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RECENT CHANGES IN THE NORTH SEA:

TEMPERATURE & SALINITY

A look at changes in recent history of salinity and temperature in the North Sea using GIS.

Introduction

The salty sea is more complex than it may appear. Salinity, along with temperature, both play key roles in analyzing the water cycle, ocean circulation, and climate change, which makes both very important variables to track.

One reason why salinity and temperature are so important is because of its influence on the climate system. Increases in temperatures of surrounding entities like ice and an increase in precipitation adds fresh water into the sea, which lower salinity. Seawater with lower salinity is lighter in density and won't sink as much as denser water. This process changes ocean currents. Also, since the vaporization of sea water and formation of ice are causes of increases of ocean salinity, then an increase or decrease in ocean salinity could indicate whether or not sea water is vaporizing and ice caps are forming.

Some key concerns of this project:

- How is seawater salinity and temperature in the North Sea changing over time?
    - What period of time? What is the trend? *Where?*
        - Furthermore, what could be causing these changes in those areas?

This is going to be accomplished by making a series of temporal and difference maps of salinity and of temperature throughout the years 2005 to 2010 using ArcGIS suite.

More specifically, the data that is being used in this project are surface seawater data. While information of salinity and temperature changes at greater depths would be conducive to determining seawater density (which is a driving force in ocean circulation), information about surface salinity and temperature is key for learning about changing surface buoyancy, which causes overturning circulation, among other effects.

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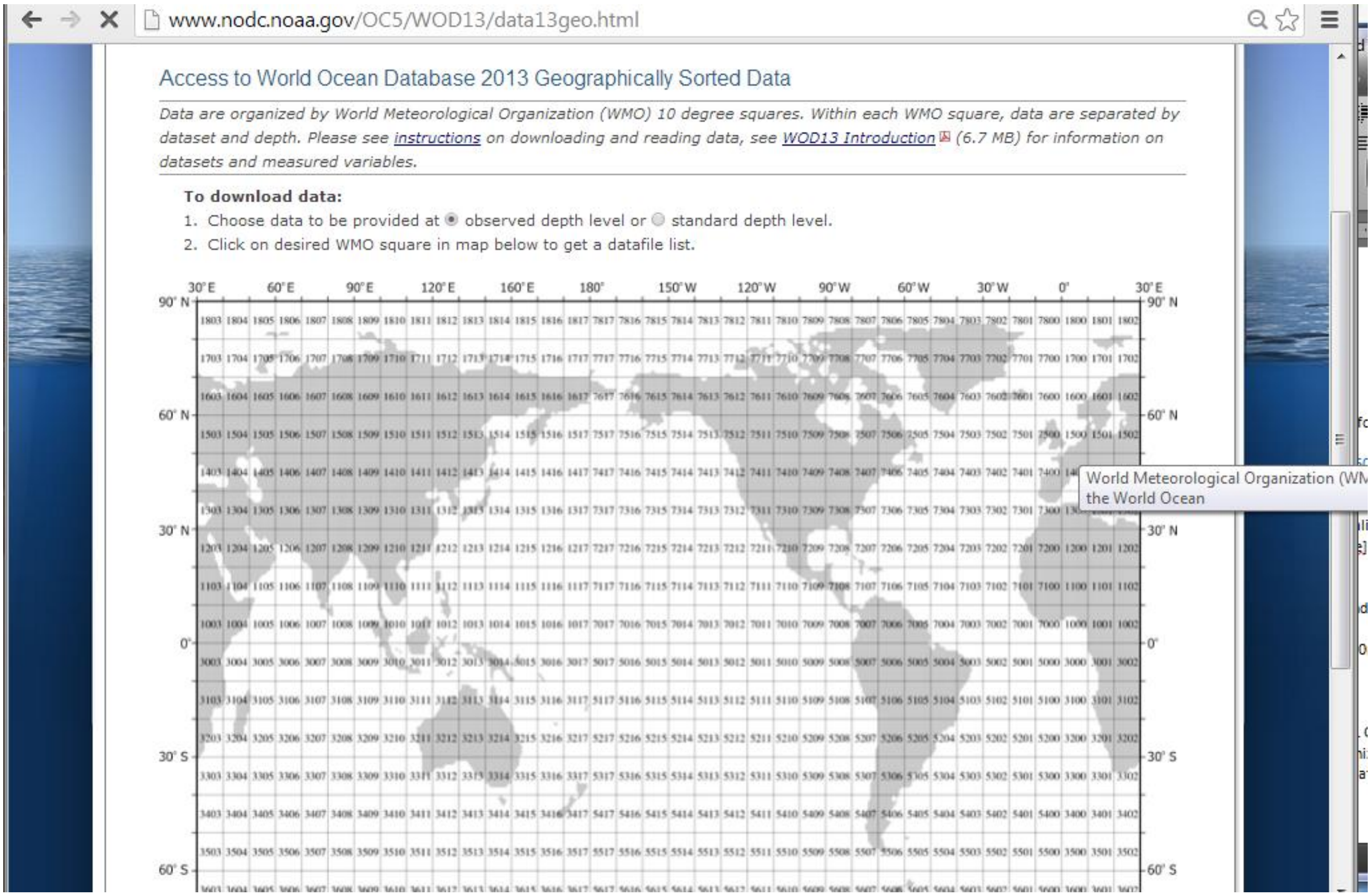
Data Collection

1. Salinity and temperature surface data was retrieved from the World Ocean Database (WOD), through the National Oceanographic Data Center (NODC), found here: http://www.nodc.noaa.gov/OC5/WOD13/data13geo.html
    a. The data used was sorted by geographically, each rectangle containing data for 10 degrees. The data used in this project is from square 1500, which covers the large majority of the North Sea in surface area. See Figure 1.
    b. There were different types of datasets (OSD, MBT, CTD, XBT, PFL, MRB, etc.). The High Resolution Conductivity – Temperature Data (CTD) was used for this project because some other datasets were limited by attributes and time span; the MBT data only had included years 1948 to 1990.
    c. The type of data was .csv.gz. The information was extracted using 7 Zip and then converted using a program also available on that website.

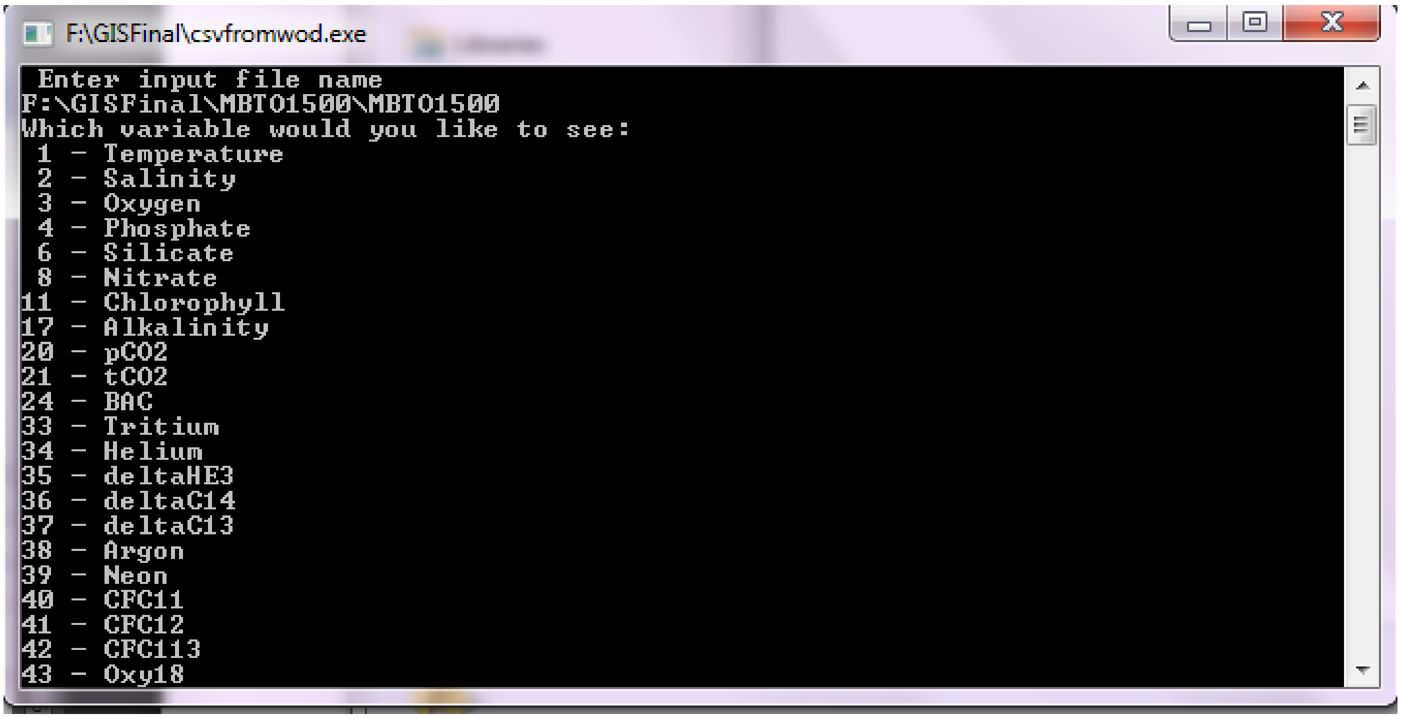
Figure 1. Retrieving data that is geographically sorted.



