Fall 2019

Physical Oceanography

MARS 4080 & 6080

Basic physical and mathematical principles applied to ocean dynamics. Topics include: properties of seawater, physical laws and classification of forces, the equation of motion, turbulence, geostrophic flow, wind-driven circulation, thermohaline circulation, waves, and tides. Students will complete homework sets and a class project. Graduate and undergraduate students will have different assignments.

Pre-requisites: MARS 3000, 3002, MATH 2214
(or equivalent experience for graduate students)

M & W: 10:30 – 11:45 @ OLC 103, OI
Undergraduate / Graduate, 3 Credits,
Instructor: David Hyrenbach (khyrenbach@hpu.edu)

Course Web-Site

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MARS 4080 & 6080
Physical
Oceanography

Last Updated August 25, 2019

Please report any problems here:

khyrenbach (at) hpu (dot) edu

Syllabus

(Last Updated: Aug 25)

Quiz Keys

Quiz#1

Instructor

Dr. David Hyrenbach *Offices:* AC 249, HLC EMSB, Oceanic Institute *Phone:* (808) 236-3563	*Office Hours:* HLC: Tu & Th; 10:45 - 12:00 OI: Tu & Th; 12:00 - 13:00 or by appointment at EMSB, OI

Lectures (pdfs)

Readings
- Assigned
- Extra

Homework Keys

Quiz Keys

www.pelagicos.net/classes_physicaloceanography_fa19.htm

Course Objectives

- An in-depth survey of marine systems from a physical perspective. The study of ocean physics is of fundamental importance to marine science.
- Physical processes in the global ocean underlie the chemical and biological processes in the sea.
- Global ocean also dominates the Earth's surface and is a primary driver of many processes that control our planet's climate.
- Therefore a understanding of ocean physics is essential for understanding ocean dynamics.

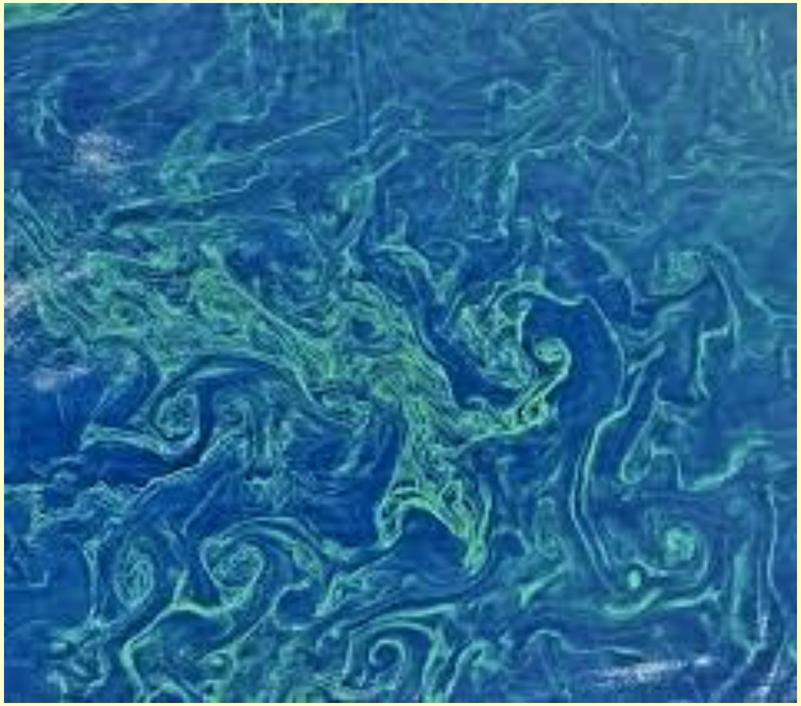
Course Scope

- Topics in this course include:

  physical and thermodynamic properties of seawater, temperature, salinity and density distributions, ocean heat budget, geostrophic flow, Ekman balance, potential vorticity, Sverdrup balance, waves, tides, thermohaline circulation, and a description of the general circulation in the global ocean.

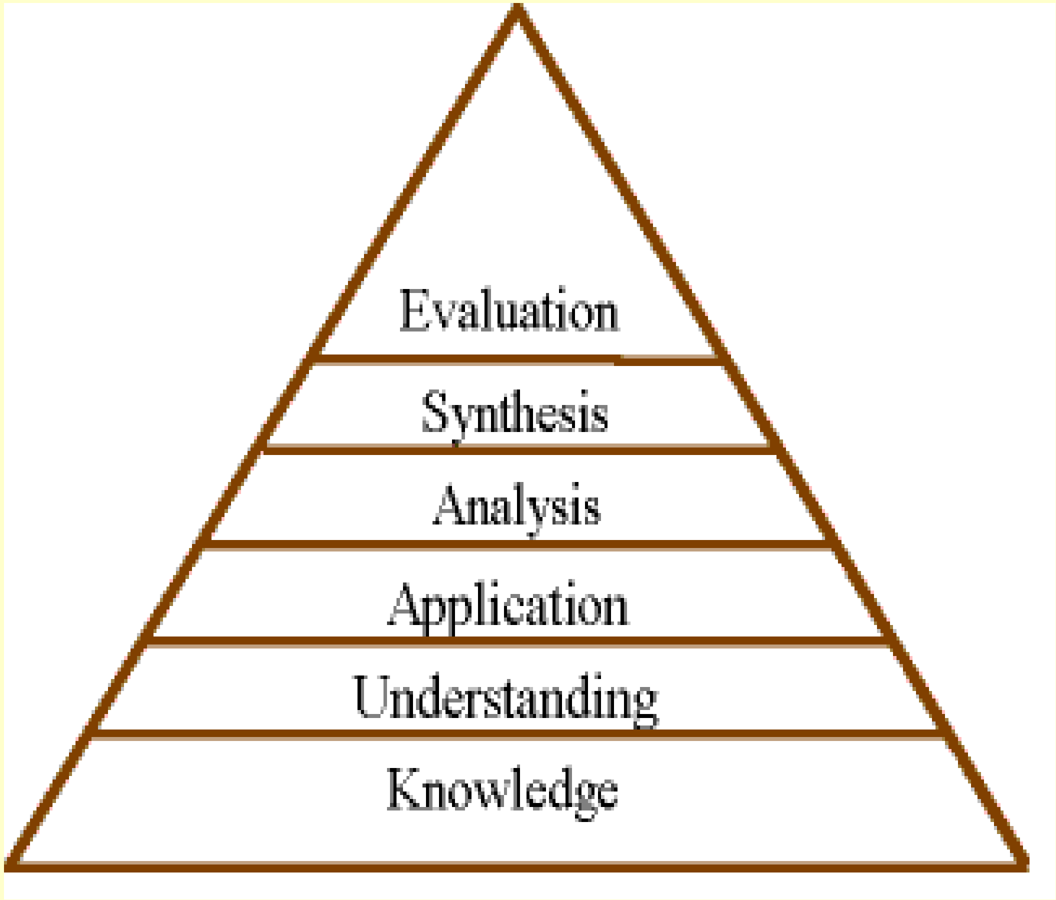
Pragmatic Course Objectives

- Upon completion of this course, students will be expected to have knowledge of the general physical aspects of ocean science, and to be able to integrate these concepts into a broader understanding of ocean processes.
- Students will also gain insights into physical – biological coupling in the ocean, by developing and presenting a literature review on a topic of their choice, agreed-upon with the instructor.



