Introduction to Offshore Engineering

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UNIVERSITY *of* NICOSIA

Offshore Engineering course outline

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

Offshore Engineering course outline (2)

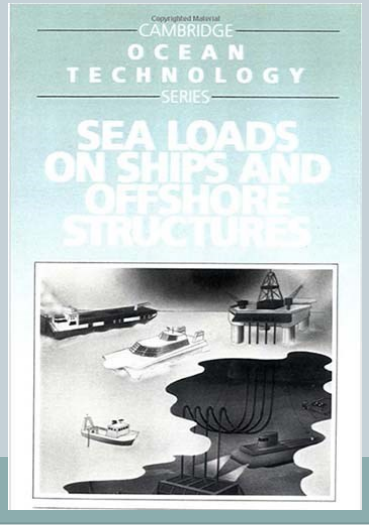
- Operational and environmental hazards
- Pollution avoidance and mitigation measures
- Decommissioning

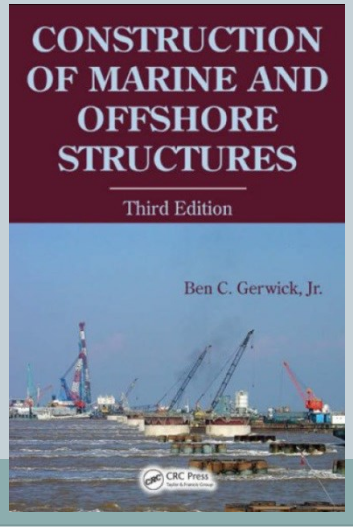
Lecture 1: Introduction to Offshore Engineering

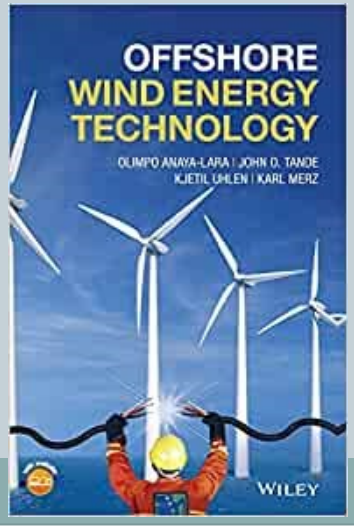
- Offshore engineering textbooks
- Other resources
- What is offshore engineering?
- Why/what is offshore engineering?
- Offshore arena
- Physical oceanography
- Oceanic heat energy budget

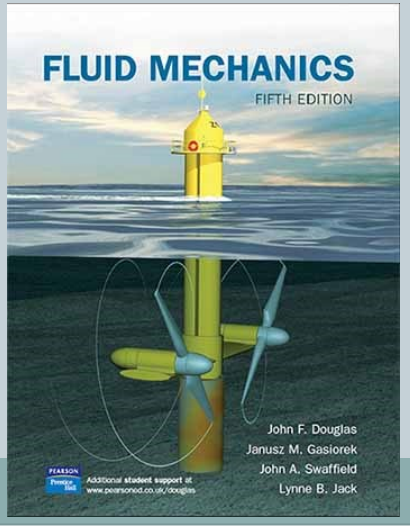
Offshore engineering textbooks

- Faltinsen OM. *Sea Loads On Ships And Offshore Structures*. Cambridge; CUP; 1993.
- Gerwick Jr BC. *Construction of Marine and Offshore Structures*. CRC Press; 2007.
- Tande J.O., Anaya-Lara O., Uhlen K. & Merz K. *Offshore Wind Energy Technology*, 2018, John Wiley, ISBN: 9781119097785
- Douglas JF, Gasiorek JM, Swaffield JA. *Fluid mechanics*. 5th ed. NY; Wiley; 2005.



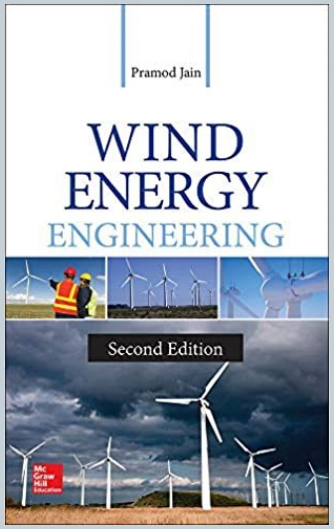






Offshore engineering textbooks (2)

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



Other resources

Professional bodies

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

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

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 Tidal Power Farm, Sept 2016: https://www.youtube.com/watch?v=8p8CKRK72F0



MENG-370 Offshore Engineering – Assessment

- **Mid-Term Exam:** 25%
- **Final Exam** (comprehensive): 40%
- **Problem sheets:** 30%
- **Class Participation:** 5%

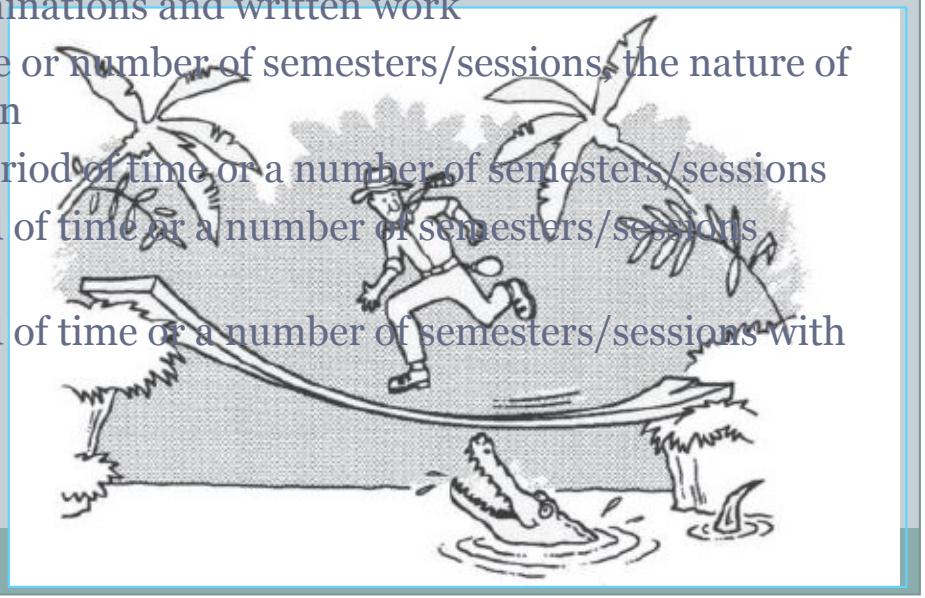
- **Pass mark:** >60%
- Actual pass: >73%

