



Fall 2020



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](mailto:khyrenbach@hpu.edu)

Lectures (pdfs)

Readings
Assigned
Extra

Homework Keys

Quiz Keys

[Syllabus](#)
(Last Updated: Aug 25)



[Quiz Keys](#)



[Quiz#1](#)



Instructor

<p>Dr. David Hyrenbach</p> <p><i>Offices:</i></p> <p>AC 249, HLC</p> <p>EMSB, Oceanic Institute</p> <p><i>Phone:</i></p> <p>(808) 236-3563</p>	<p><i>Office Hours:</i></p> <p>HLC: Tu & Th; 10:45 - 12:00</p> <p>OI: Tu & Th; 12:00 - 13:00</p> <p>or by appointment at EMSB, OI</p>
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[www.pelagicos.net/
classes_physicaloceanography_fa20.htm](http://www.pelagicos.net/classes_physicaloceanography_fa20.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

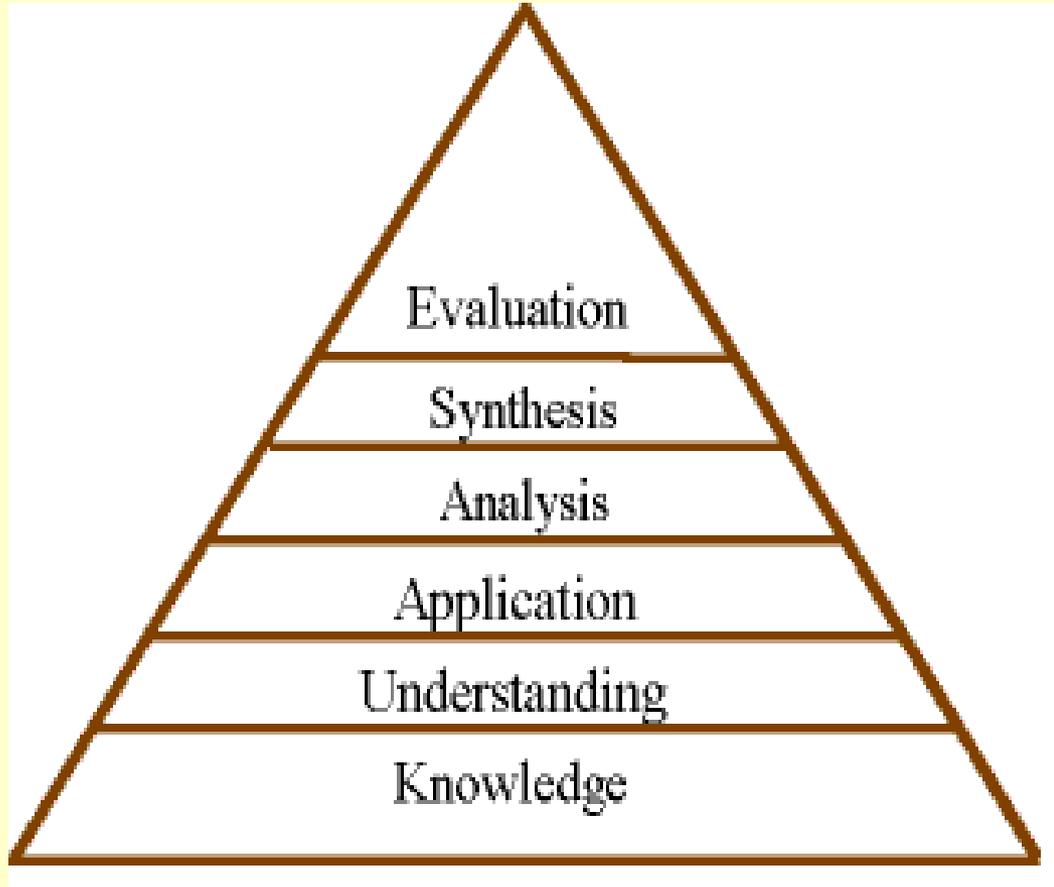
- Upon completion of this course, students will be expected to have knowledge of the general physical aspects of ocean science, and to be able to integrate these concepts into a broader understanding of ocean processes.
- Students will also gain insights into physical - biological coupling in the ocean, 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

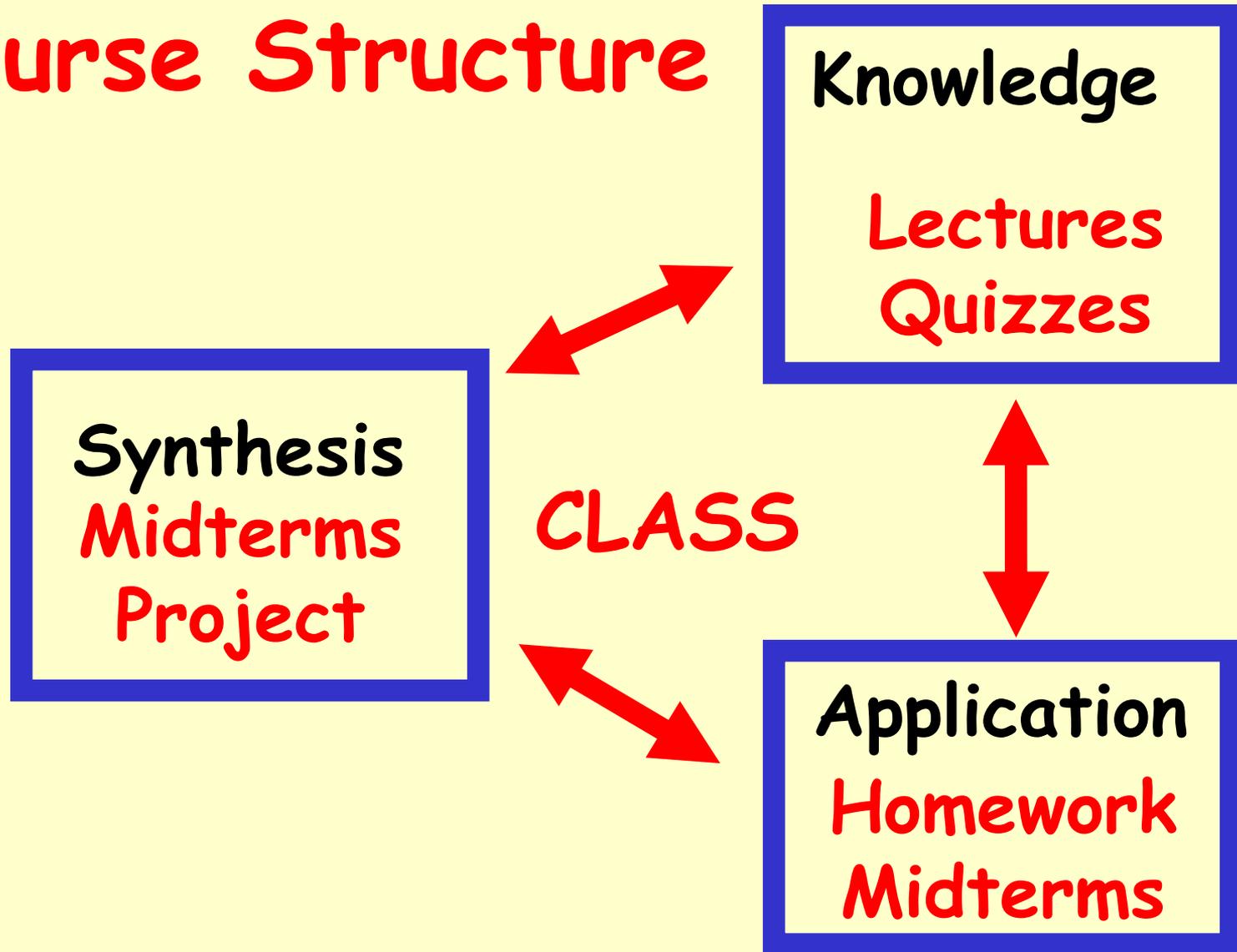
Understanding:

describe, discuss, explain

Knowledge:

define, label, list

Course Structure



Meeting Times / Places

➤ Meetings:

M & W 12:00 - 13:15

OLC 103, OI

➤ Office Hours:

@ EMSB, OI

M & W, 10:30 - 11:45

M & W, 14:00 - 15:00

➤ Or by appointment...



