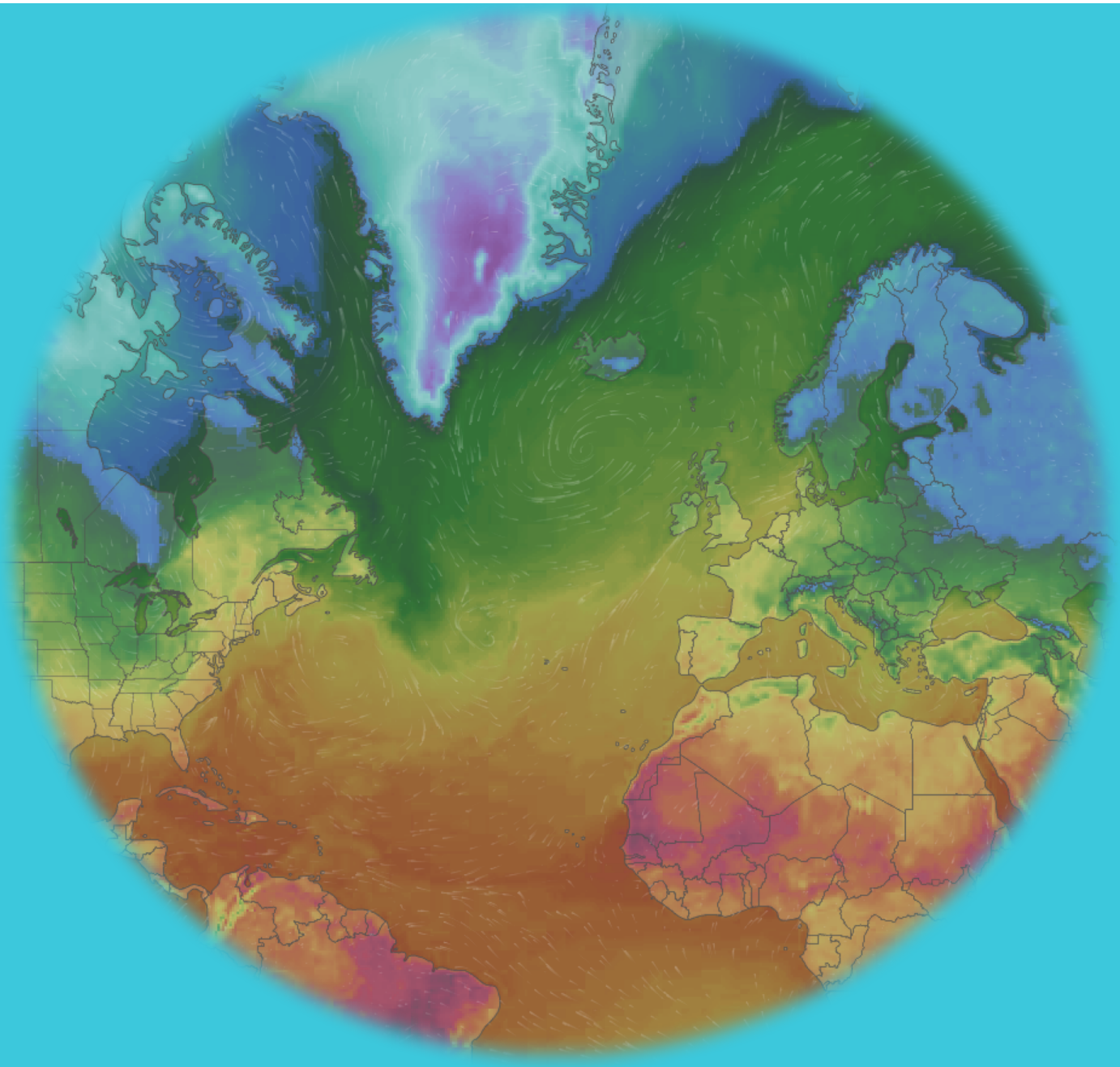

Our Earth's heartbeat:

Ocean circulation

Key Stage 4 Programme

Pupil Name	
Handbook Designed By	Dr. Joshua Griffiths

Timetable and Assignment Submission

Timetable – Tutorials

1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Late submission	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSEl
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor	Dr. Joshua Griffiths		
Title of Assignment	Our Earth's heartbeat: Ocean circulation		
Name of Pupil			
Name of School	Oasis Academy Oldham		
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 - Critical thinking	
What did you do?	How you could improve?
Learning Feedback Comment 2 – Data analysis	
What did you do?	How you could improve?
Learning Feedback Comment 3 – Scientific communication	
What did you do?	How you could improve?
Resilience Comment	
How did you show resilience?	How you could build resilience?

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Course Rationale

What is the key focus of the course?

Over 70% of the Earth's surface is Ocean, ~2,000 times the size of the UK. We depend on our oceans for holidays, for food and for travelling.

The scientific consensus is that the global average temperature is increasing, with influences upon temperature-driven circulation in the ocean. In the U.K. we benefit from the Atlantic section of the global ocean circulation, which gives us far warmer weather than other locations with the same latitude (i.e. areas of Canada, Russia).

The scientific consensus is that as the warming occurring is due to increasing concentrations of Greenhouse Gases (water vapour, H_2O, Carbon Dioxide, CO_2, Methane, CH_4, Nitrous Oxide, N_2O and Ozone, O_3) present in the atmosphere, increasing what is referred to as the Greenhouse Effect. The Greenhouse Effect reduces the amount of radiation from the Sun which is reflected out of our atmosphere, increasing the temperature of the Earth. The Greenhouse Effect is a large component of sustaining Earth as a habitable planet, increasing our average temperature from -18°C to 14 ° C. However, the large increases in the output of CO_2 generated through human activity has caused this to be accelerated beyond natural proportions.

The Ocean has a key role as a remover of CO_2 from the atmosphere, dampening increases in the Greenhouse Gas concentrations. Approximately 93% of all sequestration (storing in the seafloor/ground) of Carbon occurs in the Ocean. As the ocean warms, the saturation level is dropping, reducing the amount of CO_2 which can be absorbed. This means that as the level of Carbon Dioxide in the atmosphere increases, not all Carbon captured by the ocean is being completely sequestered, which leads to acidification of the Ocean. Ocean acidification greatly hampers the ability for small algae and animals to develop, stopping shelled creatures from developing their protective structures and increasingly mortality of juvenile plankton/small creatures. This is already having a damaging effect upon our ocean ecosystem (i.e. the bleaching of coral reefs) and potentially a wider and more catastrophic impact in the near future, with the potential to decimate the entire food web.

In this course, you will find out about the main drivers of ocean circulation, look at how the ocean responds to changes to climate and learn to predict how your ocean changes over the year and into the future. This course comes at a time where the Earth is in dire straits and it is crucial to know how to monitor our Earth's heartbeat.

