Introduction to Offshore Engineering

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Sept.-Oct., 2026

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Offshore Engineering course outline

- Introduction to offshore engineering
- Marine hydrodynamics, wind and sea currents
- Fixed-foundations and floating platforms e.g., jack-ups, FPSO, semis, …
- Wave loads, stresses & fatigue
- Marine corrosion & biofouling
- Subsea engineering
- Ocean renewable energy

Offshore Engineering course outline (2)

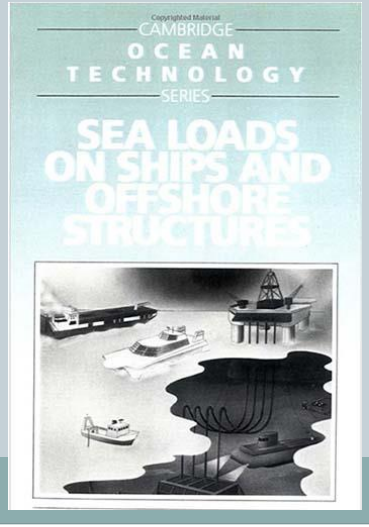
- Operational and environmental hazards
- Pollution avoidance and mitigation measures
- Decommissioning

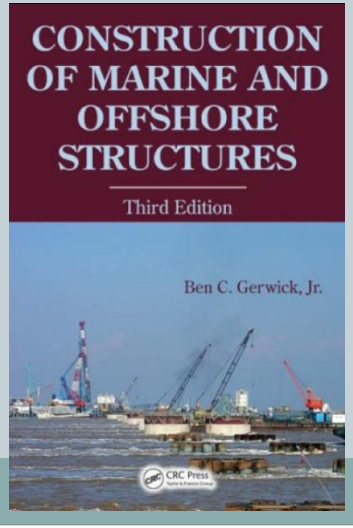
Lecture 1: Introduction to Offshore Engineering

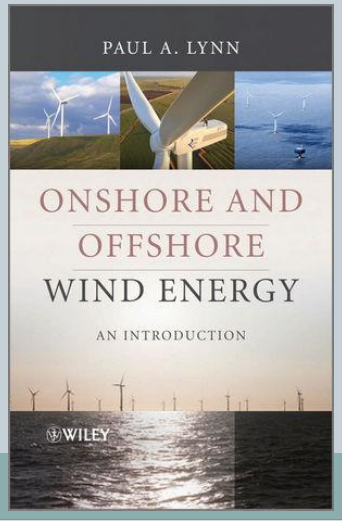
- Offshore engineering textbooks
- Other resources
- What is offshore engineering?
- Why/what is offshore engineering?
- Offshore arena
- Physical oceanography
- Oceanic heat energy budget

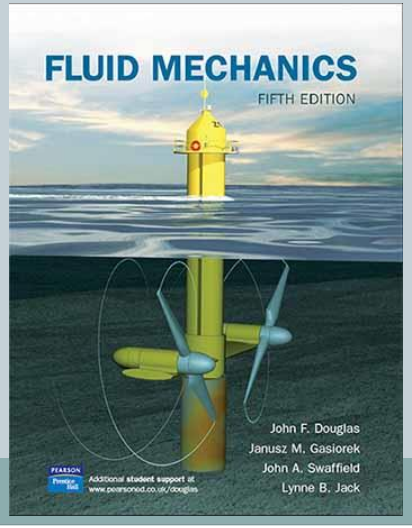
Offshore engineering textbooks

- Faltinsen OM. *Sea Loads on Ships and Offshore Structures*. CUP; 1993.
- Gerwick Jr BC. *Construction of Marine and Offshore Structures*. CRC Press; 2007.
- Paul A Lynn. *Onshore & offshore wind energy: An Intro*, Wiley, 2011
- Douglas JF, Gasiorek JM, Swaffield JA. *Fluid mechanics*. 5th ed. NY; Wiley; 2008.



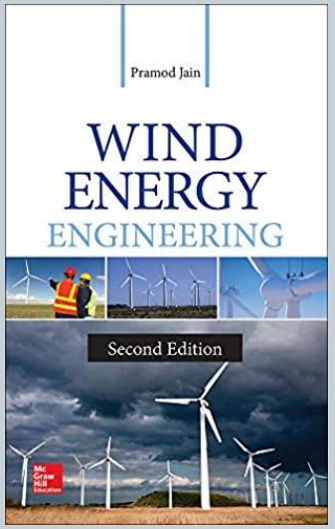






Offshore engineering textbooks (2)

- Pramod J. *Wind Energy Engineering*, McGraw Hill, 2011, ISBN: 9780071714785



- Marine & Carbon Lab:
  www.carbonlab.eu/offshore-energy-engineering

Other resources

Professional bodies

- RINA: www.rina.org.uk
- IMAREST: www.imarest.org
- SNAME: www.sname.org
- International Maritime Organization (IMO): www.imo.org/

The Royal Institution of Naval Architects

Institute of Marine Engineering, Science & Technology

IMAREST

THE SOCIETY OF NAVAL ARCHITECTS & MARINE ENGINEERS

IMO

Other resources

- MIT Ocean Engineering; OCW: http://ocw.mit.edu/courses/mechanical-engineering/
- Super Rig Troll 'A' Gas Platform: https://www.youtube.com/watch?v=x3K1RoJRXZg
- BBC Life Offshore: http://docuwiki.net/index.php?title=Life_Offshore

CENTER FOR OCEAN ENGINEERING





Other resources (2)

- Explosion in the North Sea (Piper Alpha), NG: https://www.youtube.com/watch?v=Nwbw5PHZnqk
- Shell's Olympus platform, GOM: https://www.youtube.com/watch?v=ibH7maY_eKk
- World's First 20-MW Offshore Wind Turbine: https://www.youtube.com/watch?v=z6sf1_86w8M

Appomattox, Shell: video; 650MMbboe; semi-sub

- Water depth: 2,255m (7,400ft); Production: 05/2019 ; 175,000bbl/d





MENG-370 Offshore Engineering – Assessment

- **Mid-Term Exam**: 25%
- **Final Exam** (comprehensive): 45%
- **Problem sheets**: 20%
- **Assignment**: 10%

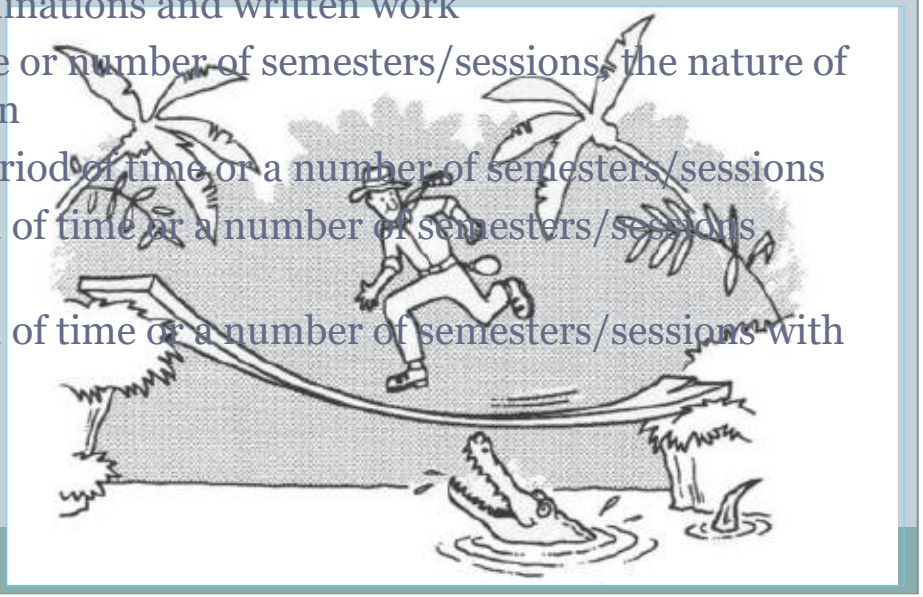
- **Pass mark**: >60%
- Actual pass: >73%