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%
- Class Participation 5% (various activities)

MARS 6080 - Individual Project

- Graduate students will develop an independent literature review on physical - biological interactions (topic approved by instructor)
- Students will turn in:
 - A proposal detailing the proposed topic and a list of references (2.5 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)
 - An extended abstract, summarizing the review of the literature and the findings (10 points)
 - A quiz and an answer key (2.5 points)

MARS 4080 - Individual Project

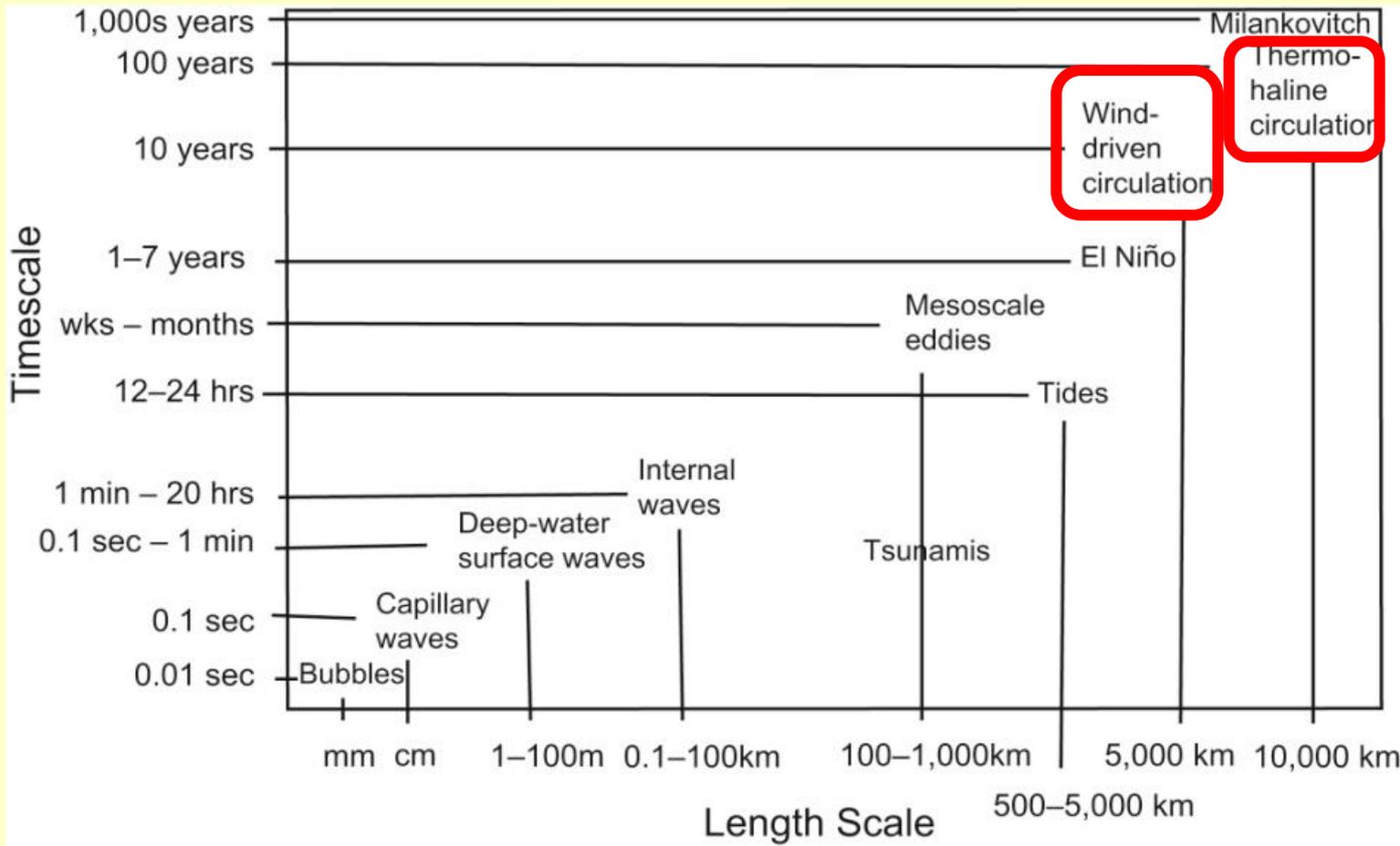
- Students Undergraduate students will participate in the literature class discussions and will be a critical audience for the presentations by the graduate students. Undergraduate students will:
- Submit written evaluations of the articles discussed in class (10 points)

Take quizzes written by the graduate students about the literature reviews (10 points)

Ask questions during paper discussions and presentations by graduate students (5 points)

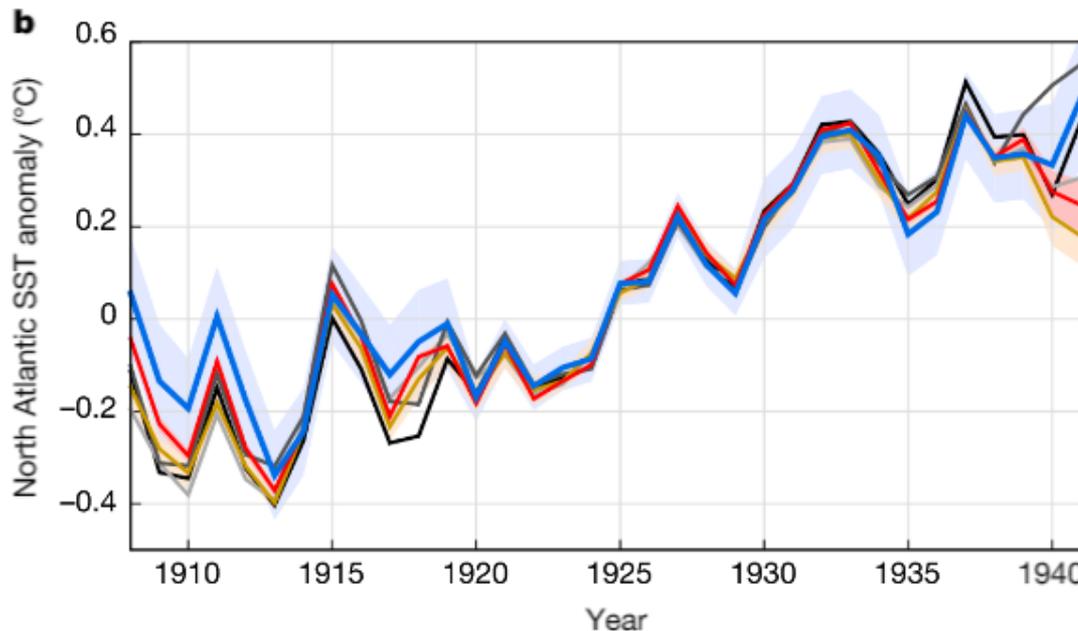
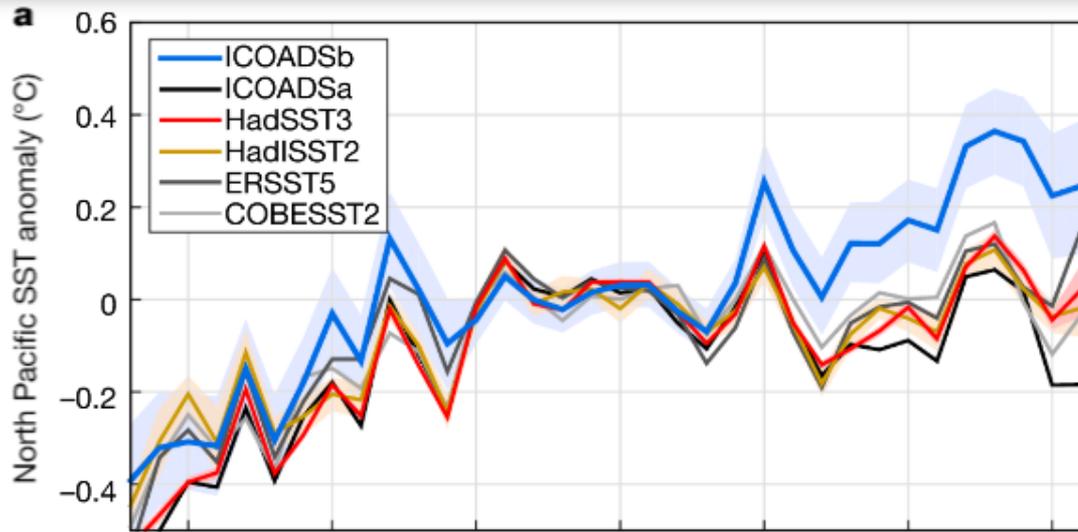