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



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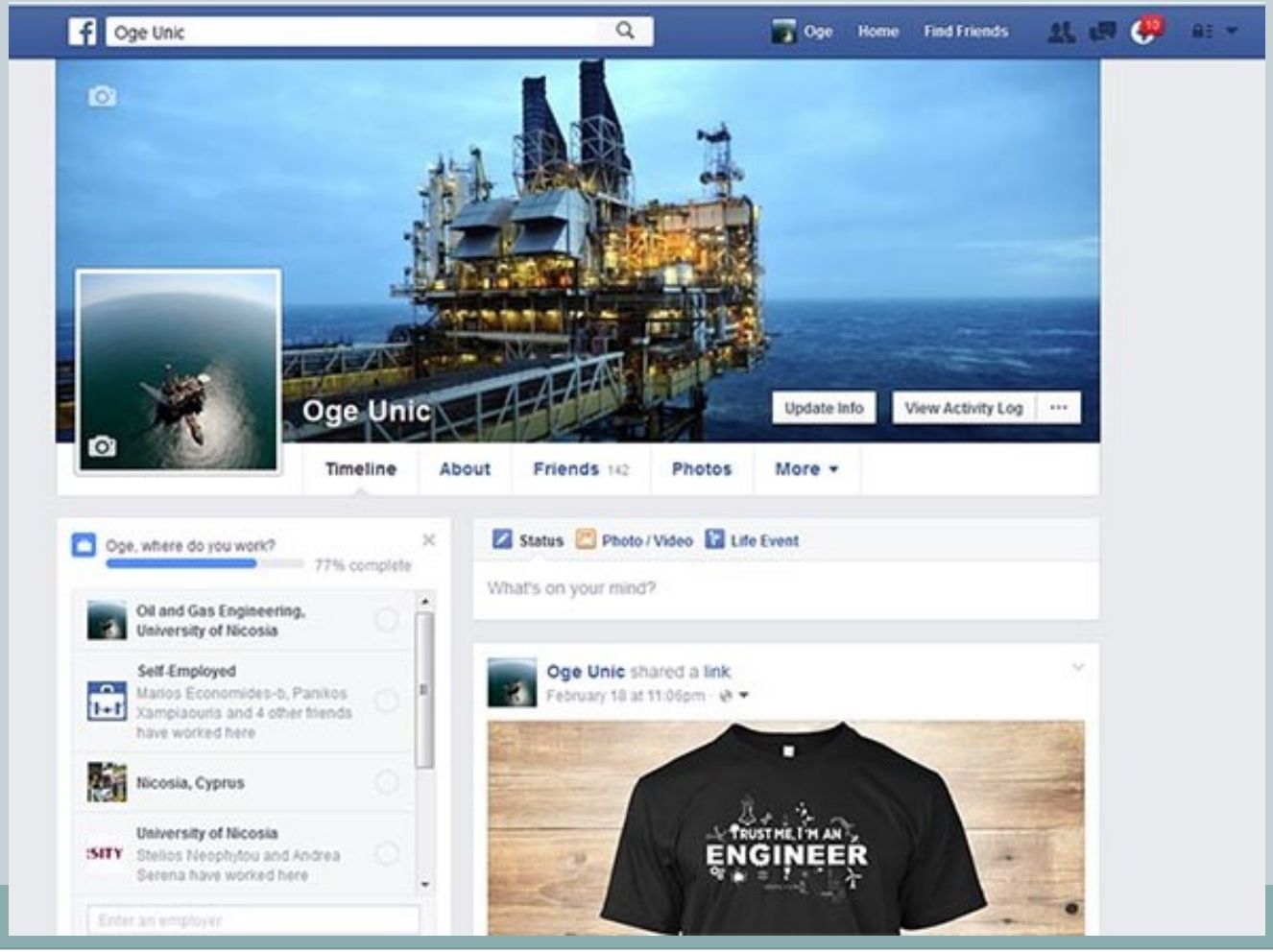


Water world

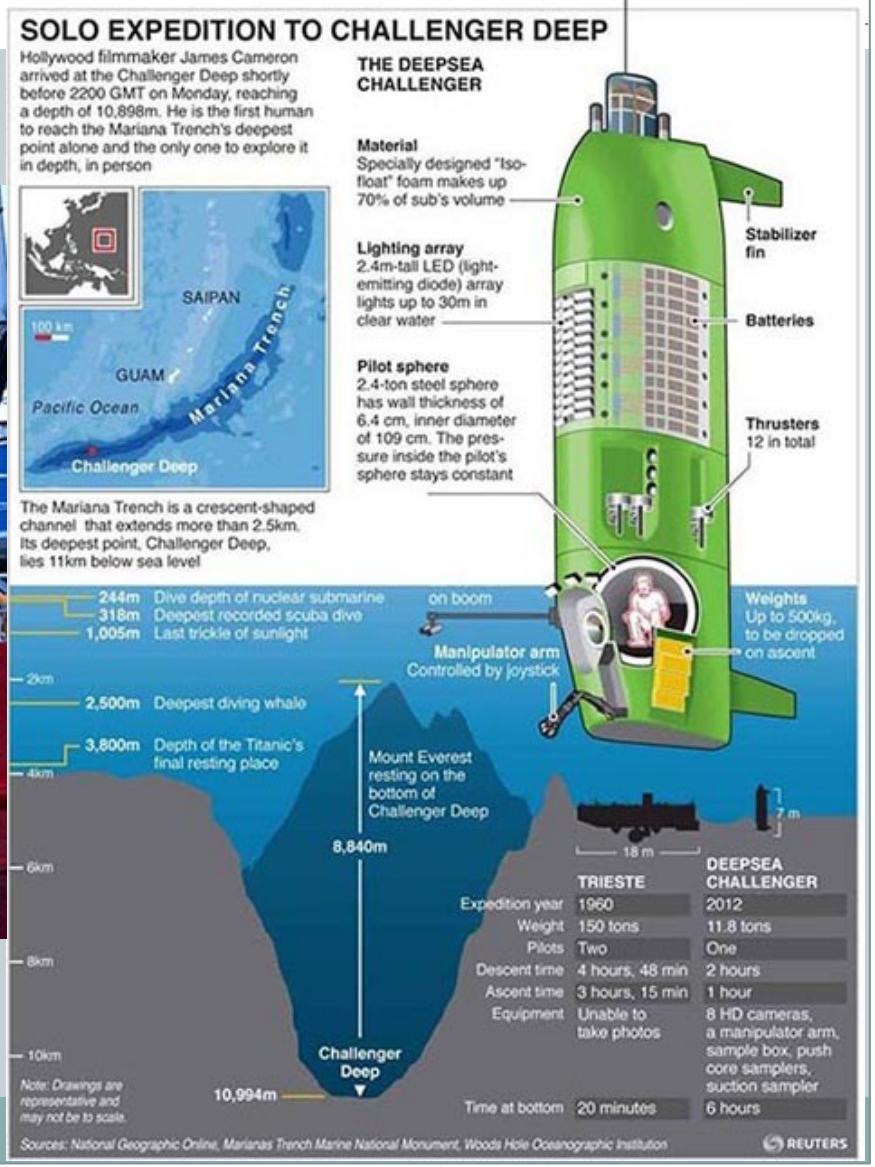
- World's oceans are older than 3bn years
- Water covers ~71% of the earth's surface area
- World consists of 1 ocean & continents as islands

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 eg, 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.

