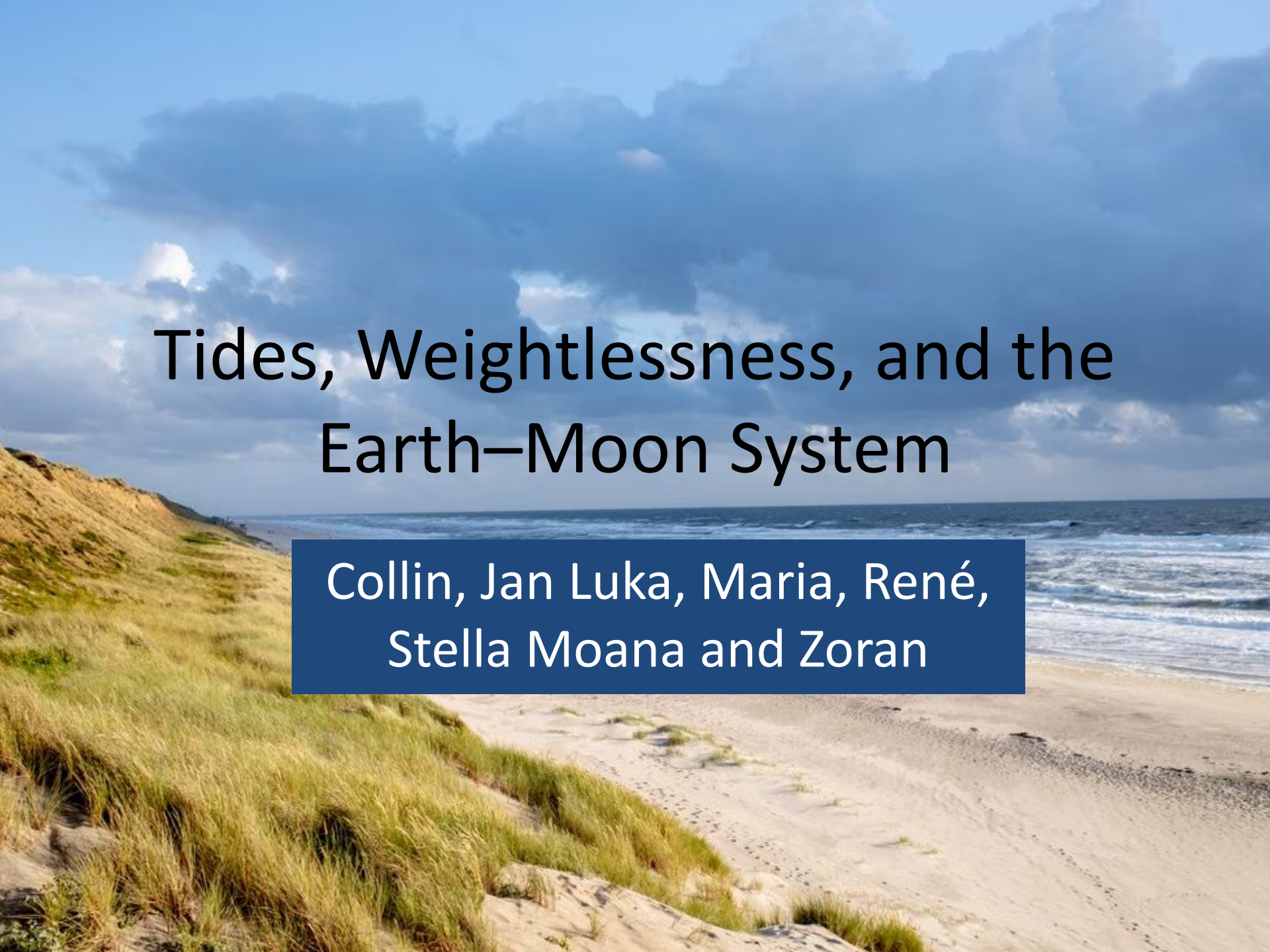
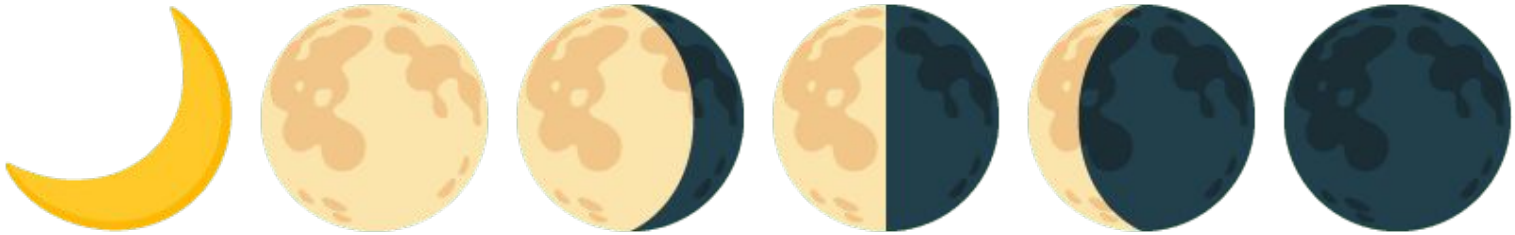