Data Preprocessing

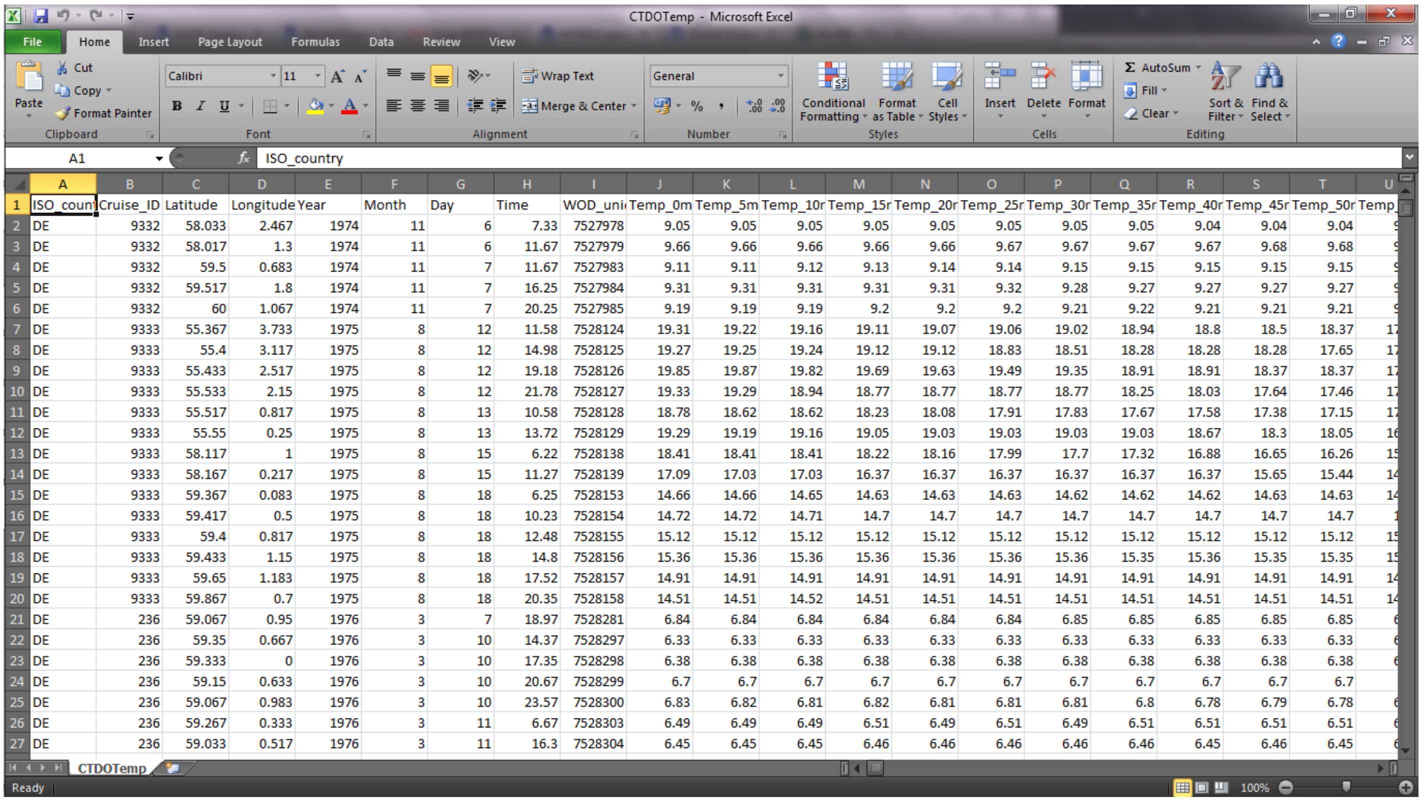
2. Because the unzipped, unaltered file contained information for many attributes (See Figure 2.), the csvfromwod.exe program was downloaded in order to extract particular variables.

Figure 2. The csvfromwod.exe program that converted data from WOD format to csv format.



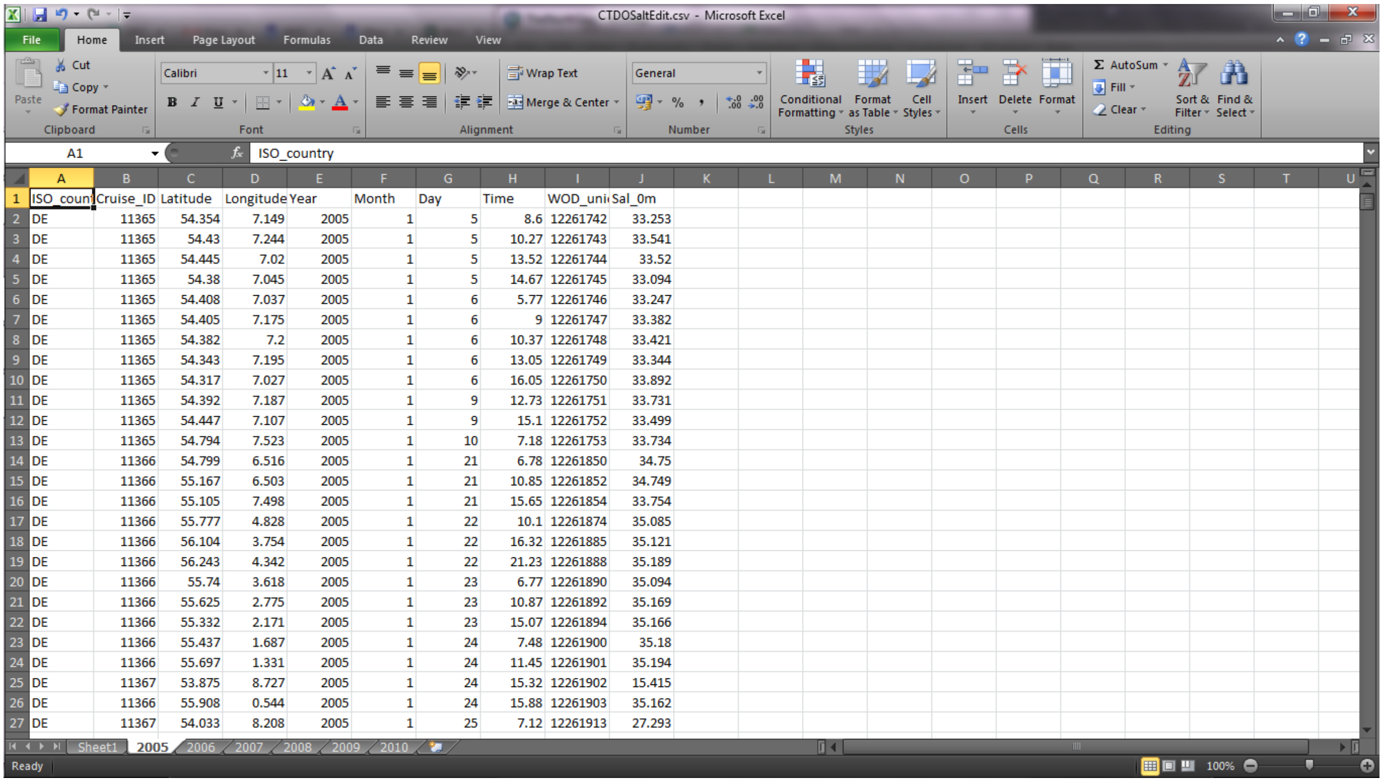
3. Next, a new Excel spreadsheet was created with only the extracted data. However, the file is still rather large and contains information for all of the years and all depths in a single file. So, new spreadsheets should be created, separating the data and grouping data by year with the surface information only at 0m (the original file contains information from 0m to 9000m below surface.) Figure 3.1 and 3.2 display the sequence of information extraction.