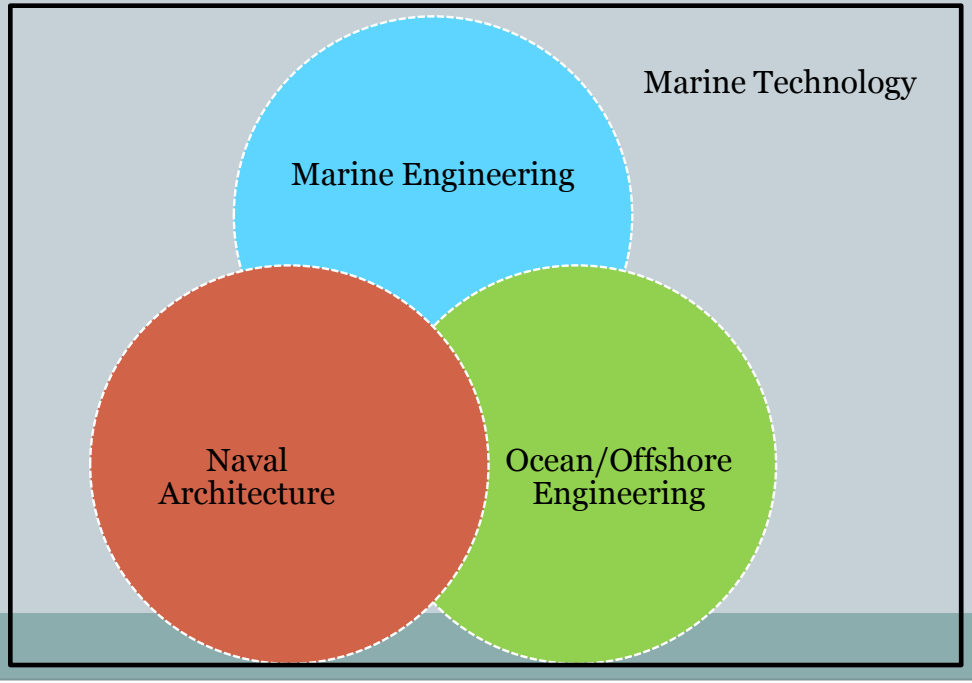


Engineering Marvel #2

- Feb., 2014
- 130m high
- Depth: 945m
- 126,000 tons
- 100,00bpde

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?

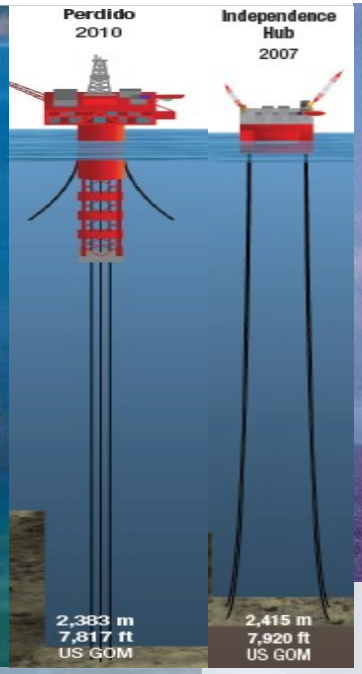
- Design, develop, construct, test, operate ocean systems , technologies, and structures enabling a score of activities.

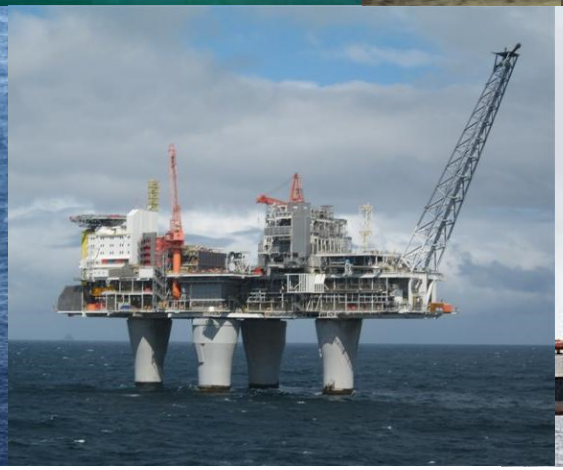
- Examples: design offshore platforms, offshore drilling, deep sea mining, offshore pipelaying, buoy design, salvage, mooring, towing, ship design, offshore power, O&G exploration, sea mapping, communications, …

- 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.

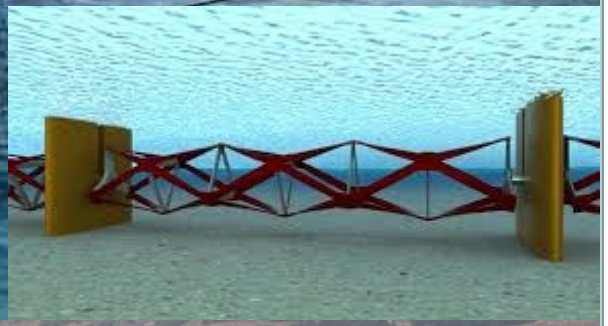
Marine activities

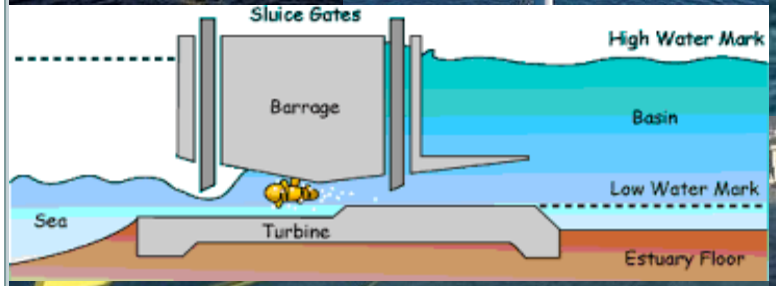
Offshore drilling rigs, FPSOs & production facilities