Tides, Weightlessness, and the Earth–Moon System

Collin, Jan Luka, Maria, René, Stella Moana and Zoran

Introduction: (Zoran)

- Tides on the beautiful island of Sylt
- Gravity & free fall
- Tidal bulges
- Spring and neap tides
- A world without tides? What?
- Climate change and future tides



Quizz time! (Zoran)

Why does the sea disappear twice every day?

A Moon

B Rotation

C Wind

D Combination

E It just has an existential crisis and takes a break?

Quizz time! (Zoran)

Why does the sea disappear twice every day?

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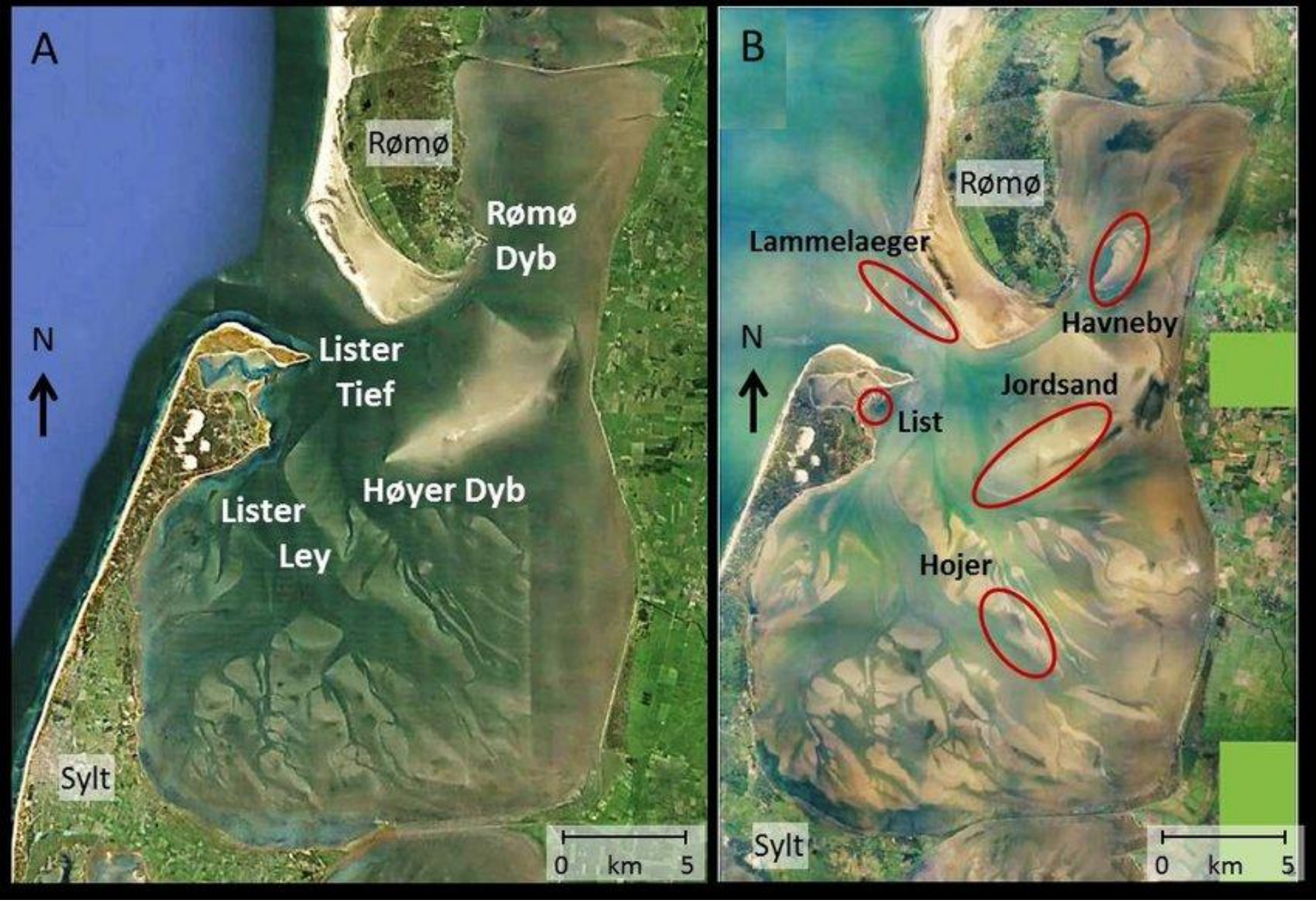
E It just has an existential crisis and takes a break?