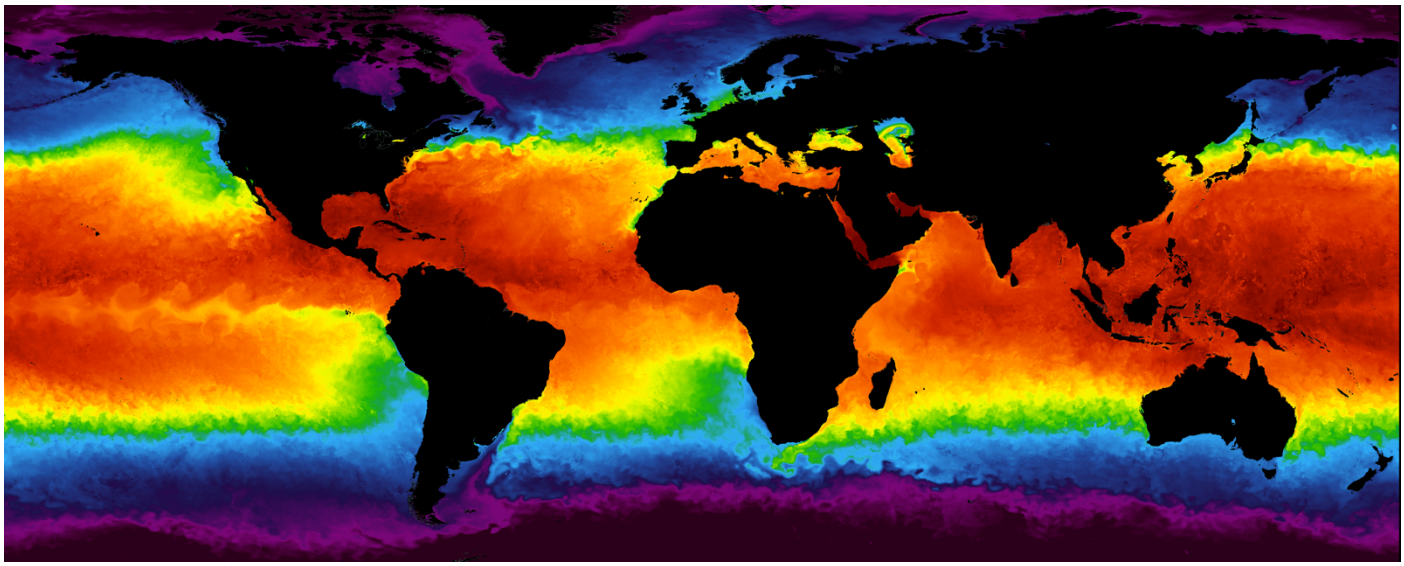


Fig. 1. Global ocean surface temperature from the GHRSST using NASA satellites (EOSDIS Worldview, 2017).

<u>What skills and knowledge will pupils develop on the course?</u>

Skills:

- Critical thinking
    - Why do processes happen?
    - Can that be believed?
- Scientific literacy
    - Understanding terminology.
    - Understanding and producing structured arguments.
- Scientific communication
    - How to produce a scientific paper/report.
    - Producing a concise and informative abstract
    - Producing and presenting a group presentation.
- Data analysis
    - Using analysis tools to examine raw data.
    - Presenting data in the form of plots.
    - Analysing plots, describing the main features.
    - Understanding the wider implication of a set of results.

Knowledge, includes:

- *What is stratification? Why and when does stratification occur?*
- *What are the tides? What controls the tides? How do we predict the tides?*
- *Where do waves come from? What is a tsunami? How can we estimate wave height?*
- *What is ocean circulation? Why do we have warm weather for our latitude?*
- *How does mixing occur in the ocean? Why are temperature and salinity so important?*

What key topics will be covered in tutorials?

1. Density
2. Tides
3. Waves
4. Ocean circulation
5. Mixing

What will the final assignment challenge pupils to do?

1. Describe the role tides, wind and surface heating upon stratification.
2. Analyse numerical model outputs describing the effect of changing the tides, wind and the surface heating.
3. Produce a scientific report (introduction, methods, results and discussion/conclusion) (70%)
4. Summarise key points of report in a conference-style scientific abstract (10%)
5. Present collaborative presentation of your reports with your fellow Ocean Physicists to present at the University Pathways conference (20%)

Biography of Dr. J.W. Griffiths

My interest in Oceanography began looking in rockpools as a child and being fascinating at what I saw. When going to university, I chose to do a broad BSc degree in Marine Biology and Oceanography. I followed this up with a more specific MSc in Physical Oceanography, following my interest in Ocean Physics. This gave the opportunity to learn numerical modelling skills, alongside theoretical and observational projects. For my MSc thesis, I worked alongside Prof. Tom Rippeth and co-supervisors at the National Oceanography Centre in Southampton (Drs. Sheldon Bacon and Yevkeny Aksenov). This project used the NEMO global ocean model in the Arctic Ocean to analyse the transport of heat and salt over the Arctic boundary and how this related to observations from the region (i.e. sea ice extent and Arctic river discharge).

Following on from this, I was accepted as one of only 10 binational PhD candidates within the U.K. and France to begin a PhD with the DSTL and DGA (the U.K. and French Ministry of Defence Research facilities, as a result of the Lancaster House Treaties, 2010) under supervision at Bangor University (with Prof. David Bowers) and Ifremer (in Brest, with Drs. Francis Gohin and Romaric Verney). This project improved satellite remote sensing of the oceans and used the large dataset to reinterpret these observations, involving fieldwork in both the U.K. and France and both numerical and statistical modelling. My project also included providing a method of how best to utilise our understanding of water visibility in an operational capacity. During my PhD, I gave presentations at École Polytechnique, École Militaire and the DGA in Paris (meeting the French Minister of Defence), the M.O.D. Dstl base at Porton Down, the Challenger Society for Marine Science and in front of almost 1,000 scientists at the European Geosciences Union in Vienna (Austria). In addition to presentations, I have had work published in peer-reviewed scientific journals and have had several photos published, including in the world's most cited scientific journal, Nature.

I have taken part in fieldwork in both the Atlantic and Arctic Oceans (NERC-funded OSMOSIS, ACCACIA and TEA-COSI projects). In the Arctic, I assisted a team looking at the effect of Ice upon mixing in the Arctic Ocean and how this may effect ocean circulation, going to within 400 miles of the North Pole and seeing several Polar Bears up close! In the Atlantic Ocean, I assisted a team looking at how mixing processes vary along the shelf break of the Atlantic Ocean and how they change over the year.

I am now happy to be working at Oasis Academy Oldham and continuing my research with Researchers in Schools through King's College London.

Mark Scheme Table

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Subject knowledge	Knowledge and Understanding	○ All content included is relevant to the general topic and to the specific question/title ○ Good understanding of all the relevant topics. ○ Scientific terms are defined and used accurately throughout ○ Clear justification on how the content included is related to the specific issues that are the focus of the assignment	○ Most of the content included is relevant to the general topic and to the specific question/title ○ Good understanding of most the relevant topics ○ Scientific terms are used accurately but not always clearly defined. ○ Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	○ Some of the content included is relevant to the general topic and to the specific question/title ○ Good understanding on some of the relevant topics but occasional confusion on others. ○ Scientific terms are used mostly accurately with occasional confusion and often not defined. ○ Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical thinking	Research and Evidence	○ Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions /ideas, consistently clearly and convincingly ○ Evidence of further reading beyond materials provided which were used in an appropriate context ○ Data is effectively analysed and appropriate assumptions/conclusions are reached	○ Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions/ ideas, mostly clearly and convincingly ○ Evidence of further reading beyond materials provided ○ Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	○ Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions/ ideas, at times clearly and convincingly ○ Limited evidence of further reading beyond materials provided ○ There is an attempt to analyse data is and draw assumptions/conclusions

	Developing an Argument	○ A point of view or position in relation to the title or question is consistently clear ○ Argument/proof exceptionally well-developed and well-justified ○ A position is clearly established in relation to the question, and is developed effectively and consistently throughout the essay ○ Makes links effectively between subjects that have not previously been associated ○ Uses concepts from the tutorials in an unfamiliar context, and does so accurately and confidently. ○ Content is analysed effectively to support the argument	○ A point of view or position in relation to the title or question is adequately clear ○ Argument/proof clear and well-developed and position justified ○ A position is established in relation to the question, and is well-developed in most of the essay ○ Some evidence of linking subjects that have not previously been associated ○ Use some concepts from the tutorials in an unfamiliar context, but not always accurate ○ Analysis of content to support the argument	○ A point of view or position in relation to the title or question is somewhat clear ○ Argument/proof clear but not well-developed ○ A position is established in relation to the question, and is well-developed in parts of the essay ○ Limited evidence of linking subjects that have not previously been associated ○ Limited use of concepts from the tutorials in other contexts ○ Some analysis of content to support the argument
	Critical Evaluation	○ Moved beyond description to an assessment of the value or significance of what is described ○ Evaluative points are consistently explicit/systematic/reasoned/justified ○ Effective critiques on the reliability of sources provided	○ Mostly description but some assessment of the value or significance of what is described ○ Evaluative points are mostly explicit/systematic/reasoned/justified ○ Some evidence of critiques on the reliability of sources provided	○ Only description with minimal assessment of the value or significance of what is described ○ Evaluative points are at times explicit/systematic/reasoned/justified ○ Limited evidence of critiques on the reliability of sources provided
Written communication	Structure and Presentation	○ Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment ○ The introduction	○ Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment ○ The introduction	○ Ideas are presented in paragraphs and arranged in a structure ○ The introduction mentions how the essay/report will deal with the