Offshore energy installations

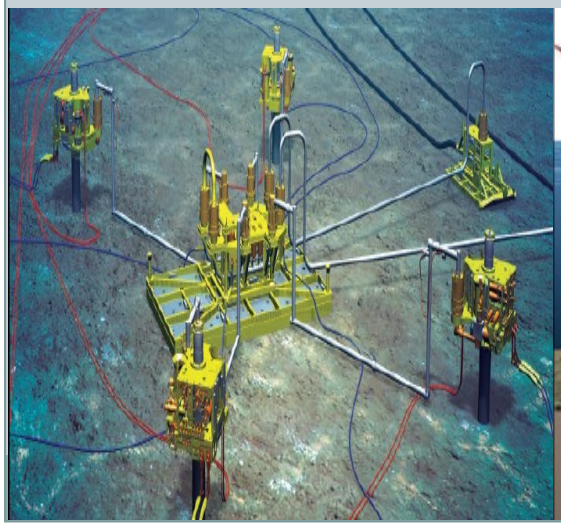




Offshore arena

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



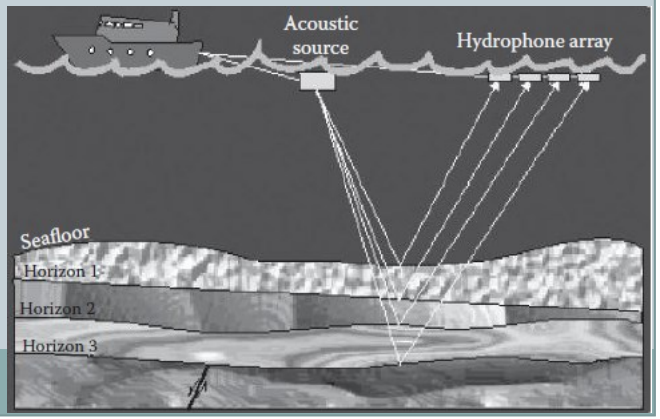
Offshore arena (2)

- ~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

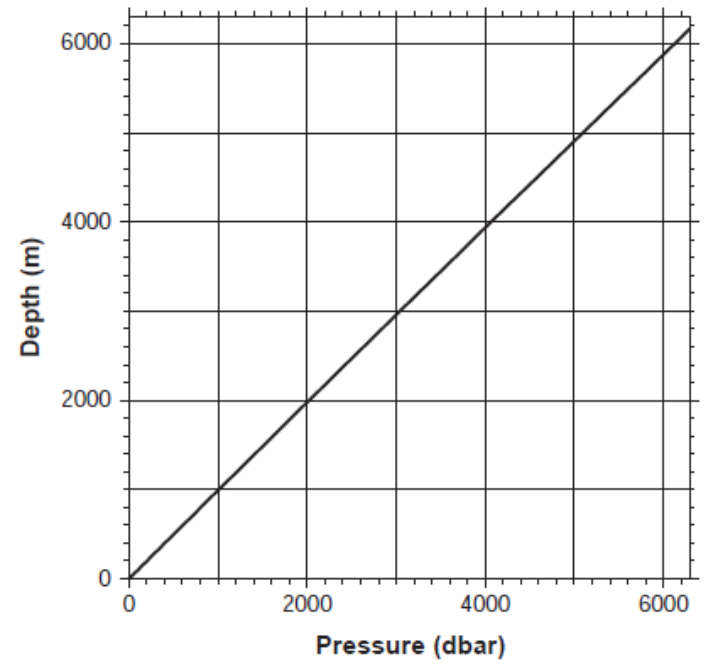


Elements of physical oceanography

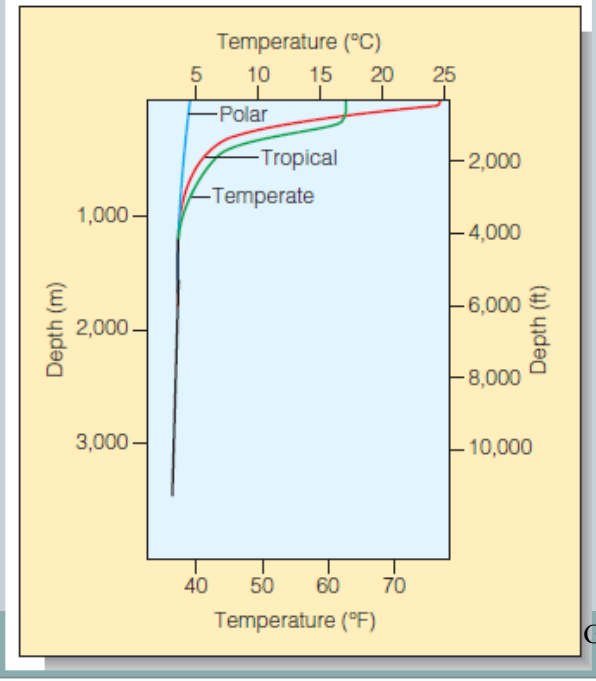
- Distinction between *sea* & *ocean*:
  - Sea is the seawater with depths <2,000m-3,000m
  - Ocean has water depth >3,000m

- 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.

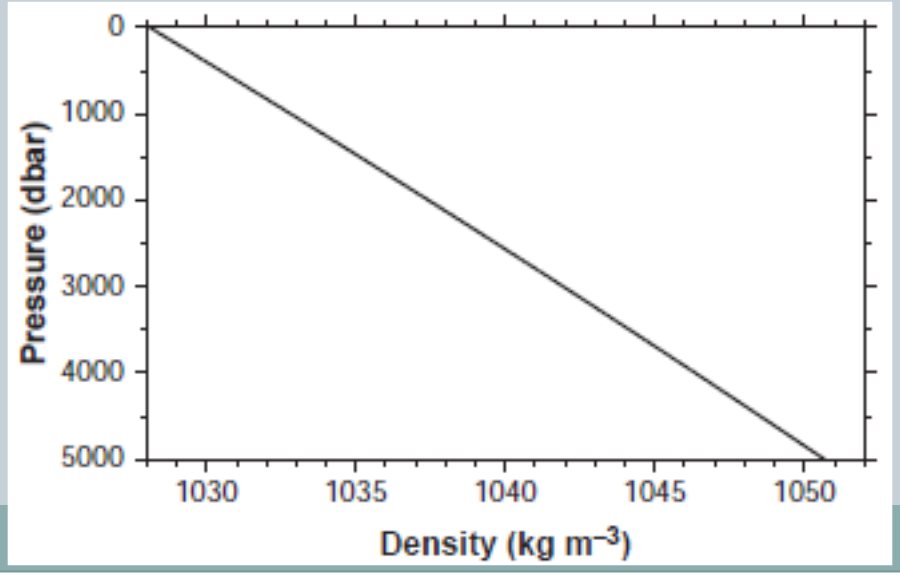


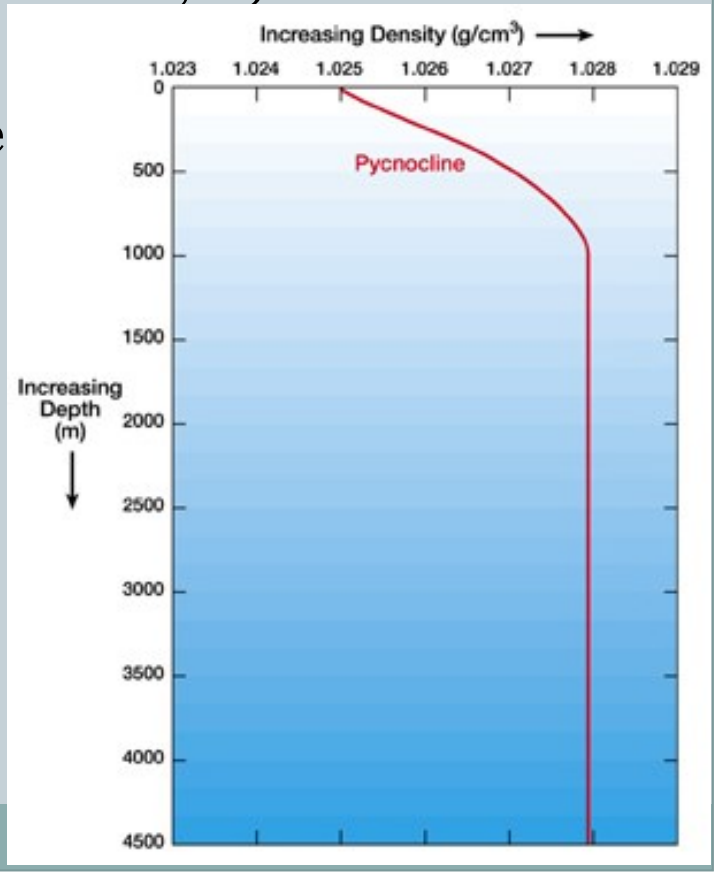
Garrison(2012)