Course Structure

Bloom's Taxonomy: (Bloom, 1956)
describes six levels of cognitive domains



Evaluation:
appraise, argue, evaluate

Synthesis:
arrange, develop, formulate

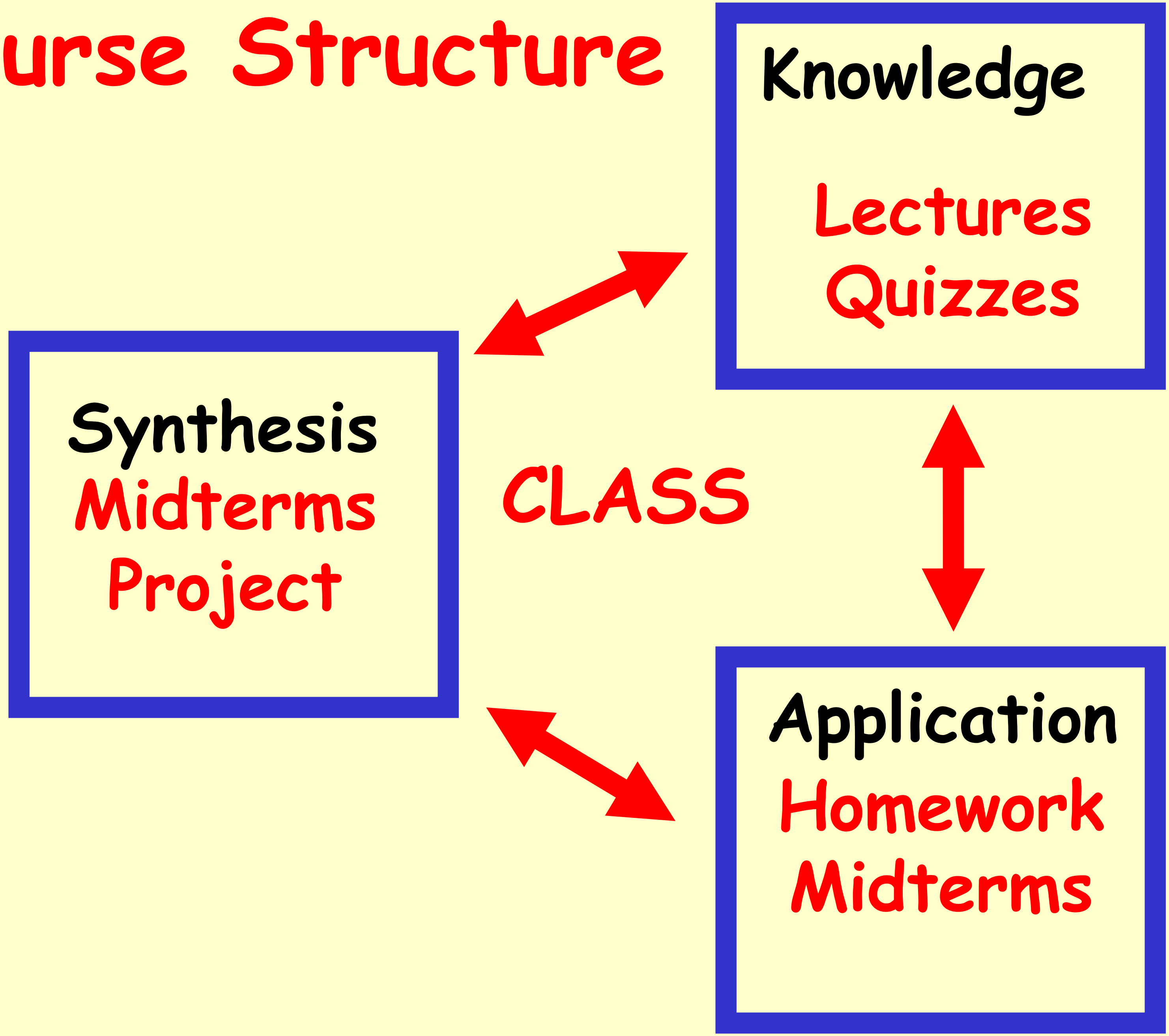
Analysis:
analyze, compare, contrast

Application:
apply, employ, practice

Understanding:
describe, discuss, explain

Knowledge:
define, label, list

Course Structure



Meeting Times / Places

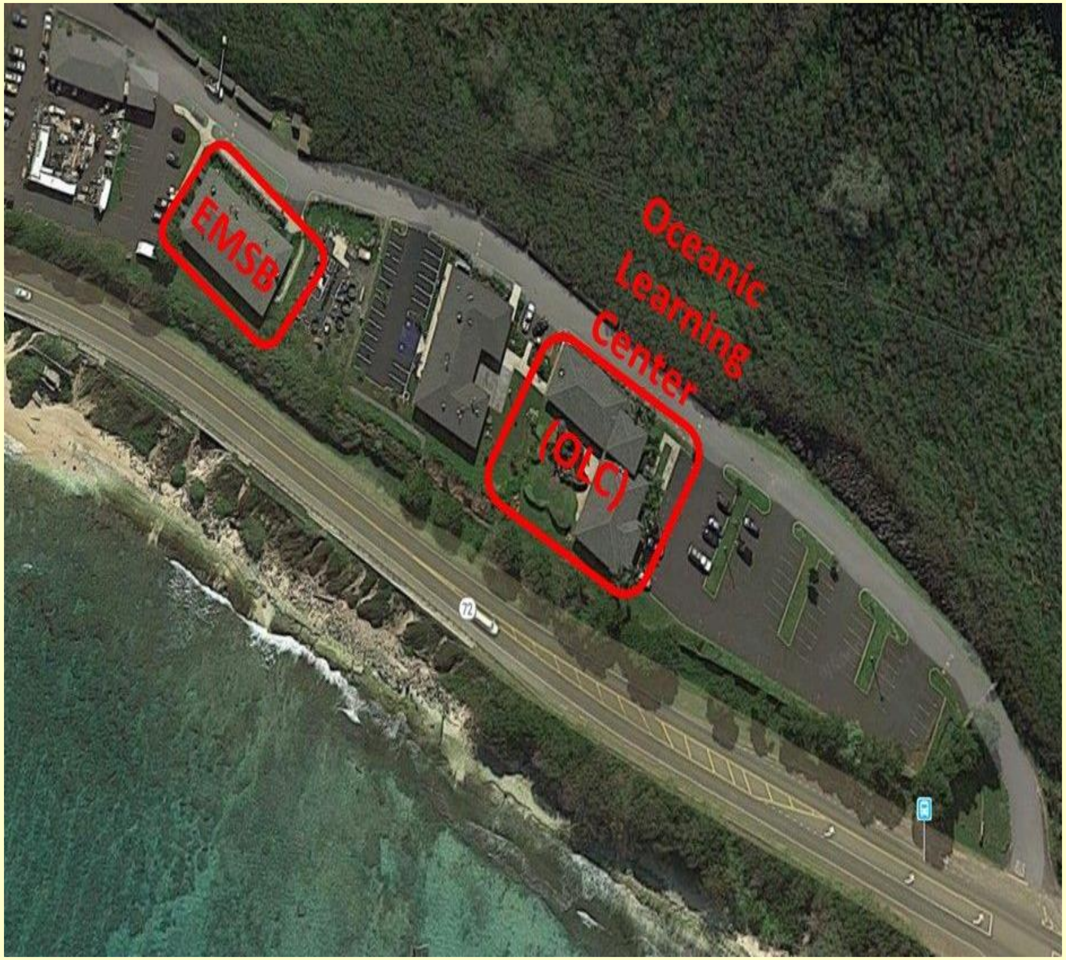
- Meetings: M & W 10:30 – 11:45, OLC, OI
- Office Hours:

@ HLC: AC 249:

- Tu & Th
- 10:30 – 12:00

@ EMSB, OI

- M & W
- 12:00-13:00



Required Readings

- Texts:

Descriptive Physical Oceanography: An Introduction (DPO)
Lynn D. Talley, George L Pickard and William J. Emery and James H. Swift (2011), Elsevier

Introduction to Physical Oceanography (IPO)
Robert H. Stewart (2008), Texas A&M University

Regional Oceanography: An Introduction (RO)
Matthias Tomczak and J.S. Godfrey (2004)
Daya Publishing House

Ocean Circulation (Open Univ Oceanography) (OC)
Pergamon Press (1989)

Waves Tides and Shallow Water Processes (WTSP)
(Open Univ Oceanography) Pergamon Press (2000)

Other Resources

Text Web-Sites: See syllabus

- http://www.colorado.edu/oclab/sites/default/files/attached-files/stewart_textbook.pdf
- http://gyre.umeoce.maine.edu/physicalocean/Tomczak/regoc/pdfversion.html

Scientific Articles: 1 – 2 each week

Grading

- 2 Midterms
- NO FINAL

- Knowledge Exams: 40% (20% each)
- Homework: 15% (5% each)
- Quizzes: 15% (5% each)
- Individual Literature Project: 25% (proposal, literature, presentation, write-up)
- Class Participation   5% (various activities)

Individual Project

- Students will develop an independent literature review on physical – biological interactions.
- Specific topic approved by instructor).
- Students will turn in:

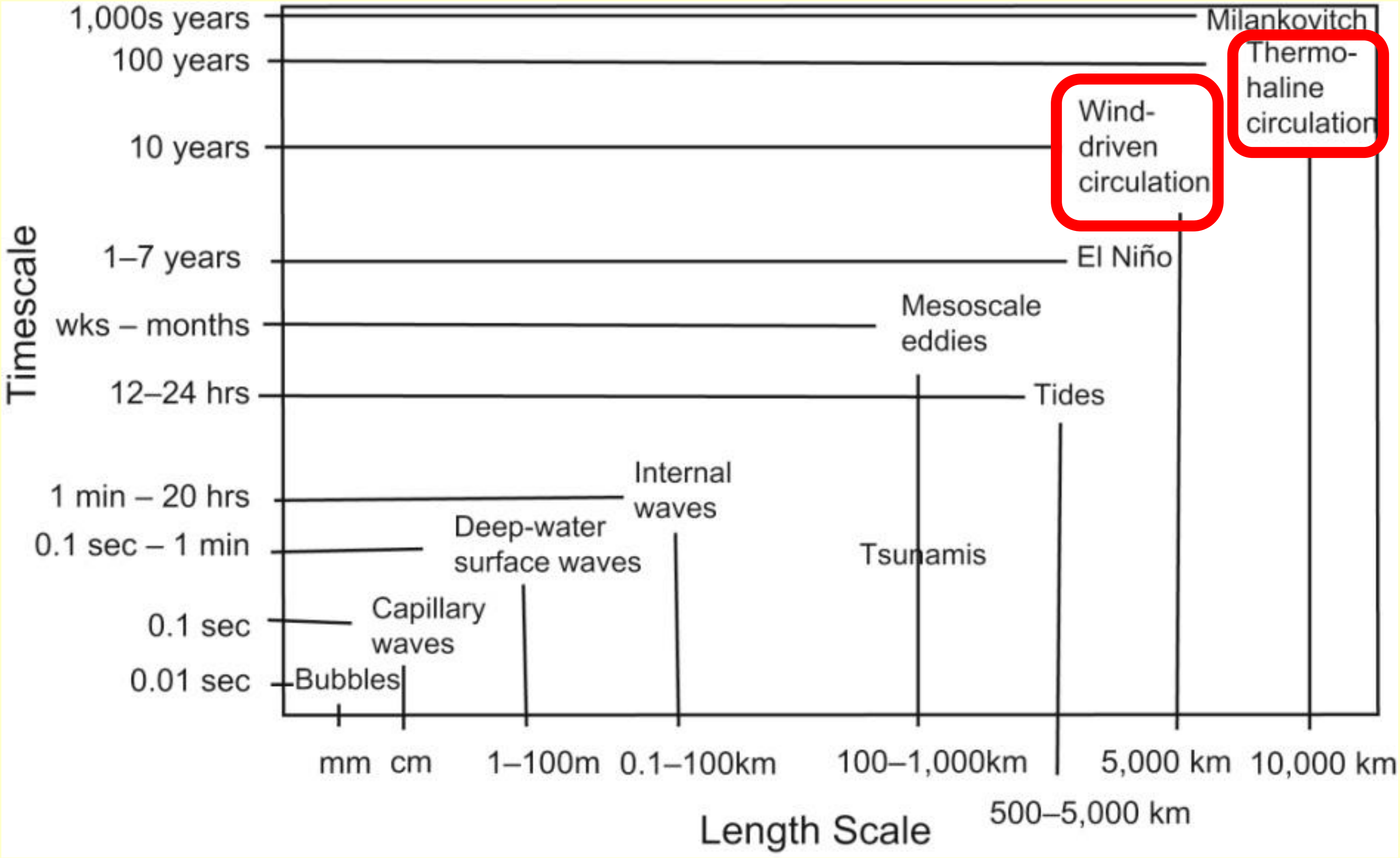
  A proposal detailing the proposed topic and a list of references (5 points)

  A journal summary presentation, discussing two key papers on the topic (5 points)

  A 15-minute presentation, outlining the project's goals, approach, and findings (5 points)

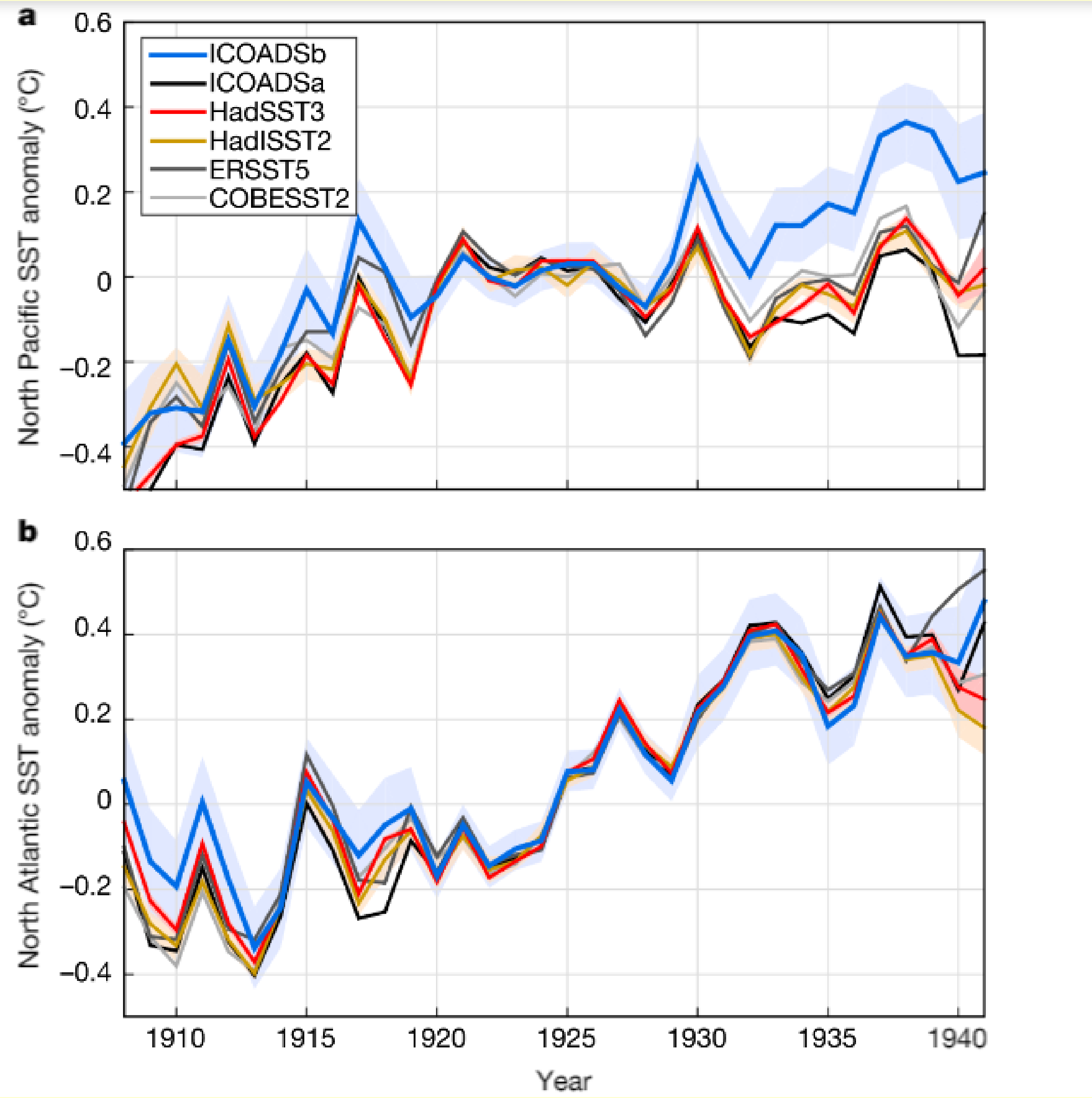
  A write-up, summarizing the review of the literature and the findings (10 points)