		clearly outlines how the essay/report will deal with the issues ○ The conclusion summarises all the main points clearly and concisely ○ All calculations, formulas and methods are clearly structured, clear to follow and correct ○ Tables and graphs are effectively constructed including appropriate headings, units and scales. ○ All sources are referenced correctly in an agreed format	adequately describes how the essay/report will deal with the issues ○ The conclusion summarises most of the main points clearly ○ Calculations, formulas and methods are mostly structured, clear to follow and correct ○ Most tables and graphs are well constructed ○ Most sources are referenced correctly in an agreed format	issues ○ The conclusion summarises some of the main points clearly ○ Calculations, formulas and methods are not always structured, clear to follow and correct. ○ Some tables and graphs are well constructed but contains some errors ○ Some sources are referenced correctly in the agreed format with occasional errors
	Language and Style	○ No spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style consistently clear, appropriate for scientific documents and easy to follow ○ Accurate and consistent use of technical language and vocabulary	○ Minimal spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style mostly clear, appropriate for scientific documents and easy to follow ○ Some attempts of using technical language and vocab alary, but not always accurate	○ Some spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout with occasional errors ○ Writing style moderately clear, appropriate for scientific documents and easy to follow ○ Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

Word	Definition	In a sentence	In your own words
Amphidromic point	A point in the ocean with no vertical tidal motion but with a high tidal current.	The tidal range is zero at the amphidromic points.	
A.M.O.C.	The Atlantic Meridional Overturning Circulation is a major current within the Atlantic Ocean, characterised by the flow of warm saline water northwards and cold water southwards.	The Gulf Stream represents the northernmost component of the AMOC.	
Dew point	The temperature below which water droplets condense and dew forms.	Dew point is a good representation of the humidity of the air.	
Double diffusion	Convective process driven by two different density gradients, with different rates of diffusion.	Double diffusive processes, such as 'salt-fingering' are driven by the presence of hot saline water lying above cold fresh water.	
Ebb	The receding movement of the tide.	During the spring tide, there was a strong ebb current.	
Entrainment	The process by which one layer expands into another.	Wind driven entrainment causes the surface mixed layer to deepen.	
Flood	The incoming movement of the tide.	The flood tide flooded the car left on the beach,	
Halocline	A place in the ocean where salinity changes with depth.	The halocline was visible in the water column.	
Neap tide	The point at which the tidal range is the least.	The best time to look in rock pools is on a neap tide.	
Pycnocline	A place in the ocean where density changes with depth.	The pycnocline was observed deep in the water column.	
R.A.P.I.D. Array	A monitoring array across the Atlantic Ocean at 26°N, with deep moorings observing changes in oceanographic properties with depth across the ocean.	The R.A.P.I.D. Array continues to provide us with new information about our ocean.	

Spring tide	The point at which the tidal range is the greatest.	Some coastal areas become flooded on especially high spring tides.	
Standing wave	Created by two equal progressive waves travelling in the opposite direction.	Standing waves have multiple nodes.	
Stochastic	Something which has a random distribution but which can be analysed statistically.	Turbulence is a stochastic process.	
Stratification	Vertical variability in the layering of water as a result of differences in density.	During the summer, thermal stratification occurs in most shelf sea regions.	
Swell wave	Regular waves, with a long wavelength.	Swell waves propagate along the interface between water and air.	
T-S diagram	Diagram showing variation in the temperature and salinity with depth.	The T-S diagram showed the mixing of different bodies of water.	
Thermocline	A place in the ocean where temperature changes with depth.	The surface water was far colder than that at the bottom, signifying a steep thermocline.	
Thermohaline circulation	Circulation driven by temperature differences between the layers within the water	Heat was circulated throughout the ocean by the thermohaline circulation.	
Tidal harmonic	Different amplitudes and frequencies of the tide to take account of variability in the relative positions of the Sun, Moon and the Earth.	M2 (lunar semidiurnal) and S2 (solar semidiurnal) results in spring-neap tidal cycle (~14.5 day between highest and lowest tidal range).	
Tidal-mixing front	Fronts separating thermally-stratified water from vertically mixed water.	Tidal mixing fronts are often observed in shelf seas in the summer months.	
Tidal range	The vertical displacement between high and low tide.	The tidal range in the Bay of Fundy is astonishing 16.3m (4 double-decker buses).	
Tsunami	Waves with long wavelengths, produced by activity underneath the seafloor.	The speed of tsunamis is characterised by the shallow-water wave equation.	
Wavelength	The distance between wave crests.	A tsunami has a very long wavelength.	

Wave orbitals	Circular motions occurring under a surface wave. Energy decreases as you move deeper below to wave, with smaller wave orbitals.	The wave orbitals reduced dramatically with depth, with little effect on the seabed.	
Wave period	The time between wave crests passing a location.	The wave period was large, with a long wavelength.	
Wave speed	The speed of a wave.	The wave speed was fast, with three waves passing in 10 seconds.	

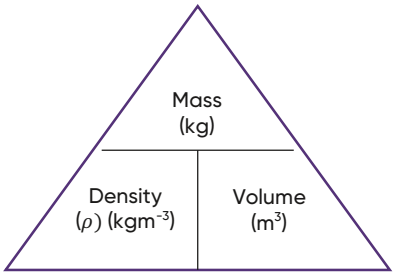
Tutorial 1 – Density

Over 70% of the surface of the Earth is water, not land.

Density of water, ρ_w, is controlled by two main properties: the temperature (T) and the salinity (S) (the proportion of salt). Fresh water has a density of approximately 1,000kg^{-3}, with salt water having a density normally between 1,020kgm^{-3} and 1,030kgm^{-3}.

1. Temperature:
    a. heating at the ocean surface by the sun
    b. mixing through the water column.
2. Salinity:
    a. evaporation of water
    b. input of freshwater from discharging rivers.

Density (ρ) = Mass/Volume
kgm^{-3} = kg / m^3



The density of water increases with increased salinity

The density of water decreases with increased temperature (the water expands, increasing in volume)

When water bodies above each other have different densities, this is called STRATIFICATION. A stratified layer can be thought of a as a location with a steep gradient in density.

The layer between two heat stratified layers is called a THERMOCLINE
The layer between two salinity stratified layers is called a HALOCLINE
More broadly, the layer between two density stratified layers is called a PYCNOCLINE

TIDAL MIXING FRONTS are locations where WELL-MIXED waters transition to STRATIFIED waters (what can you see here?)

Fig. 2. A diver passing through a halocline in Mexico (PBS, 2017).

Practical: LOCK-GATE EXPERIMENT

Two bodies of water separated by a sheet of plastic:

- One is cold and dyed blue.
- The other is warm and dyed red

When the sheet of plastic is removed, it is possible to see the formation of two stratified layers and a density-driven circulation.