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 0C & salinity 35.0 at the sea surface.

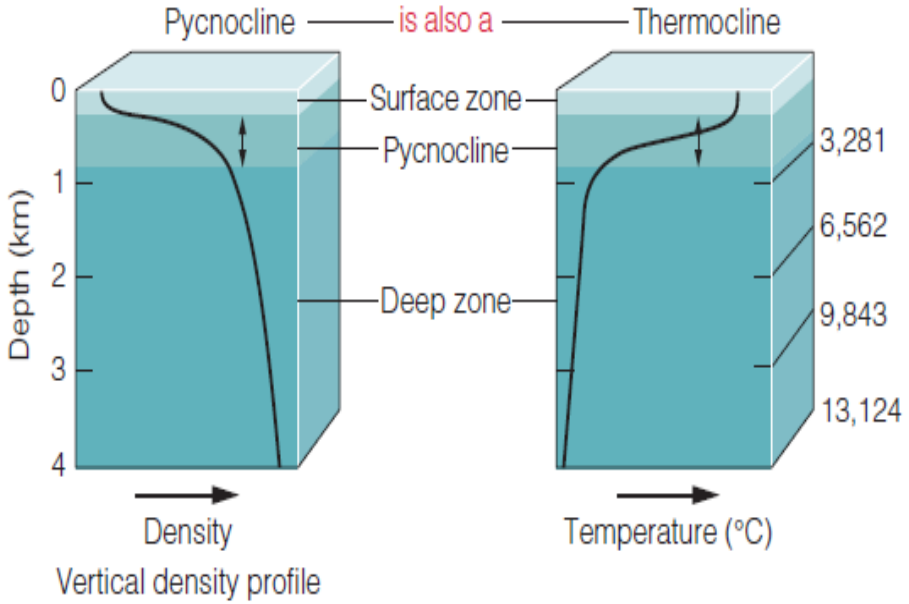


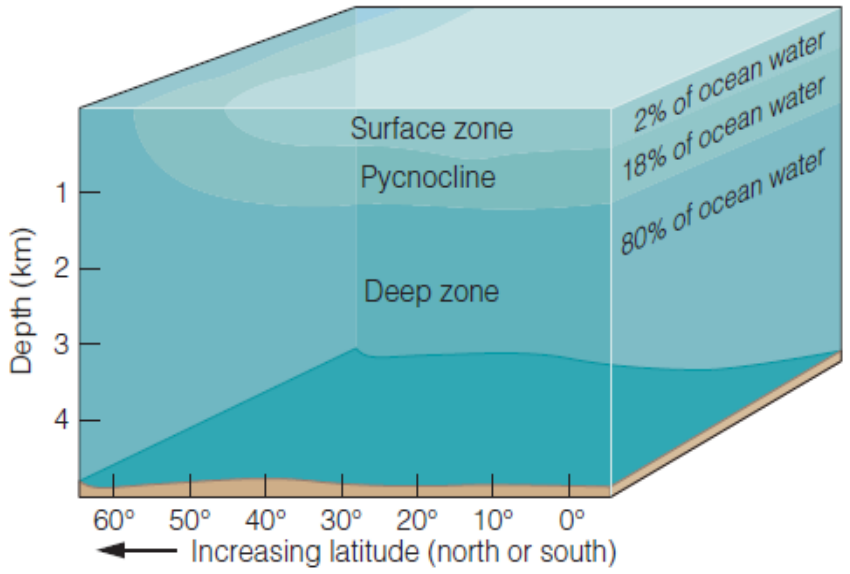


Ocean stratification

- 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.

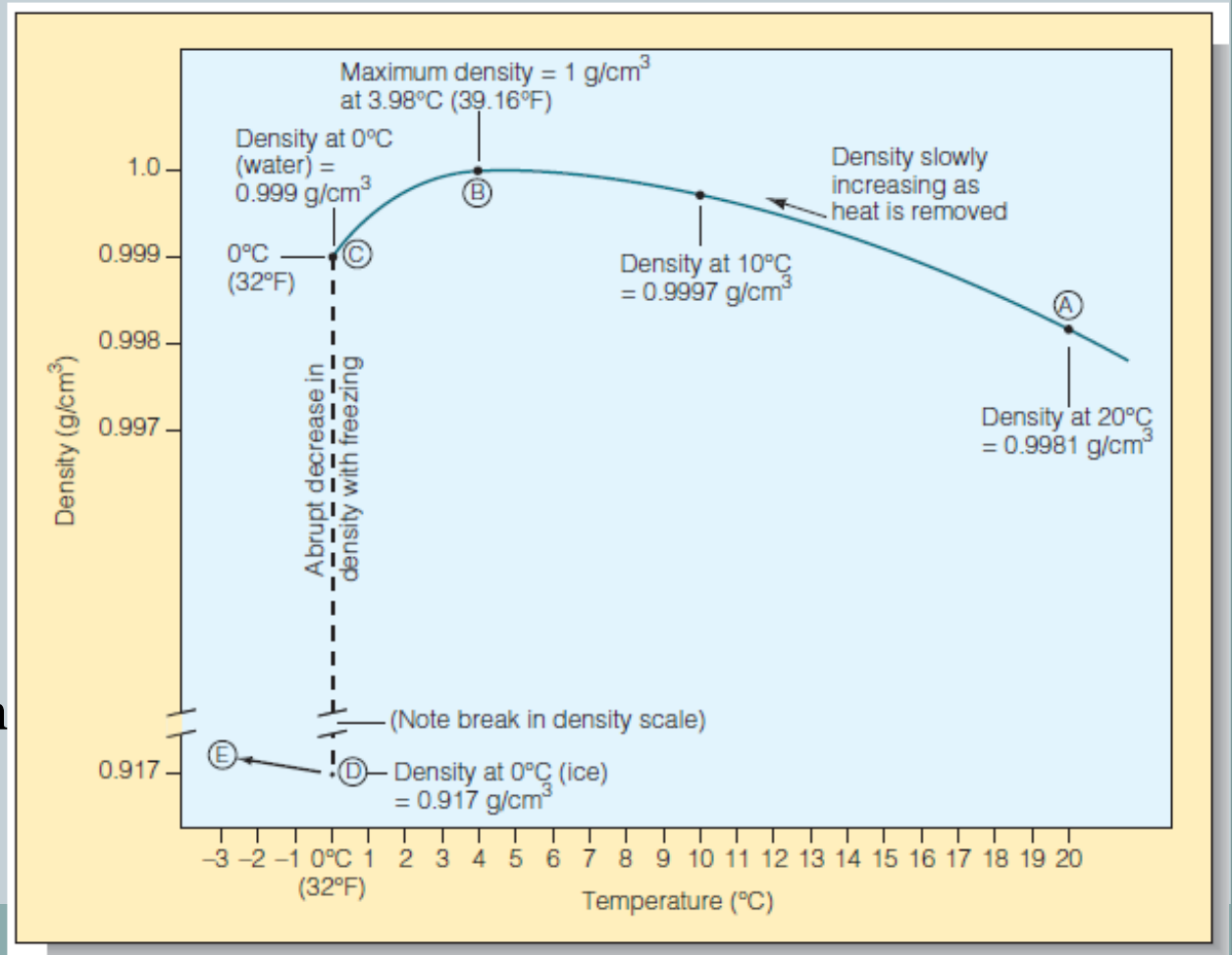
Garrison(2012)