Grading Policy

Letter Grade	*Meaning*	*Numerical Grade*	*Grade Points*
A	Excellent	93-100	4.0
A-		90-92	3.7
B+	Very Good	87-89	3.3
B		83-86	3.0
B-		80-82	2.7
C+	Good	77-79	2.3
C		73-76	2.0
C-		70-72	1.7
D+	Poor but Acceptable	67-69	1.3
D		63-66	1.0
D-		60-62	0.7
F	Failure	0-59	0.0

Plagiarism and cheating

- Academic plagiarism and cheating related to examinations or written work is a *major offence*.
- Lecturer can decide to: A: To impose a penalty of up to 100% of mark deduction for the specific assessment or B: To refer the disciplinary offence to the Department Council
- **Penalties for Major Offences (including Cheating and Plagiarism)**
- These are as follows:
  - Oral reprimand
  - Written reprimand
  - Grade penalties for offences related to examinations and written work
  - Withdrawal of privileges for a period of time or number of semesters/sessions, the nature of which does not affect the students' education
  - Withdrawal of all student privileges for a period of time or a number of semesters/sessions
  - Suspension from the University for a period of time or a number of semesters/sessions without withdrawal of all student privileges
  - Suspension from the University for a period of time or a number of semesters/sessions with withdrawal of all student privileges
  - Dismissal from the University



Water world

- World's oceans are older than 3bn years
- Water covers ~71% of the earth's surface area
- World consists of 1 ocean & continents as islands



Why offshore?

- Oceans/seas provide:
  - Shipping/transportation and trade
  - Source of food e.g., fish
  - Major transport lanes e.g., US-EU, EU-Asia, Asia-US, …
  - Minerals, oil & gas
  - Land reclamation, artificial islands
  - Recreational activities e.g., yachting, fishing, diving
  - Renewable energy sources
  - Defense and security
  - Water for desalination and aquaculture
  - Biotechnology from ocean environment
  - Maritime tourism e.g., Caribbean, Mediterranean, Antarctic expeditions.







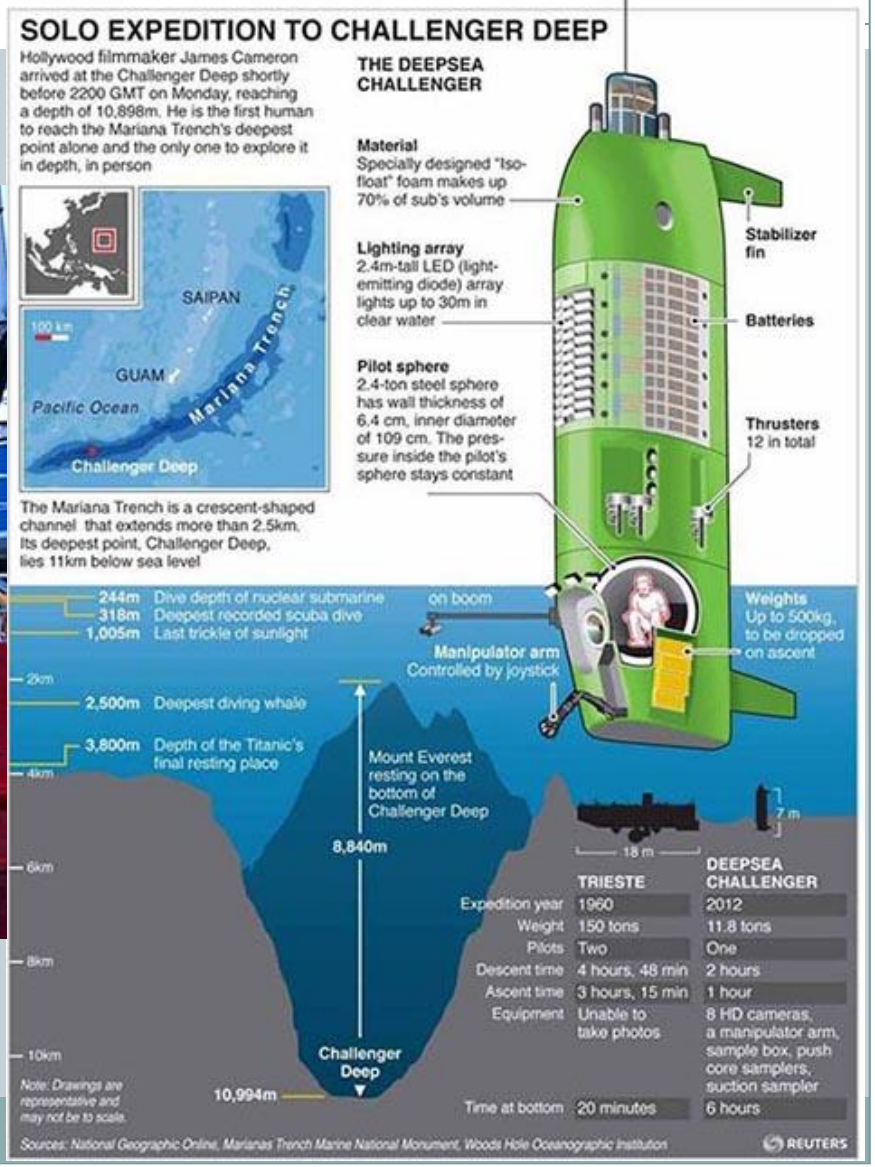




Engineering Marvel #1



CONTEXT
"Titanic" film director James Cameron has completed the world's first solo dive to the deepest known point on Earth, reaching the bottom of the Pacific Ocean's Mariana Trench southwest of Guam in a specially designed submarine. The filmmaker arrived at the site known as "Challenger Deep" shortly before 2200 GMT Monday, reaching a depth of 35,756 feet (10,898 meters), said the National Geographic Society, which is overseeing the expedition.



Engineering Marvel #2

- Olympus rig
- Feb., 2014
- 130m high
- Depth: 945m
- 126,000 tons
- 100,000bpde



Great sea interconnector (GSI)