1. What are tides?

Tides are the regular rise and fall of sea level caused mainly by the gravitational attraction of the Moon and, to a lesser extent, the Sun. As Earth rotates, most coastal regions experience two high tides and two low tides each day.

2. Gravity vs. tidal forces

- **Gravity** is the attractive force between two masses. The Moon's gravity pulls on Earth and its oceans.
- **Tidal forces** arise because the Moon's gravitational pull is stronger on the side of Earth closest to the Moon and weaker on the far side. This difference in gravitational pull stretches the oceans and produces tides.



Aerial pictures of the Sylt-Rømø Bight at A-high tide and B-low tide

Quelle:Map data ©2016 GeoBasis-DE/BKG (©2009), Google Imagery ©2016 TerraMetrics

King’s Bay, Sylt (high tide)

King’s Bay, Sylt (low tide)

Astronaut Puzzle

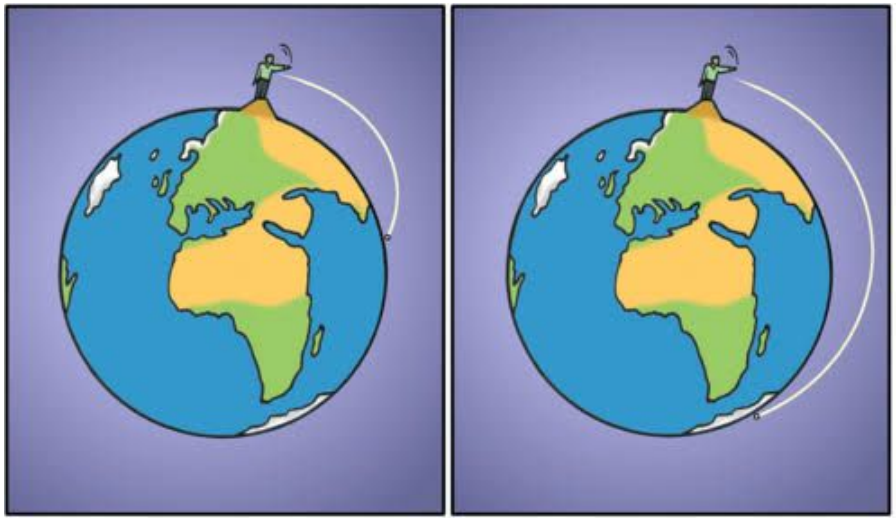
- Why do astronauts float although Earth's gravity is strong?

https://www.nasa.gov/wp-content/uploads/2015/06/iss043e174193.jpg

-> At the altitude of the International Space Station, Earth's gravity is still about **90% as strong** as it is right now under your feet!

Continuous Free Fall

Orbiting: <u>Newton´s Ball</u>



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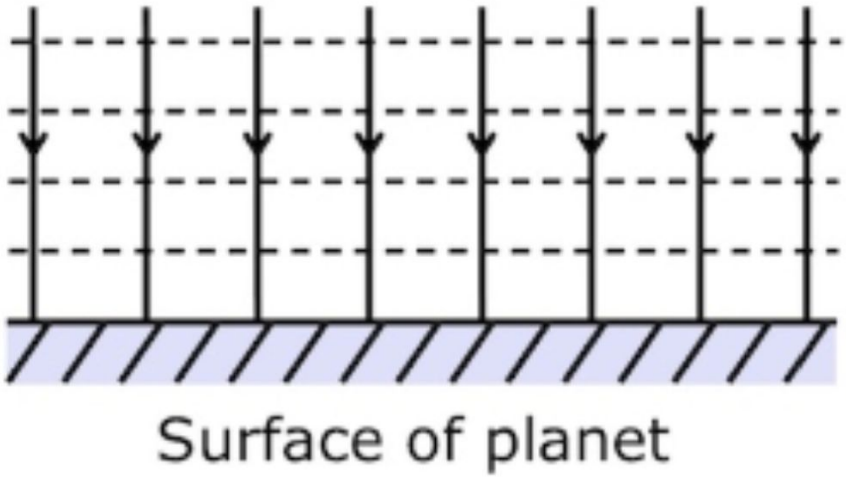
-> exactly what is happening to the spacecraft and the astronauts inside!