Multiple Scales: Affect the Biology



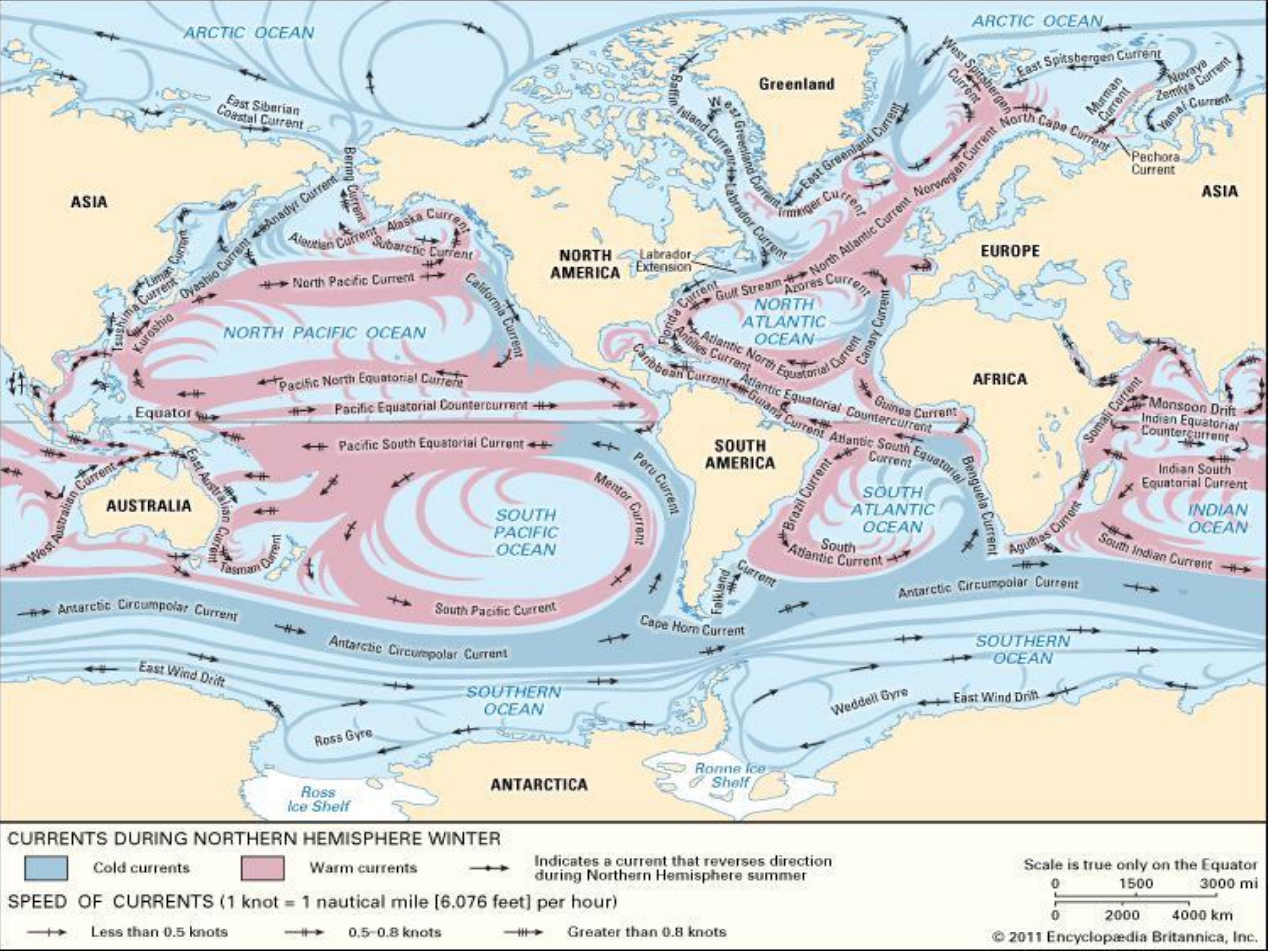
Time and space scales of physical oceanographic phenomena ranging from bubbles to changes in ocean circulation associated with Earth's orbit variations.

Analyze Trends & Predict the Future



Correcting data sets leads to a more homogeneous trend of early-twentieth-century sea surface warming

(Chan et al. 2019)


ARCTIC OCEAN
ARCTIC OCEAN
East Siberian Coastal Current
Bering Current
Anadyr Current
Greenland
Baffin Island Current
West Greenland Current
East Greenland Current
Labrador Current
Irminger Current
West Spitsbergen Current
East Spitsbergen Current
Novaya Zemlya Current
Yamal Current
Murman Current
North Cape Current
Pechora Current
Norwegian Current
ASIA
ASIA
Alaska Current
Aleutian Current
Subarctic Current
Oyashio Current
Liman Current
Tsushima Current
Kuroshio
North Pacific Current
California Current
NORTH AMERICA
Labrador Extension
North Atlantic Current
EUROPE
Gulf Stream
Azores Current
Florida Current
NORTH ATLANTIC OCEAN
Canary Current
Antilles Current
Atlantic North Equatorial Current
Caribbean Current
NORTH PACIFIC OCEAN
Pacific North Equatorial Current
Pacific Equatorial Countercurrent
Equator
AFRICA
Atlantic Equatorial Countercurrent
Guinea Current
Guiana Current
Somali Current
Monsoon Drift
Indian Equatorial Countercurrent
Pacific South Equatorial Current
Atlantic South Equatorial Current
SOUTH AMERICA
Peru Current
Mentor Current
Brazil Current
Benguela Current
Indian South Equatorial Current
East Australian Current
West Australian Current
AUSTRALIA
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
Agulhas Current
South Indian Current
Tasman Current
South Atlantic Current
Falkland Current
Antarctic Circumpolar Current
Antarctic Circumpolar Current
Antarctic Circumpolar Current
South Pacific Current
Cape Horn Current
SOUTHERN OCEAN
SOUTHERN OCEAN
East Wind Drift
East Wind Drift
Weddell Gyre
Ross Gyre
ANTARCTICA
Ross Ice Shelf
Ronne Ice Shelf
CURRENTS DURING NORTHERN HEMISPHERE WINTER
Cold currents
Warm currents
Indicates a current that reverses direction during Northern Hemisphere summer
SPEED OF CURRENTS (1 knot = 1 nautical mile [6.076 feet] per hour)
Less than 0.5 knots
0.5–0.8 knots
Greater than 0.8 knots
Scale is true only on the Equator
0 1500 3000 mi
0 2000 4000 km
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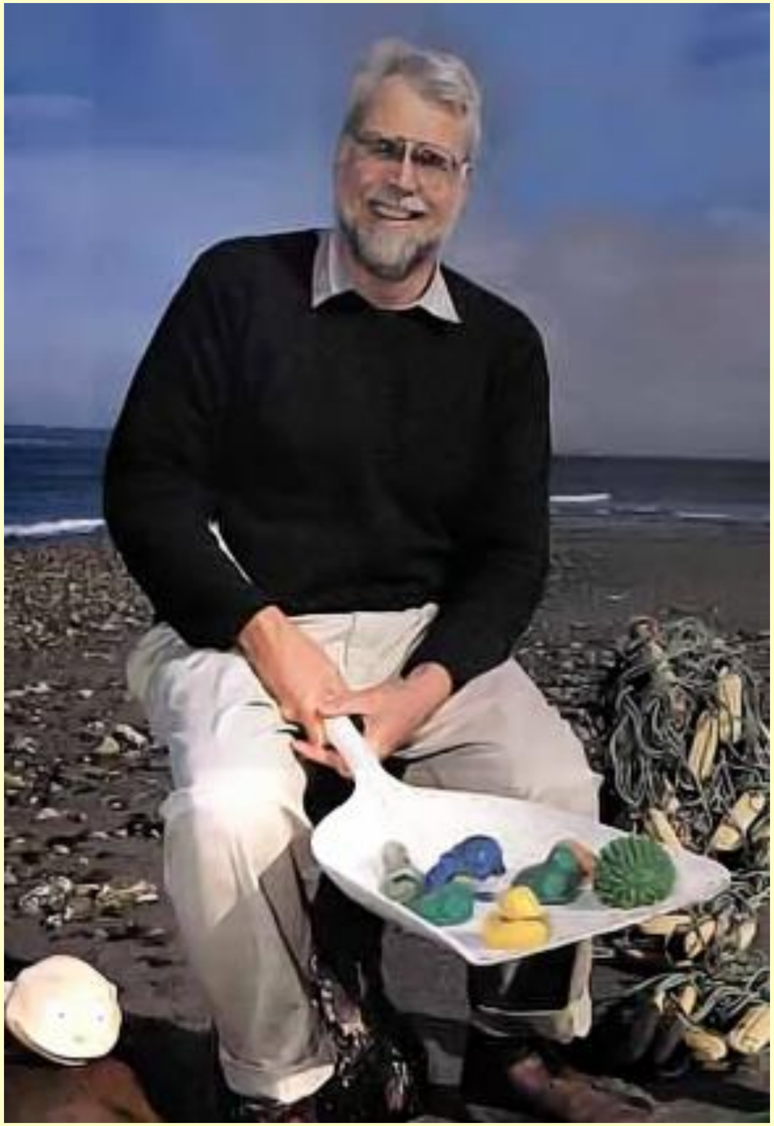
Motivation

A shipment of Friendly Floatee toys, departed from Hong Kong on *Ever Laurel container ship* for Tacoma, WA.

On 10 January 1992, during a storm in, twelve 40-foot (12m) containers washed overboard close to the Date Line: 44.7° N, 178.1° E.

One container held 28,800 Floatees.

Can we anticipate where / when they will wash ashore?



Motivation

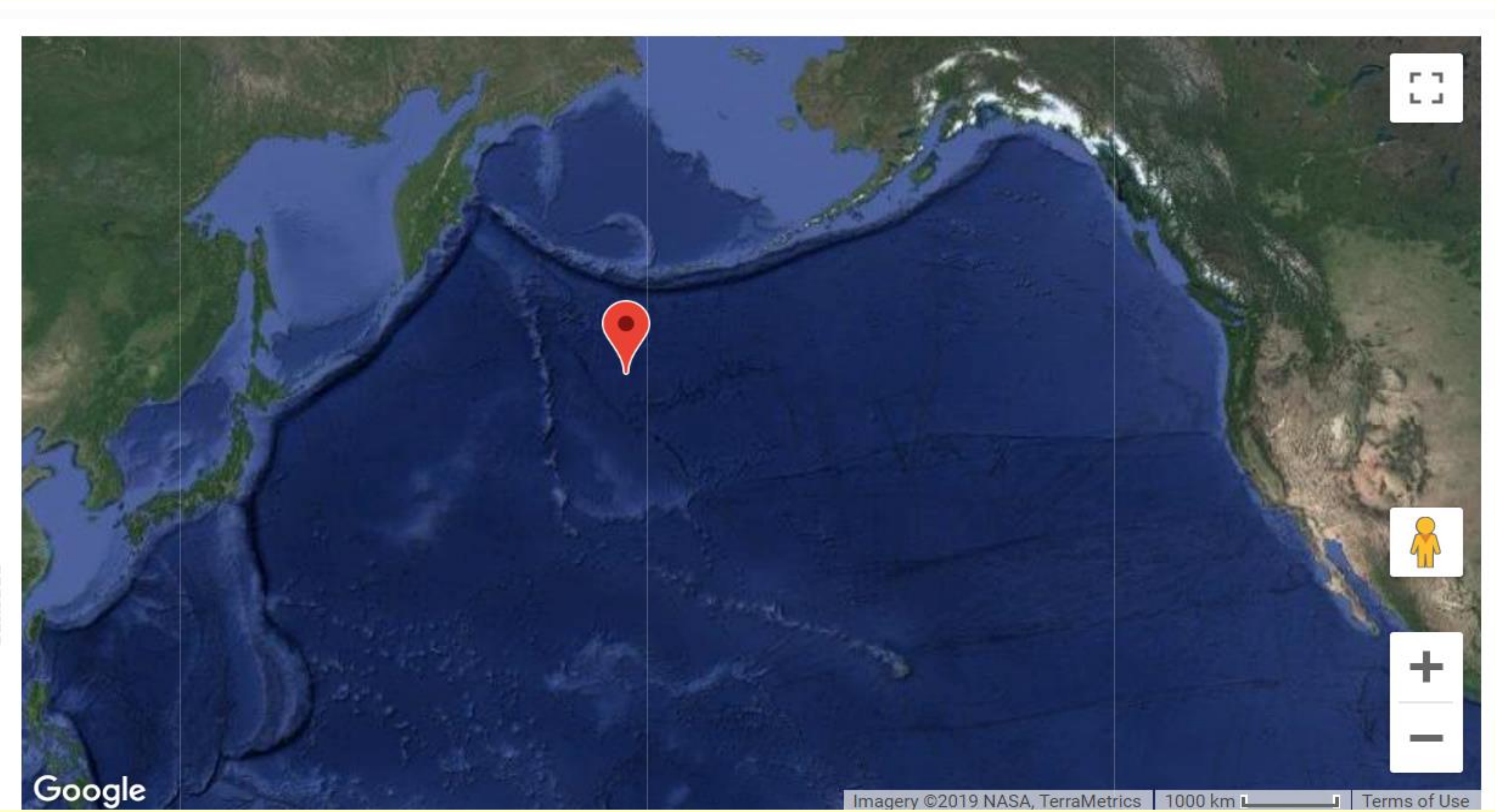
Standard methods entail releasing 100s of drift bottles or 10s of drifters. The recovery rate of drift bottles from the Pacific Ocean is typically around 2%.