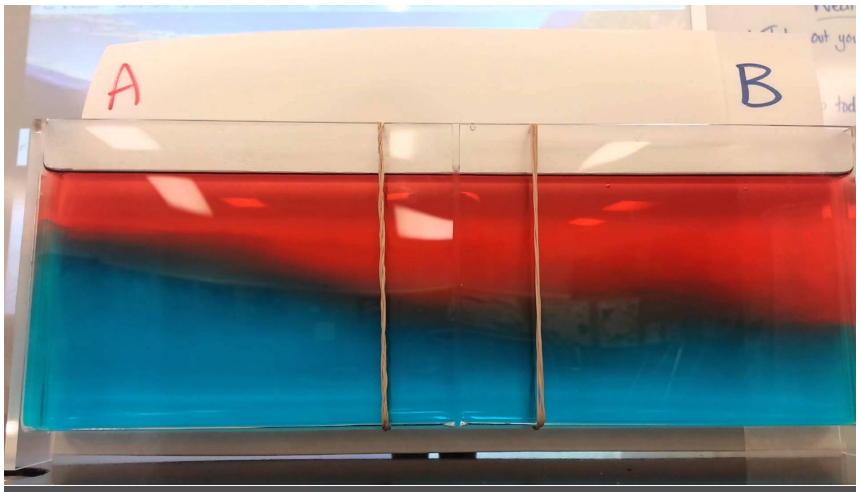


Fig. 3. Lock-gate density tank (YouTube, 2017a).

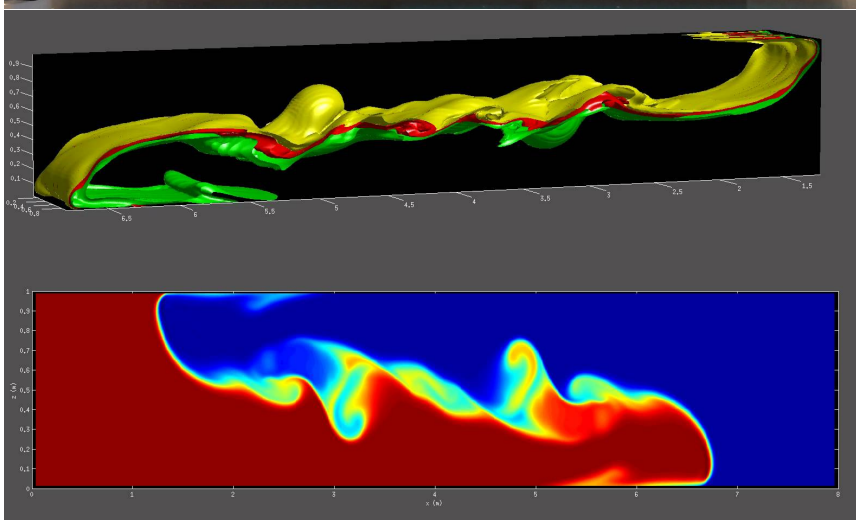


Fig. 4. Lock-gate 3-D simulation. (YouTube, 2017b).

Questions

Q1. What happened in the tank?

.....

.....

.....

Q2. Why do you think that this happened?

.....

.....

.....

Q3. What do you think would happen if you keep heating/cooling each end?

.....

.....

.....

Check this out! : https://www.youtube.com/watch?v=t4kJUmt7rjc

Activity: Thermal expansion

As water heats up, assuming salinity remains constant, the density decreases and therefore the volume of water increases, this is known as THERMAL EXPANSION.

Fill in the following table using the following equation, $\rho_w = -0.137T+1028$

Temperature, T, °C	Water density, ρ_w, kgm^{-3}
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

The volume of the ocean is ~$1.3x10^{18}m^3$ = 1,300,000,000,000,000,000 m^3
The surface area of the ocean is ~$3.5x10^{14}m^2$

What is the average sea level?.....

EUSTATIC SEA LEVEL – dependent upon changes to the volume of the ocean, effects the global ocean equally.

ISOSTATIC SEA LEVEL – dependent upon changes in the height of land.

Assuming that the present average oceanic water temperature is 8 °C, calculate the eustatic sea level rise for 1 °C, 2 °C and 3 °C temperature increase.

1 °C temperature rise = ... m eustatic sea level rise
2 °C temperature rise = ... m eustatic sea level rise
3 °C temperature rise = ... m eustatic sea level rise

Density of the water (ρ_w)(kgm^{-3}) = Mass of the water (kg) / Volume of the water (m^3)

Homework: Sea level rise

Of big concern to the global community, is the potential increase in global sea level as a result of the Greenland Ice Sheet melting. The volume of the Greenland Ice Sheet is approximately $2.63 \times 10^{15} m^3$ of ice, with a density of $920 kgm^{-3}$. As ice melts, the density increases, with freshwater having a density of approximately $1{,}000 kgm^{-3}$.

Firstly, calculate the volume of freshwater produced by the entire melting of the Greenland Ice Sheet.

..... = ... m^3

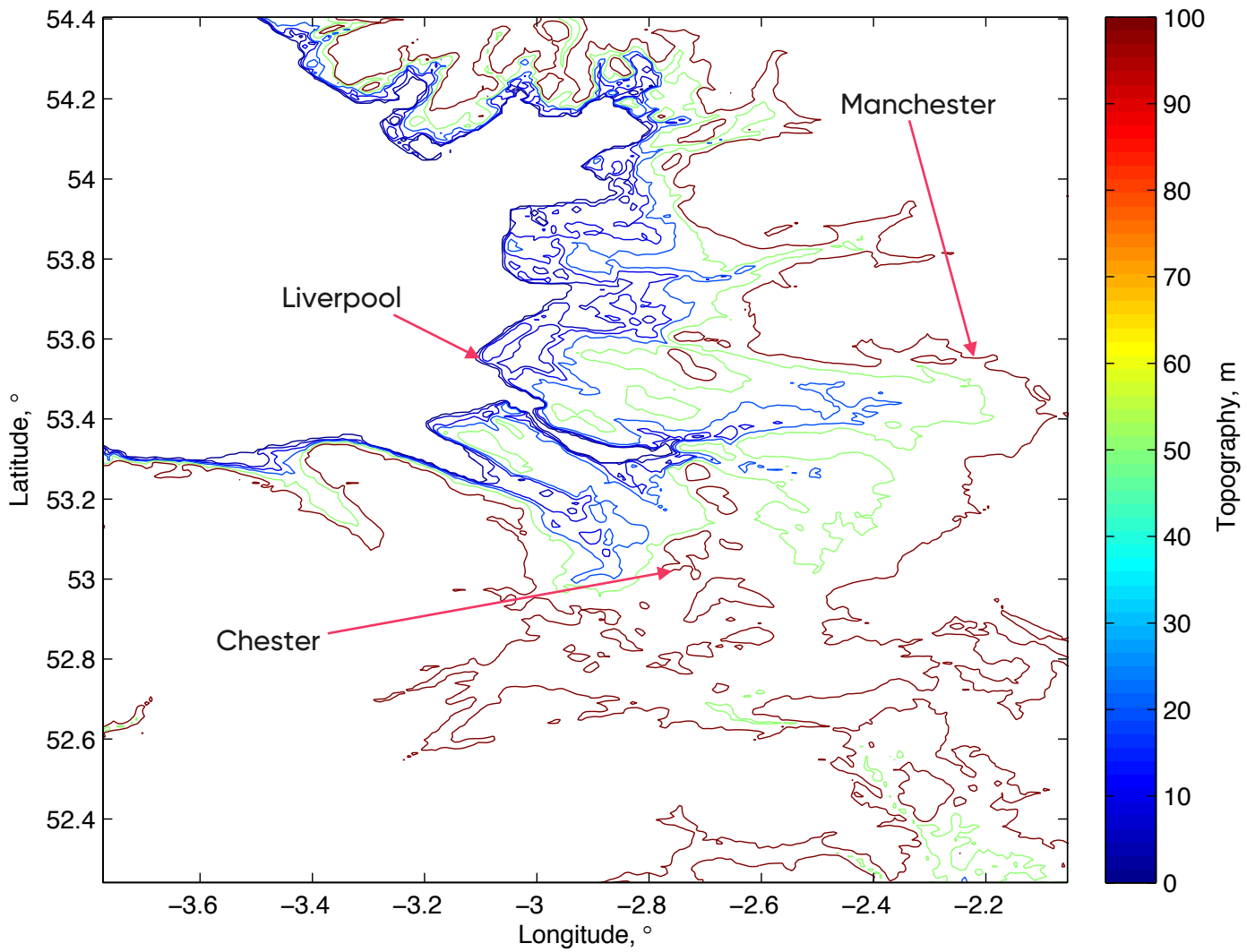
Now, calculate the sea level rise as a result of this water entering the ocean.