Multiple Scales: Affect the Biology



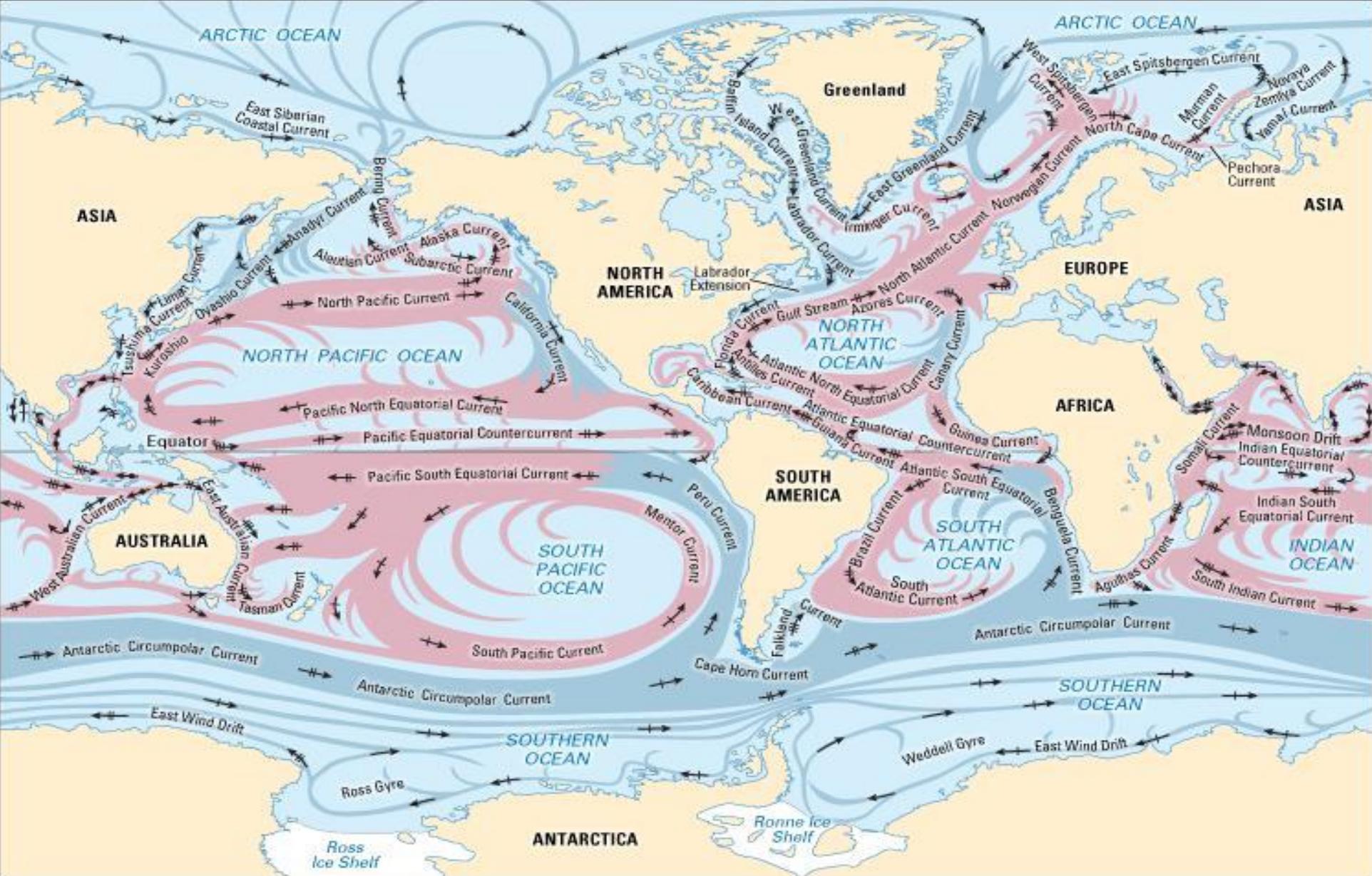
Time and space scales of physical oceanographic phenomena ranging from bubbles to changes in ocean circulation due to Earth's orbit variations.

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)