Mass release of 28,800 objects into the ocean at once offered great experiment.

NOAA Oceanographers Ebbesmeyer and Ingraham, who developed the Ocean Surface Current Simulator (OSCURS) model, began to track their progress.

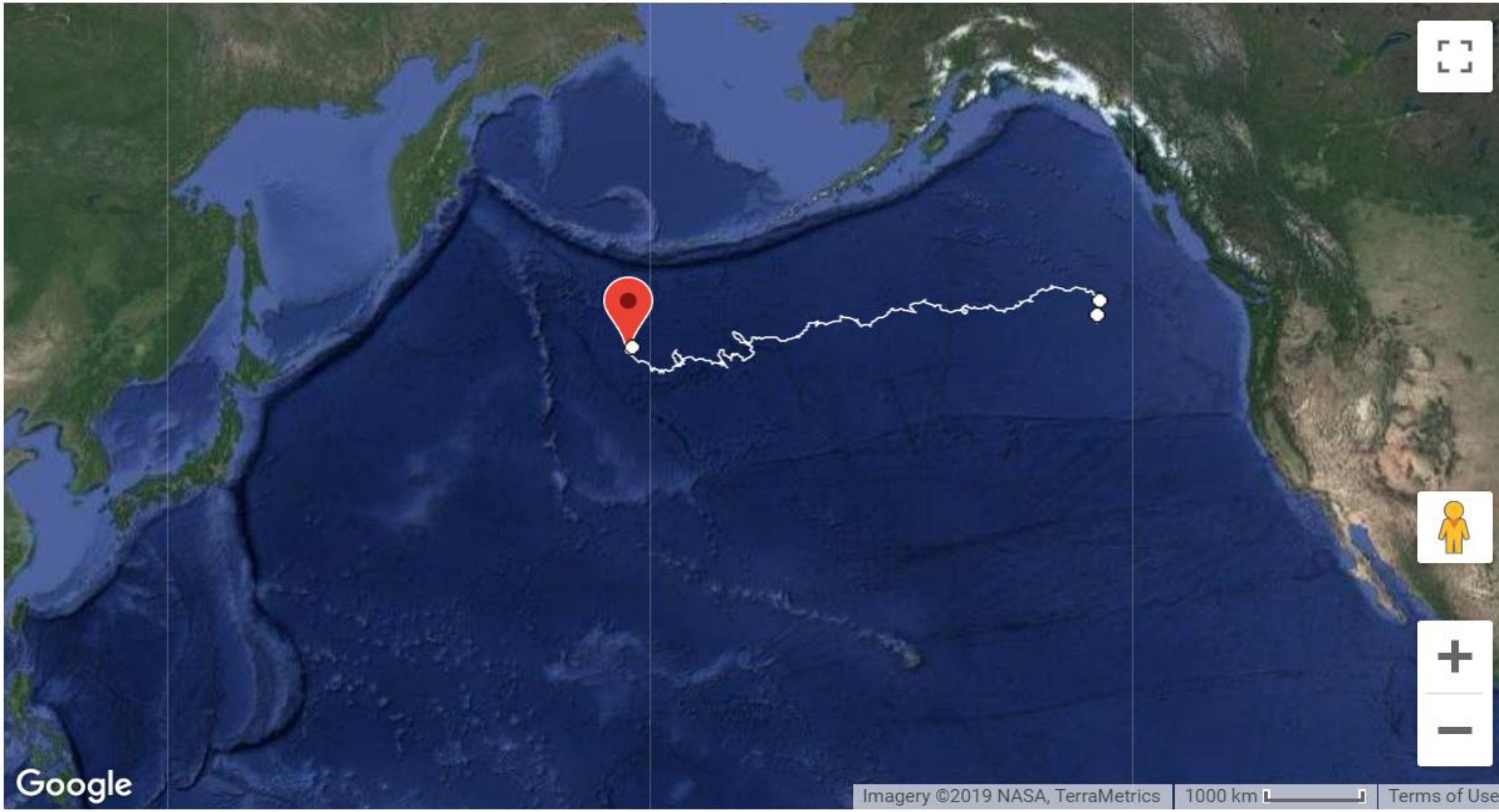
https://oceanview.pfeg.noaa.gov/oscurs/

What Would You Expect ?



Where will the toys go ?

What Would You Expect ?

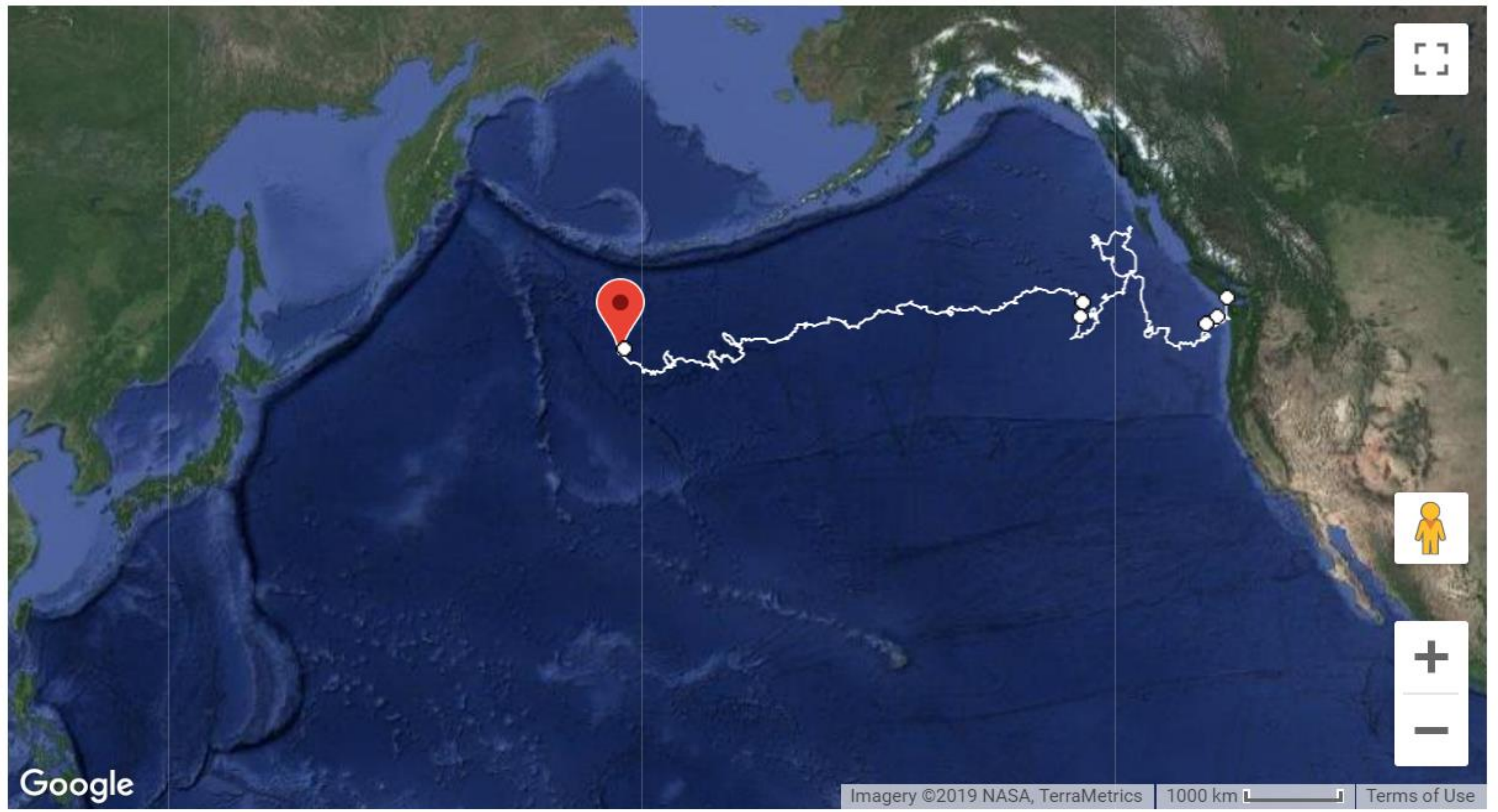


Water parcel moves a large distance in year 1

What Would You Expect ?

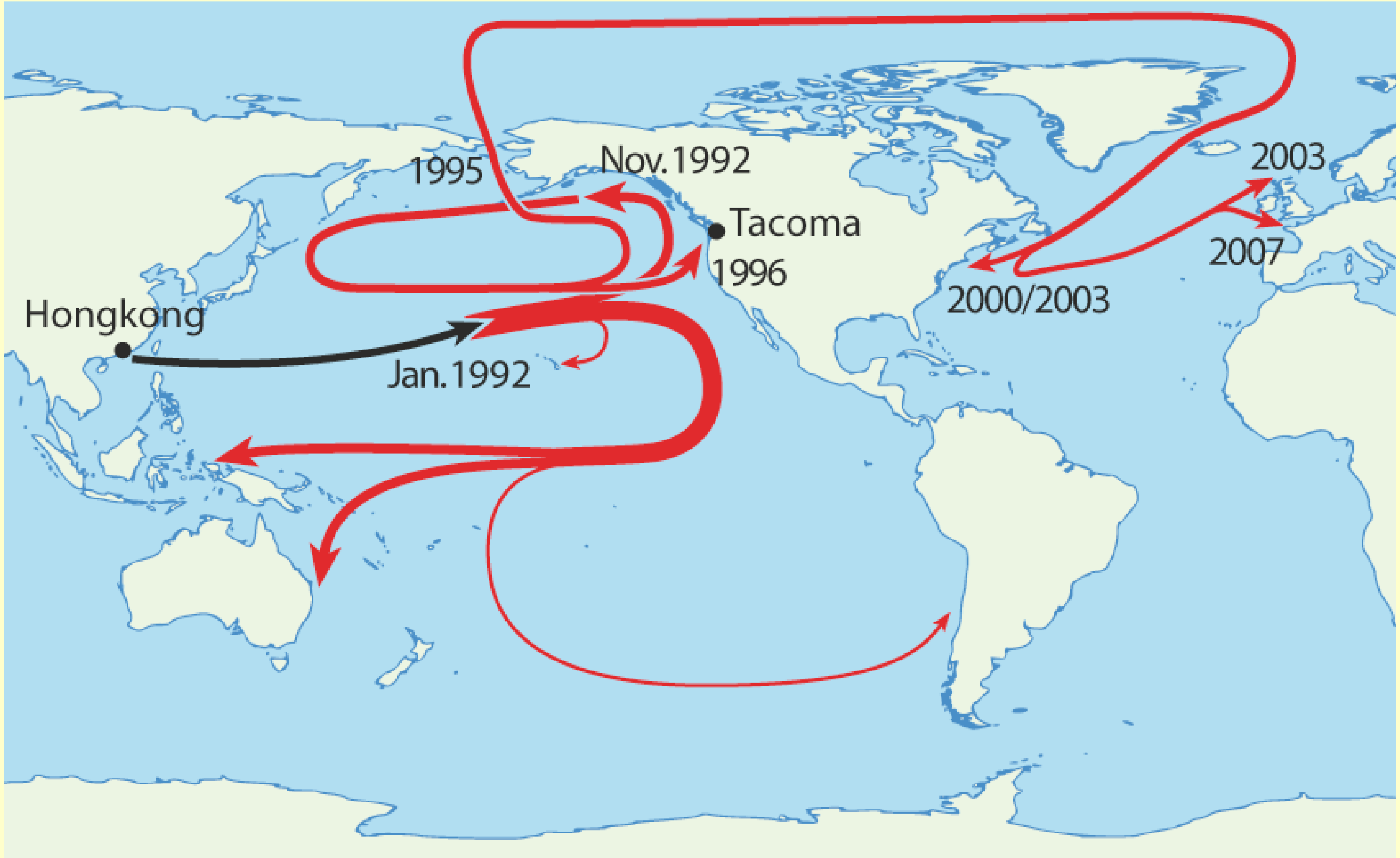
Water parcel stuck off WA – BC in year 2

What Would You Expect ?



Water parcel reaches B.C. coast in year 3

What Actually Happened



Some toys landed along Pacific Ocean shores of Alaska and Hawaii. Others traveled over 17,000 miles and reached the U.S. East Coast and British shores in 2007

What Actually Happened

AUG. – SEPT. 1992: after 2,200 miles adrift, hundreds beached near Sitka, Alaska.