..... = ... m

The volume of the Antarctic Ice Sheet is ~$2.65 \times 10^{16} m^3$ (10x as much ice as Greenland).

Using the provided regional contour map, shade in areas that would become flooded if the Greenland Ice Sheet melted (vertical lines), the Antarctic Ice Sheet melted (horizontal lines) and both the Greenland and Antarctic Ice Sheets melted (shaded).

The colour scale shows the topography contours – the height of the land (produced using the GEBCO 08 dataset).



Questions

Q1. If this sort of flooding were to occur, what would be the result?

.....

.....

.....

Q2. Which areas would be most at risk?

.....

.....

.....

Q3. State and briefly (one sentence) describe 3 forms of coastal flood protection.

.....

.....

.....

Q4. Why does Ice float on top of water? (Use data to explain your answer)

.....

.....

.....

Q5. How would an increase in temperature of 1°C, 2°C and 3°C affect the total sea level rise if both the Antarctic and Greenland Ice Sheets melted (Hint: use water density from tutorial activity)?

.....

.....

.....

.....

.....

.....

Q6. If both the Antarctic and Greenland Ice Sheets melted, what would the temperature difference necessary be for a total 80m sea level rise?

.....

.....

.....

Q7. If I had $1m^3$ of fresh water (density = $1{,}000kgm^{-3}$), what mass of salt would be necessary to change the density to $1{,}045kgm^{-3}$?

.....

.....

.....

Q8. What is the difference between sea ice extent and sea ice thickness?

.....

.....

.....

Tutorial 2 – Waves

If the water is calm, you will often see a repeating sequence of waves in the ocean caused by a storm far from the location, these are called SWELL WAVES.

A TSUNAMI is a form of wave generated by a tectonic activity below the seafloor, here the waves move outwards from the source of the activity. Waves from a TSUNAMI can be seen to be like those formed by a pebble thrown into a puddle of water.

WIND WAVES are caused by direct wind activity at the surface, similar to the effect of blowing on a cup of tea.

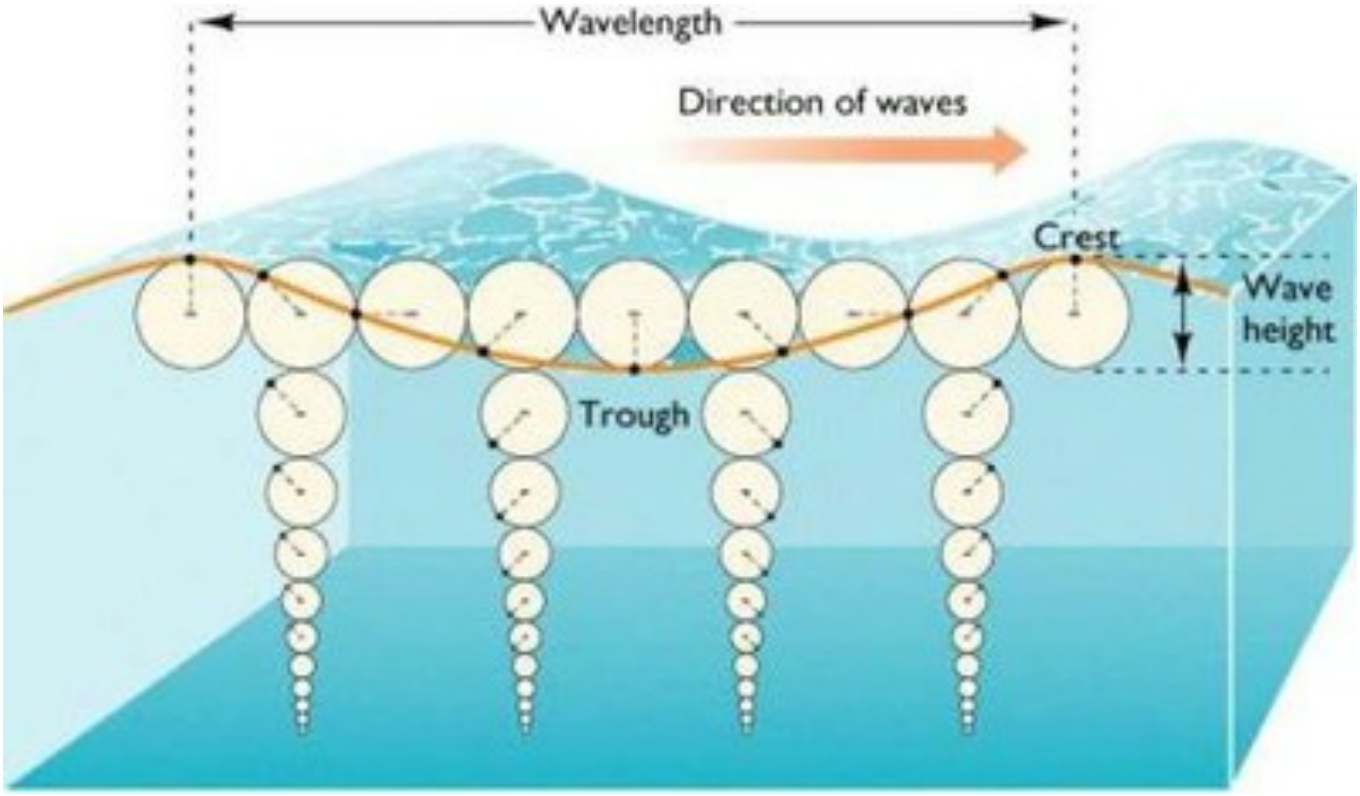


Fig. 5. Main features of a wave (CircumInvent, 2015)

The WAVELENGTH (λ, m) is the distance between two crests or two troughs of a wave.

The WAVE HEIGHT (m) is the vertical distance between the crest and the trough of a wave.

The PERIOD (s) is the time between two crests/troughs passing a fixed location.

The PHASE SPEED (ms^{-1}) is calculated as the WAVELENGTH/PERIOD

When considering the impact of waves upon the water column, it is important to discuss ORBITALS. Orbitals are the circular currents occurring underneath a wave, decreasing in intensity with depth below the wave. These can be seen in the circular features in Fig. 2.

The speed of a wave is directly controlled by the water depth:

WAVE SPEED = $\sqrt{(gd)}$ (ms^{-1})

g is the acceleration due to gravity ($9.81ms^{2}$)
d is the depth is in m

Discussion Questions

DQ1. Why are Tsunamis especially dangerous?

.....

.....

DQ2. Where will the impact of waves upon the seabed be greatest?

.....

.....

DQ3. What is significant wave height?

.....

.....

DQ4. Why do waves break?

.....

.....

DQ5. Are waves fastest in deep water or shallow water?

.....

.....

Check this out!:
https://goo.gl/dEJdjF

Practical: Let's make some waves

Use piece of guttering as primitive wave tank.
Raise guttering 0.05m, 0.10m and 0.15m off the table top.

Fig. 6. Wave tank at HR Wallingford, Oxfordshire (Howbery Park, 2014).

Today we will:

- measure the wavelength (λ,m)
- measure the wave height (m)
- measure the period (s)
- calculate the phase speed (ms^{-1})

Height of gutter, m	Wavelength, m	Wave height, m	Period, s	Phase speed, ms^{-1}

As the height of the guttering increases, what happens to the

a) WAVELENGTH, m

.....

.....

b) WAVE HEIGHT, m

.....

.....

c) WAVE PERIOD, s

.....

.....

d) PHASE SPEED, ms^{-1}

.....

.....

Homework: predicting waves

WAVE SPEED = $\sqrt{(gd)}$ (ms^{-1})

Using the provided graph paper, draw a graph describing the relationship between wave speed and depth, in depths (d) from 0m to 1000m, assuming that g is $9.81ms^{-2}$ (with at least 20 graph points).

Write this up as brief scientific report (introduction, methods, results, discussion/conclusion). Use the following template as a guideline.