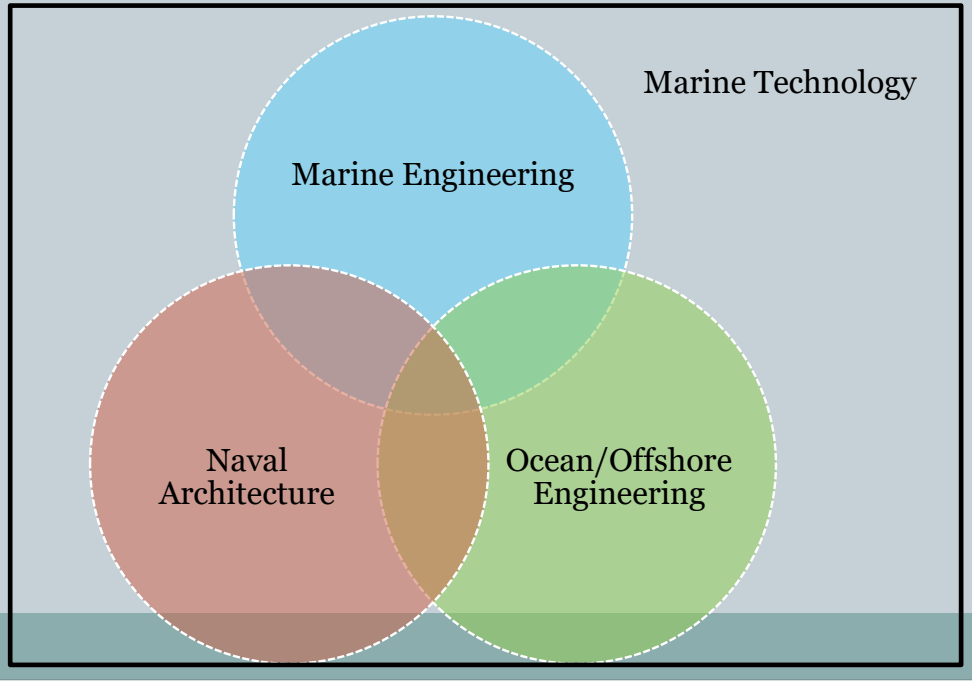
- Submarine power cable to connect Cyprus-Greece-Israel
- Two subsea 1,000MW, 500kV (dc) cables connecting Cyprus & Crete
- Estimate cost €1.94bn of which €657m are EU funds
- Maximum water depth reaching ≈3,000m offshore Crete
- World record (sea trials) laying cable at 2,150m by Prysmian
- Full notice to proceed is still pending
- Idea is to source/export electricity from RES btw Cyprus-Greece
- Interconnector to be completed by 2030. See: https://t.ly/tW88O





What is offshore engineering?

- Offshore (or ocean) engineering equips the Engineer with the necessary background to successfully complete engineering projects in the marine environment.
- Offshore engineering is the study of science, technology, engineering & mathematics incl. the ocean sciences, mechanical, electrical, civil and computer engineering and naval architecture.



Offshore Engineering

What do Offshore Engineers do?

- Design, develop, construct, test, operate ocean systems, technologies, and structures enabling a score of activities.

- Examples: design offshore platforms, offshore drilling, deepsea mining, offshore pipelaying, buoy design, salvage, mooring, towing, ship design, offshore power, O&G exploration, sea mapping, communications, …

- Offshore Engineers work on principles & techniques in:
  - Design, construct, maintain, survey/inspect ships, submarines & offshore structures;
  - Tracing & understand natural and anthropogenic signatures in the sea;
  - Enhance performance, survivability, lifetime of mobile and stationary sea structures;
  - Improve environmental footprint of ships and offshore structures.

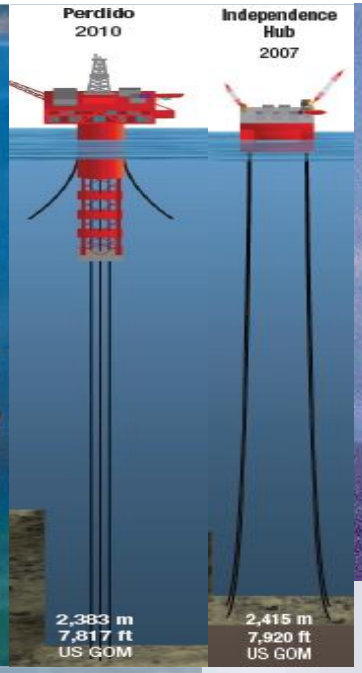
Marine activities

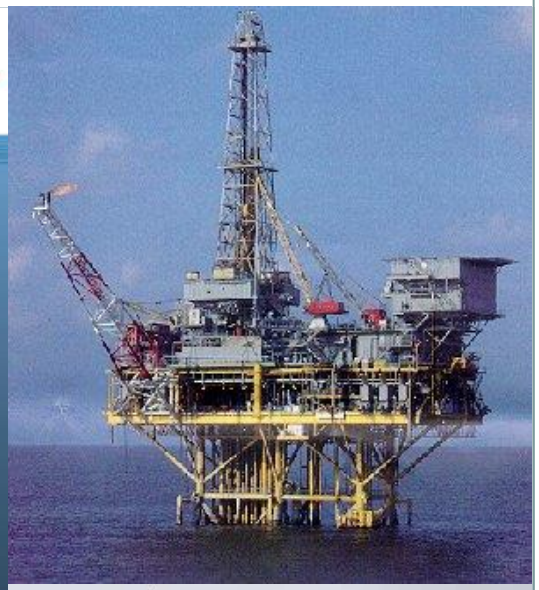


Offshore drilling rigs, FPSOs & production facilities















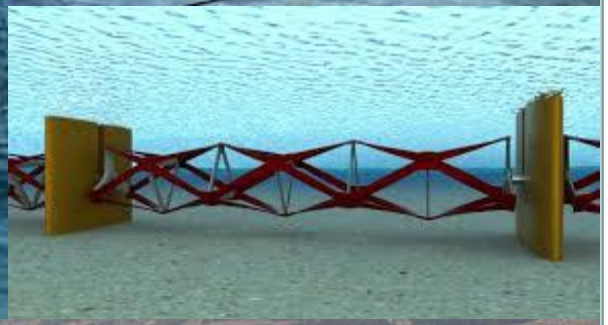
Offshore energy installations

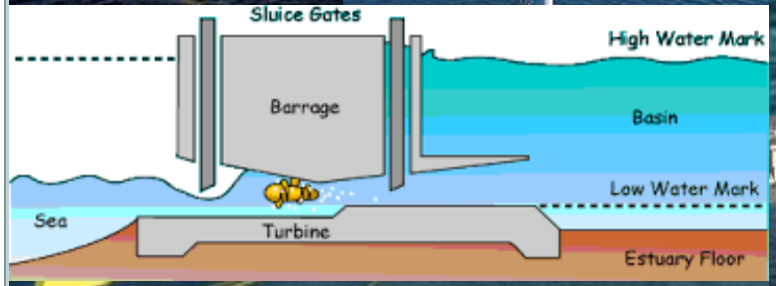












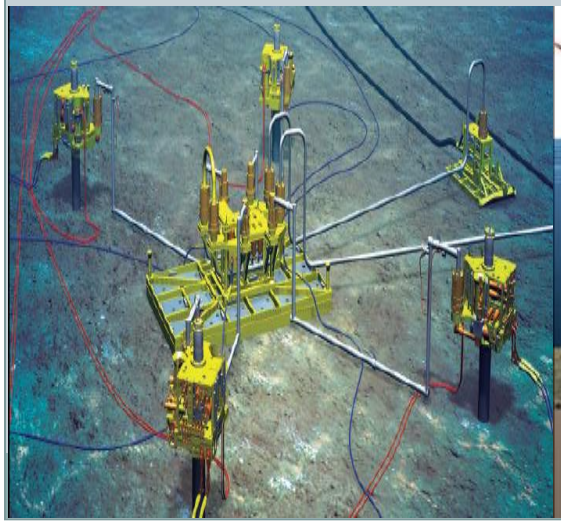




Offshore arena

W. Rowley, 2004. *Deepwater, Key Sectors*

- Offshore oil & gas exploration in ~7,100 fields over 120 countries
- Offshore platform (fixed, gravity & floating) count: 14,500
- Subsea units: ~8,200
- About 30,000 offshore pipelines siphon O&G to shore









Offshore arena (2)

- ~100 gravity-based platforms
- 1,000 single point moorings
- About 560 onshore oil terminals
- Offshore often divided into:
  - 1. Platforms
  - 2. Subsea installations
  - 3. Offshore pipelines
  - 4. Renewable energy