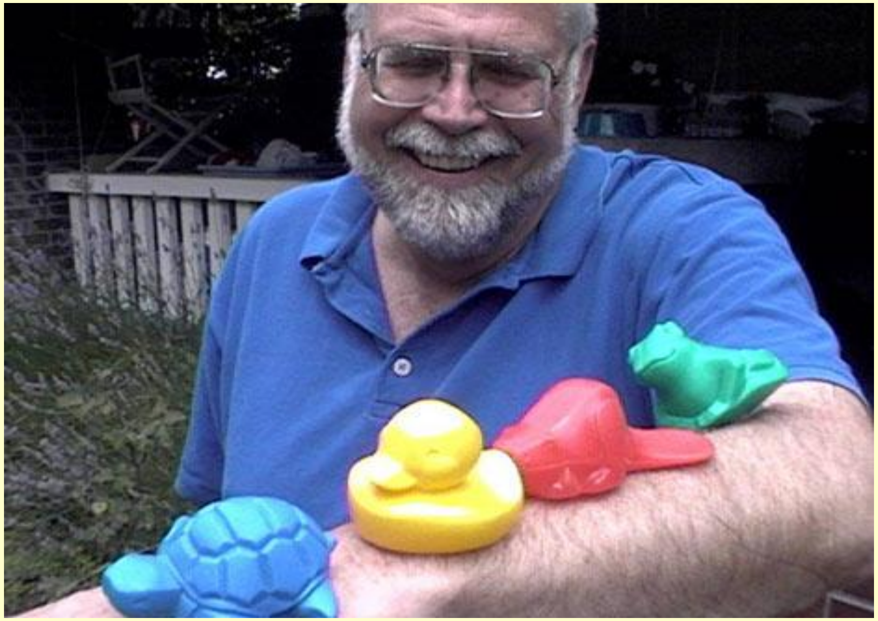
NOVEMBER 1992: Caught in the Subpolar Gyre (counter-clockwise ocean current), the ducks land on the shores of Alaska after 10 months.

EARLY 1995: The ducks take 3 years to circle around the North Pacific. East from the drop site to Alaska, then North and West past the Aleutians, then South to Japan… before turning back North and East and again landing in North America. Some ducks reach Hawaii.

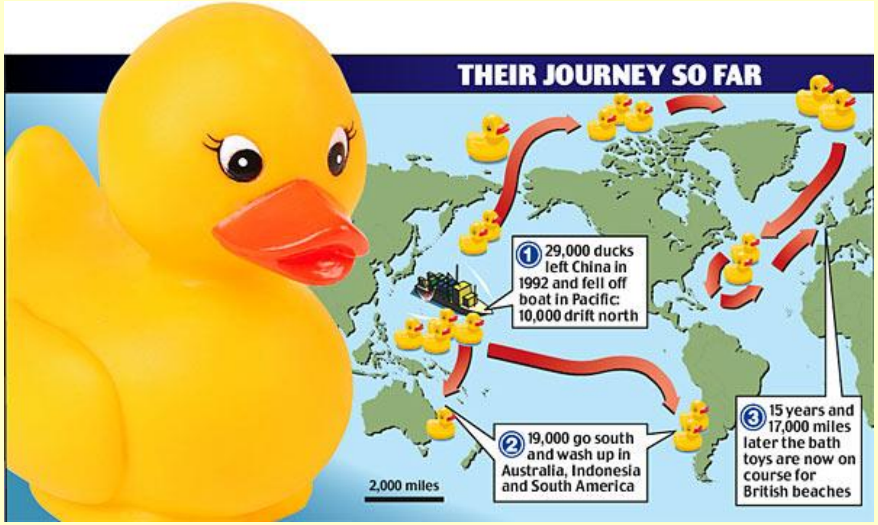
1995 - 2000: Some ducks escape the Subpolar Gyre and head North, through the Bering Straight and into the Arctic. Frozen into the ice the ducks travel slowly across the pole, moving ever eastward.

What Actually Happened

2000: Ducks begin reaching the North Atlantic where they begin to thaw and move Southward. Soon ducks are sighted bobbing in the waves from Maine to Massachusetts.



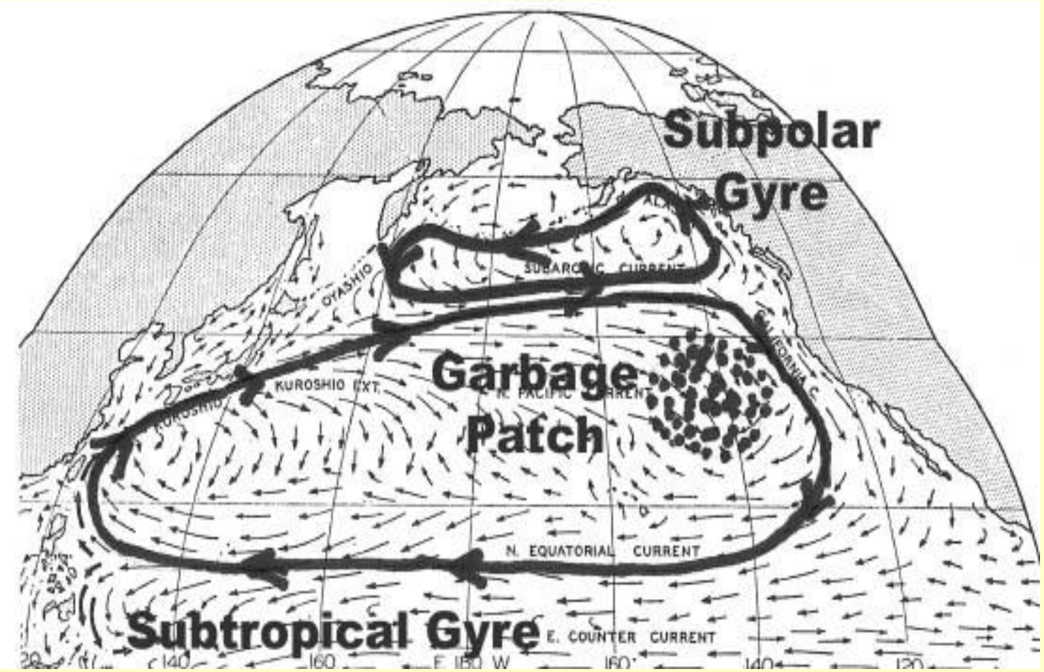
2003: A lawyer called Sonali Naik was on holiday in the Hebrides in north-west Scotland when she found a faded green frog on the beach marked with the magic words 'The First Years'.



What Did We Learn ?

Toy deposition maps major North Pacific currents:

Subpolar Gyre
Subtropical Gyre



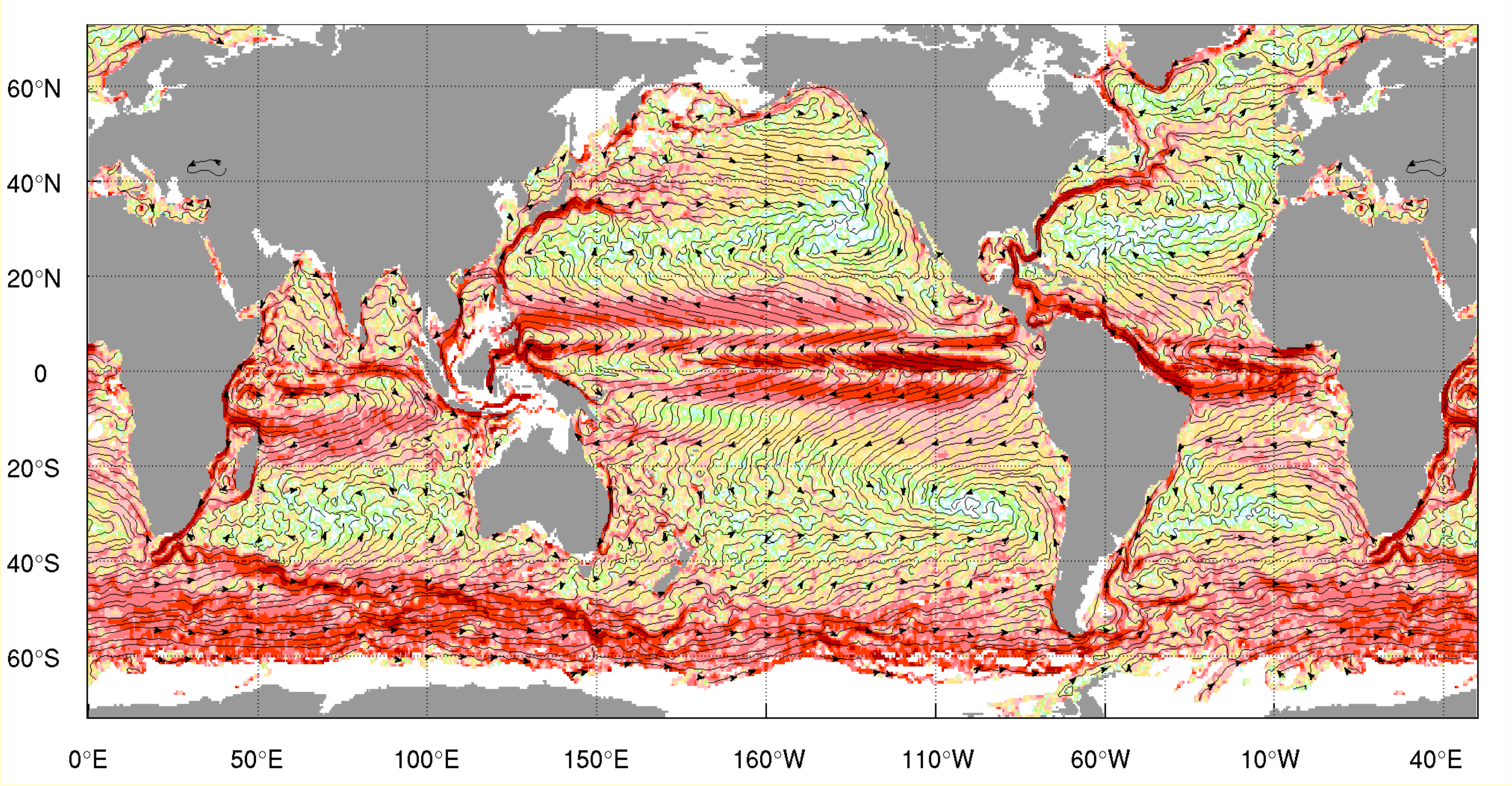
Standardized surveys in Sitka (AK), reveal peak toy recoveries in 5 years: 1992–1994–1998–2001–2004.

With intervening gaps of 2, 4, 3, and 3 years.

What Did We Learn ?