-> same as falling in an elevator with exact same speed

Uniform Gravity

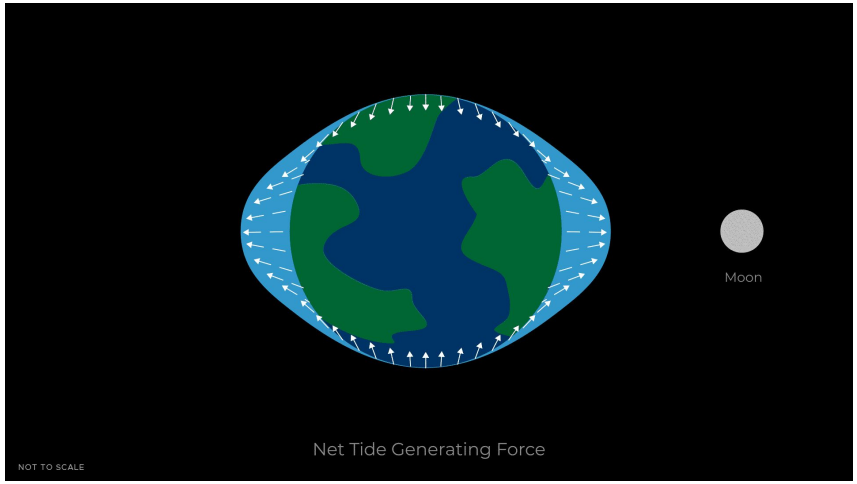
- **Definition:** Gravitational strength and direction are completely identical at every single point in space.
- All parts accelerate equally → weightlessness.



Uniform gravitational field

Non-Uniform Gravity

- **Definition:** Gravity is radial (points toward a center) and its strength decreases with distance
- Different accelerations ⟶ tidal forces.
- the same principal: Microgravity on ISS



https://assets.science.nasa.gov/content/dam/science/psd/earths-moon/lunar-science/tide-generating-force.gif?w=1920&h=1080&fit=clip&crop=faces%2Cfocalpoint

Tidal Forces

Fc / Fs = force on centre / surface of earth
ma = mass of an astral body influencing earth
me = mass of earth
d = distance between earth and astral body
p = equatorial radius of earth
Df = differential force

$$Fc = g * ma * me / d^2$$

$$Fs = g * ma * me / (d + or - p)$$

(+ or - depending what side of earth)

$$Df = + or - g * (2 * ma * me * p) / r^3)$$

Near-Side Bulge

- as seen previously the tidal forcing becomes stronger with closer distance to the astral body

  > the water body closest to the moon has the “biggest bulge”, the near-side bulge

Far-Side Bulge

- rotation introduces inertia - the body of water will lag behind

- could the water accelerate enough to ever overcome its inertia?

NO - it is also part of the geometry of the gravitational field relying on the gravitational difference