Why does seawater not freeze at seabed?

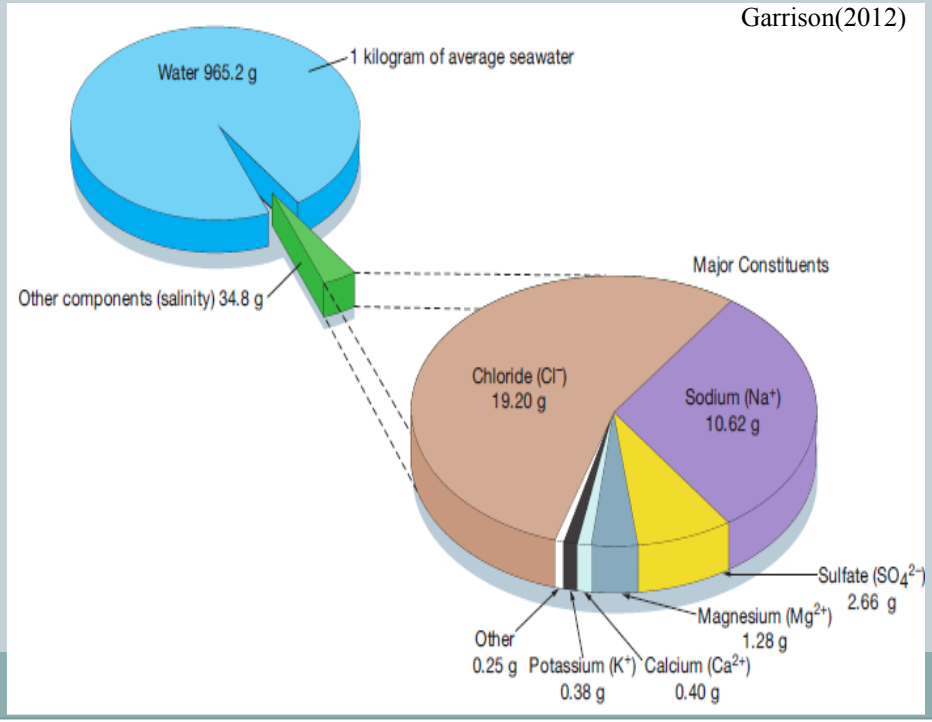
- Mass density of seawater peaks at about 4°C
- Seawater could be liquid @ −2°C
- Water's unusual properties make life at sea possible
- ρ drop [0°C, 4°C] permits ice to float in water
- $\rho_{ice} > \rho_{sw}$ by 9%

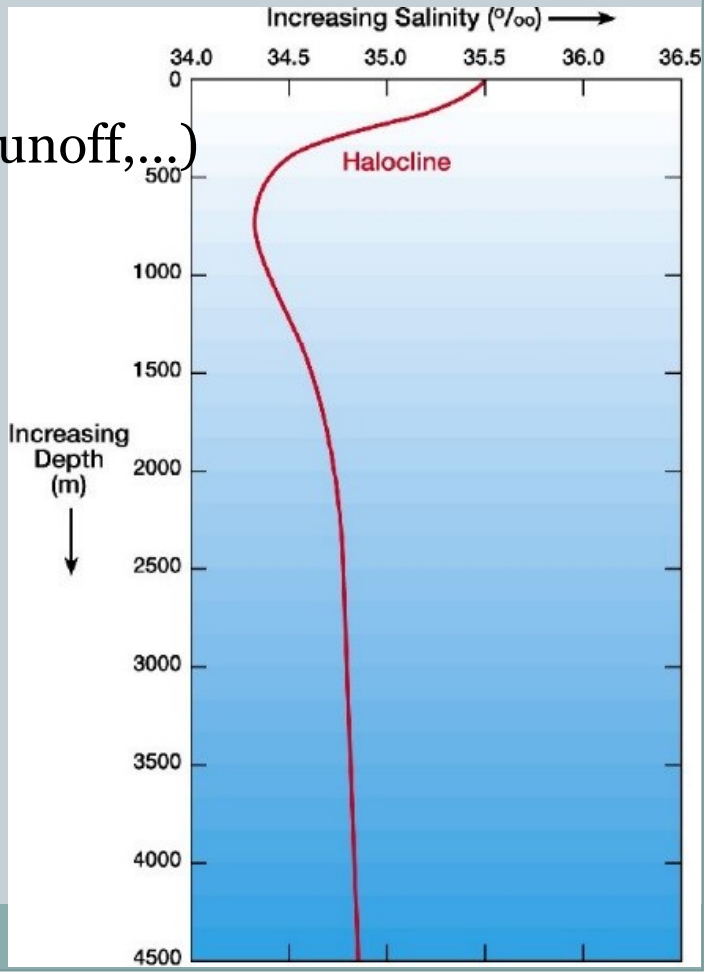


Seawater salinity (S)

- 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, fresh water runoff,…)
- Salinity varies with geographic location

Garrison(2012)