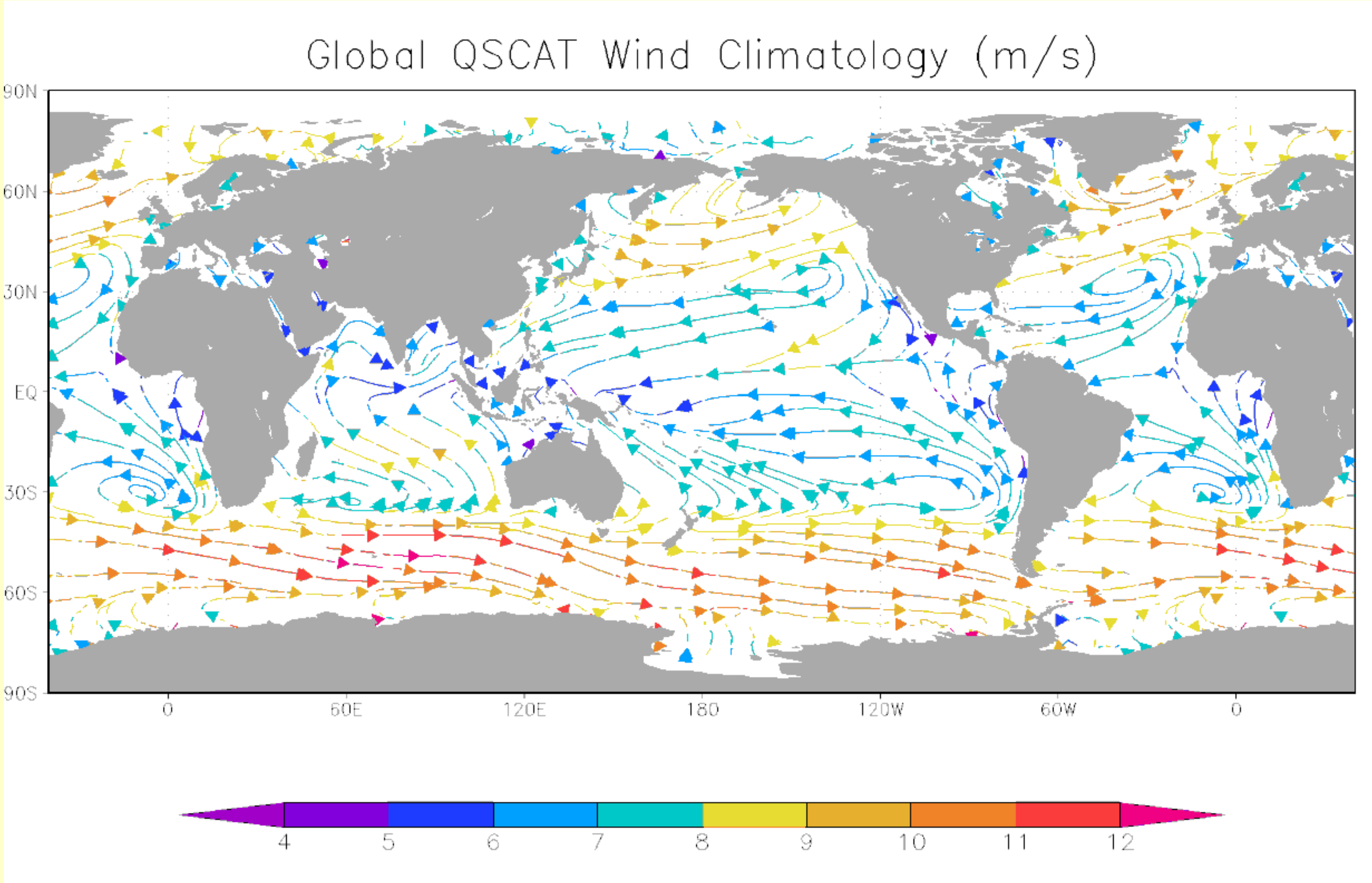
Toys followed major North Pacific currents:

Mean streamlines of surface currents



What Did We Learn ?

- However, NOAA researchers worked out that the toys travelled approximately 50% faster than the water in the current. **Why ?**



The wind affects both the water movement and the object's movement

What Did We Learn ?

- By 2004, toys had completed 4 orbits of ST Gyre.
- The first orbit (2 yrs) faster than the latter three (4, 3, 3 yrs), because the toys developed holes but continued floating full of water buoyed by the low specific gravity of their plastic.

- Historic drift bottles confirm the Gyre's orbital period from the toy deposition time series.

- In the 1950s, oceanographers deployed 33,869 drift bottles into the Gulf of Alaska.
- 12 drifted around Gyre in 1.9 - 4.2 years, matching interval of toy deposition (2 - 4 years)

What Did We Learn ?

- Time to drift around the Gyre equals 6,800 nautical miles (nm) divided by the speed between the drifter's start and ending observed time and position. Speeds between start and end points: mean = 6.93 mpd; S.D.= 2.06 mpd; (n = 20);

- Time to complete circuit around the Gyre (6,800 nm): mean = 2.93 yrs; S.D.= 0.86 yrs; (n = 20);
  95% confidence limits on the mean = ±0.40 yrs;
  median = 3.0 yrs; range = 1.9 - 4.5 yrs.

Hollister, H.J., and A.J. Dodimead, 1962. Canadian drift bottle releases and recoveries in the North Pacific Ocean. Fisheries Research Board of Canada, Manuscript report series. No. 141, October 22, 1962.

Windage

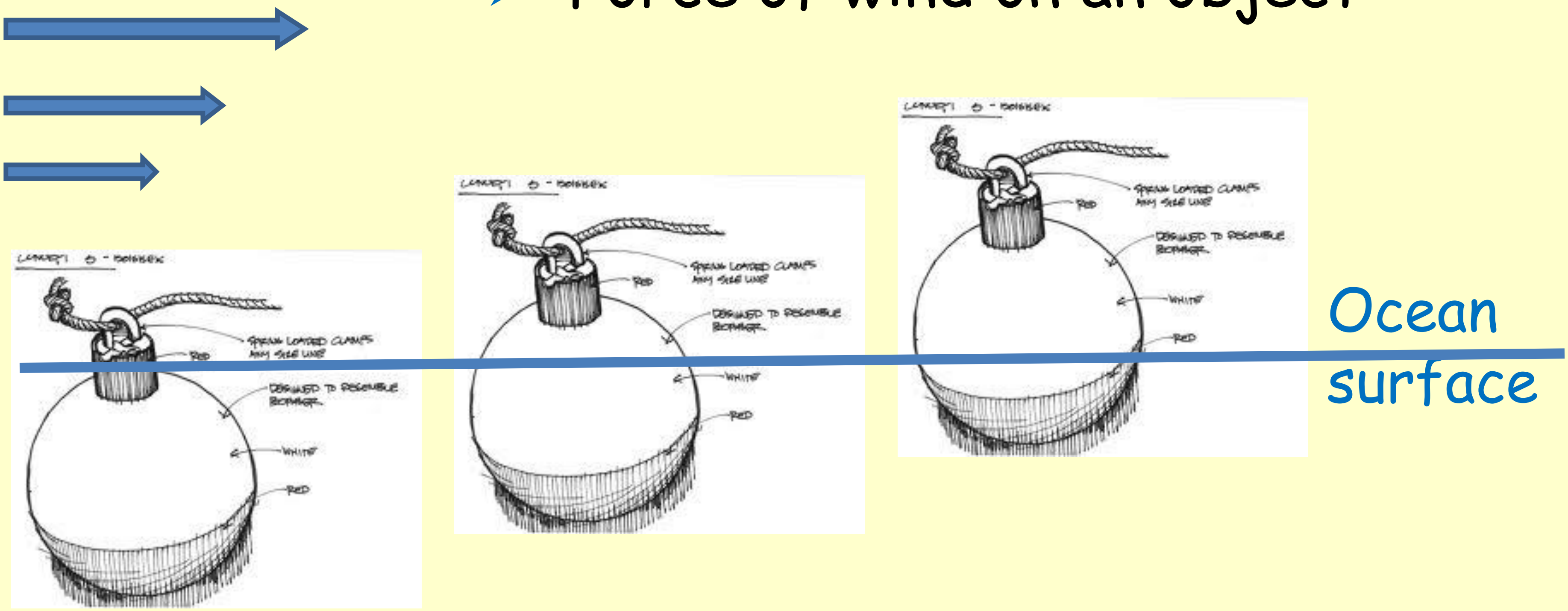
Low windage, object sitting deep in water

Medium windage, object sitting half in water

High windage, object sitting high on water

Windage

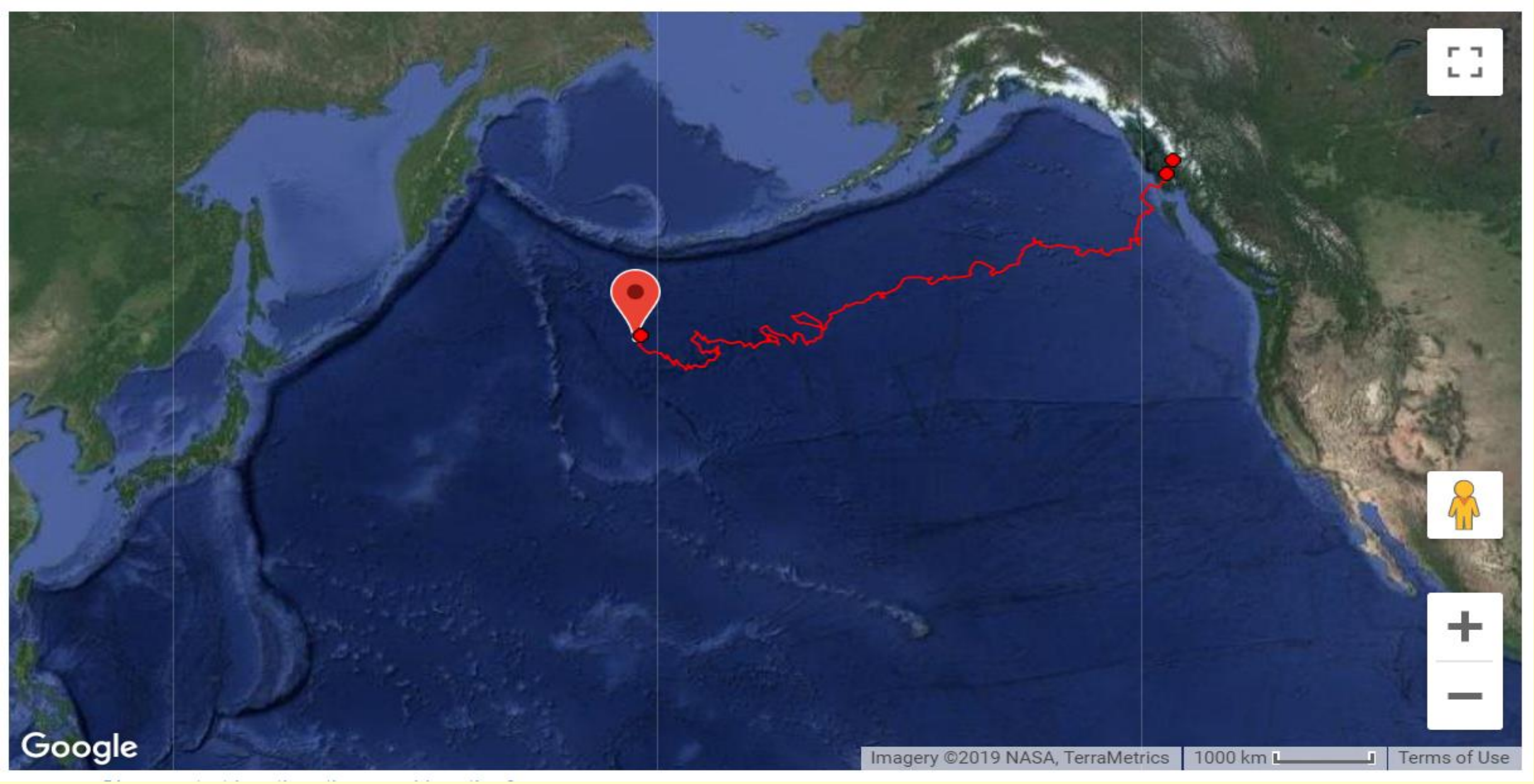
- Force of wind on an object



Wind current speed ('wcsc')
Value of 1.6 means that the object travels 20% faster than the surrounding water