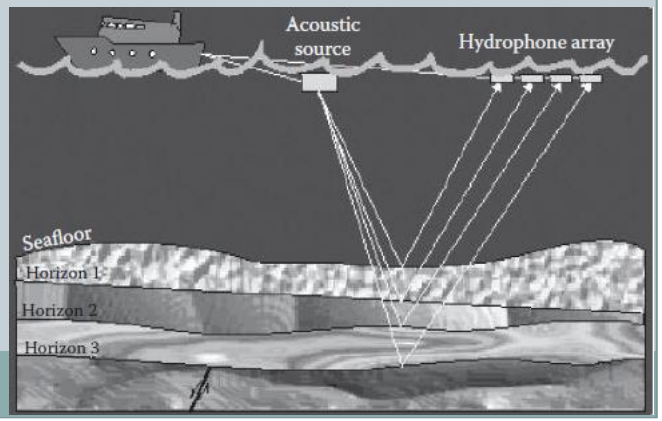




Offshore arena (3)

- Seismic surveys
- Deep sea mining
- Offshore support vessels
- Construction of bridges
- Drilling for scientific purposes
- Port development
- Coastal engineering
- Laying subsea cables
- Retrieving ship/airplane wrecks
- Exploring marine life
- Diving for pleasure
- Heavy lift operations
- Naval operations
- Port, canal/strait dredging

- In 2009, 33% total oil demand originated from offshore fields
- Offshore gas extraction in 2009 accounted for 31% of global production

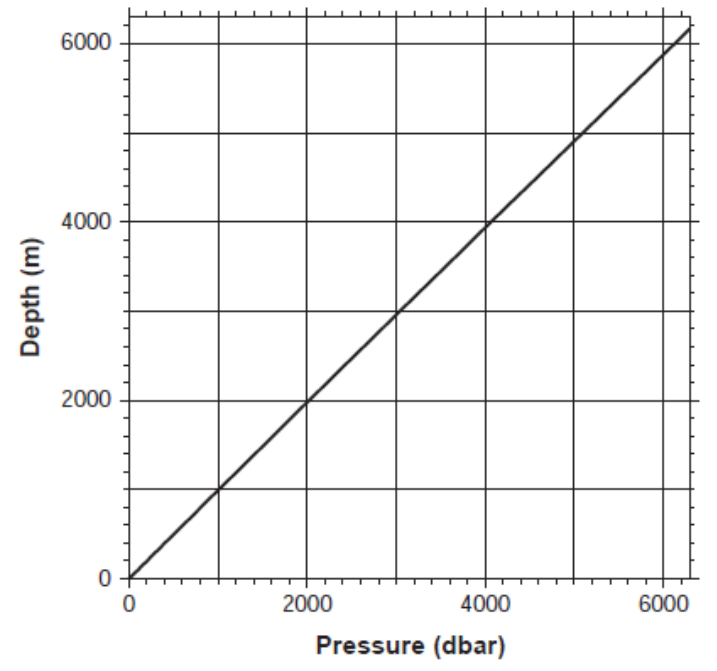


Elements of physical oceanography

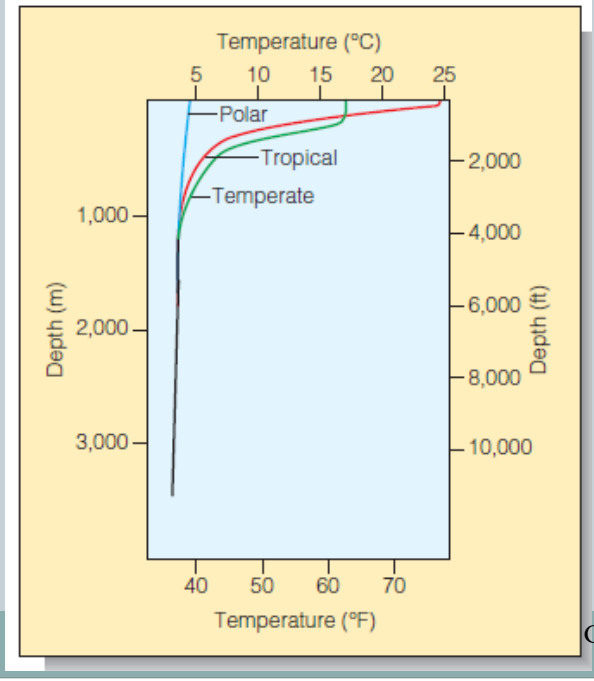
- Distinction between *sea* & *ocean*:
  - Sea is the seawater with depths <2,000m–3,000m
  - Ocean has water depth >3,000m

- Ocean water volume = $1{,}370 \times 10^6$ m^3 or 97% of total water

Depth v Pressure @ a NW Pacific



Pressure v seawater temp.

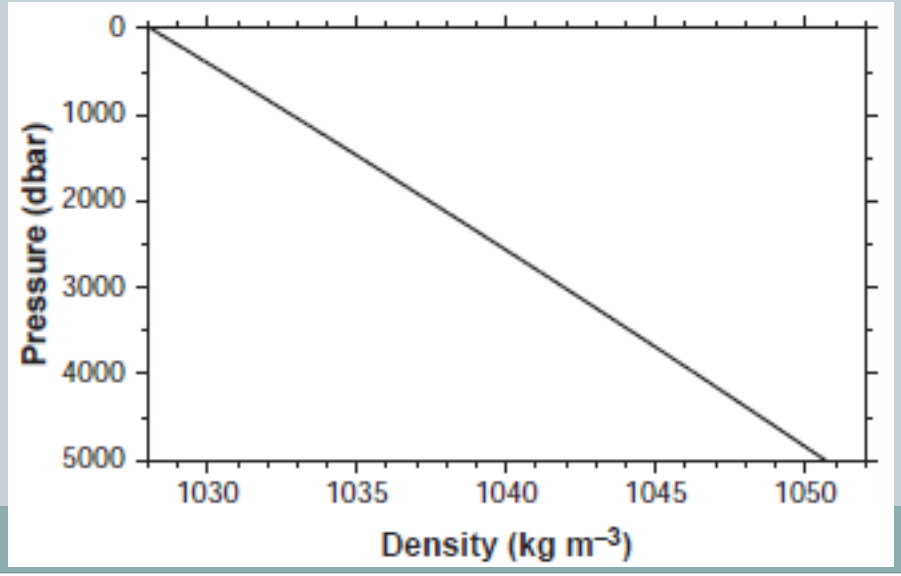


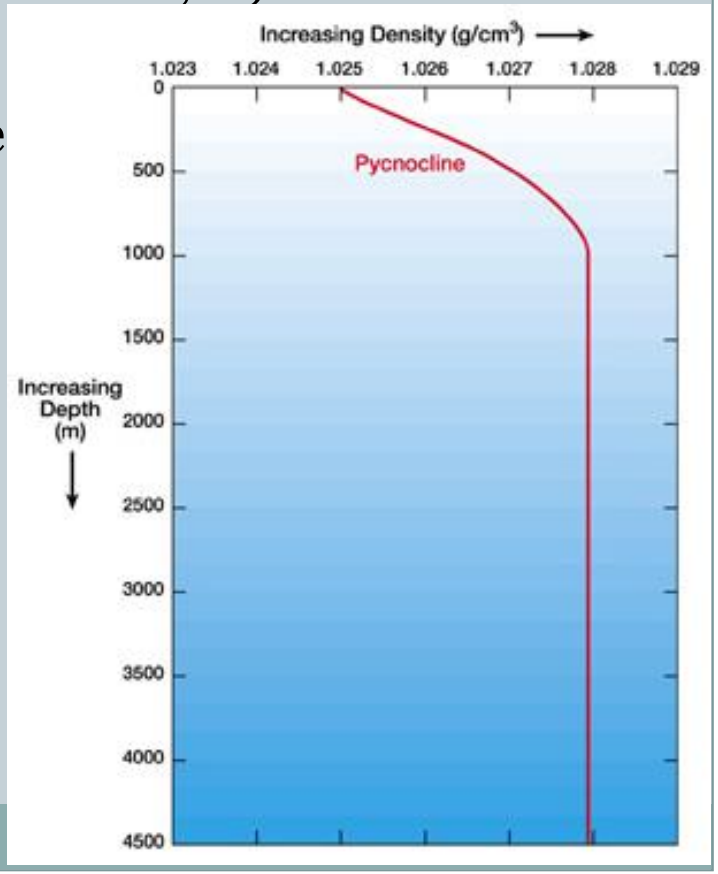
Garrison(2012)

