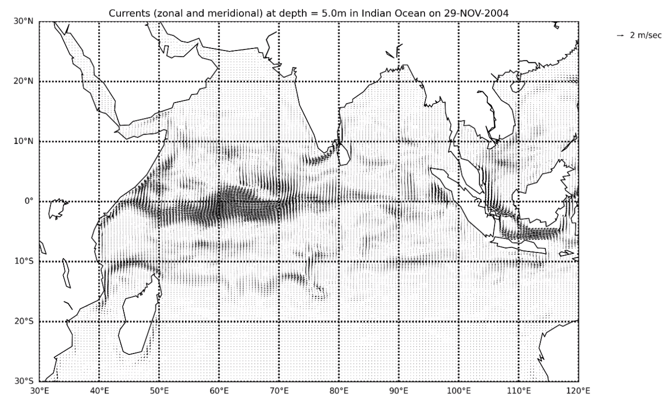

Figure 8. Variation of current pattern in Indian Ocean with time

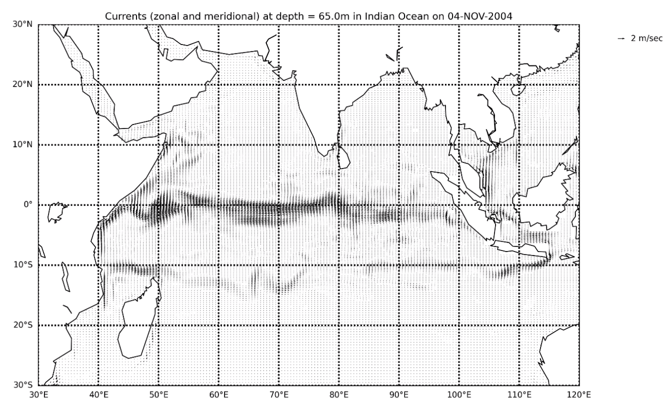

Figure 9. Variation of current pattern in Indian Ocean with depth

1) **Depth constant:** The depth is kept as 5m (i.e. closest to the surface). The reason behind this being, the magnitude of the currents decrease with increase in depth. The pattern of current is shown in figure 8.
2) **Time constant:** Here the direction and magnitude of currents can be seen with varying depth. The data has been plotted for one particular day. An example is shown in figure 9. Here, one can note that the direction of current doesn't vary much with variation of depth.

3. Results

The visualized variables can be used to infer a lot of results. Additionally mean, variance and standard deviation was computed for all the variables using Google Sheets. Some of the major inferences are as follows:

3.1. Salinity

It is very interesting to note that the facts mentioned in this source [1] could be verified using our visualizations. These are:

- It is observed that the average salinity of the Indian Ocean is 34.9 psu (In the source, the mentioned average is 35 psu).
- The low salinity trend is observed in the Bay of Bengal due to influx of river water by the river Ganga.
- On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water.
- In higher latitudes, salinity increases with depth.

3.2. Potential Temperature

The facts mentioned in this source [2] is verified using our observations and visualisations. These are:

- Temperatures in the oceans decrease with increase in depth.
- The horizontal temperature distribution is shown by isothermal lines, which in our case can be approximated as isosurfaces. Isotherms are closely spaced when the temperature difference is high and vice versa. In our results it can be observed that the isosurfaces for salinity are sparsely placed as compared to the potential temperature. This might be due to the fact that the difference in temperature is higher than the difference in salinity.

3.3. Meridional and Zonal currents

The facts mentioned in this source [3] is verified using our observations and visualisations. These are:

- Magnitude of the currents decreases with increase in depth
- The currents in the northern portion of the Indian Ocean change their direction from season to season in response to the seasonal rhythm of the monsoons.

4. Conclusion

The possibilities of interpretations of the data visualized we have visualized is very large. We have only been able to look at a few of them but they provide us with a lot of information. Depth profiling of the ocean was also done as shown in this figure 10. But, not much could be inferred using the visualization due to our limitation of knowledge in the field. Another limitation could be not interpolating the data at greater depths. The reason behind avoiding interpolation is that this is a scientific dataset and interpolation might lead to unwanted inaccuracies. The most interesting part was being able to verify the textbook results.
Note: I have used all the data for visualization of the above results.

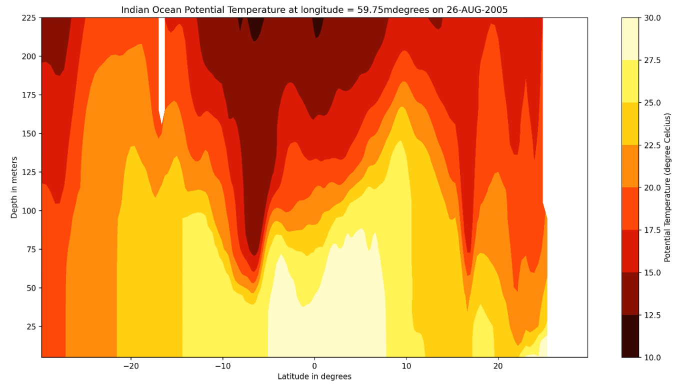

Figure 10. Indian Ocean Potential Temperature depth profile

References

[1] Ocean salinity: Vertical horizontal distribution of ocean salinity, Jul 2018.

[2] Vertical horizontal temperature distribution of oceans, Jul 2018.

[3] Indian ocean currents: Effect of monsoons on north indian ocean currents, Jul 2018.