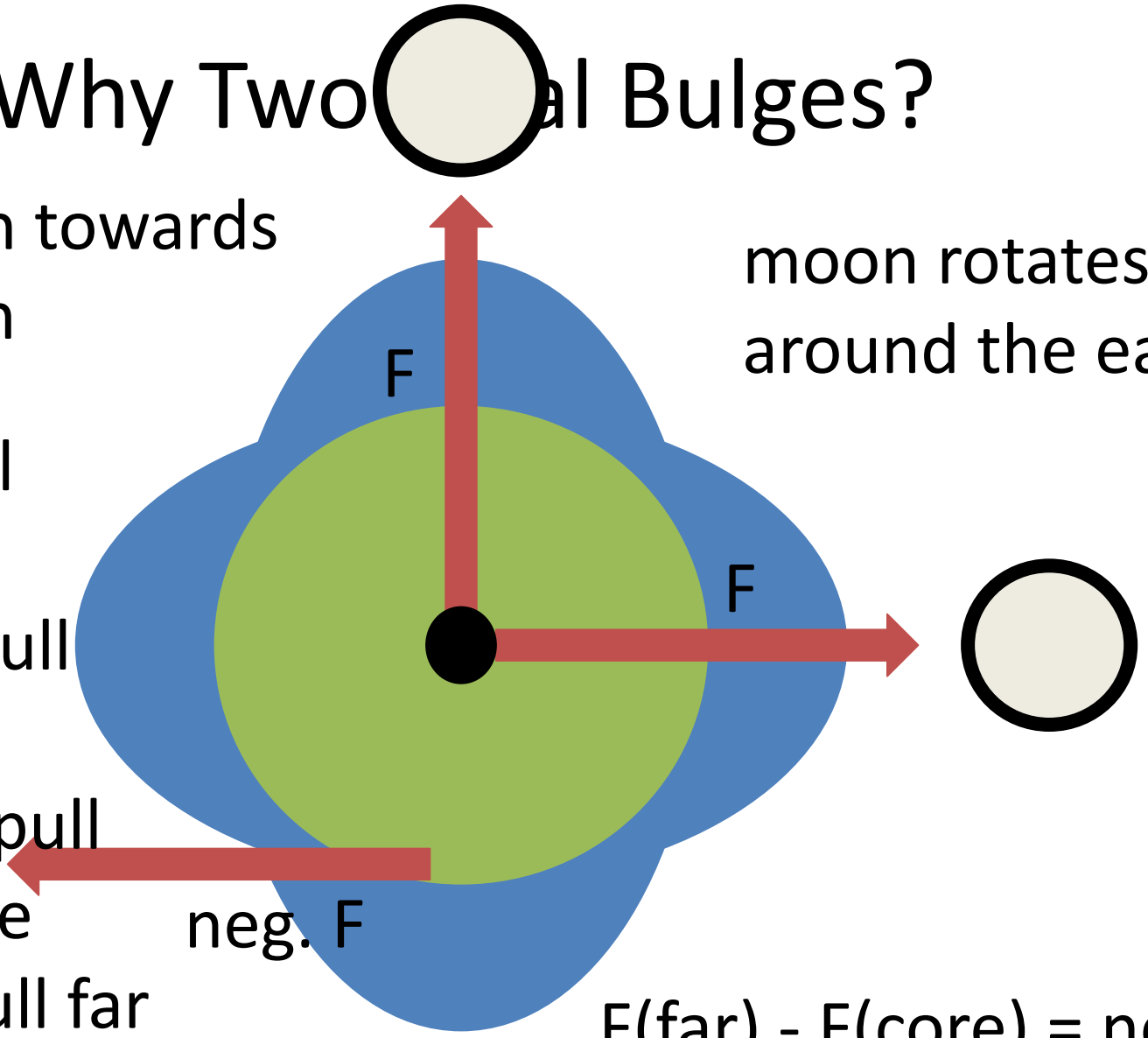
Why Two Tidal Bulges?

attraction towards the moon

moon rotates around the earth

gravitational difference:

- highest pull near side
- medium pull earth core
- lowest pull far side



F(far) - F(core) = neg. F

neg. F = moving away

Think–Pair–Share

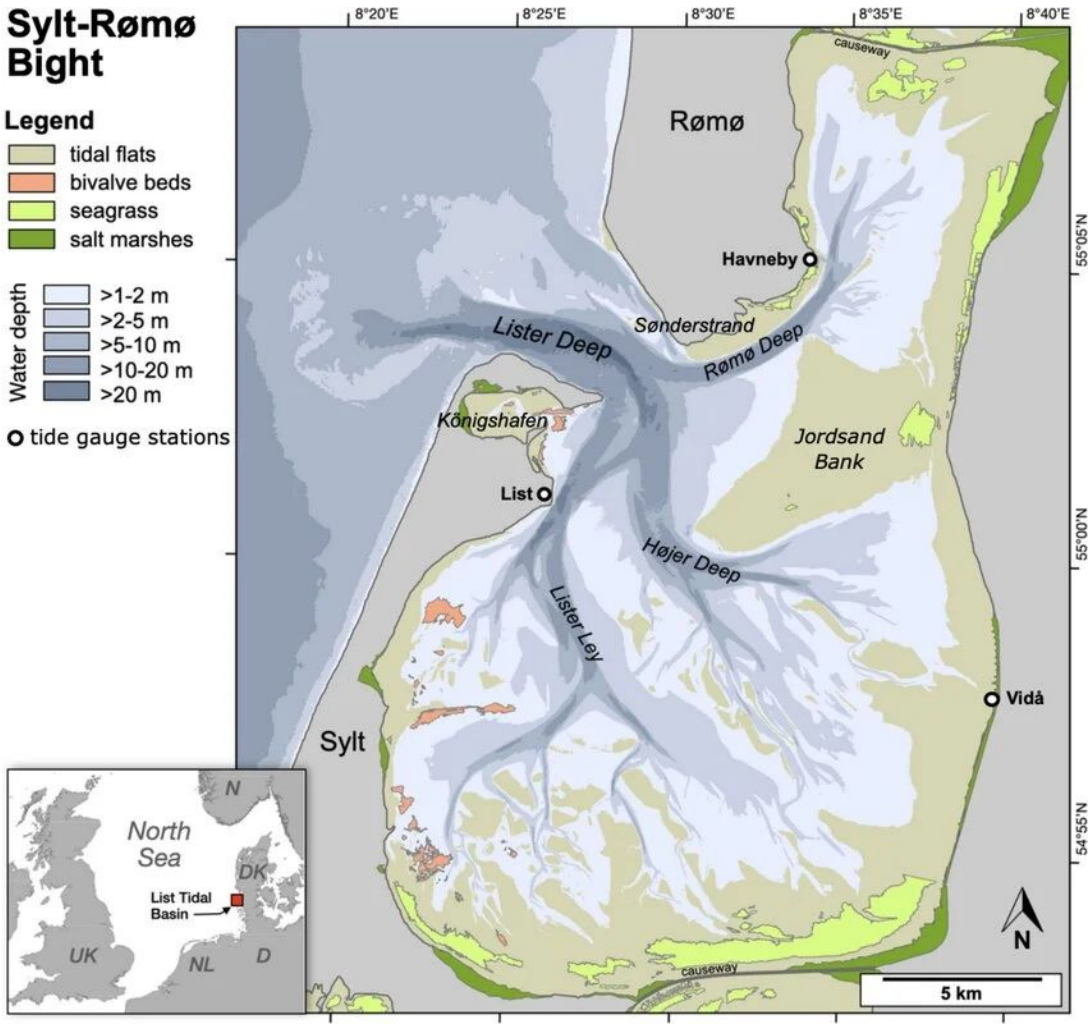
- > the moon does a full rotation around the earth in 27.3 days while the earth does a full rotation in 1 day