Mass density of seawater

- Seawater mass density>fresh H_2O: ρ_{FW}=1,000kg/m^3; ρ_{SW}=1,027kg/m^3
- Mass density, $\rho_W = f$(T, P, salinity (S), solid contents, …)
- Warmer & saltier water floats on sea surface

Water temperature 0°C & salinity 35.0 at the sea surface.

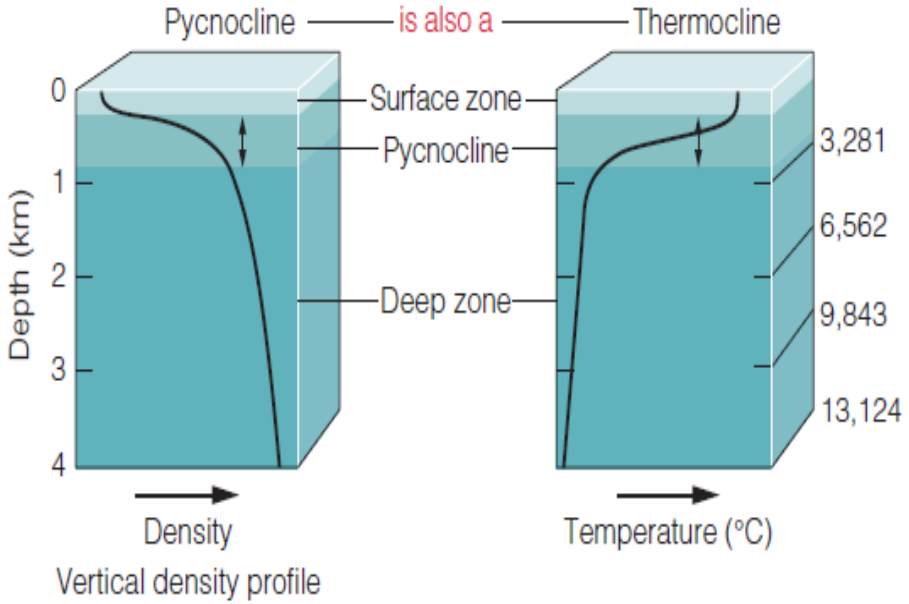


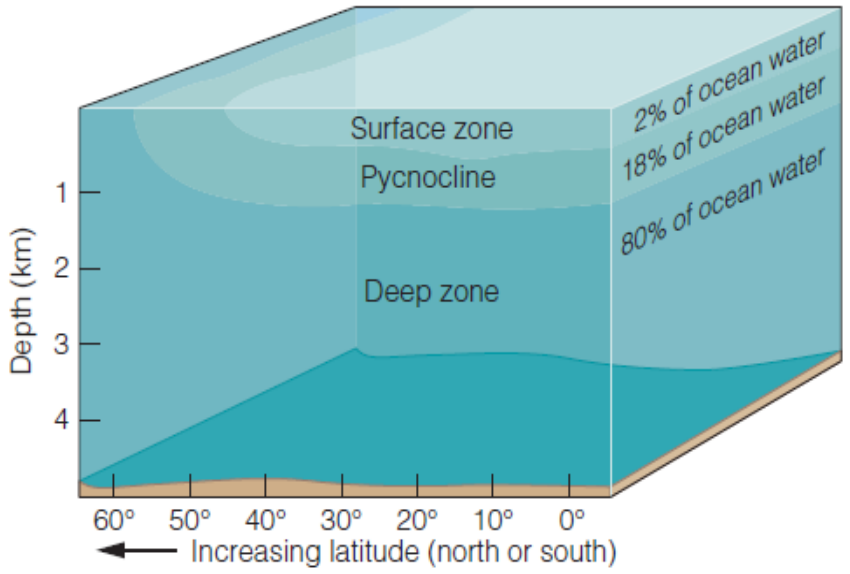


Ocean stratification

- Oceans are divided into 3 distinct density zones:
  - 1. Surface zone or mixed layer: typically, 150m;
  - 2. Pycnocline: 18% of water volume;
  - 3. Deep zone: depth >1,000m, 80% of water volume.

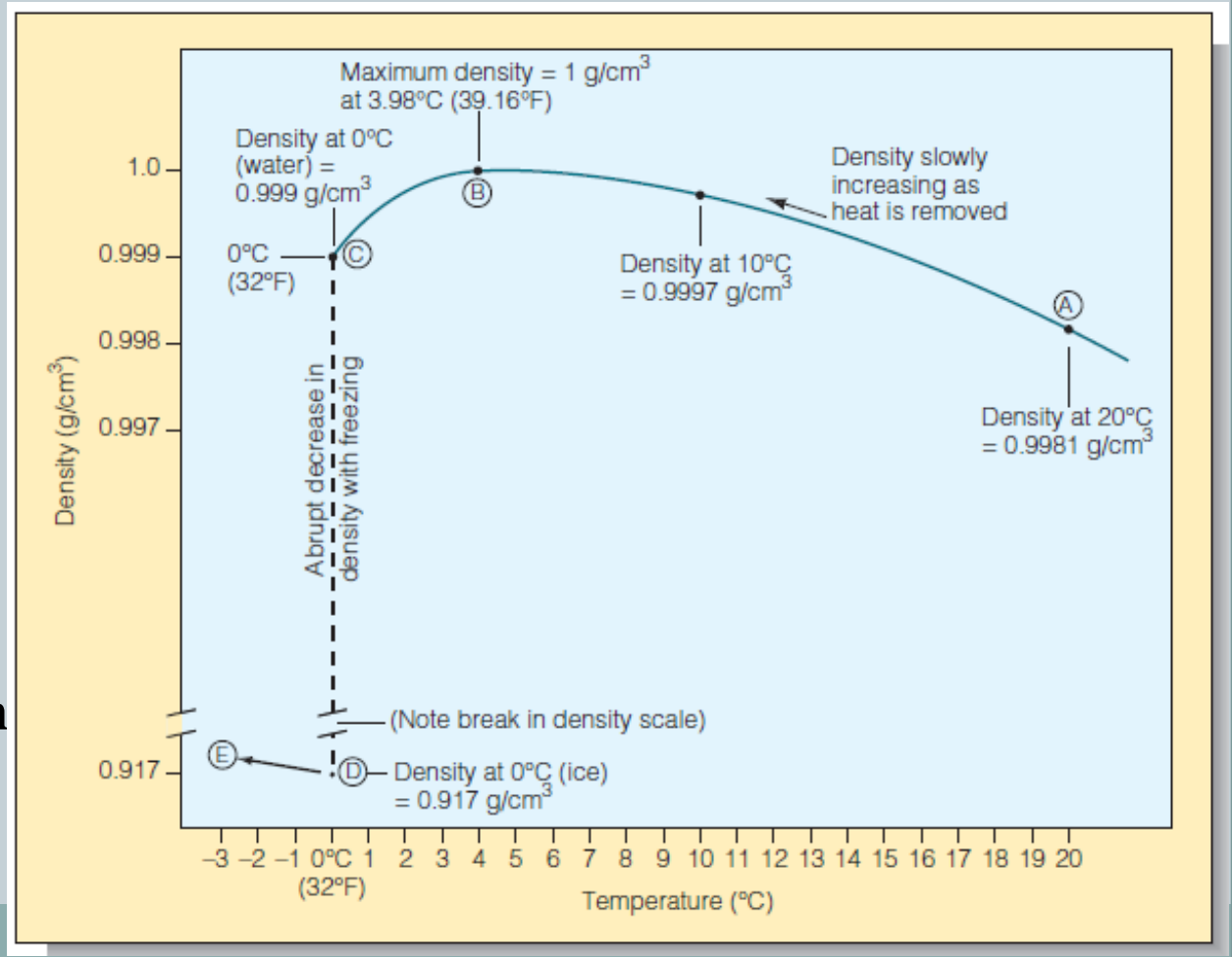
Garrison(2012)