Figure 3.1 shows the unaltered CDT Temperature data containing excessive cells.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	ISO_coun	Cruise_ID	Latitude	Longitude	Year	Month	Day	Time	WOD_uni	Temp_0m	Temp_5m	Temp_10r	Temp_15r	Temp_20r	Temp_25r	Temp_30r	Temp_35r	Temp_40r	Temp_45r	Temp_50r
2	DE	9332	58.033	2.467	1974	11	6	7.33	7527978	9.05	9.05	9.05	9.05	9.05	9.05	9.05	9.05	9.04	9.04	9.04
3	DE	9332	58.017	1.3	1974	11	6	11.67	7527979	9.66	9.66	9.66	9.66	9.66	9.67	9.67	9.67	9.67	9.68	9.68
4	DE	9332	59.5	0.683	1974	11	7	11.67	7527983	9.11	9.11	9.12	9.13	9.14	9.14	9.15	9.15	9.15	9.15	9.15
5	DE	9332	59.517	1.8	1974	11	7	16.25	7527984	9.31	9.31	9.31	9.31	9.31	9.32	9.28	9.27	9.27	9.27	9.27
6	DE	9332	60	1.067	1974	11	7	20.25	7527985	9.19	9.19	9.19	9.2	9.2	9.2	9.21	9.22	9.21	9.21	9.21
7	DE	9333	55.367	3.733	1975	8	12	11.58	7528124	19.31	19.22	19.16	19.11	19.07	19.06	19.02	18.94	18.8	18.5	18.37
8	DE	9333	55.4	3.117	1975	8	12	14.98	7528125	19.27	19.25	19.24	19.12	19.12	18.83	18.51	18.28	18.28	18.28	17.65
9	DE	9333	55.433	2.517	1975	8	12	19.18	7528126	19.85	19.87	19.82	19.69	19.63	19.49	19.35	18.91	18.91	18.37	18.37
10	DE	9333	55.533	2.15	1975	8	12	21.78	7528127	19.33	19.29	18.94	18.77	18.77	18.77	18.77	18.25	18.03	17.64	17.46
11	DE	9333	55.517	0.817	1975	8	13	10.58	7528128	18.78	18.62	18.62	18.23	18.08	17.91	17.83	17.67	17.58	17.38	17.15
12	DE	9333	55.55	0.25	1975	8	13	13.72	7528129	19.29	19.19	19.16	19.05	19.03	19.03	19.03	19.03	18.67	18.3	18.05
13	DE	9333	58.117	1	1975	8	15	6.22	7528138	18.41	18.41	18.41	18.22	18.16	17.99	17.7	17.32	16.88	16.65	16.26
14	DE	9333	58.167	0.217	1975	8	15	11.27	7528139	17.09	17.03	17.03	16.37	16.37	16.37	16.37	16.37	16.37	15.65	15.44
15	DE	9333	59.367	0.083	1975	8	18	6.25	7528153	14.66	14.66	14.65	14.63	14.63	14.63	14.62	14.62	14.62	14.63	14.63
16	DE	9333	59.417	0.5	1975	8	18	10.23	7528154	14.72	14.72	14.71	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
17	DE	9333	59.4	0.817	1975	8	18	12.48	7528155	15.12	15.12	15.12	15.12	15.12	15.12	15.12	15.12	15.12	15.12	15.12
18	DE	9333	59.433	1.15	1975	8	18	14.8	7528156	15.36	15.36	15.36	15.36	15.36	15.36	15.36	15.35	15.36	15.35	15.35
19	DE	9333	59.65	1.183	1975	8	18	17.52	7528157	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91
20	DE	9333	59.867	0.7	1975	8	18	20.35	7528158	14.51	14.51	14.52	14.51	14.51	14.51	14.51	14.51	14.51	14.51	14.51
21	DE	236	59.067	0.95	1976	3	7	18.97	7528281	6.84	6.84	6.84	6.84	6.84	6.84	6.85	6.85	6.85	6.85	6.85
22	DE	236	59.35	0.667	1976	3	10	14.37	7528297	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33
23	DE	236	59.333	0	1976	3	10	17.35	7528298	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
24	DE	236	59.15	0.633	1976	3	10	20.67	7528299	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
25	DE	236	59.067	0.983	1976	3	10	23.57	7528300	6.83	6.82	6.81	6.82	6.81	6.81	6.81	6.8	6.78	6.79	6.78
26	DE	236	59.267	0.333	1976	3	11	6.67	7528303	6.49	6.49	6.49	6.51	6.49	6.51	6.49	6.51	6.51	6.51	6.51
27	DE	236	59.033	0.517	1976	3	11	16.3	7528304	6.45	6.45	6.45	6.46	6.46	6.46	6.46	6.46	6.45	6.46	6.45

Figure 3.2 shows the final spreadsheet workbook of the data, each year in a different sheet.



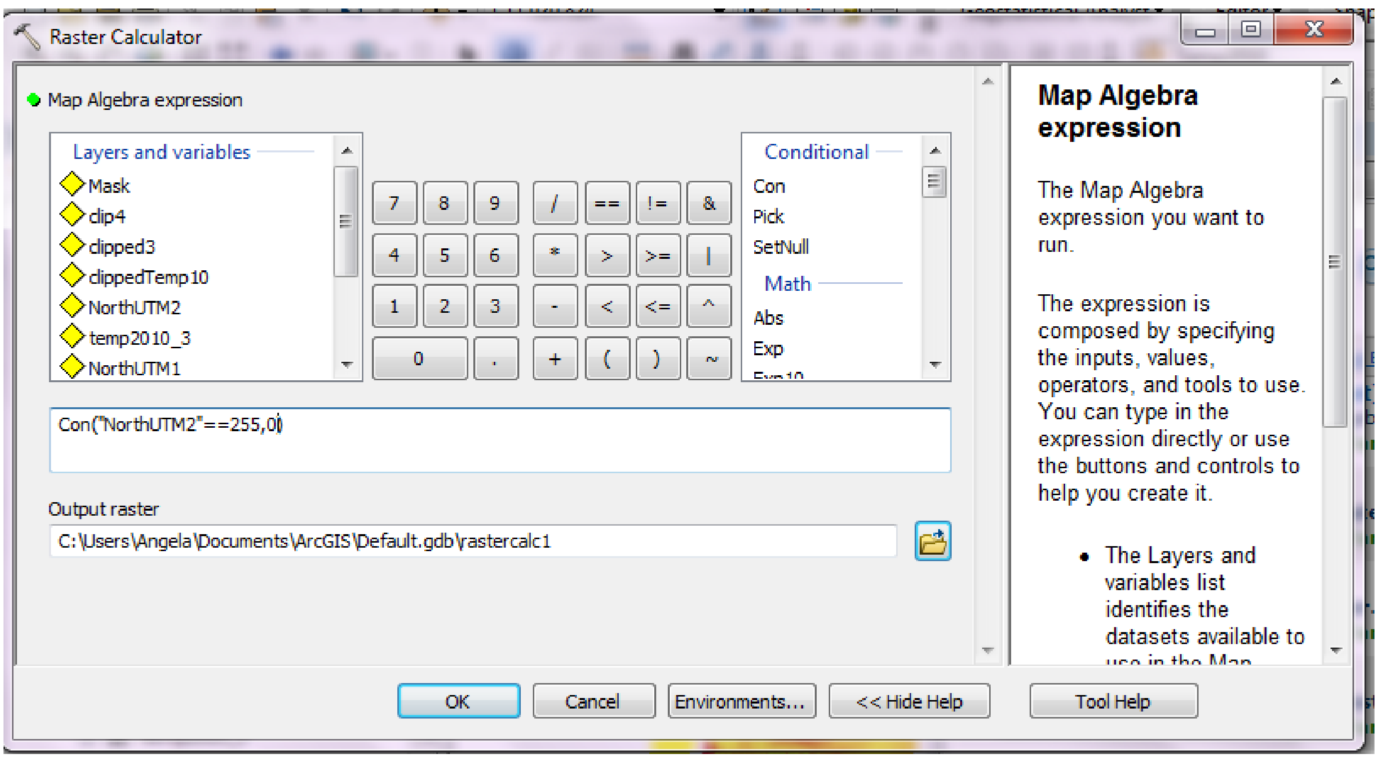
ISO_coun	Cruise_ID	Latitude	Longitude	Year	Month	Day	Time	WOD_uni	Sal_0m
DE	11365	54.354	7.149	2005	1	5	8.6	12261742	33.253
DE	11365	54.43	7.244	2005	1	5	10.27	12261743	33.541
DE	11365	54.445	7.02	2005	1	5	13.52	12261744	33.52
DE	11365	54.38	7.045	2005	1	5	14.67	12261745	33.094
DE	11365	54.408	7.037	2005	1	6	5.77	12261746	33.247
DE	11365	54.405	7.175	2005	1	6	9	12261747	33.382
DE	11365	54.382	7.2	2005	1	6	10.37	12261748	33.421
DE	11365	54.343	7.195	2005	1	6	13.05	12261749	33.344
DE	11365	54.317	7.027	2005	1	6	16.05	12261750	33.892
DE	11365	54.392	7.187	2005	1	9	12.73	12261751	33.731
DE	11365	54.447	7.107	2005	1	9	15.1	12261752	33.499
DE	11365	54.794	7.523	2005	1	10	7.18	12261753	33.734
DE	11366	54.799	6.516	2005	1	21	6.78	12261850	34.75
DE	11366	55.167	6.503	2005	1	21	10.85	12261852	34.749
DE	11366	55.105	7.498	2005	1	21	15.65	12261854	33.754
DE	11366	55.777	4.828	2005	1	22	10.1	12261874	35.085
DE	11366	56.104	3.754	2005	1	22	16.32	12261885	35.121
DE	11366	56.243	4.342	2005	1	22	21.23	12261888	35.189
DE	11366	55.74	3.618	2005	1	23	6.77	12261890	35.094
DE	11366	55.625	2.775	2005	1	23	10.87	12261892	35.169
DE	11366	55.332	2.171	2005	1	23	15.07	12261894	35.166
DE	11366	55.437	1.687	2005	1	24	7.48	12261900	35.18
DE	11366	55.697	1.331	2005	1	24	11.45	12261901	35.194
DE	11367	53.875	8.727	2005	1	24	15.32	12261902	15.415
DE	11366	55.908	0.544	2005	1	24	15.88	12261903	35.162
DE	11367	54.033	8.208	2005	1	25	7.12	12261913	27.293