Introduction (~200 words) :

- What are waves?
- Why is it important to understand waves?

Methods (~100 words):

- What did you do?
- Why did you do it?

Results (include graph with correct units/labels and title):

- What results did you get?

Discussion (~200 words):

- What did the results show?
- How does wave speed change with depth?

Conclusion (~200 words)

- What is the implication of depth upon wave speed?
- Think about coastal regions where the depth might shallow steeply.
- What could you have done differently?

Fig. 7. Tides in the Bay of Fundy, USA. (https://www.youtube.com/watch?v=EnDJ6_XpGfo)

When you go to the seaside, you will notice that the water level is at different points depending on the time of day and the location, this is due the tides. The daily tides are known as the EBB (tide going out) and the FLOOD (tide coming in). The difference between the water height on the EBB and FLOOD, is known as the TIDAL RANGE. The tidal range varies on an ~14.5 day cycle, from the SPRING TIDE (largest tidal range) to the NEAP TIDE (smallest tidal range).

The tides are caused by the gravitational pull by the Moon and the Sun.

One of the biggest advances in oceanography, is our ability to accurately predict the tides from day to day and has been crucial for our use of the oceans both recreationally and commercially.

We predict the tide using tidal HARMONICS, by measuring the phase and amplitude of the tide. Though there is similarity, the tidal harmonics vary depending on where you are in the world.

AMPHIDROMIC POINTS are points of zeros tidal amplitude for a specific tidal HARMONIC.

Tides are STANDING WAVES.

Practical:
A standing wave will be demonstrated using a piece of rope or rubber cord.

Think about:
How would the wavelength or amplitude of the tide affect what you see on the coastline?

Activity: Tides around the U.K.

Fig. 8. Map of tidal ranges around the U.K. (TES, 2017)

Here are the tidal ranges at several locations around the U.K. and Ireland.

Anglesey, 6m	Liverpool, 8m	Bristol, 12m	Plymouth, 5.5m
Southampton, 3m	Dover, 9m	Newcastle, 3.5m	Ipswich, 1m
Edinburgh, 3m	Glasgow, 3m	Belfast 2m	Dublin, 3m

Contour around the points

Questions

Q1. Where has the highest TIDAL RANGE?

.....

.....

Q2. Where has the lowest TIDAL RANGE?

.....

.....

Q3. Where might there be an AMPHIDROMIC POINT (mark them on the map)?

.....

.....

Activity: Fourier analysis - making predictions

FOURIER ANALYSIS allows us to represent repeating curves in data in the form of trigonometric functions (i.e. sine and cosine). Here, we will use a single curve (single HARMONIC). In tidal analysis, there are often many different HARMONICS used to represent forms of tidal variability (i.e. ebb and flood, spring and neap).

Using the table below, we will use Fourier Analysis to fit a curve to seasonal temperature changes.

ω is the angular frequency = (2*π)/T, where T is the length of the record (12 for the table below)

Month, t	Temperature, °C	cos(ωt)	Temp. x cos(ωt)	sin(ωt)	Temp. x sin(ωt)
1	10.8	0.866	9.353	0.500	5.400
2	10.2				
3	10.7				
4	10.2				
5	11.6				
6	13.1				
7	14.0				
8	13.7				
9	15.4				
10	14				
11	13.4				
12	12.8				

ai (=total/(2/T)) = …… bi (=total/(2/T)) = …….

Mean (average) temperature = …… °C
Equation is:

Temperature (°C) = Mean temperature + ai*cos(ωt) + bi* sin(ωt)

So….

Temperature (°C) = ……. + ……*cos(ωt) + …… *sin(ωt)

Using this equation, fill in the following table:

Month, t	Mean temperature, °C	cos(ωt)	ai* cos(ωt)	sin(ωt)	bi* sin(ωt)	Temperature, °C
24						
33						
67						
100						
1,000						
1,216						

Homework: predicting the tidal range

Tides are predicted using harmonics, using the Fourier system described in class, use a table to fit a harmonic to the following series of tidal readings and plot both the data points and the fitted curve on graph paper.

Day	Tidal range, m	Day	Tidal range, m
1	11.3	8	5.6
2	10.9	9	6.2
3	9.7	10	7.4
4	7.6	11	9.3
5	6.8	12	9.8
6	6.1	13	10.1
7	5.7	14	10.7

Questions

Q1. Describe the minimum (NEAP) and maximum (SPRING) tidal range from your graph

.....

.....

Q2. Describe the length of time between largest and smallest tidal range from your graph

.....

.....

Tidal harmonics allow you to predict the tides a long way into the future with relative accuracy. Assuming that the variation you observe is maintained, fill in the following table of values for tidal range in the future:

Day from the end of your plot (Day 34)	Tidal range, m
20	
200	
400	
767	
2,000,000	

Q3. What might limit how long you can accurately use this harmonic equation to predict the tides?

.....

.....

Q4. Why is important to know how to predict the tides

.....

.....

.....

.....

Q5. What controls the tidal range at a given location?

.....

.....

.....

.....

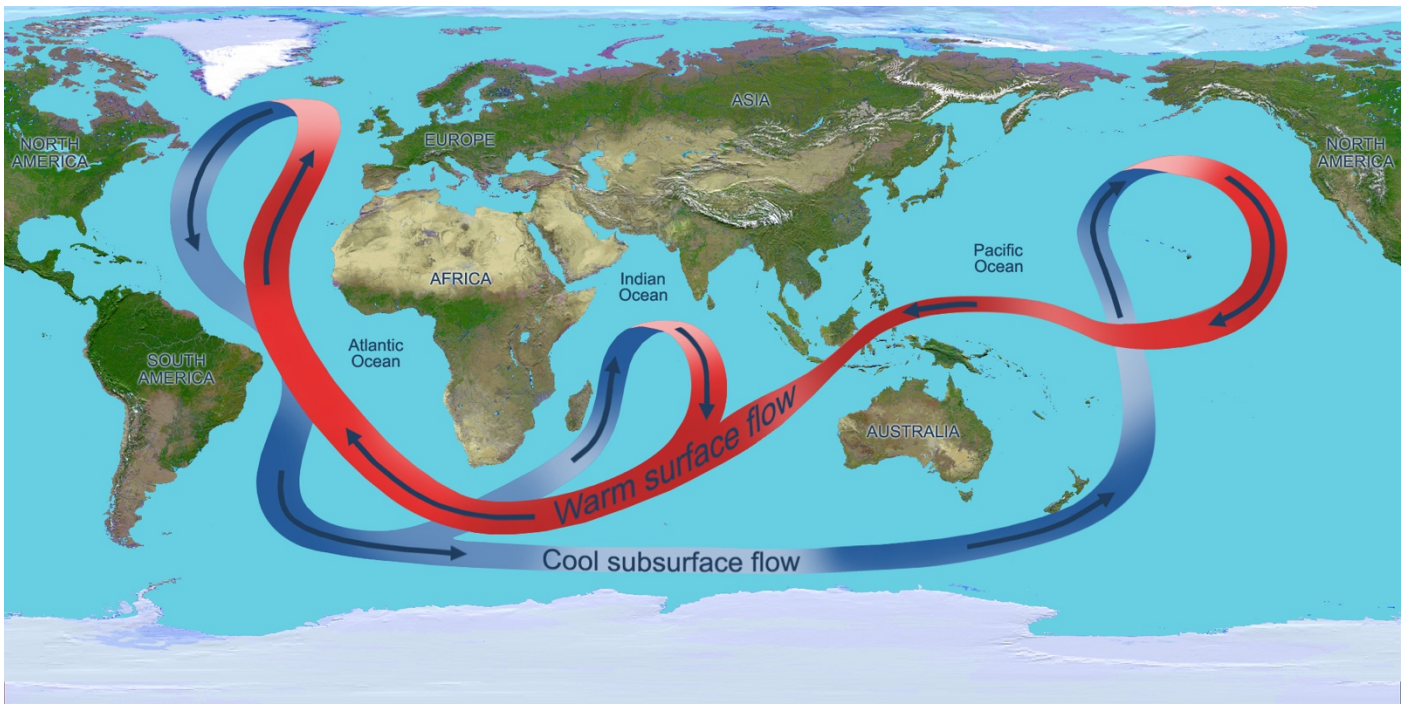


Fig. 9. Global ocean circulation.
(Jet Propulsion Laboratory, 2010)

At the equator, the ocean is warmed by the sun, leading to a warm surface layer. As this layer moves into the higher latitudes, water evaporates increasing the salinity and the water loses heat to the air, causing the density to increase and the water to sink. Once this water sinks, it then spreads along the seafloor, to be upwelled again in the equatorial region.