Why does seawater not freeze at seabed?

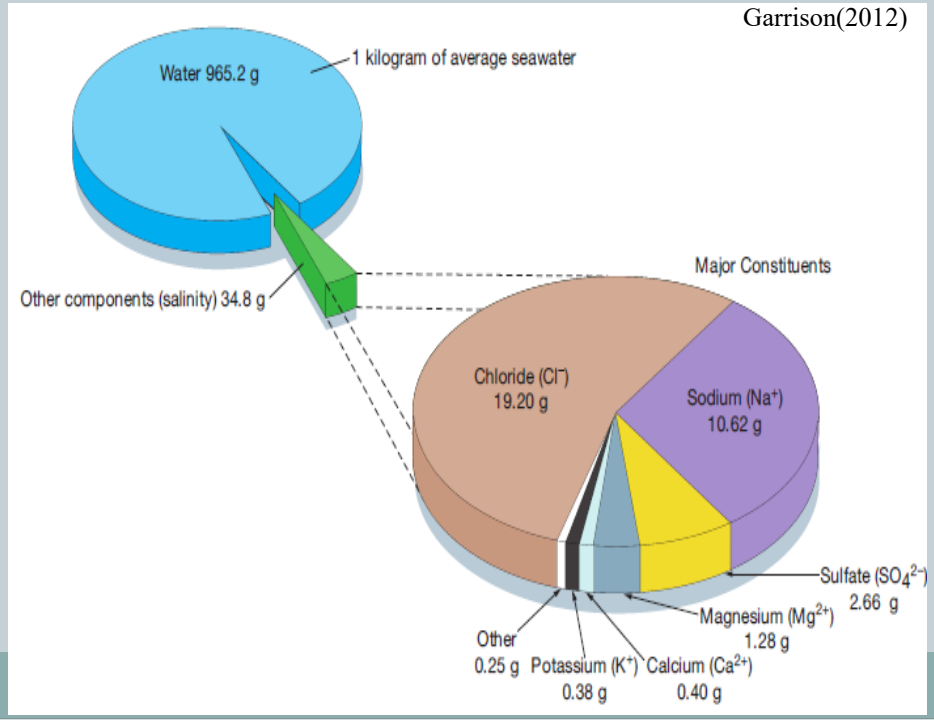
- Mass density of seawater peaks at about 4°C
- Seawater could be liquid @ −2°C
- Water's unusual properties make life at sea possible
- ρ drop [0°C, 4°C] permits ice to float in water
- $\rho_{ice} > \rho_{sw}$ by 9%

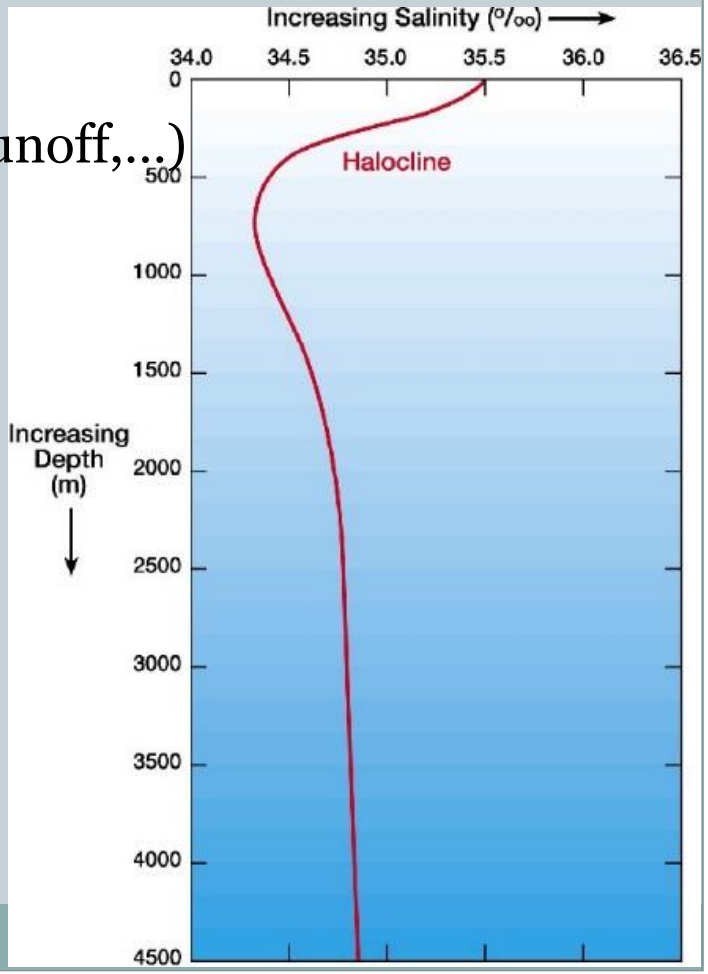


Seawater salinity (S)

- Salinity is total amount of dissolved (inorganic) substances in water incl. gases but excluding organic matter
- Ocean's salinity (S) ranges btw 3.3–3.7%
- S=*f*(evaporation, precipitation, freshwater runoff,…)
- Salinity varies with geographic location

Garrison(2012)