4. These new spreadsheets can now be loaded into ArcMap.

ArcGIS Processing

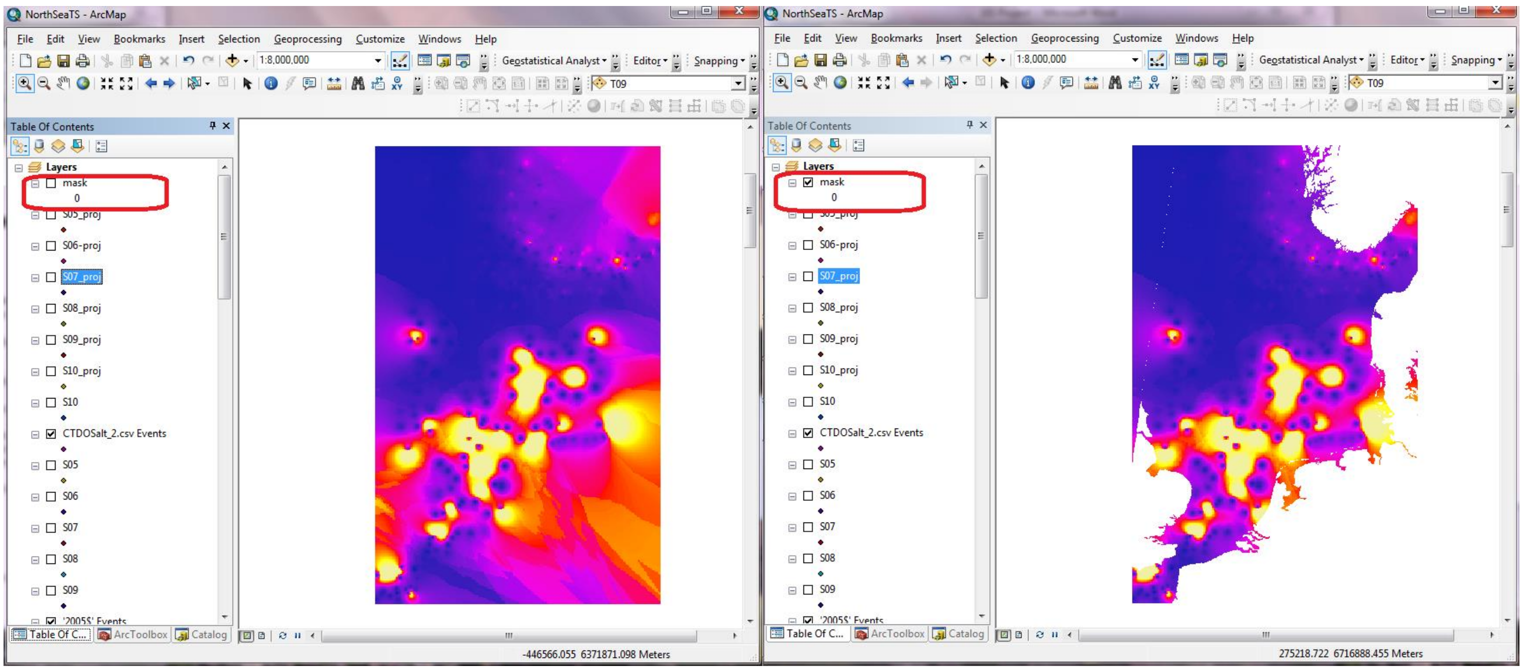
5. But before the data points were displayed, the background ocean files were loaded.
    a. http://portal.emodnet-hydrography.eu/download-bathymetry/download-selection
    b. The .tif and .asc files of the North Sea were loaded onto the map and using ArcCatalog, the projection was changed to WGS 1984 UTM Zone 32.
    c. Then a mask was made to retain the outline of the coastlines of the countries surrounding the North Sea (England, Netherlands, Denmark, Germany, and Norway). This was done using the Extract by Mask and Conditional tools, both Spatial Analyst Tools. This is shown in Figure 4.
        i. Another option would have been to clip the variable raster (temperature or salinity) to a map projection. However, the background map data used here was multi-banded, which cannot be clipped to. This is why the Masking method of showing coastlines was used instead.

Figure 4 shows the Raster Calculator Tool and the Conditional function used to create a mask.



d. The mask was dragged at the top of all of the layers in order to show land and sea borders. See Figure 5.

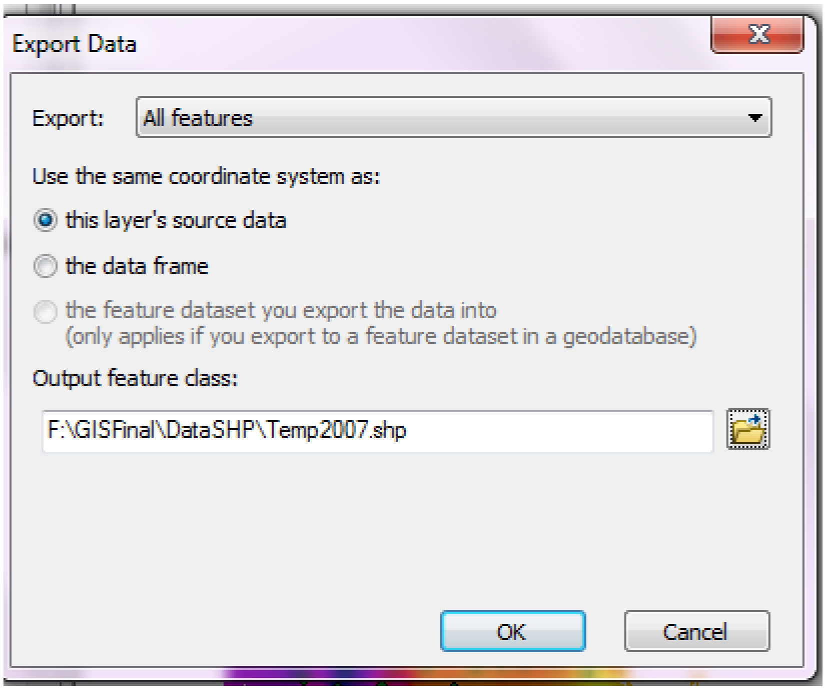
Figure 5 displays the displays the difference between layers with and without the mask on top.



6. Back to the spreadsheets, an Excel Table of each year of the two variables (Temperature and Salinity) should be loaded; there are a total of 12 tables. Display the XY Data, where X is Longitude, Y is Latitude, and Z is the variable of interest.

7. The XY Events now have to be exported into a shapefile. See Figure 6.

Figure 6 shows the XY Event being exported as a new shapefile.