water	1.0
athletic shoes	1.2
plastic bathtub toys	1.6
large bottles	2.0

OSCURS Model With Windage



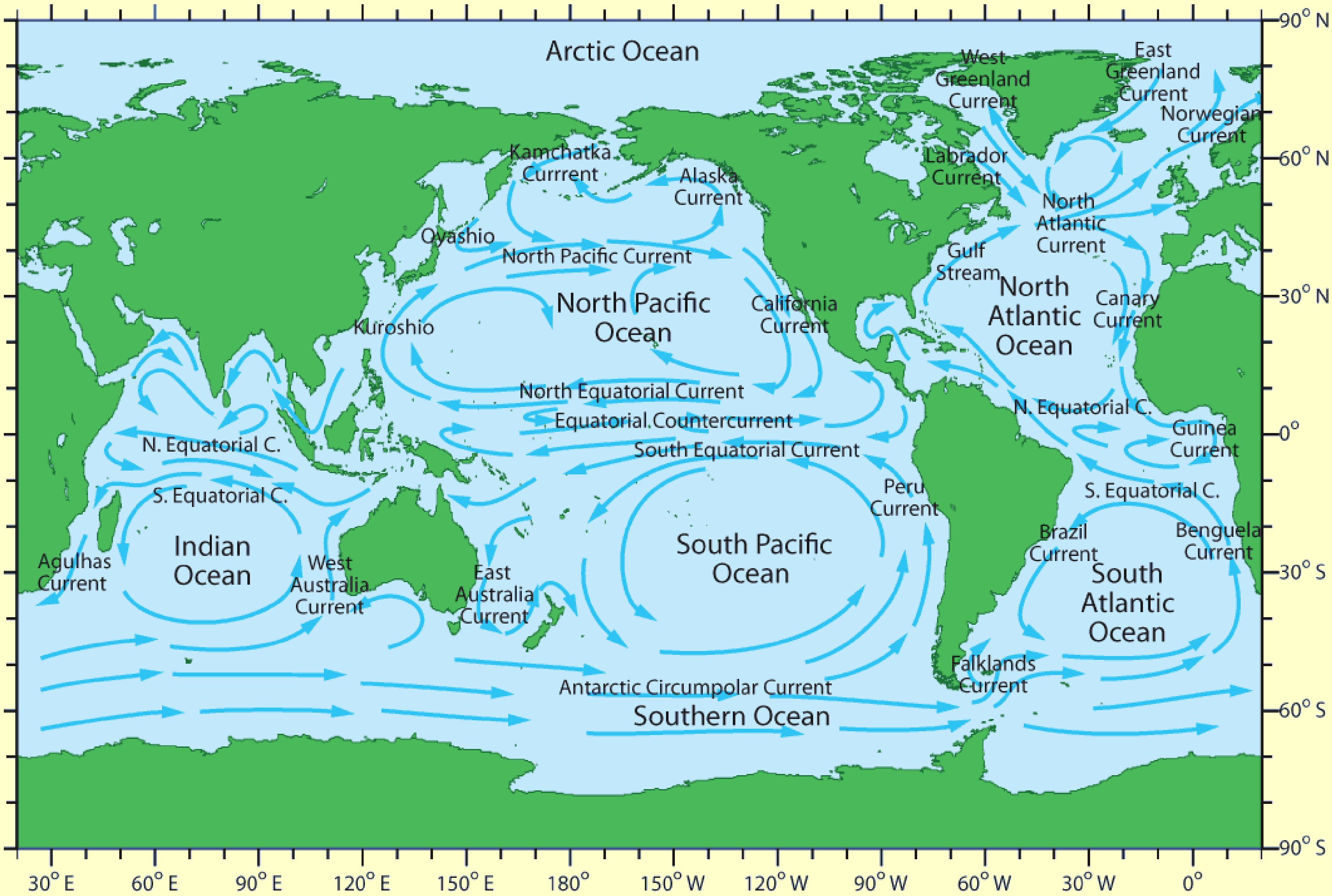
Movement of floating object (WSC: 1.6) in one year

What drives surface ocean currents ?

What drives the wind patterns ?

Ocean Surface Currents and Gyres

Ocean currents driven by: WIND + DENSITY

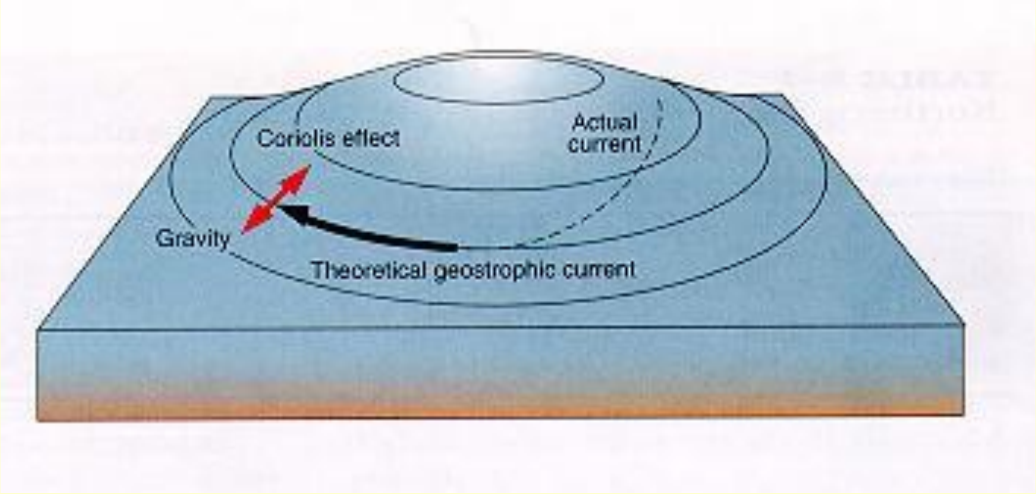


Ocean Surface Currents and Gyres

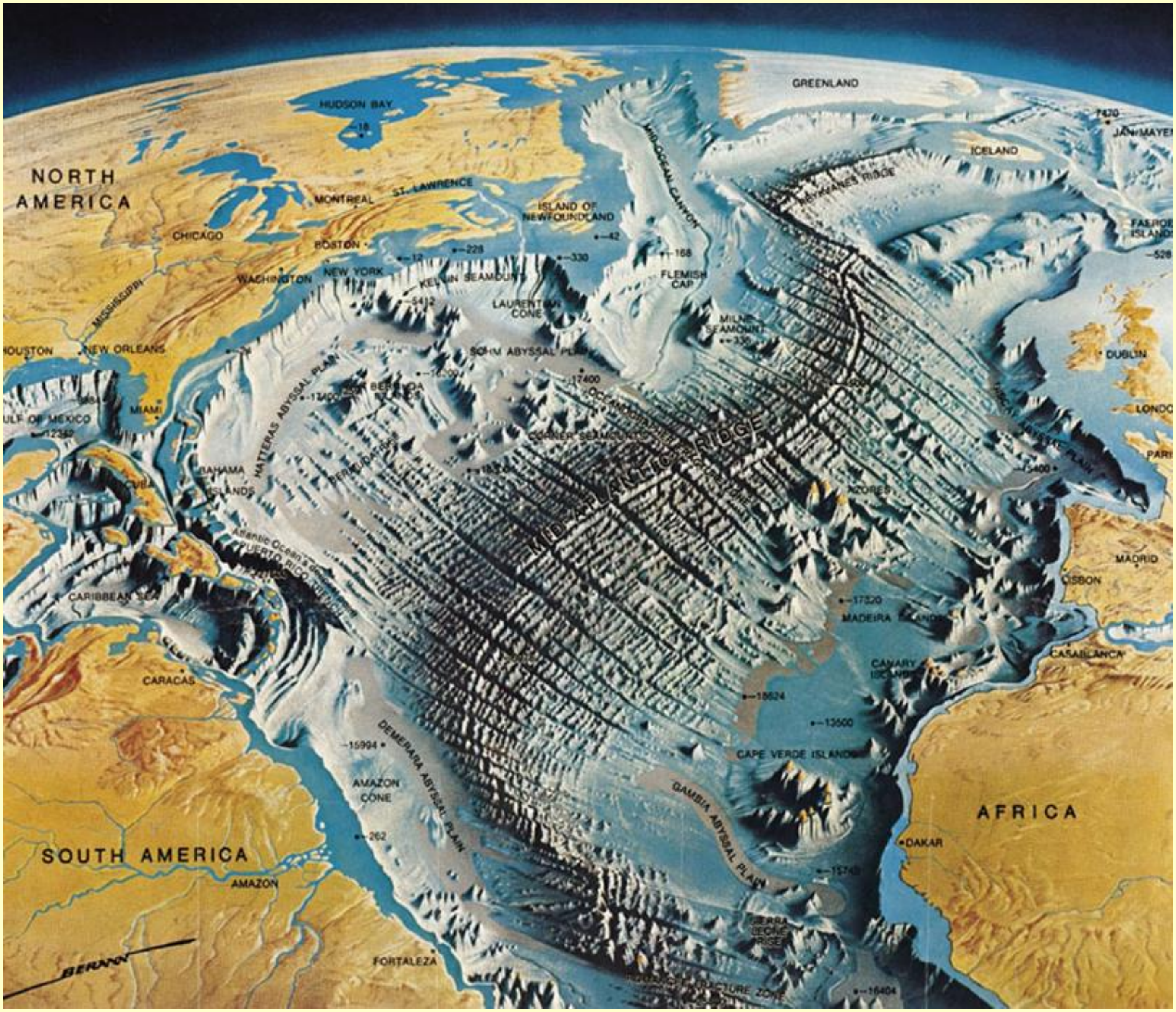
Ocean currents are influences by: CORIOLIS

Coriolis Effect makes objects (planes, water parcels) traveling long distances around Earth appear to move along a curve as opposed to a straight line.

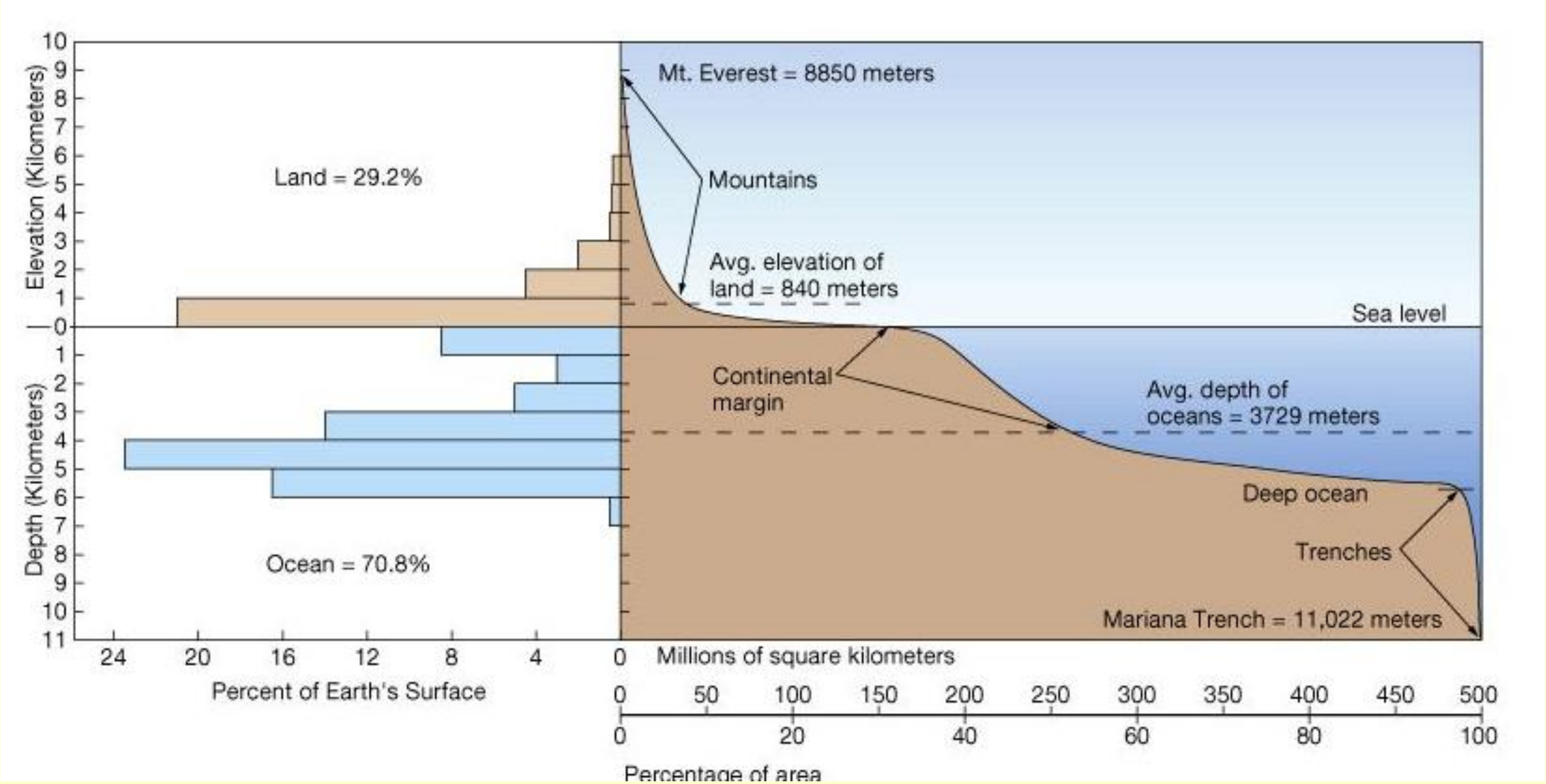
Geostrophic:
Component of a current from a balance of pressure gradients (density) and coriolis force.