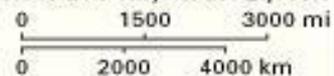
CURRENTS DURING NORTHERN HEMISPHERE WINTER

- 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



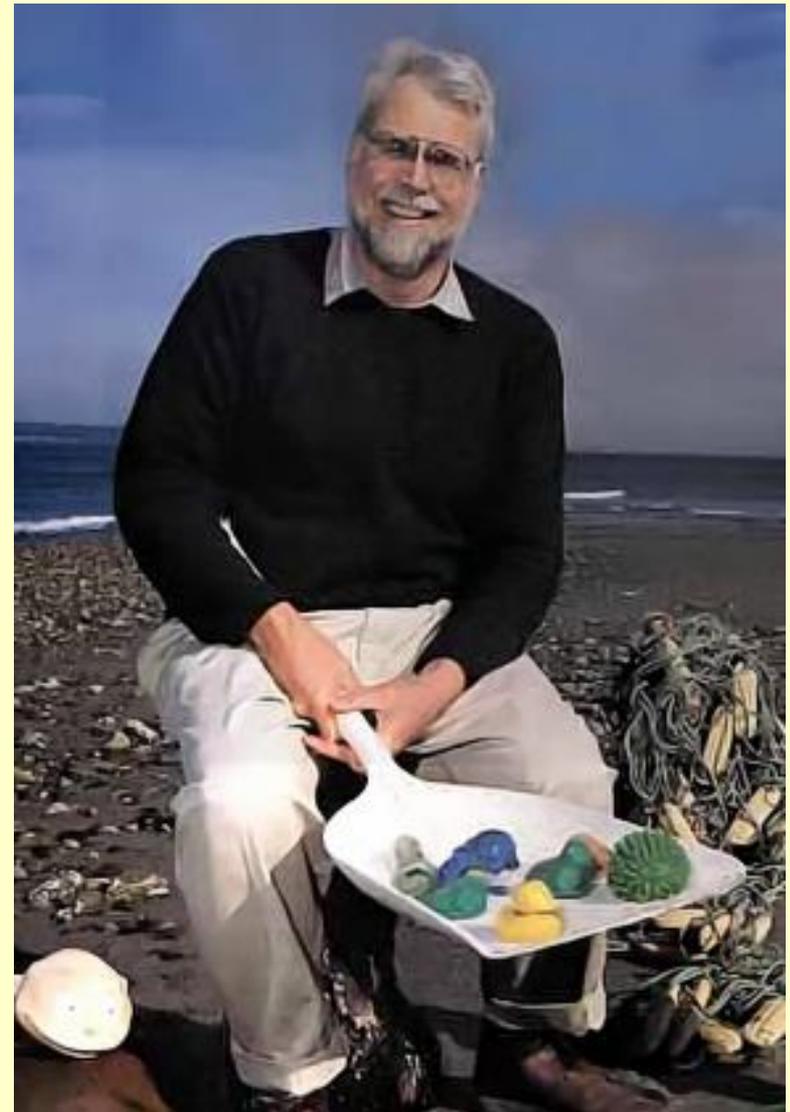
Motivation

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 around 2%.

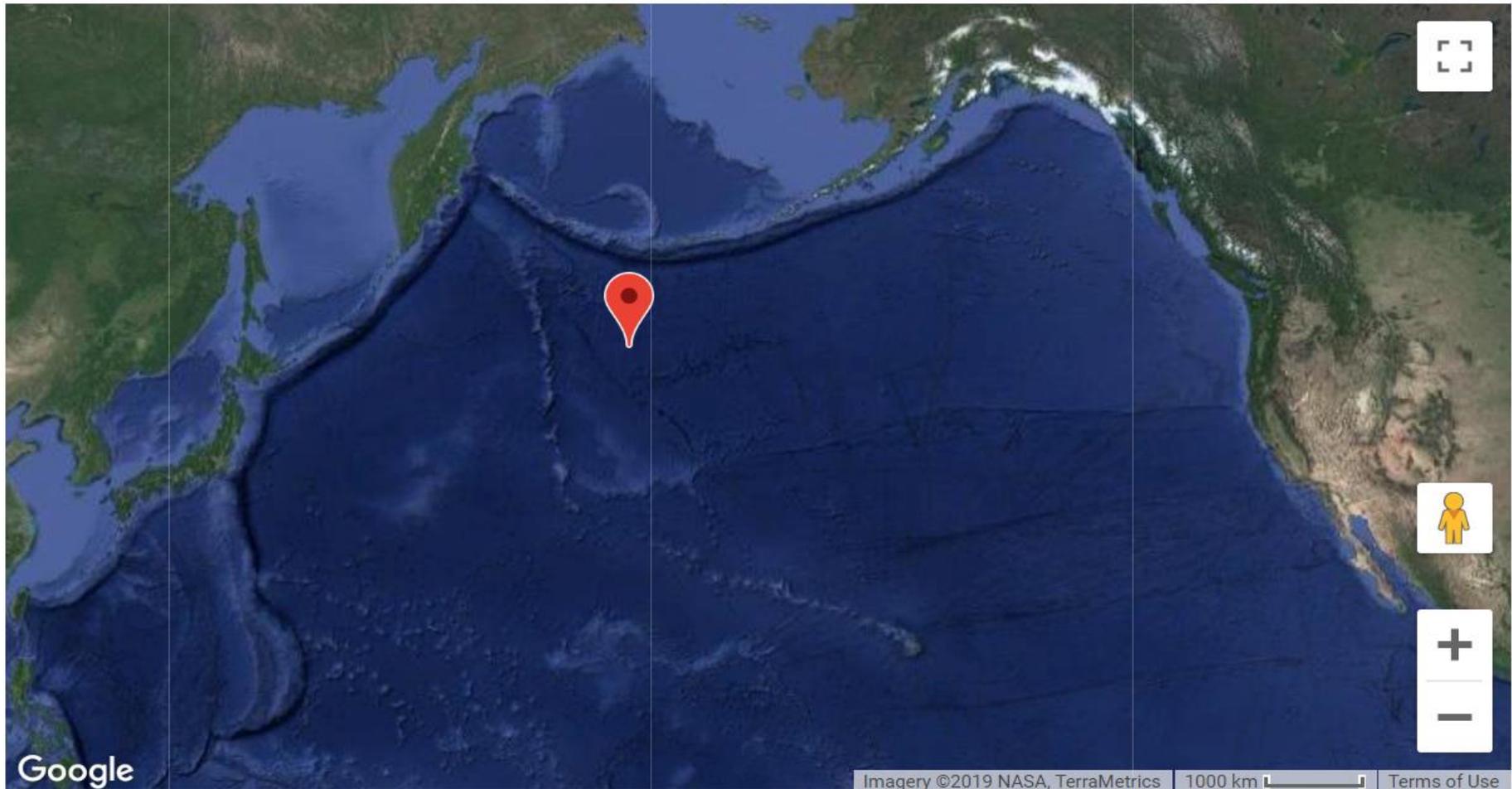
Mass release of 28,800 objects into the ocean at once offered great experiment.