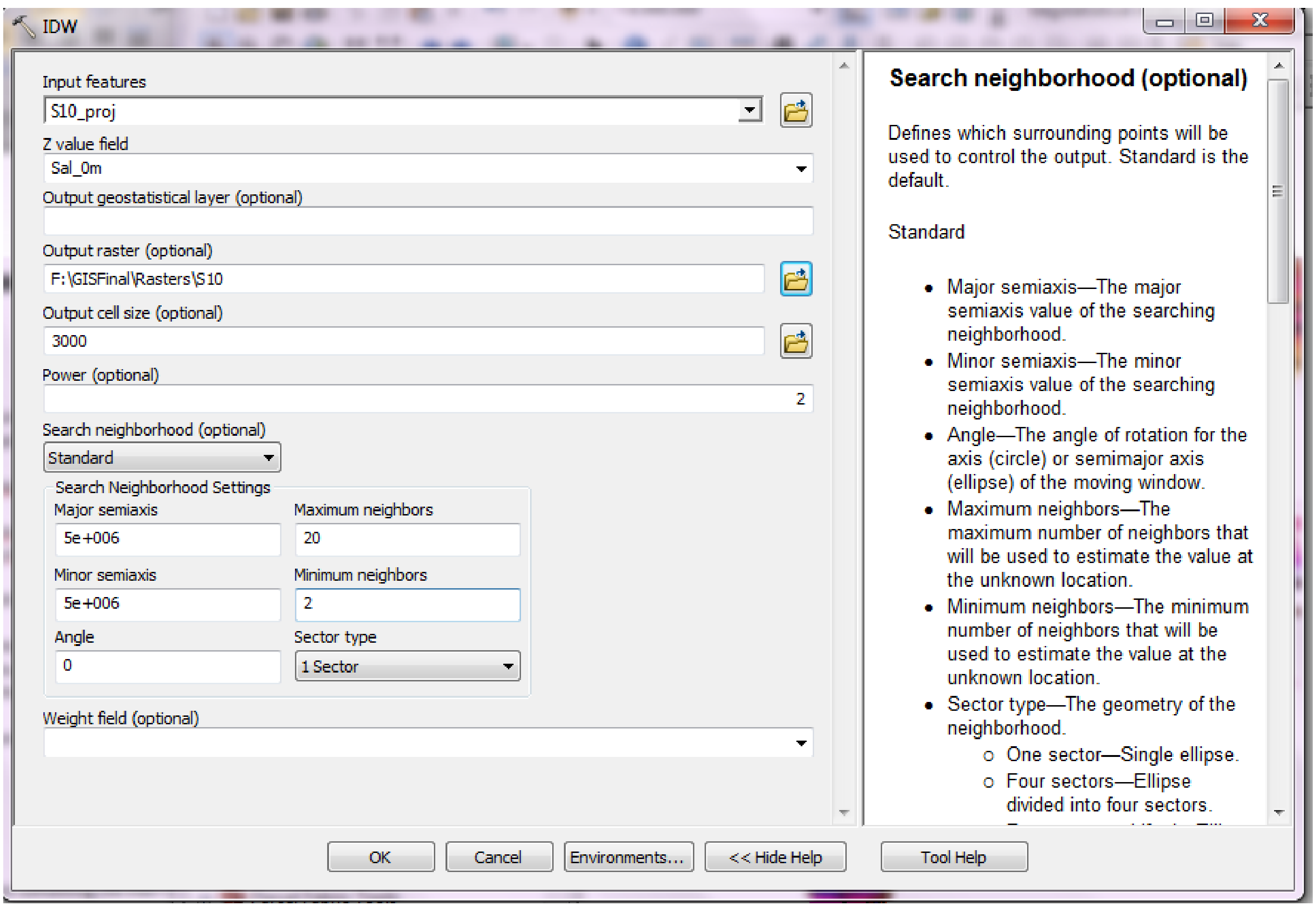


8. Using ArcCatalog, the XY Coordinate System of each of the shapefiles should be changed to GCS WGS 1984.

9. Next, change the projection of the shapefiles to WGS 1984 UTM Zone 32 using ArcToolbox > Data Management Tools > Feature > Project. Shapefiles with the new projections should be created. If this step is not taken, the IDW Interpolation will not work properly.

10. Interpolating the data is the next step. As near things are more related than distant things, especially in terms of seawater temperature and salinity. Therefore, in this project, Inverse Distance Weighting (IDW) was used to interpolate the characteristic of the seawater between the data points. IDW was used because seawater temperature and salinity is not expected to change dramatically over a short distance.
    a. A raster was created using the IDW tool under Geostatistical Analyst Tools > Interpolation. The Z-field must be set to the variable being observed. See Figure 7.
    b. Another option for interpolation was Spline. However, Splining over-smoothed the sea surface and the change in temperature or salinity were underwhelming. Also, because Splines tend to keep smaller features, it was unfitting for this project.

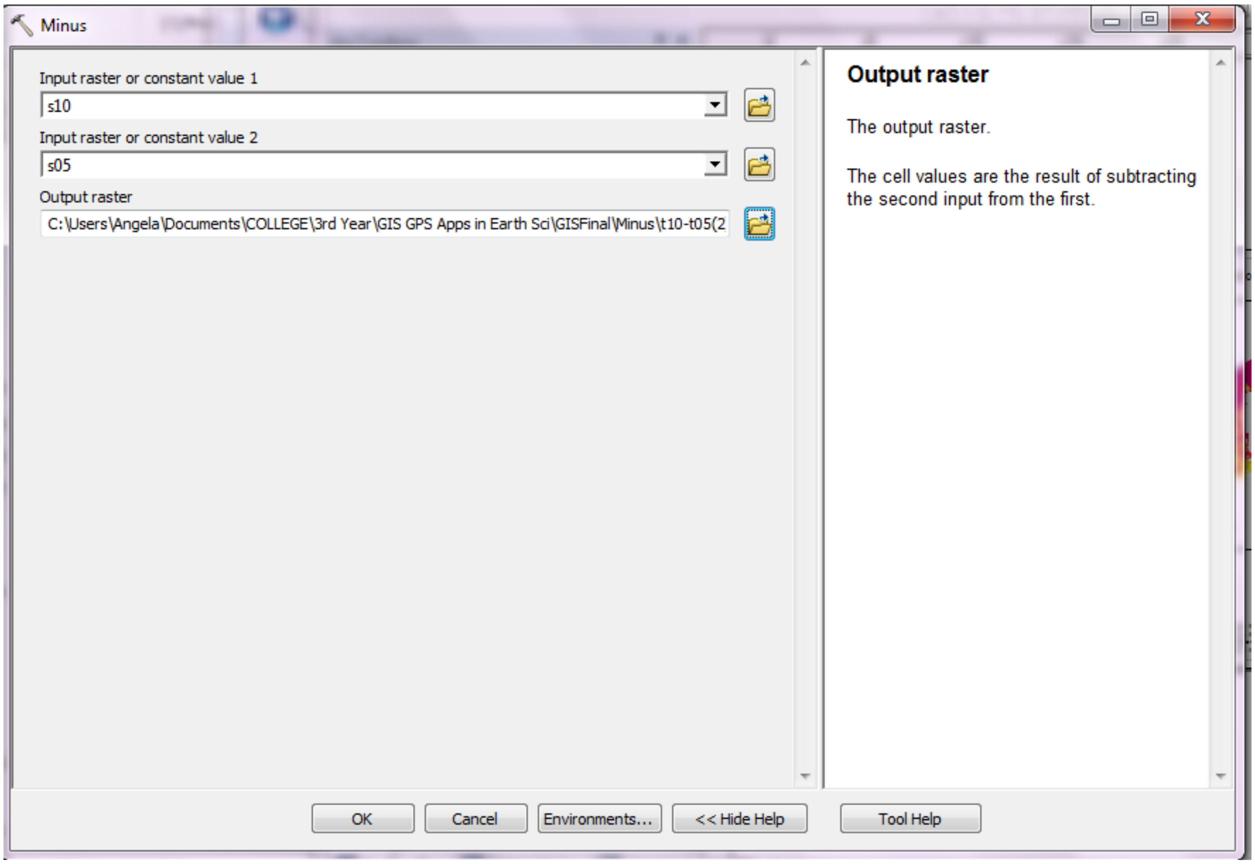
Figure 7. displays the IDW Interpolation Tool. A shapefile projected in WGS 1984 UTM Zone 32 is inputted along with the designated variable to create a raster.



11. After the raster is created, the Symbology was changed to show Stretched Colors across a ramp.

12. To find the difference between rasters, the Minus Tool was used (< Math < Spatial Analyst). See Figure 8.

Figure 8 show an input of two rasters. The second being subtracted from the first, although when tested vice versa, with the first being subtracted from the first, the result was the same.



Data Analysis & Conclusions

From what it appears like, salinity in the North Sea has decreased in the very recent history. From these six salinity maps, it looks like the southern coast of Norway has become more saline. Also concerning salinity, the red circles of unusually low salinity in the 2005 and 2006 maps may or may not be because of the Dogger Bank, a sand bank near that area of the North Sea. However, their disappearance on the map in 2007, 2008, and 2009 is strange.

Figure 9.1 displays areas of interest in the surface salinity maps. The vibrant blue and red represent areas of consistency and the lighter red and lighter blue encircle areas of change.