-

This process is referred to as the THERMOHALINE CIRCULATION, with the Atlantic Ocean off the coast of Europe being home to the ATLANTIC MERIDIONAL OVERTURNING CIRCULATION (AMOC) component of this wider global ocean process. The result of this in the UK, is that due to warm water moving from the equator, we observe far higher temperatures than we otherwise would (when compared to locations at the similar latitudes i.e. Canada, Russia).

Check this out!:

Stormy Southern Ocean - https://goo.gl/dEJdjF

Activity: Watch documentary videos and discuss ocean circulation

Questions

Q1. What are ocean currents driven by?

.....

.....

Q2. In what way is water at the equator different from that in polar regions?

.....

.....

Q3. Why is the Arctic not a continent?

.....

.....

Q4. What causes increased salinity towards the Equator?

.....

.....

Q5. Which is the largest ocean?

.....

.....

Q6. What is unique about the water near Antarctica? How does it drive global ocean circulation?

.....

.....

Q7. In what ways are Earth's oceans and atmosphere connected?

.....

.....

Q8. What role has ocean circulation played in creating a habitable planet?

.....

.....

Q9. What might happen if circulation changed?

.....

.....

Q10. What may cause ocean circulation to change?

.....

.....

Homework: The Atlantic Meridional Overturning Circulation (AMOC)

Write a short report, answering the following questions:

Q1. What is the AMOC (Atlantic Meridional Overturning Circulation)? (200 words)

Q2. What is the effect of AMOC on the U.K.? (200 words)

Q3. What is DEEP WATER and where is it formed? (200 words)

Q4. What may cause the AMOC to change? (200 words)

Q5. Which sea inputs highly saline water into the Atlantic Ocean? How does it become this saline? (100 words)

Check these out:

http://www.bbc.co.uk/programmes/p00gbgmk

https://www.pbslearningmedia.org/resource/nves.sci.earth.oceancirc/global-ocean-circulation/#

https://www.pbslearningmedia.org/resource/ttv10.sci.ess.watcyc.currents/the-role-of-ocean-currents-in-climate/#.WfKIrEzMxE4

https://www.pbslearningmedia.org/resource/ess05.sci.ess.watcyc.oceancur/ocean-temperatures-and-climate-patterns/#.WfKIyUzMxE4

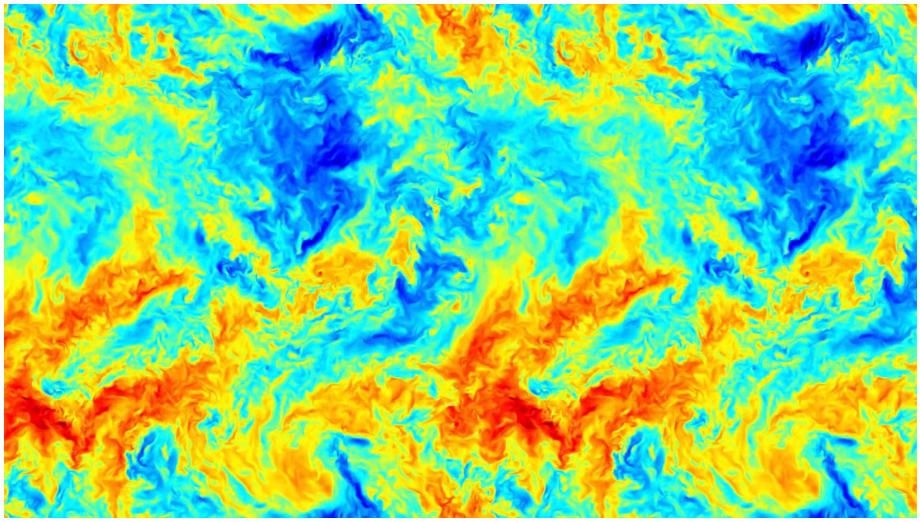


Fig. 10. 3-dimensional turbulence model (YouTube, 2017c).

TURBULENCE is a STOCHASTIC process, which drives mixing in the ocean.

ENTRAINMENT is the process by which packets of water move between layers.

DOUBLE DIFFUSION is the process of diffusion by heat and salt between layers of water in the ocean

T-S DIAGRAMS (temperature-salinity) are used to describe the sources of water in the ocean.

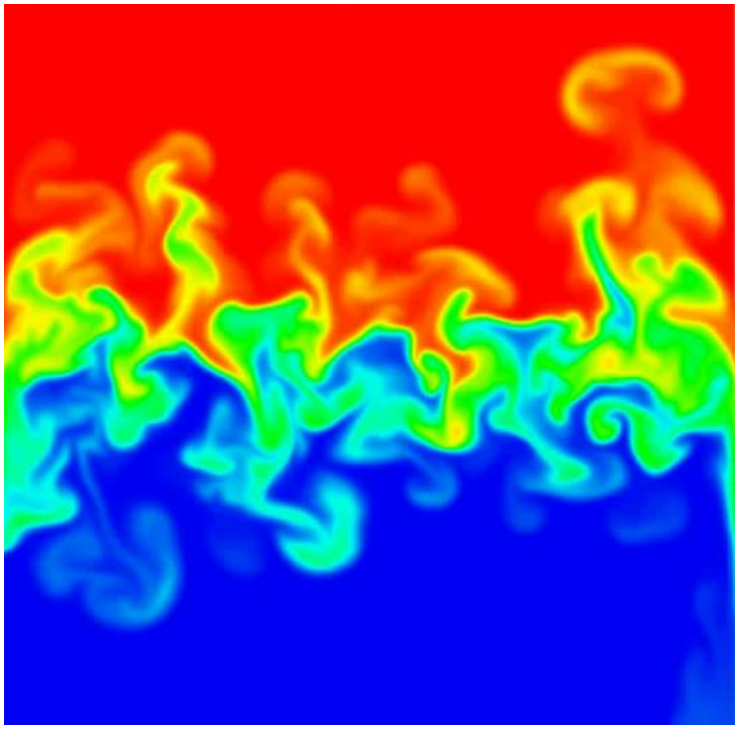
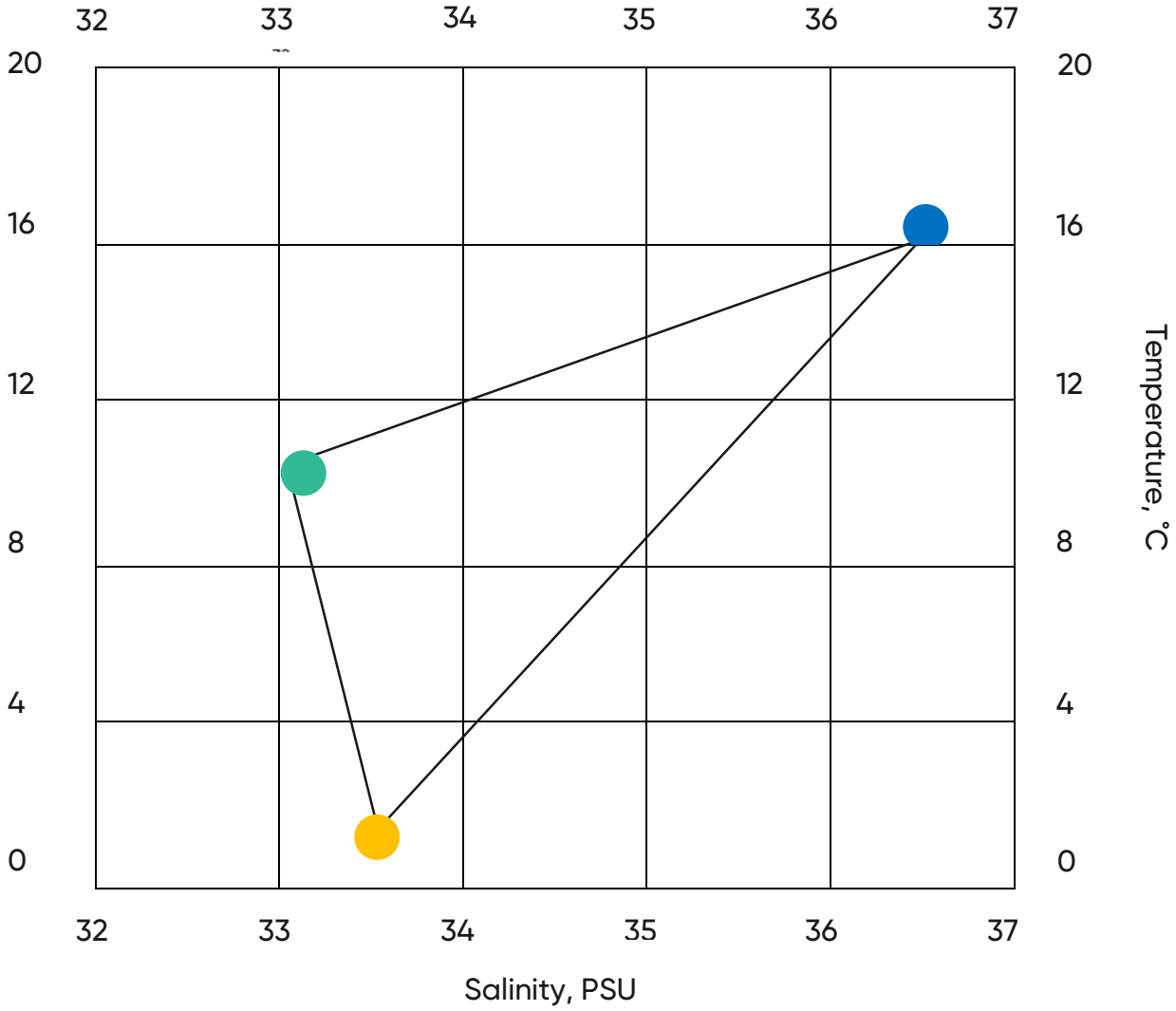