a full rotation (day) with two bulges present:
> 0h near side bulge
> 6h low tide
> 12h far side bulge
> 18h low tide
> 24h full cycle, near side bulge again

Tidal Channels and Sediment Transport

Lister Deep
Lister Tief
Lister Dyb

-separates Sylt from Rømø
-2.8km wide
-up to 40m deep



Tidal Channels and Sediment Transport

- influenced by humans
  - (climate change impacts, constructions like the Hindenburg Damm and coastal engineering)
- ebb-dominated tidal inlet

- loss of over 1 million sand m^3 per year

N↑ 800k m^3;
S↓ 400k m^3

Küstenschutz: Sylt setzt auf mehr Sand an den Stränden

Stand: 18.03.2025 15:23 Uhr

Jedes Jahr reißen Sturmfluten große Löcher in die Sylter Strände. Nun sollen 1,7 Millionen Kubikmeter Sand aufgespült werden, um die Küste zu schützen. Die Landesregierung investiert dafür 39 Millionen Euro.

A World without tides

Short: the world would become stagnant.

- tidal change due to climate change:

1. coastal/seafloor geography
2. Barometric Pressure and Wind

(meteorological effects)

- Nutrient depletion from lack of motion
- Collapse of coastal environments
- Climate swings: hotter equator, colder poles.

https://www.sciencenorway.no/forskningno-norway-planets/what-would-we-do-without-the-moon/1433295

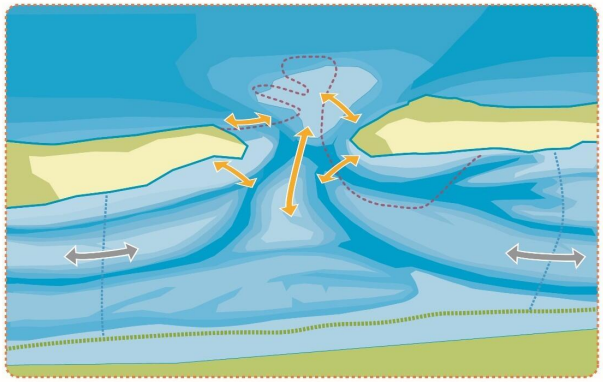
Impact on the Morphology of the Wadden Sea

https://www.visitwadden.nl/en/story-lines

- Sediment will remain trapped
- Tidal inlets & channels will flatten
- Mudlets disappear & become land
- Salinity decreasing from freshwater flooding

https://www.waddensea-worldheritage.org/one-wadden-sea-one-global-heritage

https://qsr.waddensea-worldheritage.org/reports/geomorphology



https://en.wikipedia.org/wiki/Mudflat_hiking

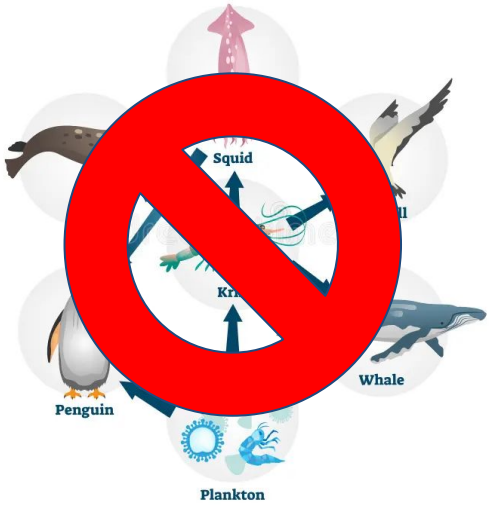
A World without tides

What happens to the ecosystem?