But the Ocean is 3-D

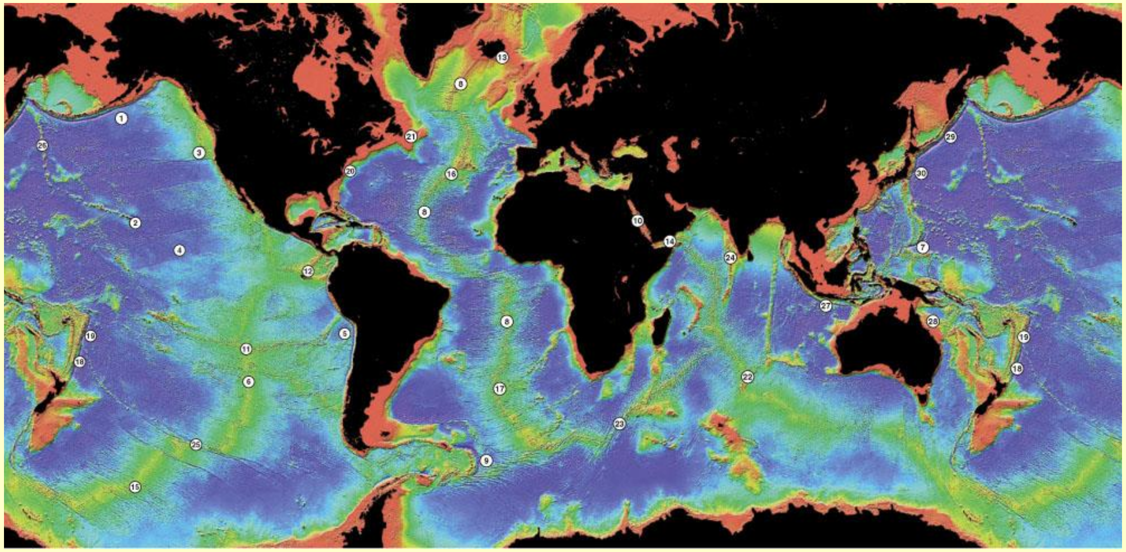


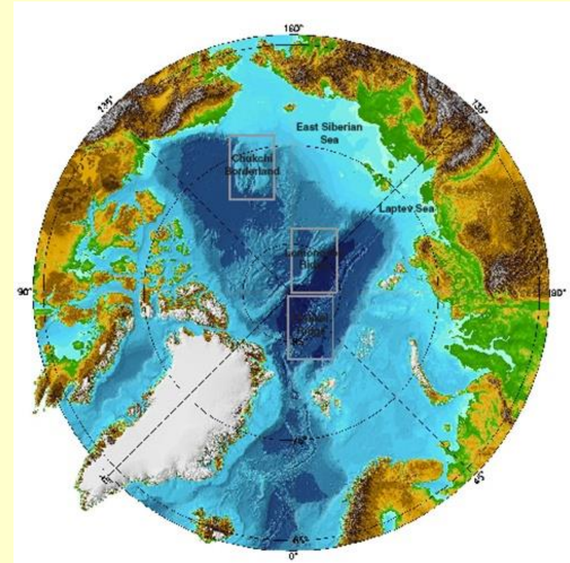
Hypsographic Curve

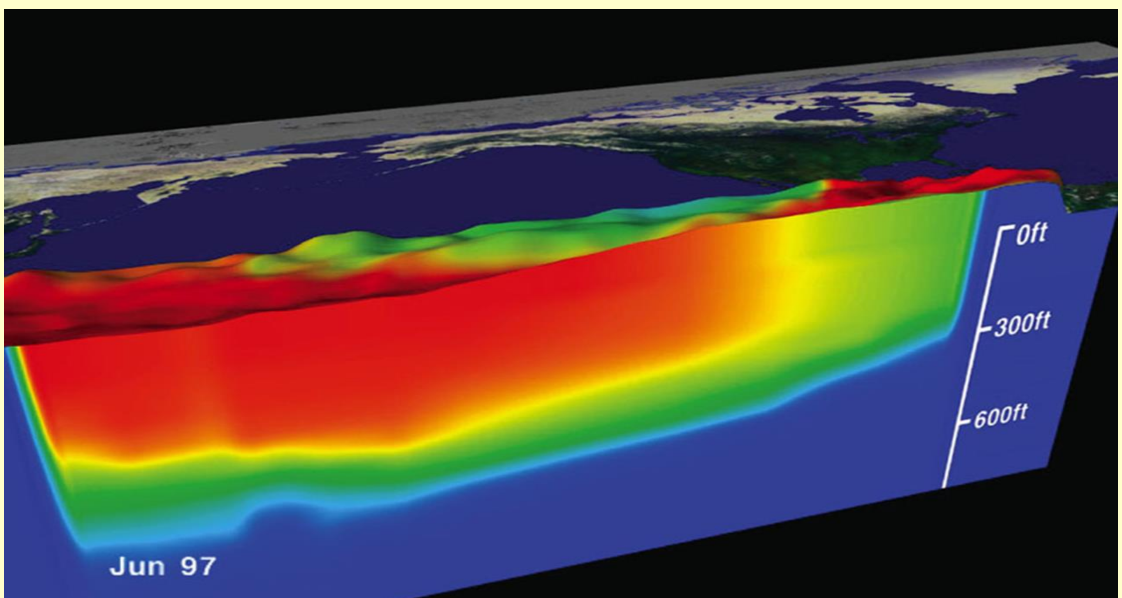


- Two modal elevations:
  3800 m below sea level & 800 m above sea level
- Small features important for wind and water flow

Typical Distortion



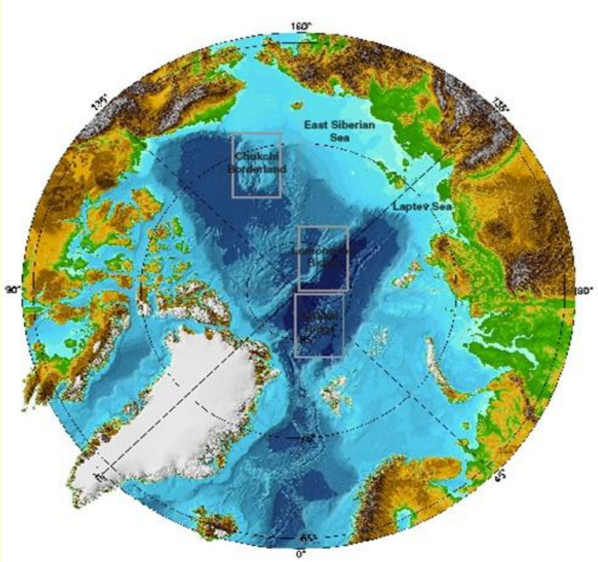


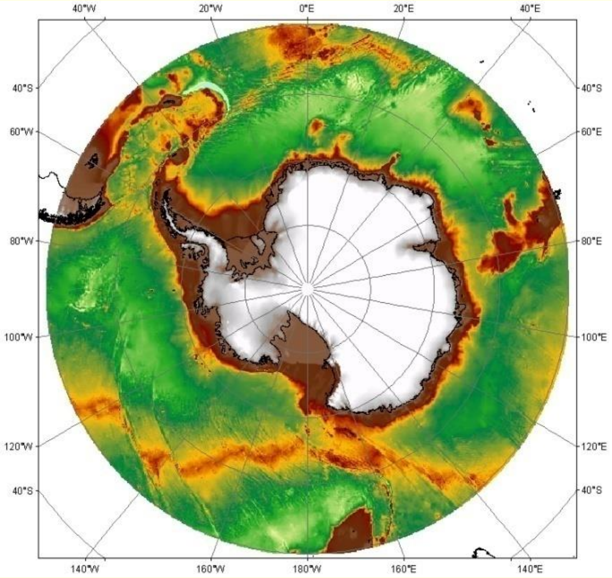


- Horizontal distortion from projection
- Vertical distortion from scaling

Major Ocean Basins

Region	% ocean	% earth
Pacific Ocean	50.1	35.4
Atlantic Ocean	25.9	18.4
Indian Ocean	20.4	14.4
Arctic	3.6	2.8
total	100	71
Southern ocean	22%	



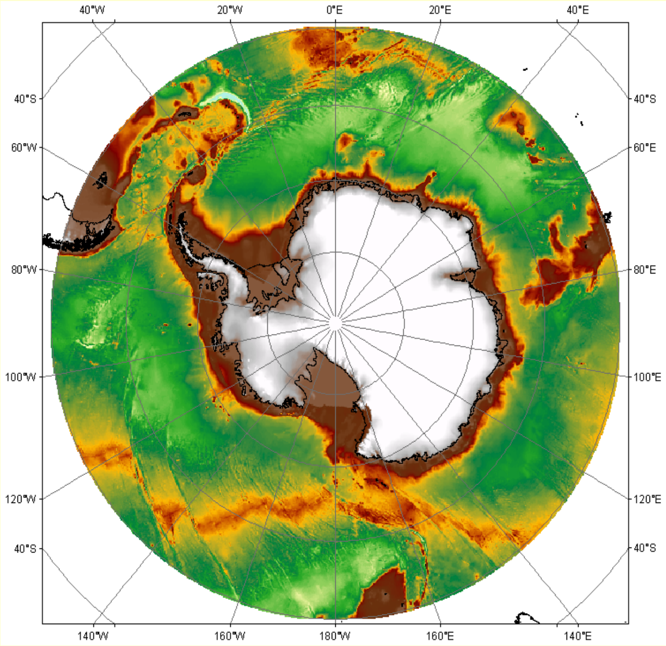


Southern Ocean

- Only ocean not bounded by continents

Northern Boundary defined by an oceanographic feature called the Subtropical Front

Extends from pole to 60^{o} S

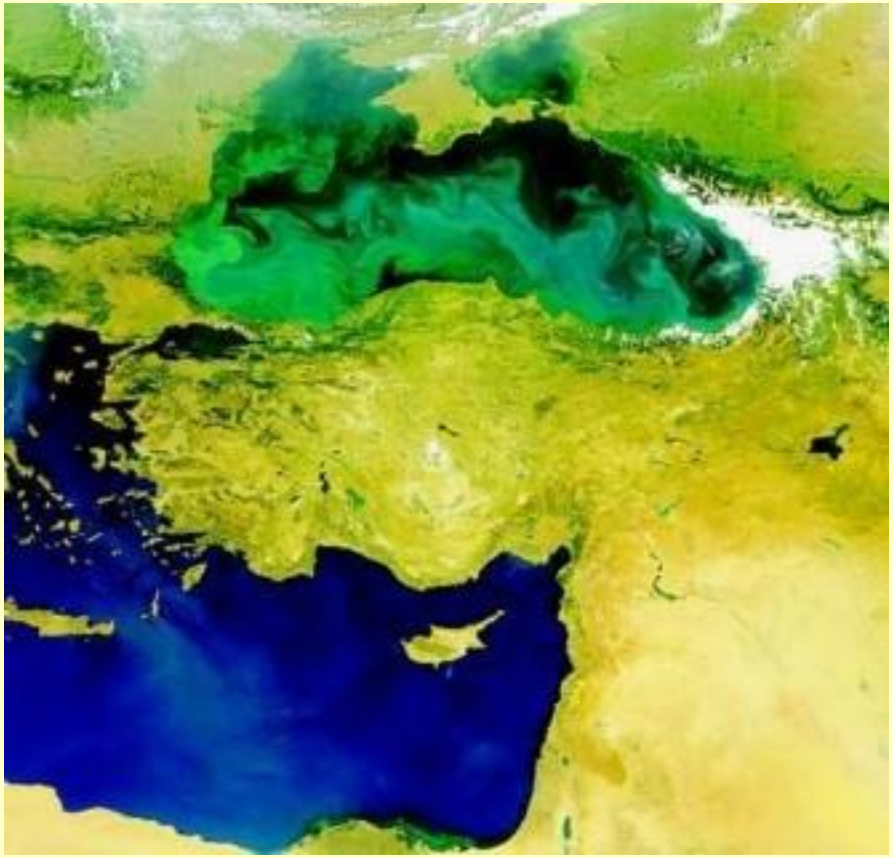


Marginal Seas

- Separated from major ocean basin by a sill (a shallow ride on the sea floor)
- Have independent deep water circulation
- Examples: Red Sea, Bering Sea, SE China Sea, Mediterranean Sea, Black Sea

Marginal Seas

Mediterranean Sea



Black Sea

- Can have large impact on the global ocean: “meddies”
- Can be impacted by human activities: irrigation, runoff

The Earth Is Very Big

Because the Earth is flattened at poles and bulges at the Equator, it is represented as an spheroid.

Mean radius	6,371.0 km
Radius	6,378.1 km (equatorial) 6,356.8 km (polar)
Circumference	40,075.02 km (equatorial) 40,007.86 km (polar)

Ocean Depth in Perspective

Average ocean depth: (mode = 3.8 km)

Variable estimates though the literature:

Talley et al., 3734 m National Ocean Service 4260 m

Mean Earth's diameter: 6,371 km

Roughness of Earth's surface like an Orange:

References

https://web.archive.org/web/20061201070158/http://www.beachcombers.org/index.html

SCIENCE

3:47

+ PLAYLIST

How Much Hotter Are The Oceans? The Answer Begins With A Bucket

August 19, 2019 · 5:04 AM ET

Heard on Morning Edition