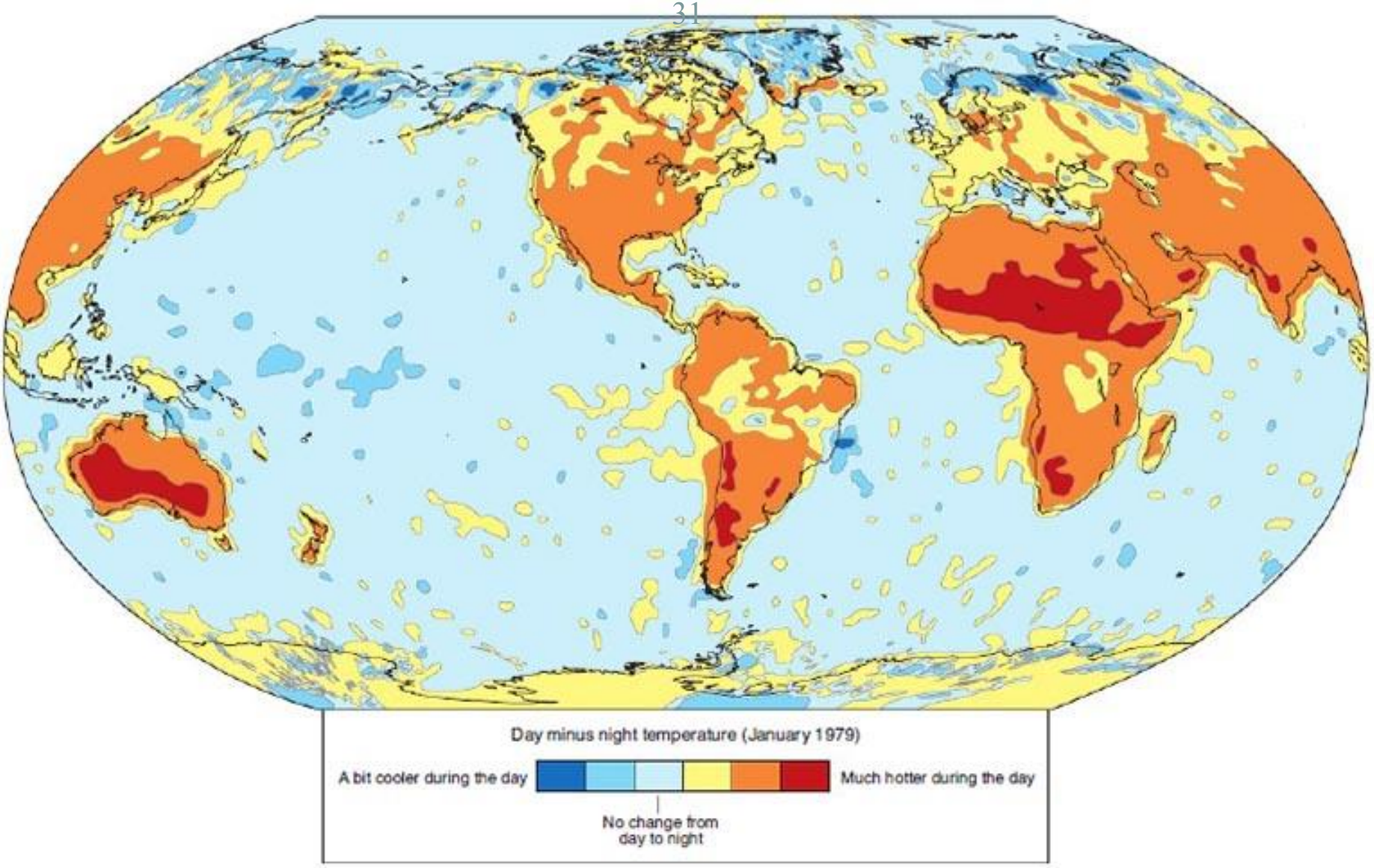


Seawater temperature

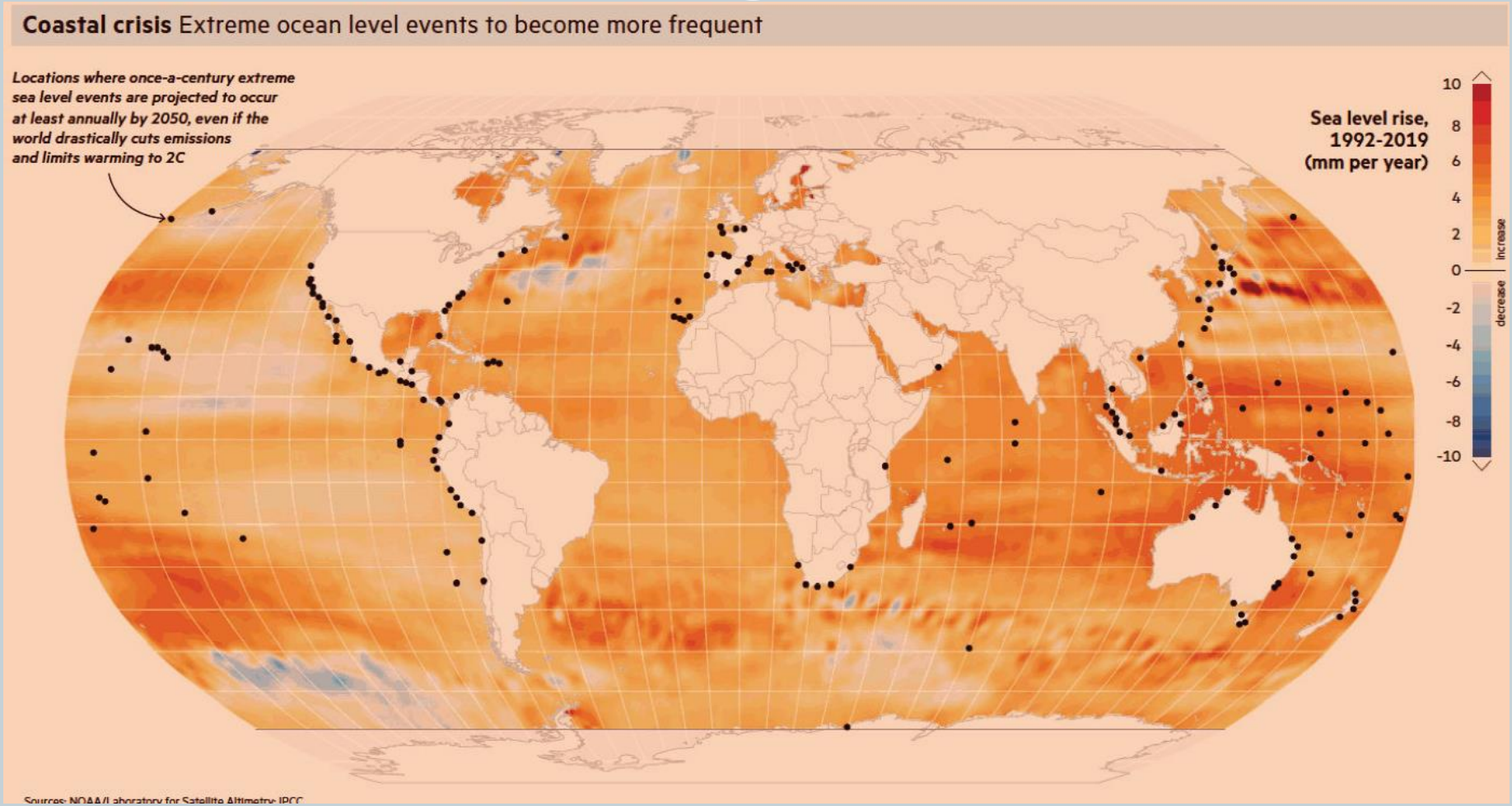
- Ocean & land absorb ~½ of solar energy reaching the earth
- Thermal energy absorbed by oceans transported to mid-depths
- Heat emitted by oceans drives oceanic circulation
- Seawater thermal energy budget affects:
  - Earth's temperature & climate
  - Tropical cyclones
  - Ocean surface currents
  - Water waves
  - Marine life
  - Ice formation/melting
  - Oil & gas activities
  - Marine transportation
  - Seawater pollution, water viscosity, evaporation, …