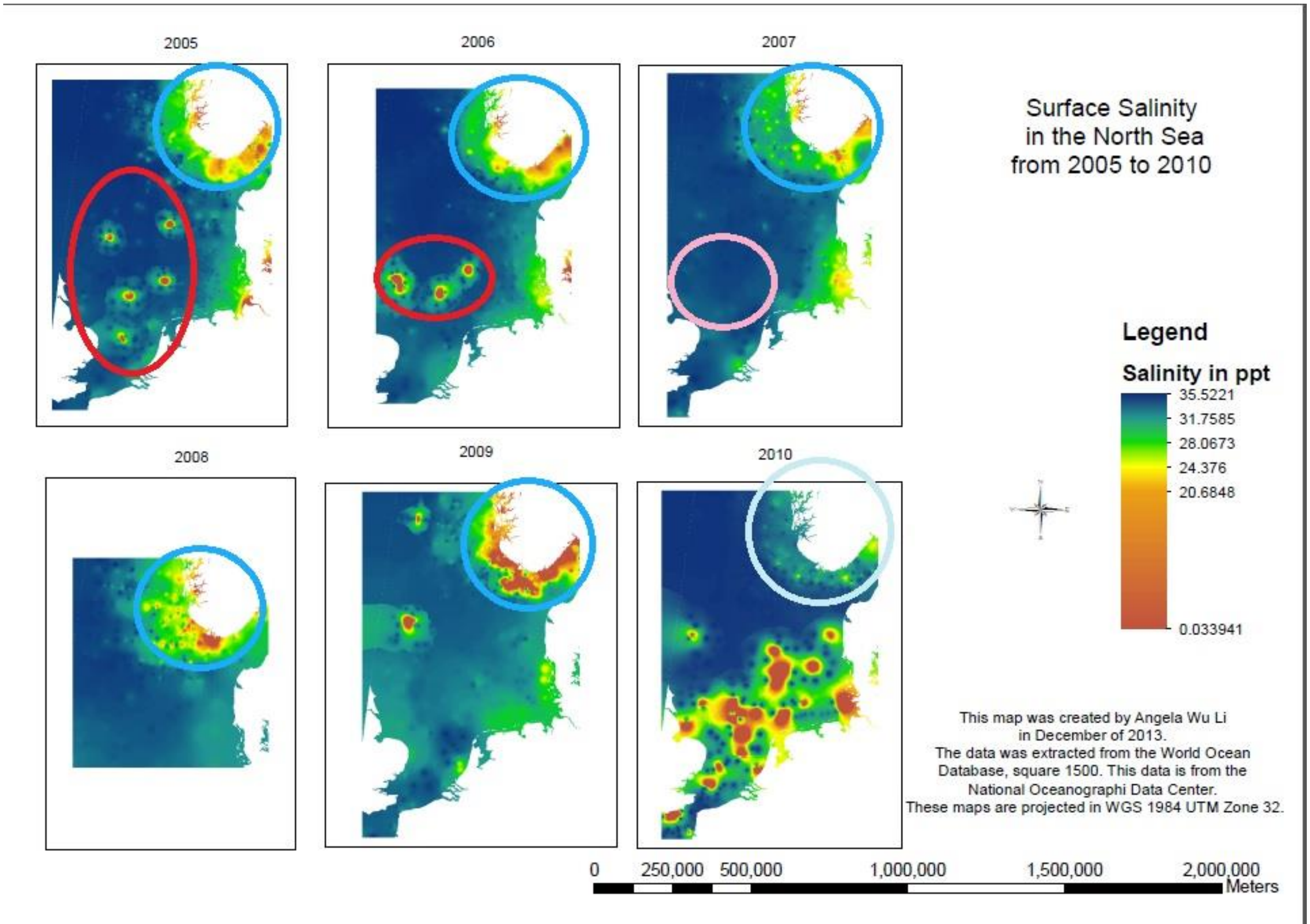
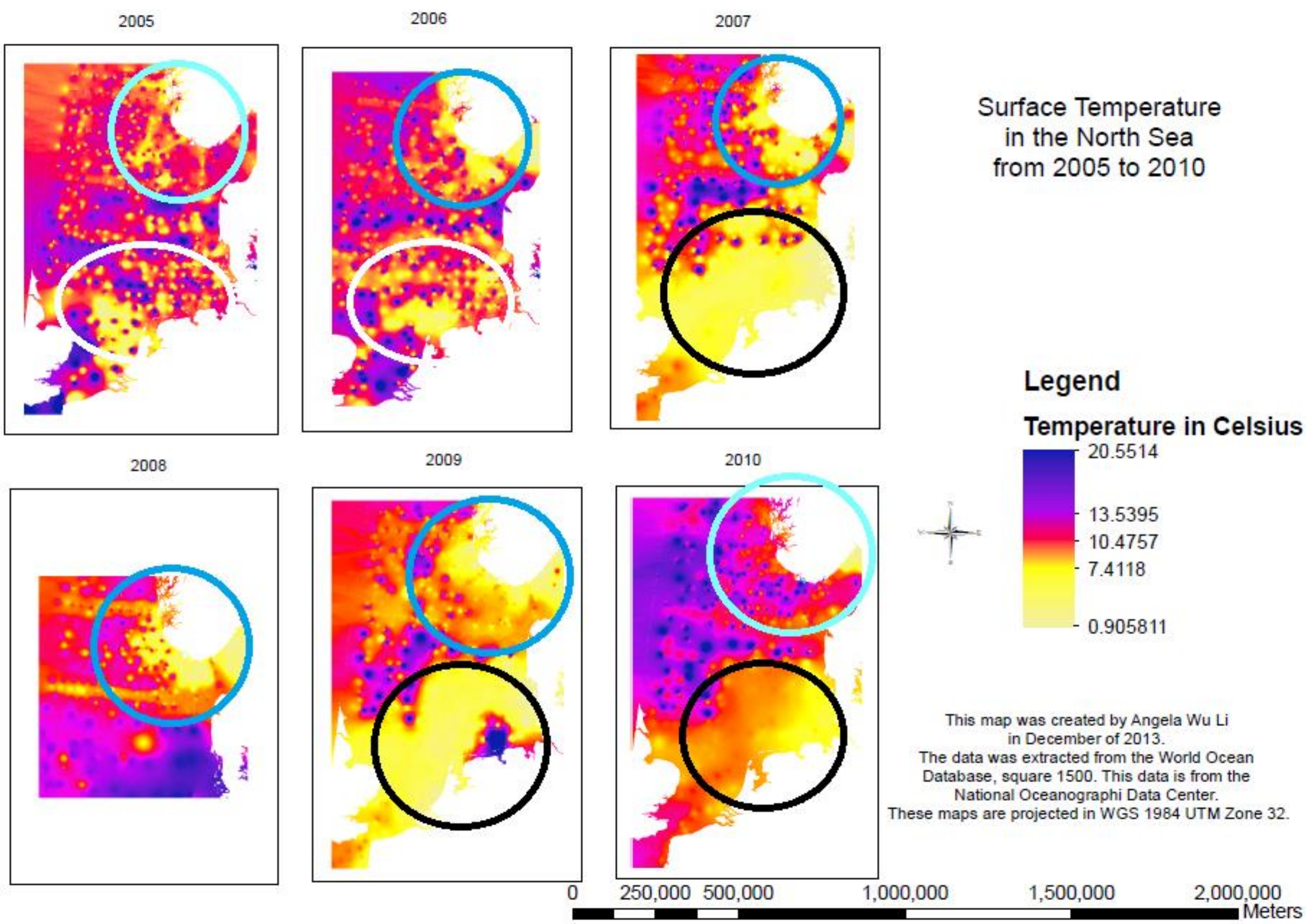
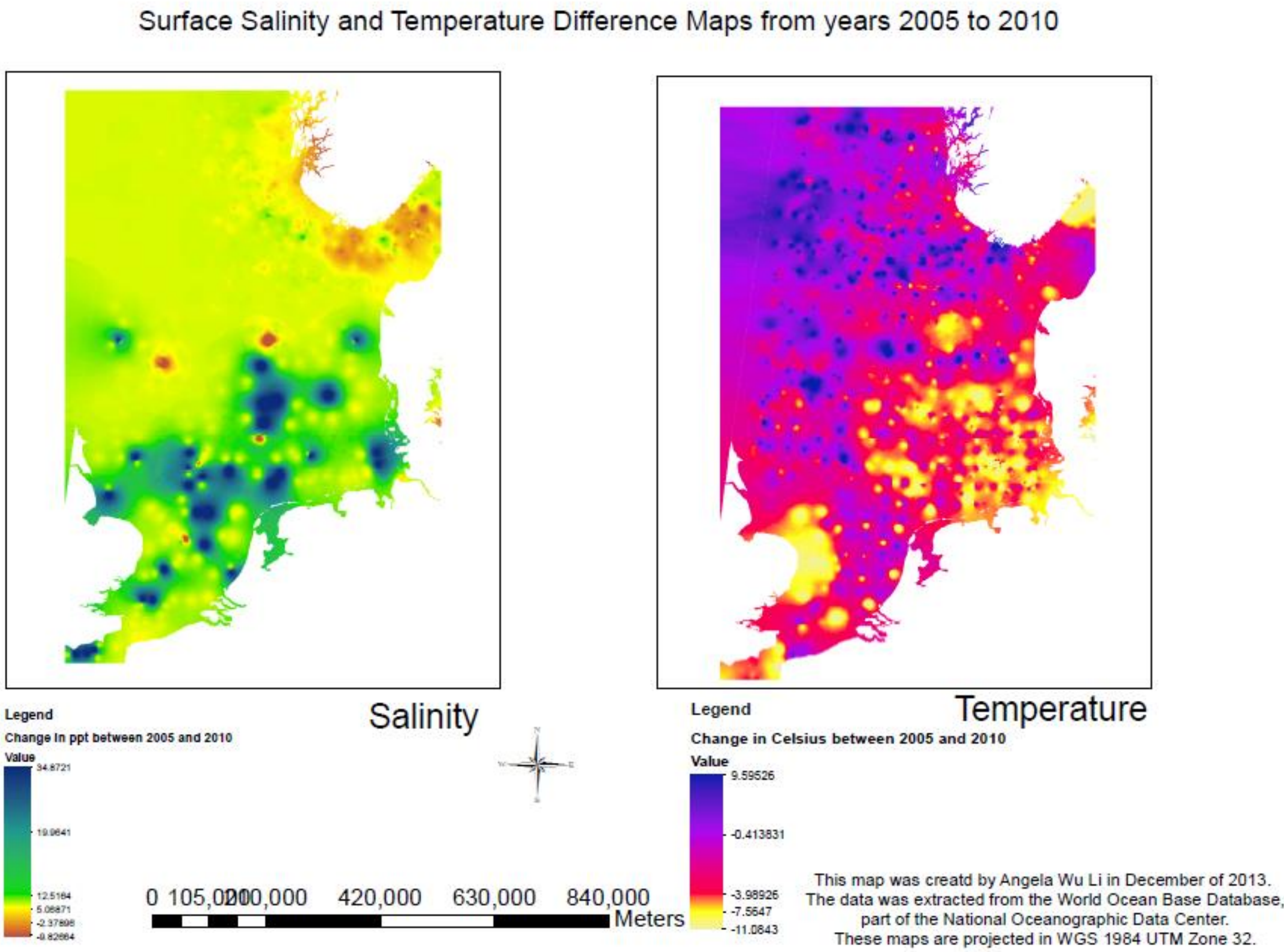