- stop of the nutrient cycle

–> collapse of the marine food web

  - local species are adapted to the tidal cycle
  - almost 2800 species around the island of Sylt
  - many birds would starve



- end of salt marshes
  - without incoming saltwater the specialized plant species would be outcompeted by terrestrial species

A World without tides

- What would happen to Sylt? -

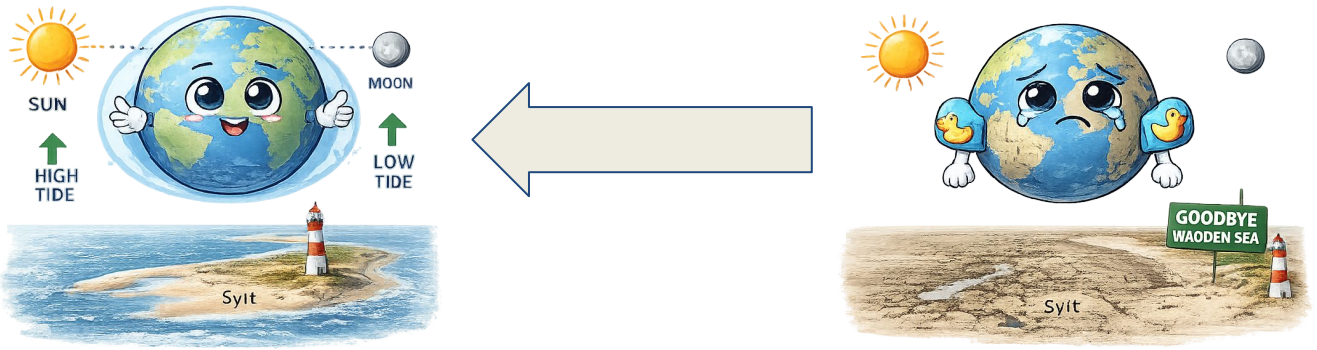
🌊 No Wadden Sea → Mudflats would disappear

🐦 Loss of wildlife → Many birds, crabs, mussels, and worms would lose their habitat

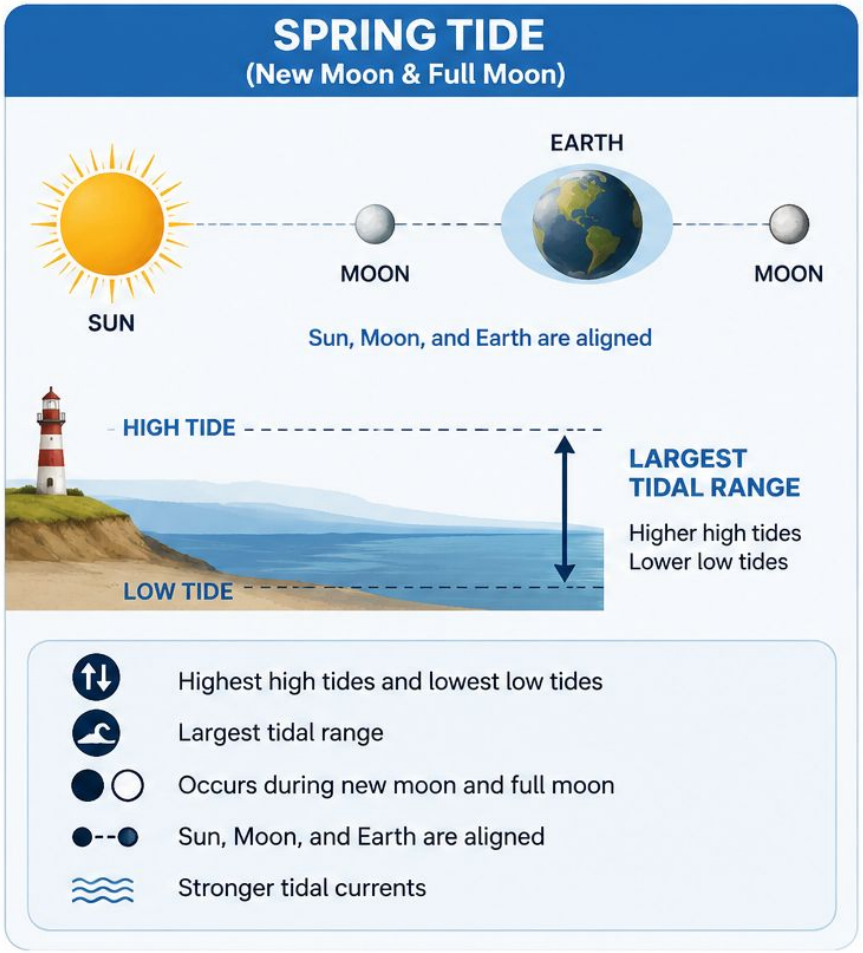
💧 Poorer water quality → Less water circulation and oxygen