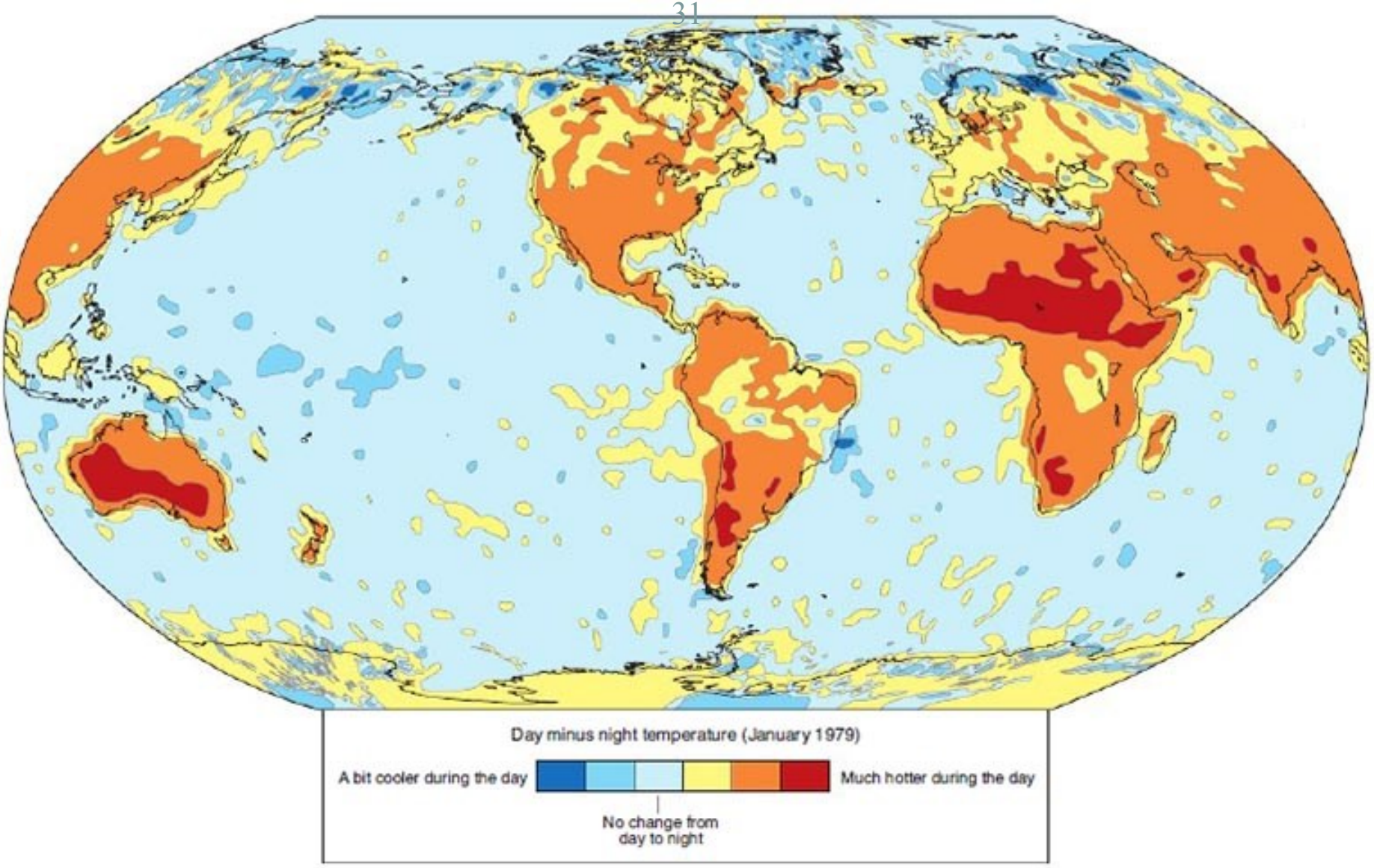




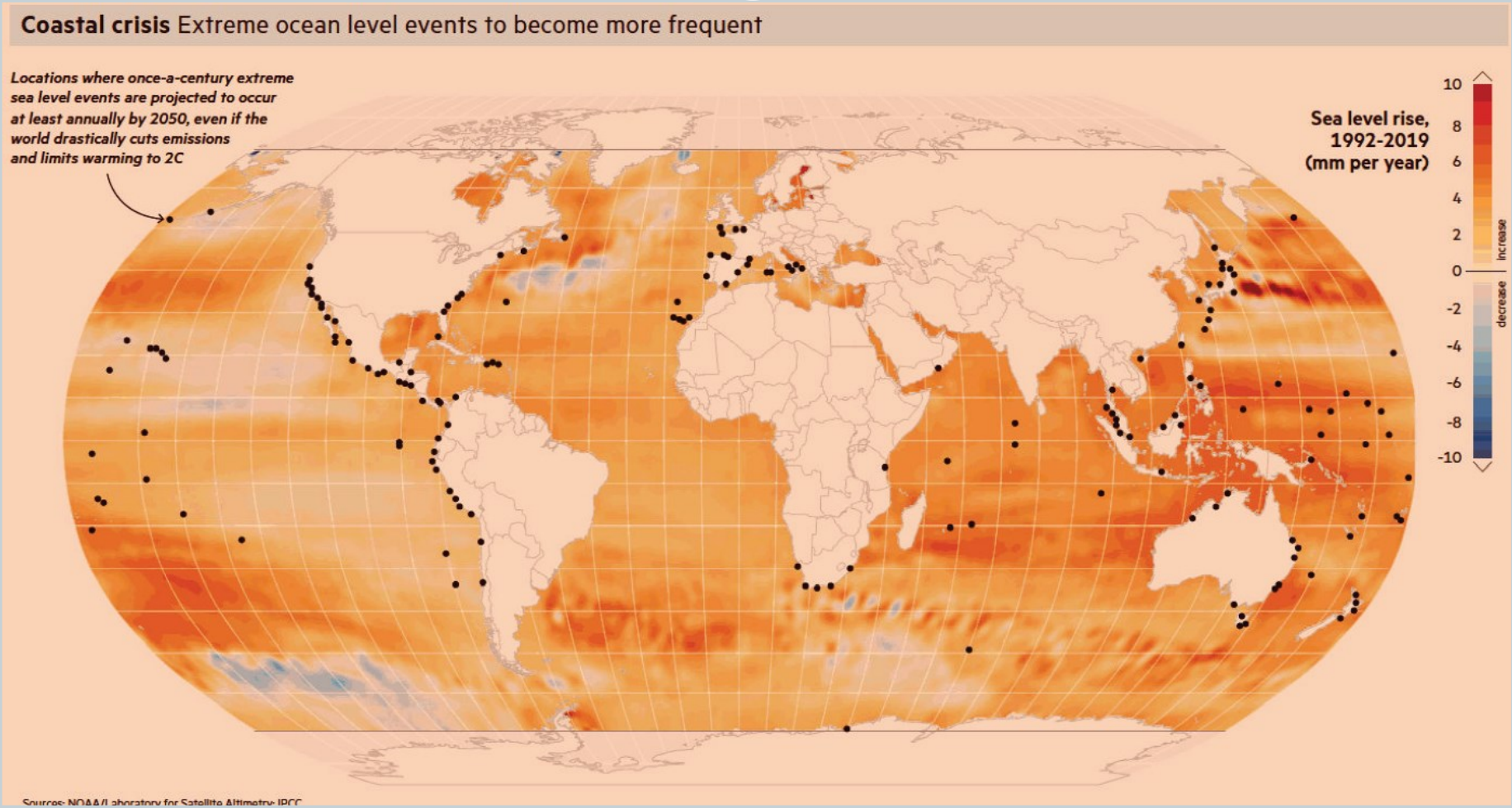
Seawater temperature

- 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 climate
  - Tropical cyclones
  - Ocean surface currents
  - Water waves
  - Marine life
  - Ice formation/meting
  - Oil & gas activities
  - Marine transportation