Figure 9.2 displays areas of interest in the surface temperature maps. The black and darker blue circles represent areas of consistency and the areas of white and light blue encircles comparative un-commonality.

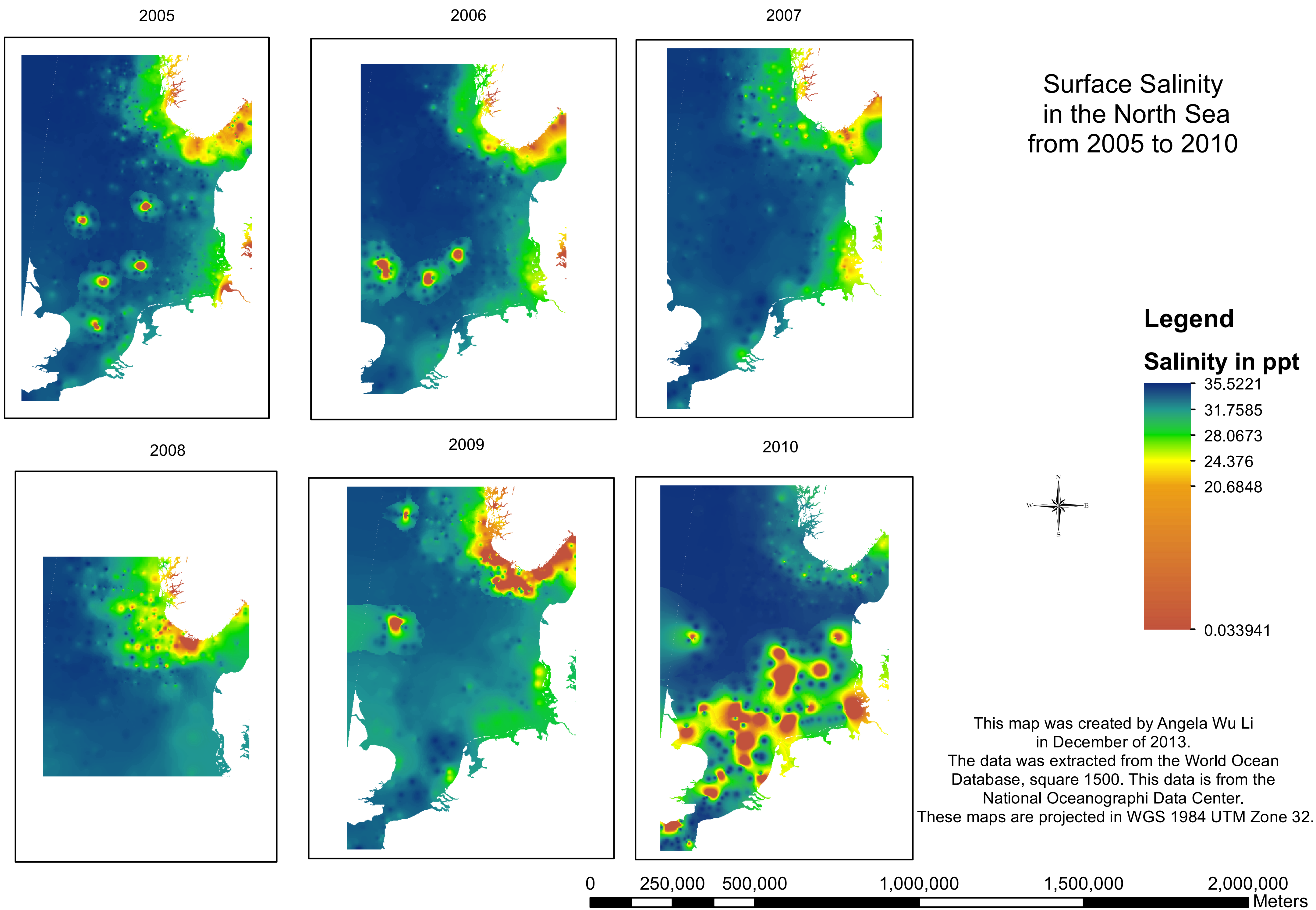


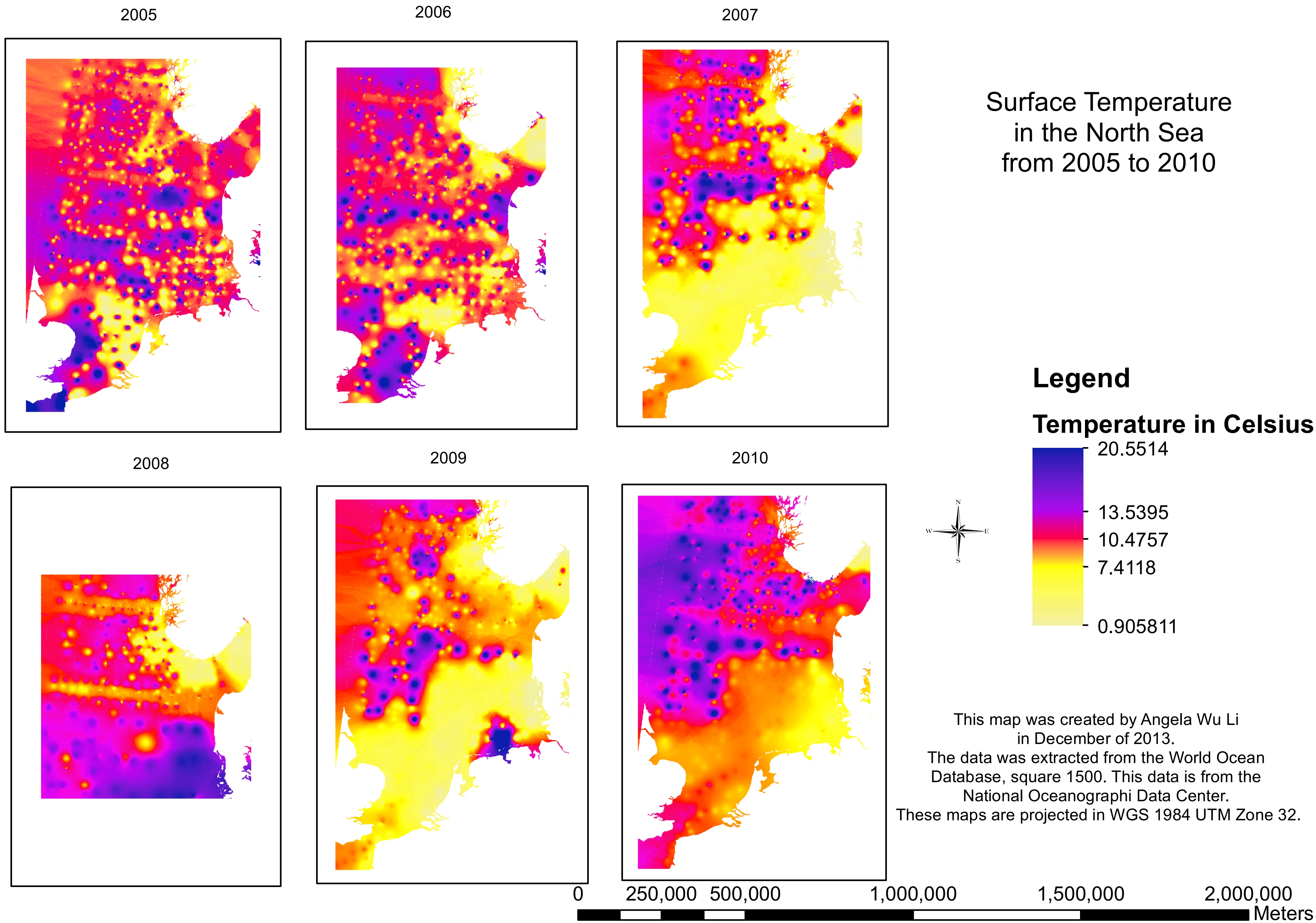
The temperature off the coasts of Denmark, the Netherlands, and Germany seems to have lowered, and the temperature at the southern coast of Norway has increased. A mentionable point of inaccuracy that could have resulted from using IDW interpolation is indicated by the white circles. These areas that seem "spotted", much like the data points that the tool was supposed to have interpolated in between.