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/>

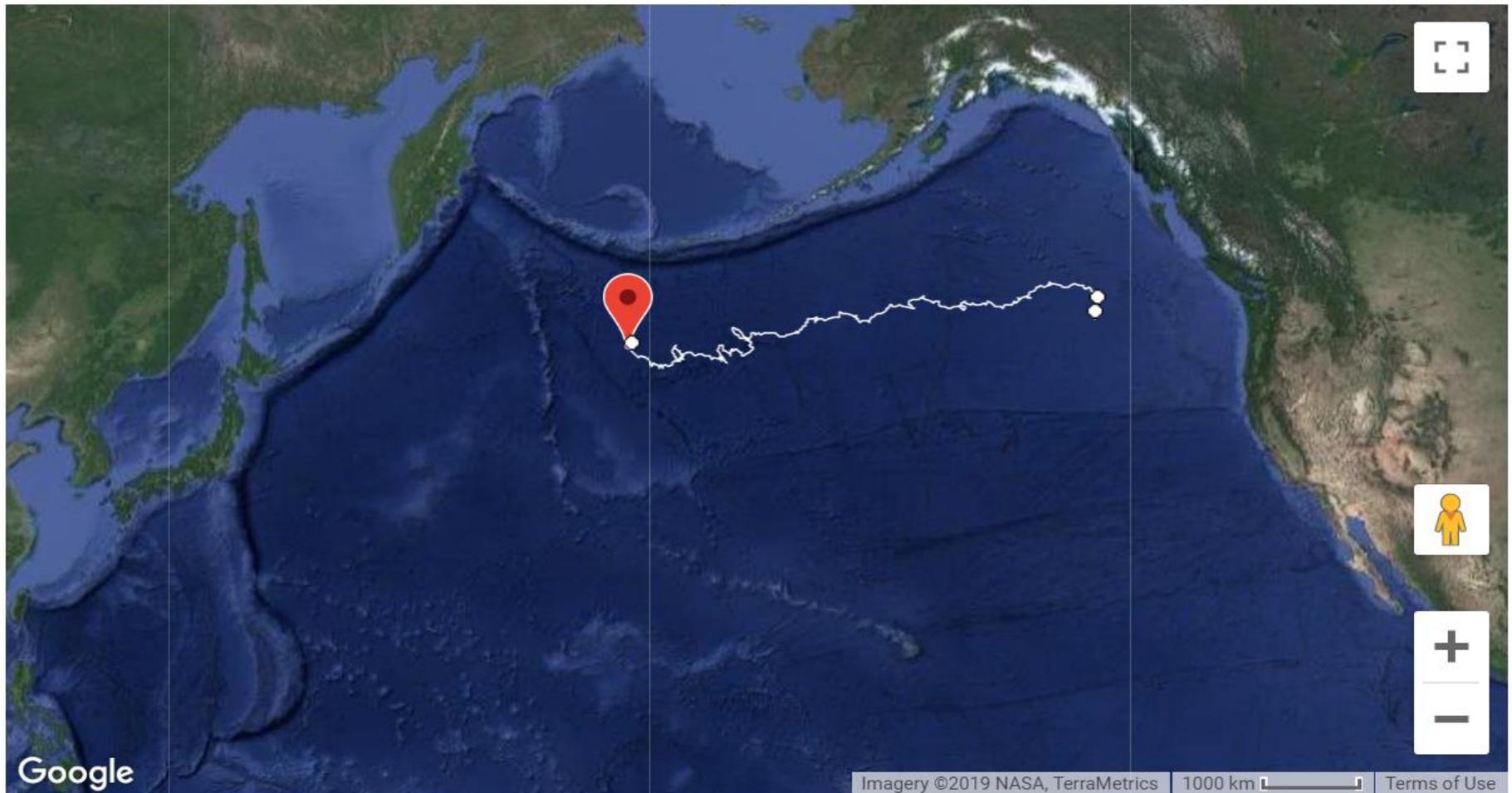


What Would You Expect ?



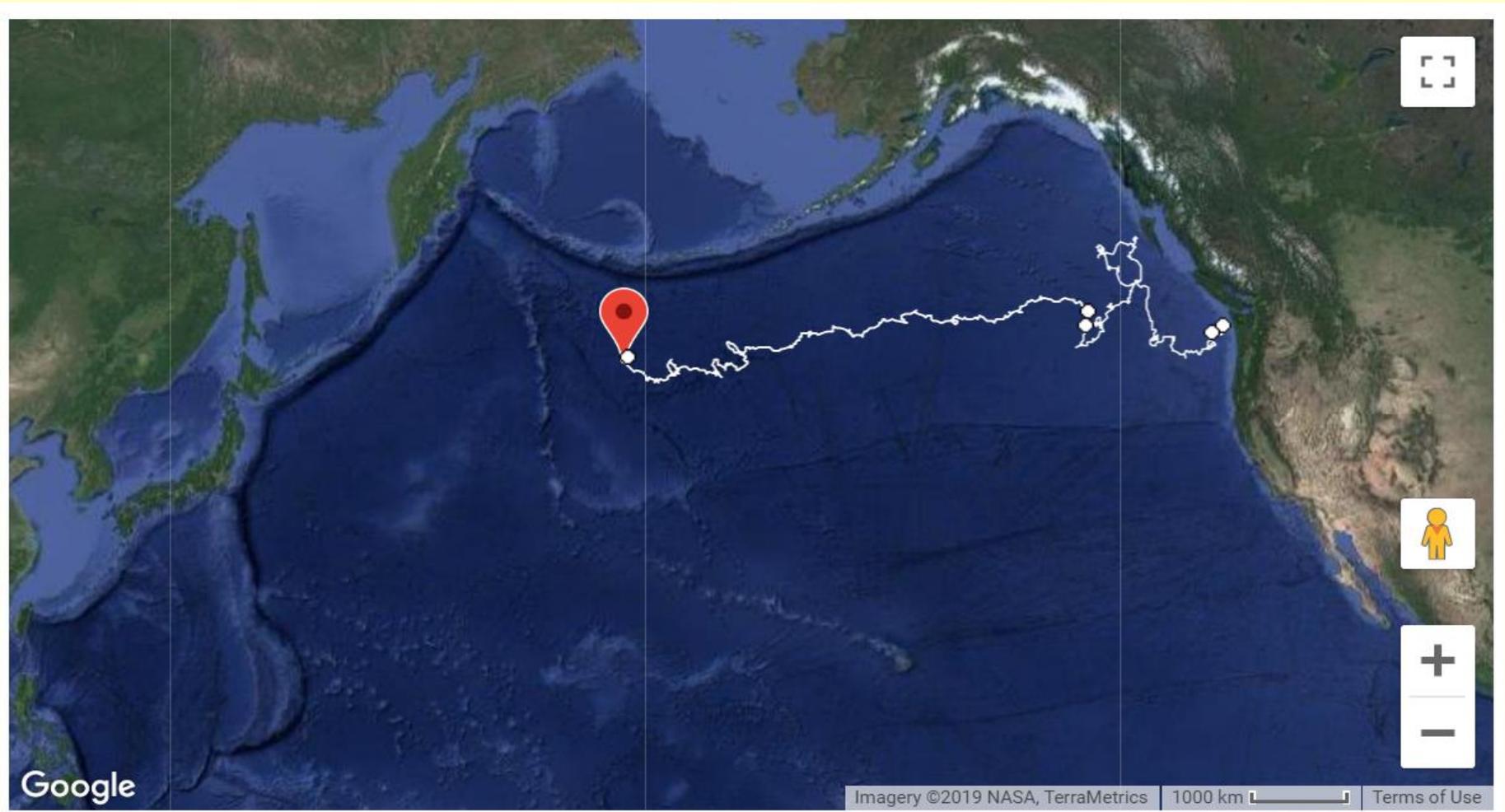
Where will the toys go ??

What Would You Expect ?