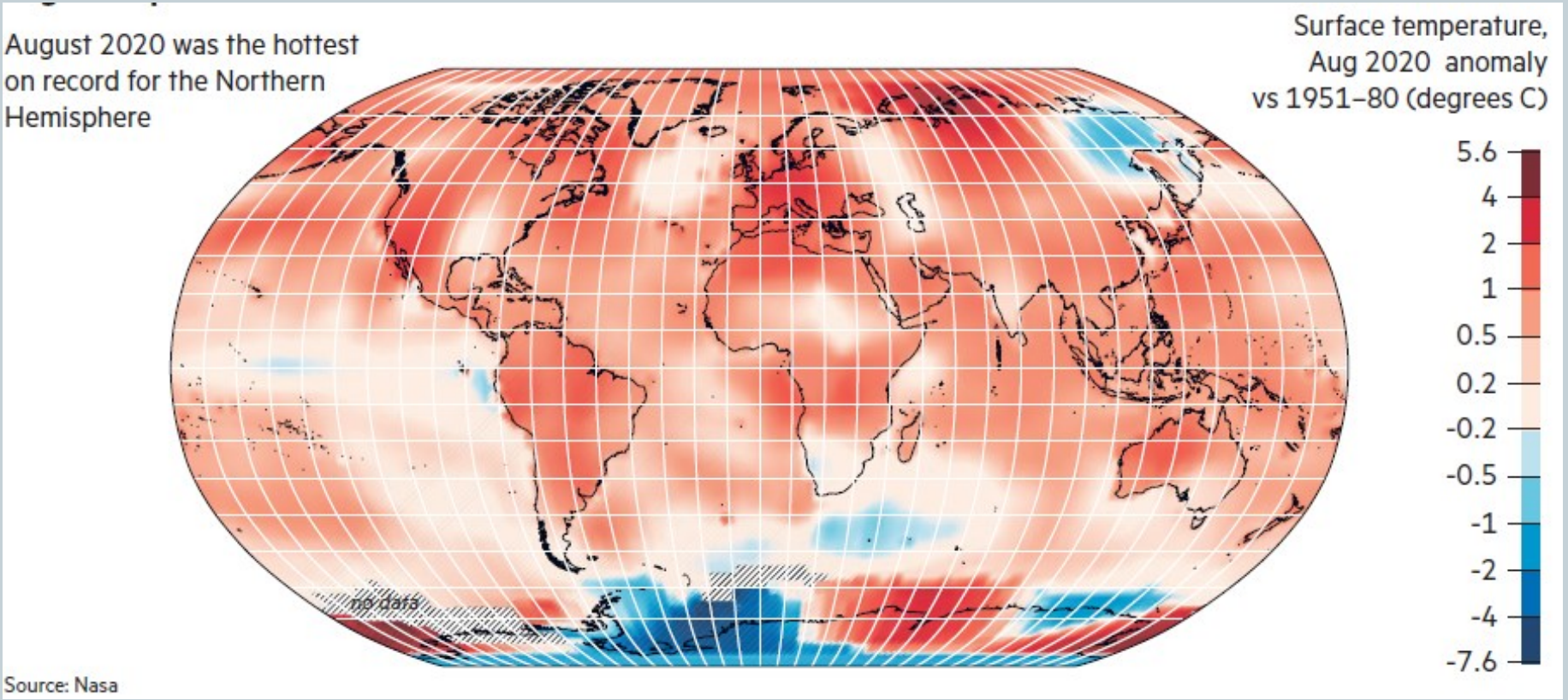
Day minus night temp. difference



Sea level rise



Hottest August 2020 ever recorded



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:

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

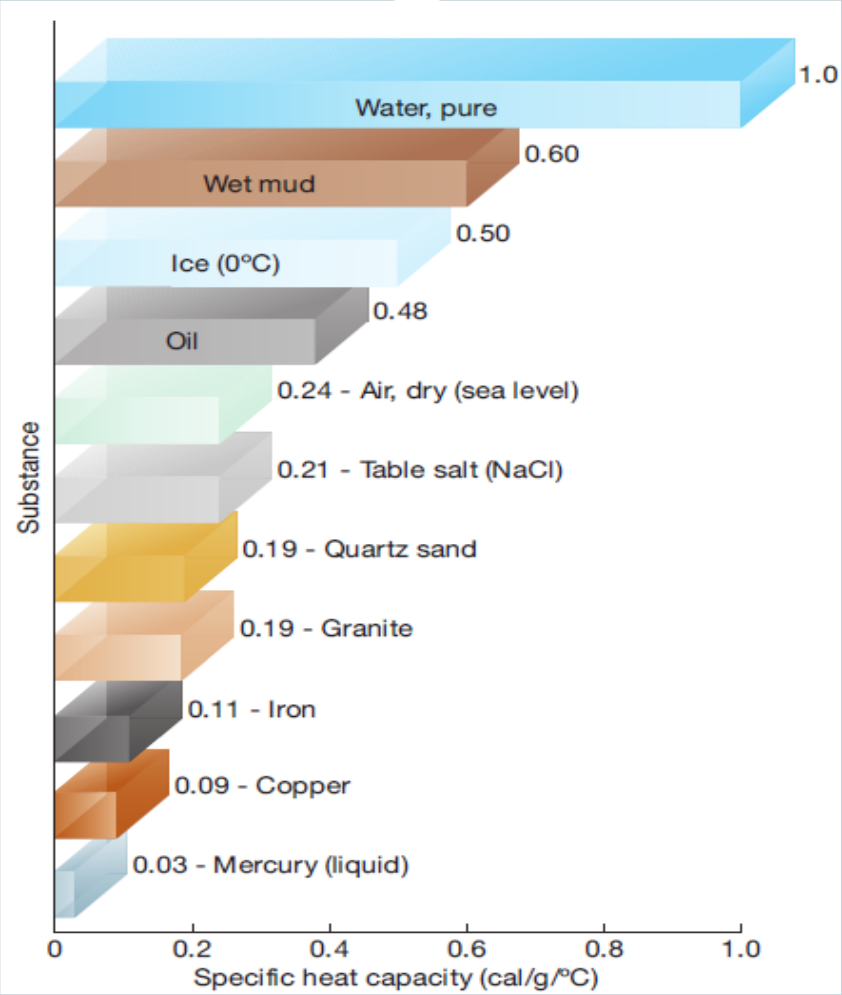
Heat flux units are in $W \cdot m^{-2}$

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

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

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):

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

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

Summary

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

Thanks for your attention!