Day minus night temp. difference

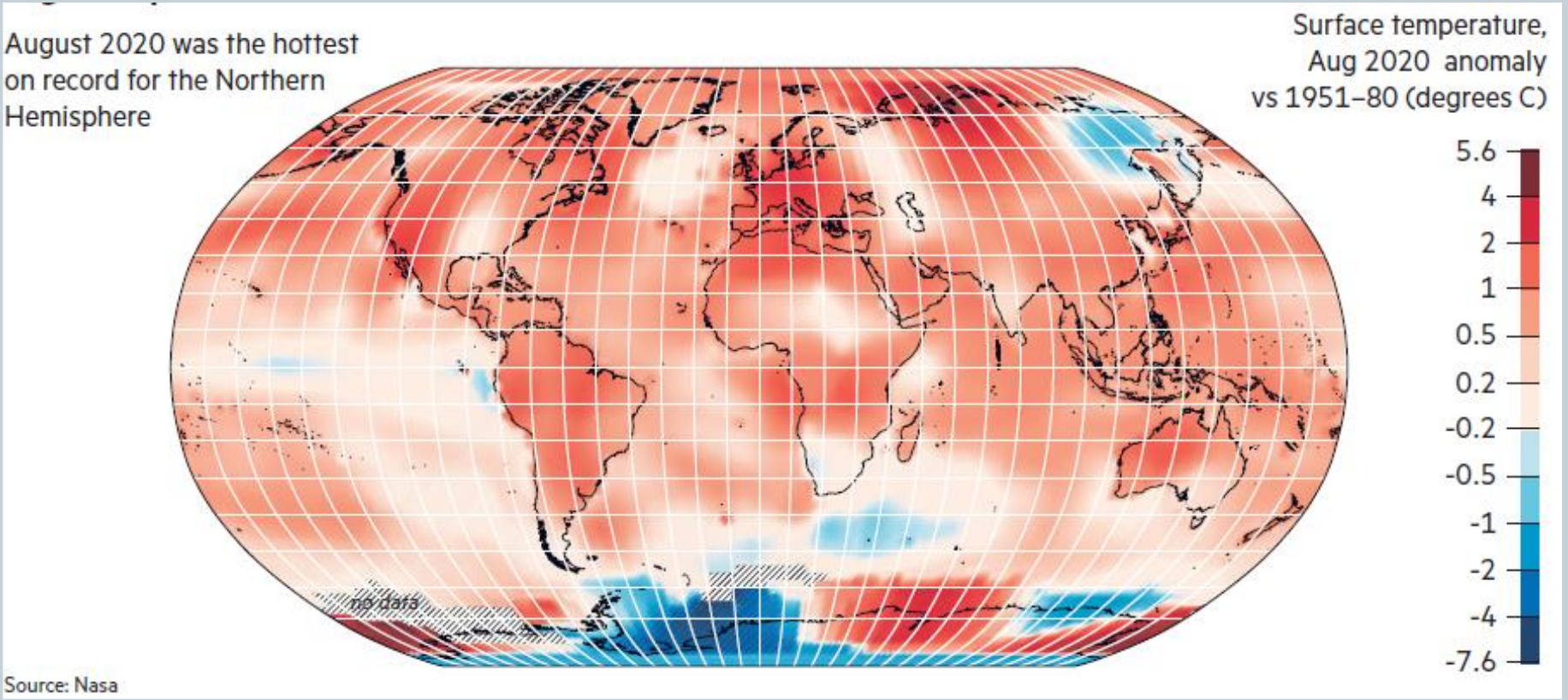


Sea level rise



Hottest August 2020 ever recorded

- Eclipsed by August 2026 with an average temp. of 16.96°C



Oceanic heat budget

- Thermal energy balance to oceans affected by:
  - 1. Solar insolation (Q_{SI}): heat flux into the sea;
  - 2. Net infrared radiation (Q_{IR}): net heat flux out of sea;
  - 3. Sensible heat flux (Q_S): flux of thermal energy (out of sea) from liquid-solid transfer
  - 4. Latent heat flux (Q_L): thermal energy flux carried (out) by evaporated water;
  - 5. Advection (Q_{Ad}): dispersed heat by advection.

- Conservation of energy yields:

$$Q_T = Q_{SI} + Q_{IR} + Q_S + Q_L + Q_{Ad} \quad (1)$$

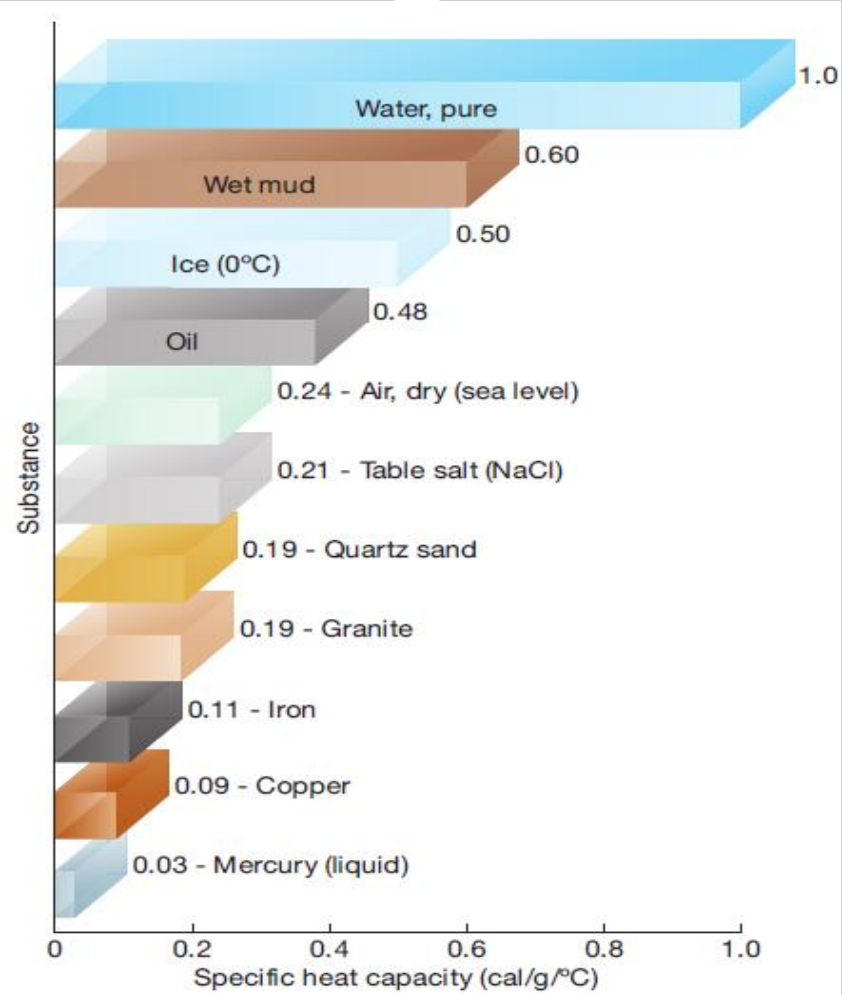
Heat flux has units of W/m^2.

- Change in temp. of water is related to its change in energy, such that:

$$\Delta E = m \cdot C_p \cdot \Delta T \quad (2)$$

where *m* is the water mass (kg).

Specific heat capacities of various substances



Oceanic vs Earth heat budget

- 1-D steady-state heat flux (conduction) [Fourier's Law]:

$$q_x'' = \frac{q_x}{A} = \frac{\lambda}{L}(T_1 - T_2) \qquad (3)$$

where q_x is the heat rate & λ is the thermal conductivity of the material (W/m-K)

- Assuming an *isothermal* surface, Newton's law of cooling states:

$$q_s'' = h(T_1 - T_2) \qquad (4)$$

where h is the *convective heat transfer coefficient* (W/m²·K). Eq (4) governs heat transfer btw fluid and solid surfaces.

Example

- Example #1

AI discussion

- Why are the world's oceans underexplored?
- How many manhours does it take to built a semi-sub?
- Why is sweater salty?
- How can we emulate fish to improve offshore structures?
- Which fish are the most energy efficient?
- It is possible to extent the lifetime of an offshore platform?

Summary

- Motivation for offshore engineering
- Offshore installations
- The ocean environment
- Ocean energy budget
- Next: marine hydrodynamics



Thanks for your attention!