Fig. 11. Double diffusion (salt fingering) of temperature and salinity. Warm, salty water lying over the top of cold, fresh water (YouTube, 2017d).

Activity: T-S (temperature-salinity) Diagrams



Plot the following points on the plot above:

Point	Temperature, °C	Salinity, PSU	Green, %	Blue, %	Orange, %
A	12	35			
B	6	34			
C	11	34.5			
D	4	34			
E	8	34			

Work out what % of Atlantic Surface, Atlantic Deep and Mediterranean water the sample is made up of.

The final assignment

Part 1 *(70% of final assignment mark)*

Using the datasheets provided and your assigned variable, analyse data from the stratification model developed by Elliot and Clarke (1991).

You will be provided by a set of data showing the influence of either tides, wind or the dew point temperature upon stratification at one location over the year.

Test the influence of:

- For tides, the tidal current speed amplitude (u, ms^{-1}).
- For wind, the wind speed amplitude (w, ms^{-1}).
- For dew point temperature, the dew point temperature amplitudes ($T_{d,}$ °C).

From this, write a scientific report (introduction, methods, results and discussion/conclusion) upon the influence of tides, wind-driven waves and dew point temperature upon stratification in the oceans

Questions to think about:

- How does wind mix the ocean, when is it windiest?
- How do tides mix the ocean?

Relevant title:

- What did you look at?

Introduction (~250 words):

- What is stratification?
- What controls stratification?
- How does stratification influence our ocean?

Methods (~250 words):

- Where did the data come from?
- How did you analyse it (i.e. plotted time series graphs)?

Results (250 words):

- Show your results here.
- What do the graphs show? (without explaining what they mean)

Discussion (~500 words)

- What do the results mean?
- How would that variability influence the ocean?

Conclusion (~250 words):

- What went well?
- What did not go well?
- How could the study have been improved?

Part 2 *(10% of final assignment mark)*

Complete an abstract for your variable, with the content to be discussed in the presentation.

This abstract should be no longer than 150 words.

Use the examples provided to assist you with this.

An abstract should contain:
- Why did you carry out the study?
- How did you carry out the study?
- What did your results show?
- What are the implications of the results?

Part 3 *(20% of final assignment mark)*

Complete a group presentation on the content of Part 1. This is to be presented at the start of the feedback session and at the Uni Pathways Conference.

The group presentation should be between 15 and 20 minutes long and include:
- Introduction – What was the Uni Pathway topic?
- Method – What did you do?
- Results & Discussion for each of the three variables
- Conclusion – What did you take from the Uni Pathways course?

Approximate timing:
1. Introduction (2 minutes)
2. Method (2 minutes)
3. Results & Discussion (5 minutes per variable)
4. Conclusion (1 minute)

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.
- Develop collaborative conference presentation

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging?	How did you overcome these challenges?
• • •	• • •

References

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https://i.ytimg.com/vi/OMoMDsI62pY/maxresdefault.jpg [Accessed 12/09/2017].

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with the surname of the author/s and the year it was published. If you are using a direct quote then you must always remember to include quotation marks around the quote.

   In the reference list: Dubner, S., & Levitt, S. (2006). *Freakonomics*. 7-9.

   In the report: (Dubner & Levitt, 2006) at the end of the relevant text or Dubner and Levitt (2006) if referring directly in text.

   If more than two authors than use expression et al. to signify 'and others', as such:

   In the reference list: Gohin, F., Bryère, P., & Griffiths, J.W. (2015). *The exceptional surface turbidity of the North-West European shelf seas during the stormy 2013-2014 winter: consequences for the initiation of the phytoplankton blooms.* Journal of Marine Systems. **148**. 70-85.

   In the report: ...as shown by Gohin et al. (2015) or (Gohin et al., 2015).

2. *Bibliography*: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

   a. *Websites* – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

      e.g. Snow, D. (2004). *How did so many soldiers survive the trenches?* Available at http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr (Accessed 11/07/2014].

   b. *Books* – Author surname, author first initials., & second author surname, second author first initials. (date published). *Title of book* (in italics). Pages where the information came from.

      e.g. Dubner, S., & Levitt, S. (2006). *Freakonomics*. 7-9.

   c. *Articles* – Author, 'title of the article' (with quotation marks), where the article comes from (newspaper, journal etc.), date of the article.

      e.g. Kennedy, M. (2014). *The lights to go out across the UK to mark First World War's centenary.* Guardian. 10th July 2014.

   d. *Images* – Author surname, author first initials. (Year). *Description of Image*. Source of Image.

      (if online include link using format for Website).

      e.g. EOSDIS Worldview. (2017). *Global Sea Surface Temperature.*
      Available at: https://worldview.earthdata.nasa.gov
      [Accessed 25/08/2017].

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details...

- You are able log into the VLE either through the link on our website (www.thebrilliantclub.org) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).
- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames
- If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: schools@thebrilliantclub.org)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

- messaging your tutor
- submitting homework
- submitting your final assignment
- accessing resources for your tutorials
- finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

- Ensure you keep a professional tone in the messages you send to your tutors.
- Ensure you always reply to your tutors in a timely manner.
- Thank your tutor for the effort they are putting in to give you your feedback etc.
- Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the 'My Activities' tab and not as an attachment to a message.

Notes

Notes

Notes

Our Earth's heartbeat

Key Stage 4 Programme

researchersinschools.org