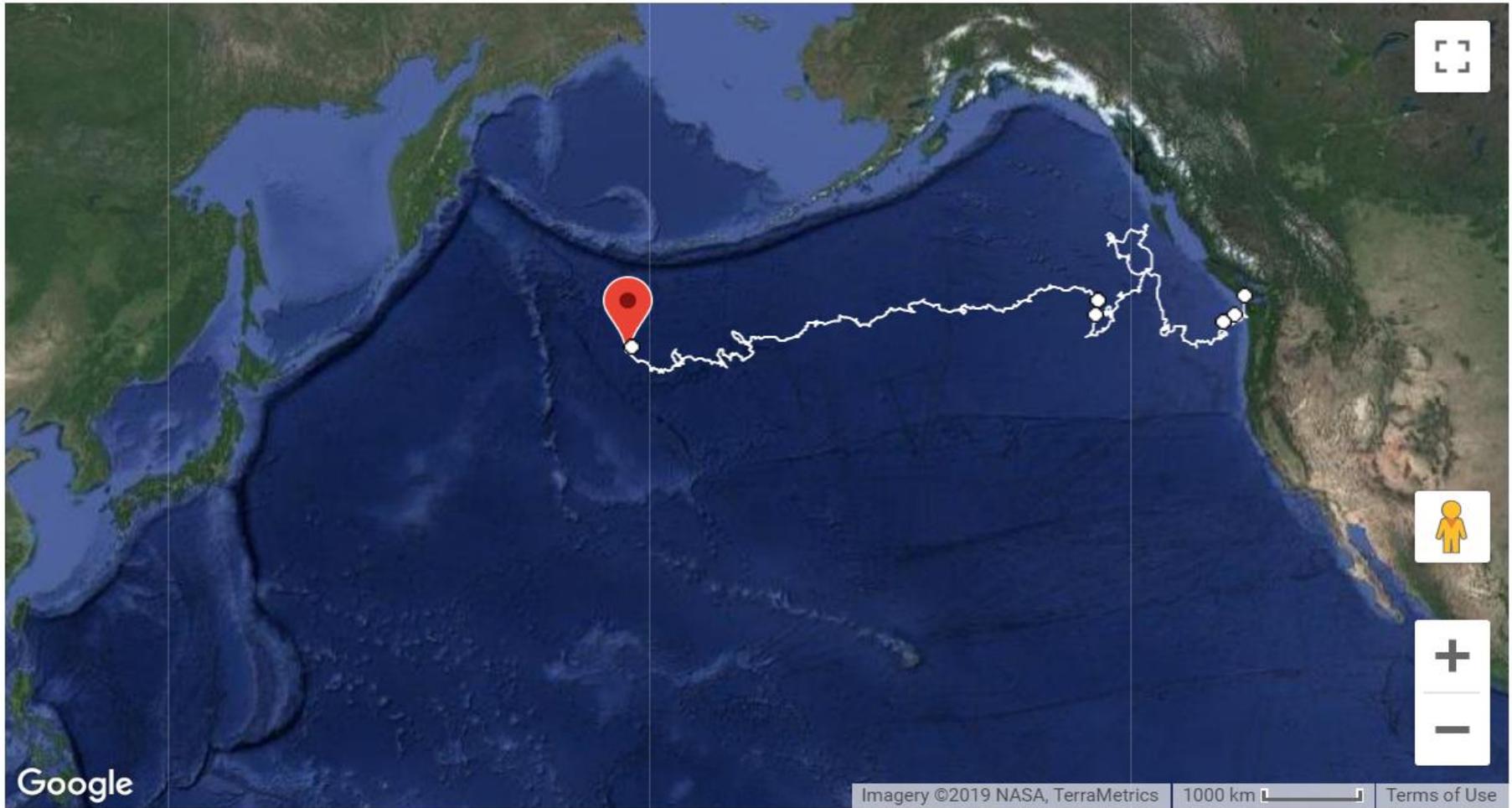
Water parcel moves a large distance in year 1

What Would You Expect ?



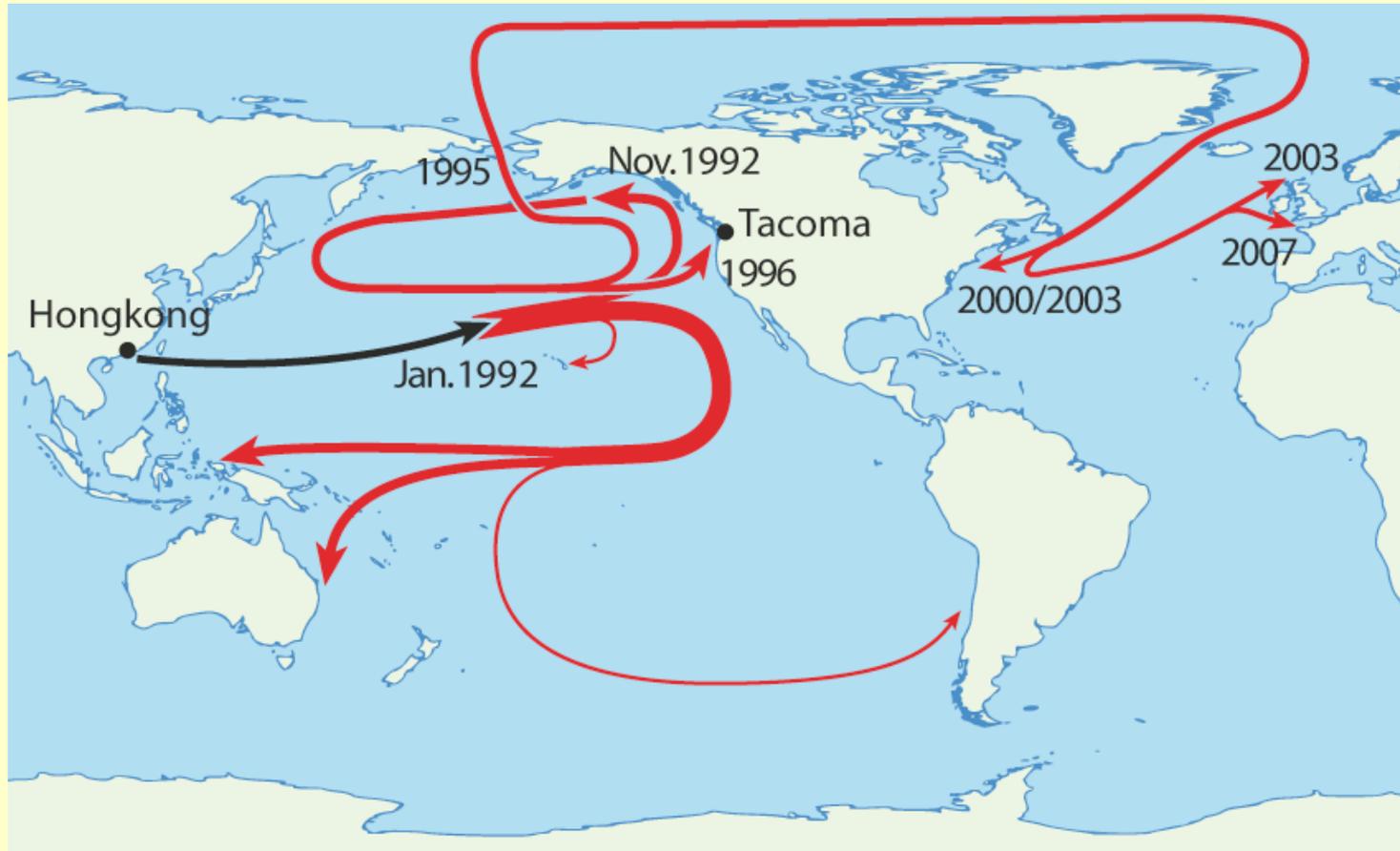
Water parcel stuck off
WA - BC in year 2

What Would You Expect ?



Water parcel reaches
B.C. coast in year 3

What Actually Happened



Some toys landed along shores of Alaska and Hawaii. Others traveled 17,000 miles and reached U.S. East Coast in 2000 and the British shores in 2007

What Actually Happened

AUG. - SEPT. 1992: After 2,200 miles adrift, hundreds beached near Sitka, Alaska.