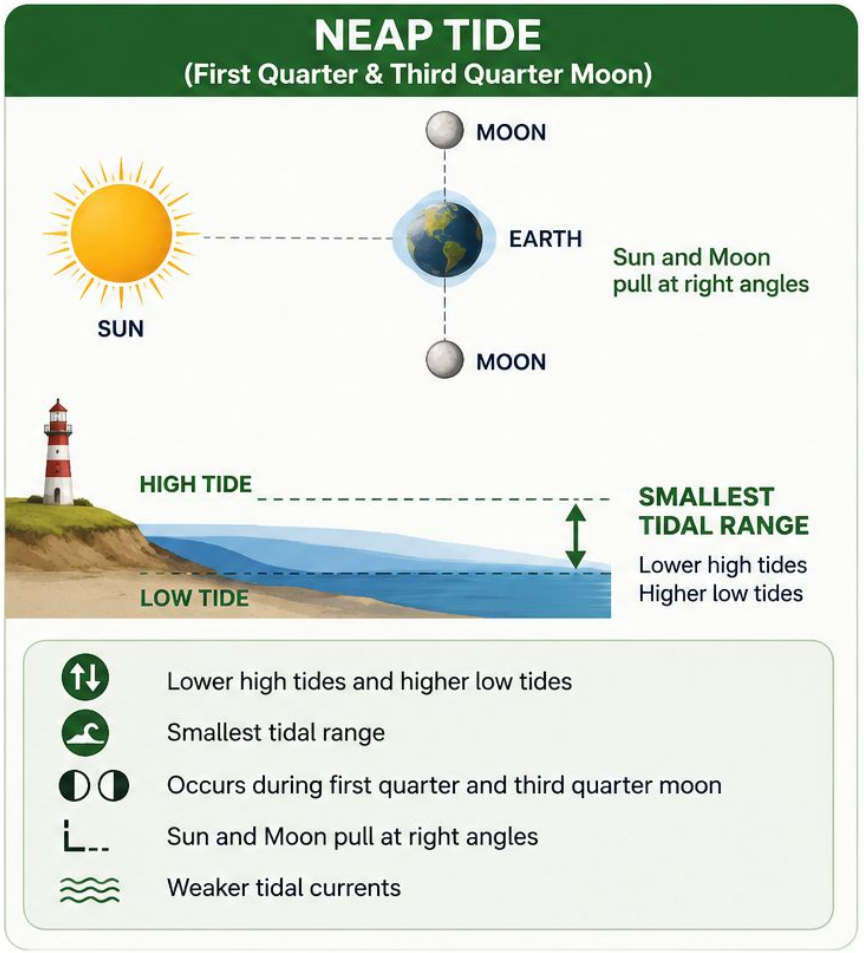
🏖️ Changed coastline → Different erosion and sand movement patterns

💰 Less tourism → No mudflat hiking and reduced nature tourism



Spring and Neap Tides





KEY IDEA: **Spring Tide** = Bigger difference between high and low tide. | **Neap Tide** = Smaller difference between high and low tide.

Reference: picture is AI generated

Climate Change and Future Tides

Rising Sea Levels

- Global warming causes sea levels to rise
- Higher sea levels increase the risk of coastal flooding

Stronger Storm Surges

- Storm surges can reach higher water levels
- Beaches, dunes, and coastal infrastructure are more vulnerable

Increased Coastal Erosion

- More frequent flooding and stronger waves can erode Sylt's coastline faster
- Greater effort is needed to protect beaches and dunes

Future Challenges

- Maintaining coastal defenses
- Protecting the Wadden Sea ecosystem
- Adapting tourism and infrastructure to changing conditions

Key takeawaves 🌊

→ Tides are caused by gravitational differences, not gravity itself just as the root cause of the physics behind weightlessness in space

→ Earth rotating through two tidal bulges creates the familiar twice-daily tidal cycle which is amplified or dampens by the sun (via spring and neap tides)

→ The Wadden Sea ecosystem: Nearly 2,800 species around Sylt, it depends entirely on this cycle to survive

→ Climate change won't alter the tidal forces, but rising sea levels make their impacts increasingly dangerous for Sylt's coastline