Figure 9.3 displays differences in surface salinity and surface temperature in a span of six years. These were created using the Minus tool, subtracting the 2005 raster from the 2010 raster.

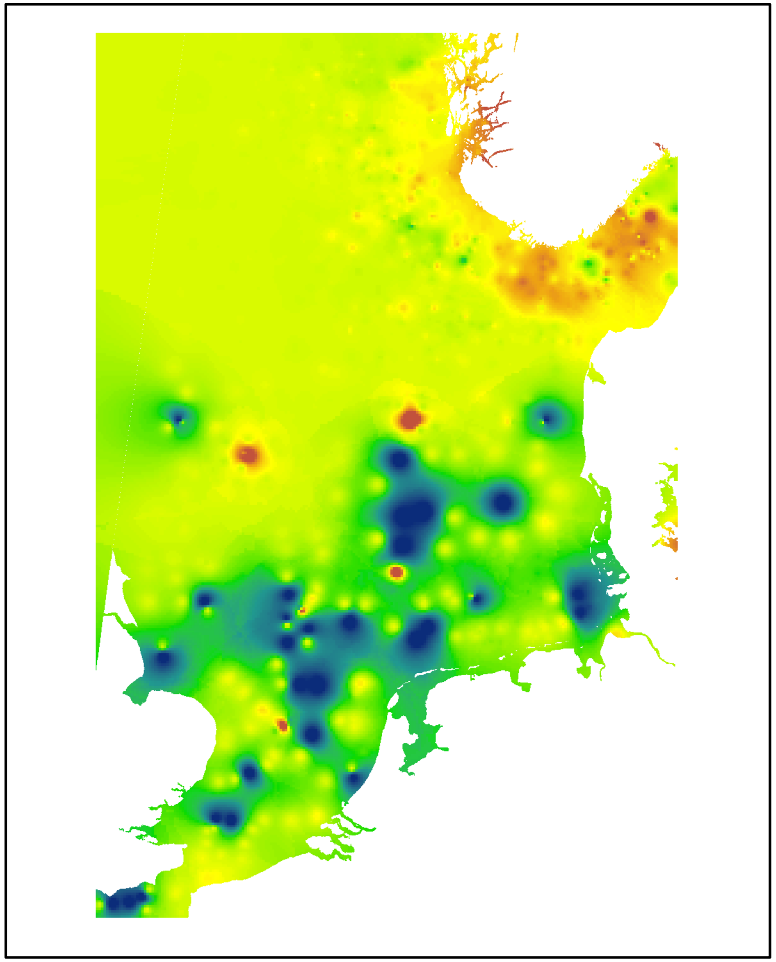


Observing year by year changes in temperature and salinity brings up many questions not all of which can be answered in this project. What can be deduced from these series of maps is that year to year, there are not drastic changes, but there are some questionable areas. See Figure 9.1, 9.2, and 9.3. Yes, the North Sea is changing in temperature and salinity every year. But perhaps a study this over a longer period of time can tell us more. To investigate salinity and temperature map patterns even further, rasters of every month or of every season could be created.


2005
2006
2007
2008
2009
2010
Surface Salinity
in the North Sea
from 2005 to 2010
Legend
Salinity in ppt
35.5221
31.7585
28.0673
24.376
20.6848
0.033941
This map was created by Angela Wu Li
in December of 2013.
The data was extracted from the World Ocean
Database, square 1500. This data is from the
National Oceanographi Data Center.
These maps are projected in WGS 1984 UTM Zone 32.
0
250,000
500,000
1,000,000
1,500,000
2,000,000
Meters


2005
2006
2007
2008
2009
2010
Surface Temperature
in the North Sea
from 2005 to 2010
Legend
Temperature in Celsius
20.5514
13.5395
10.4757
7.4118
0.905811
N
W
E
S
This map was created by Angela Wu Li
in December of 2013.
The data was extracted from the World Ocean
Database, square 1500. This data is from the
National Oceanographi Data Center.
These maps are projected in WGS 1984 UTM Zone 32.
0
250,000
500,000
1,000,000
1,500,000
2,000,000
Meters

Surface Salinity and Temperature Difference Maps from years 2005 to 2010



Salinity

Legend

Change in ppt between 2005 and 2010

Value

34.8721

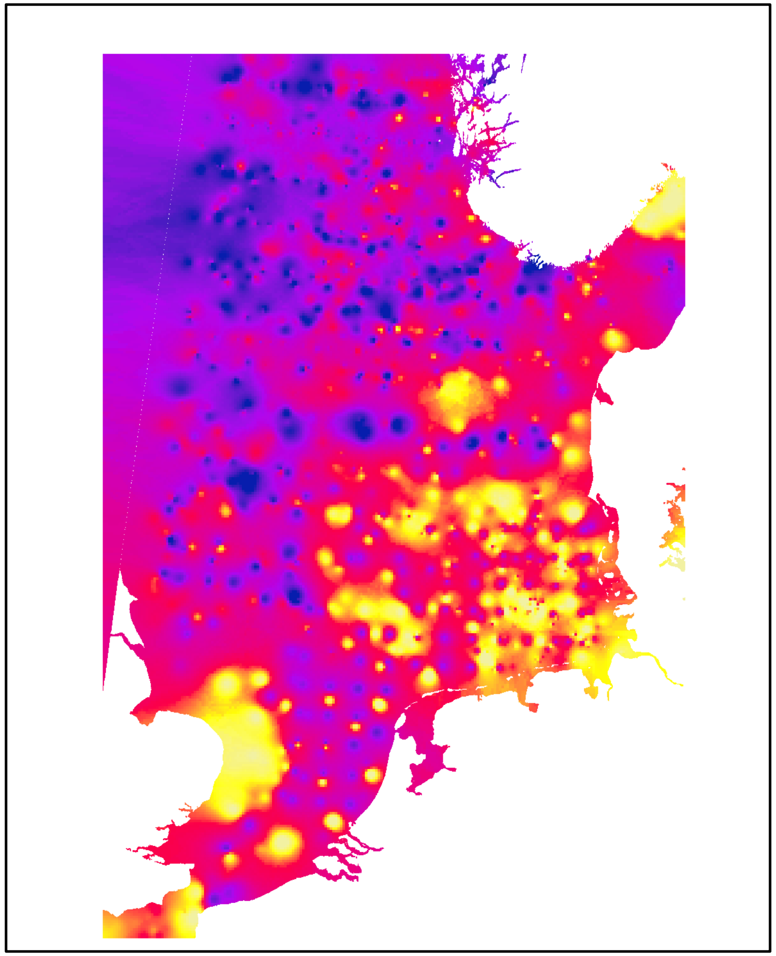
19.9641

12.5164

5.06871

-2.37896

-9.82664



Temperature

Legend

Change in Celsius between 2005 and 2010

Value

9.59526

-0.413831

-3.98926

-7.5647

-11.0843

N W E S

0 105,000 210,000 420,000 630,000 840,000 Meters

This map was creatd by Angela Wu Li in December of 2013.
The data was extracted from the World Ocean Base Database,
part of the National Oceanographic Data Center.
These maps are projected in WGS 1984 UTM Zone 32.