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

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

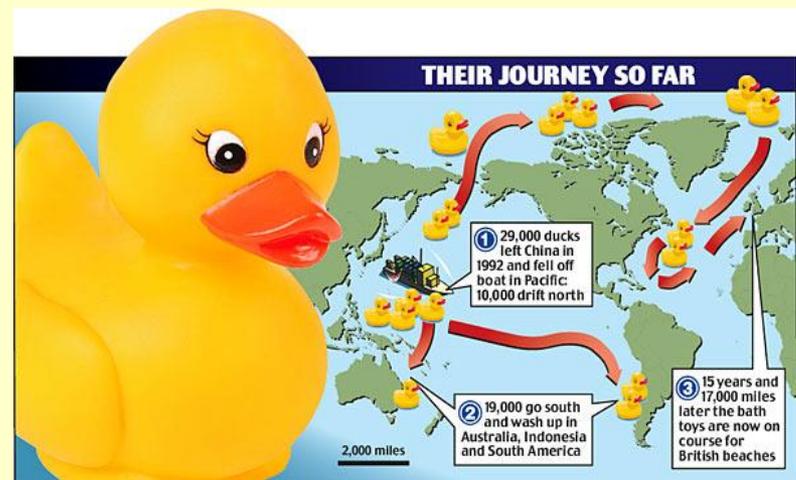
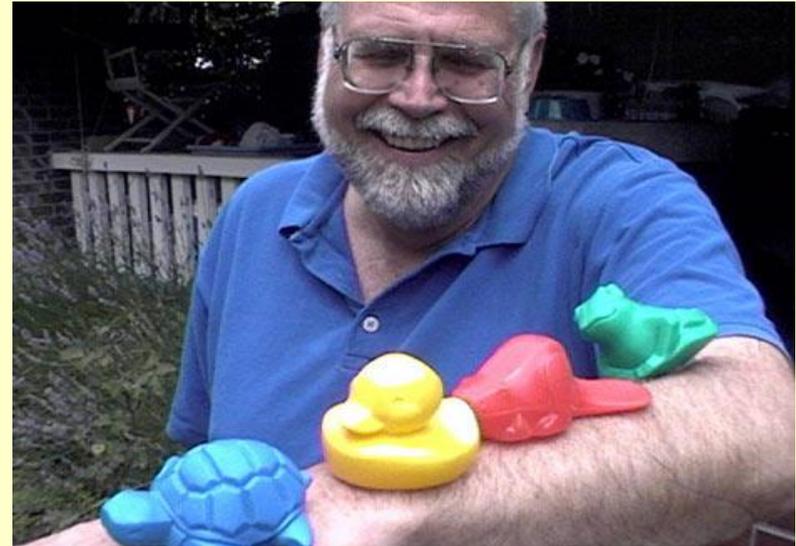
1995 - 2000: Some ducks escape Subpolar Gyre and head North, through the Bering Strait and into the Arctic. Frozen into the sea ice for winter, the ducks travel slowly across the pole, moving eastward.

What Actually Happened

2000: Ducks begin reaching North Atlantic, where they 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'.

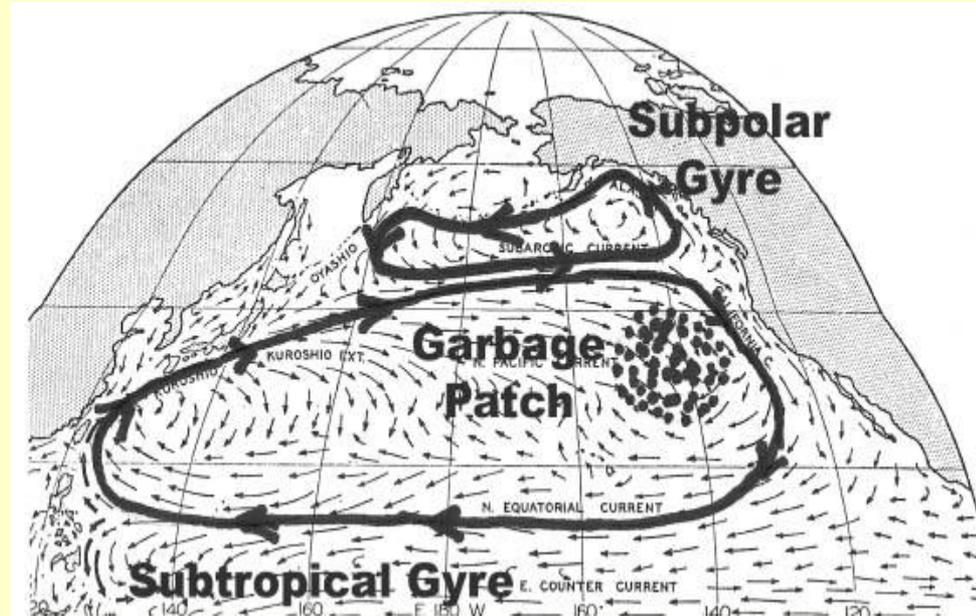


What Did We Learn ?

Observations: Toy deposition maps major North Pacific currents:

Subpolar Gyre

Subtropical Gyre

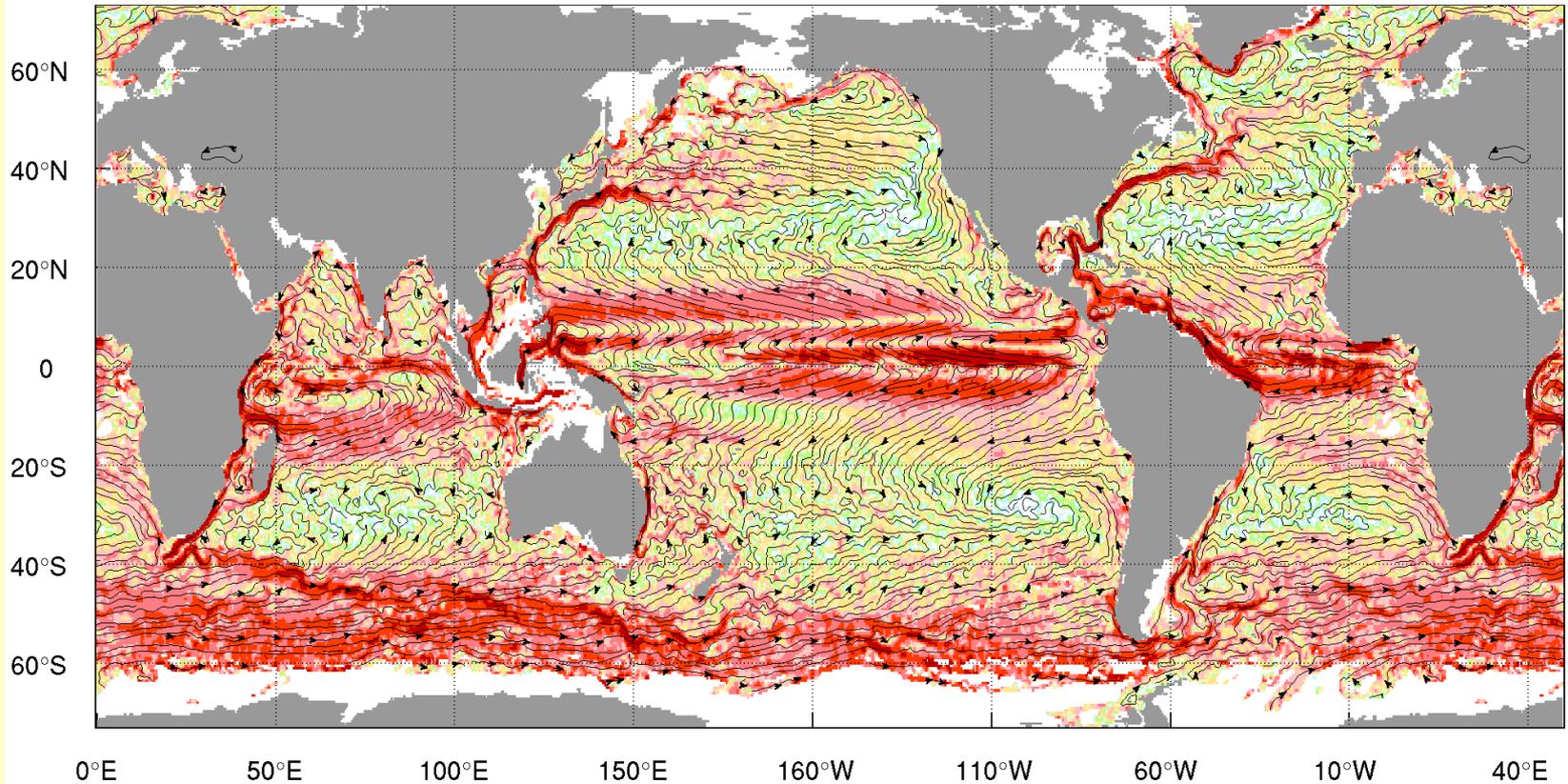


Standardized surveys in Sitka (AK), reveal peak toy recoveries in 5 years: 1992-1994-1998-2001-2004.

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

What Did We Learn ?

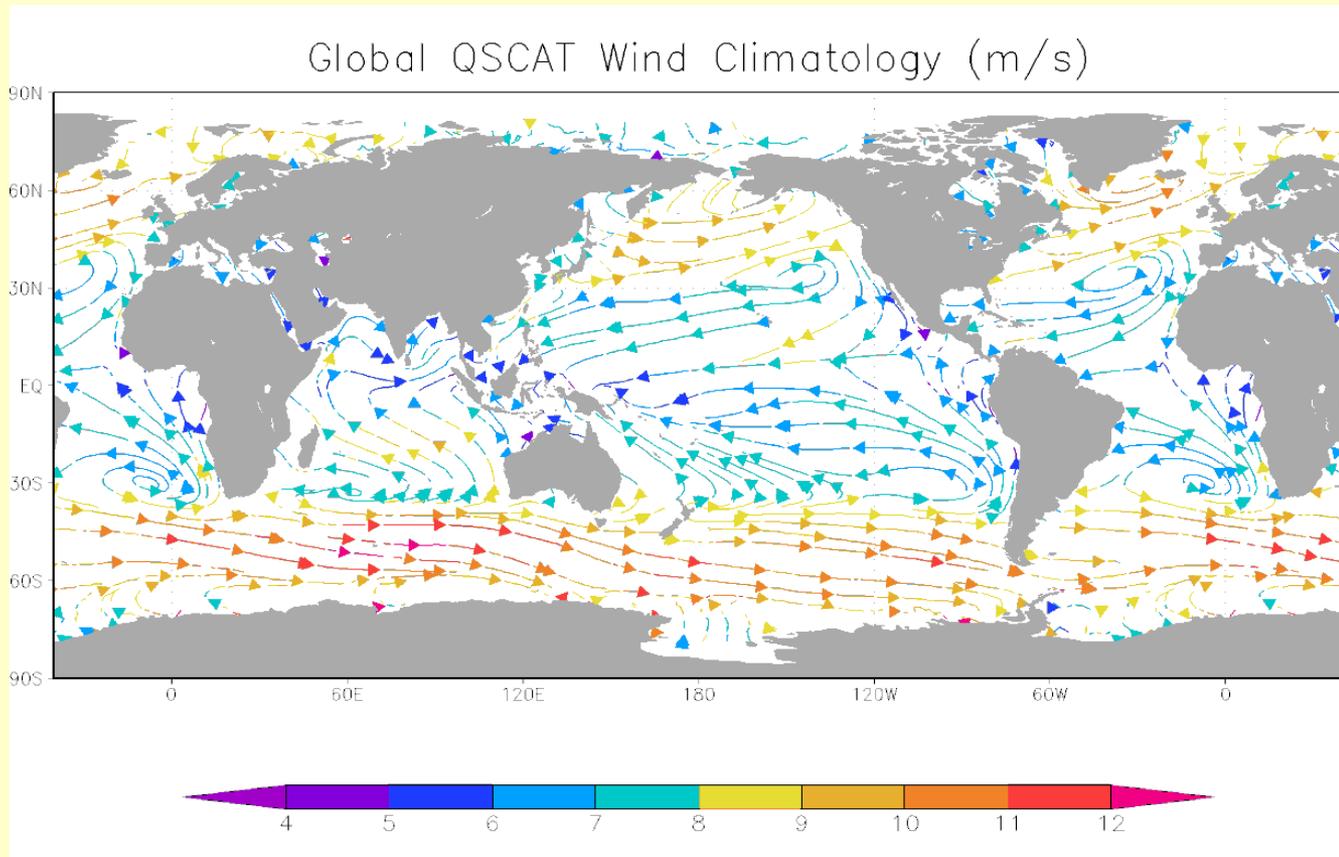
- Toys followed major North Pacific currents:



**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.
- Drift bottles confirm Gyre's orbital period from toy deposition data.
- In the 1950s, oceanographers deployed 33,869 drift bottles in Gulf of Alaska. 20 drifted around Gyre in 1.9 - 4.2 years, matching interval of toy deposition (2 - 4 years)



Windage

Low windage,
object sitting
deep in water



Medium windage,
object sitting
half in water



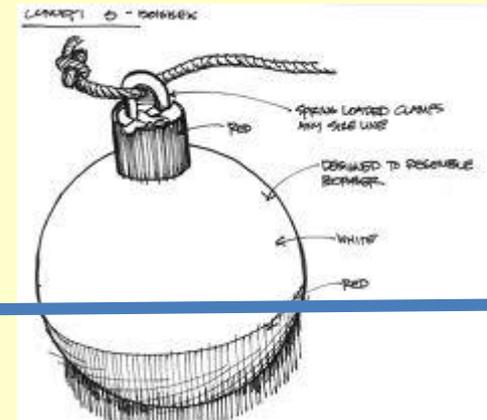
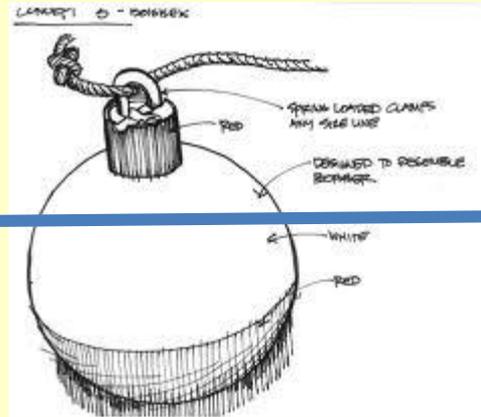
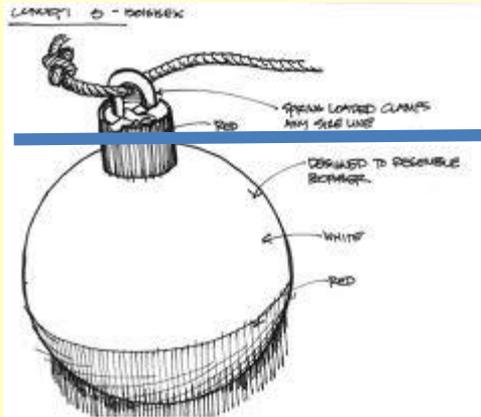
High windage,
object sitting
high on water



Windage

Wind

➤ Force of wind on an object



Ocean surface

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

Wind current speed ('wcsc')

Value of 1.6 means that the object travels 20% faster than the surrounding water

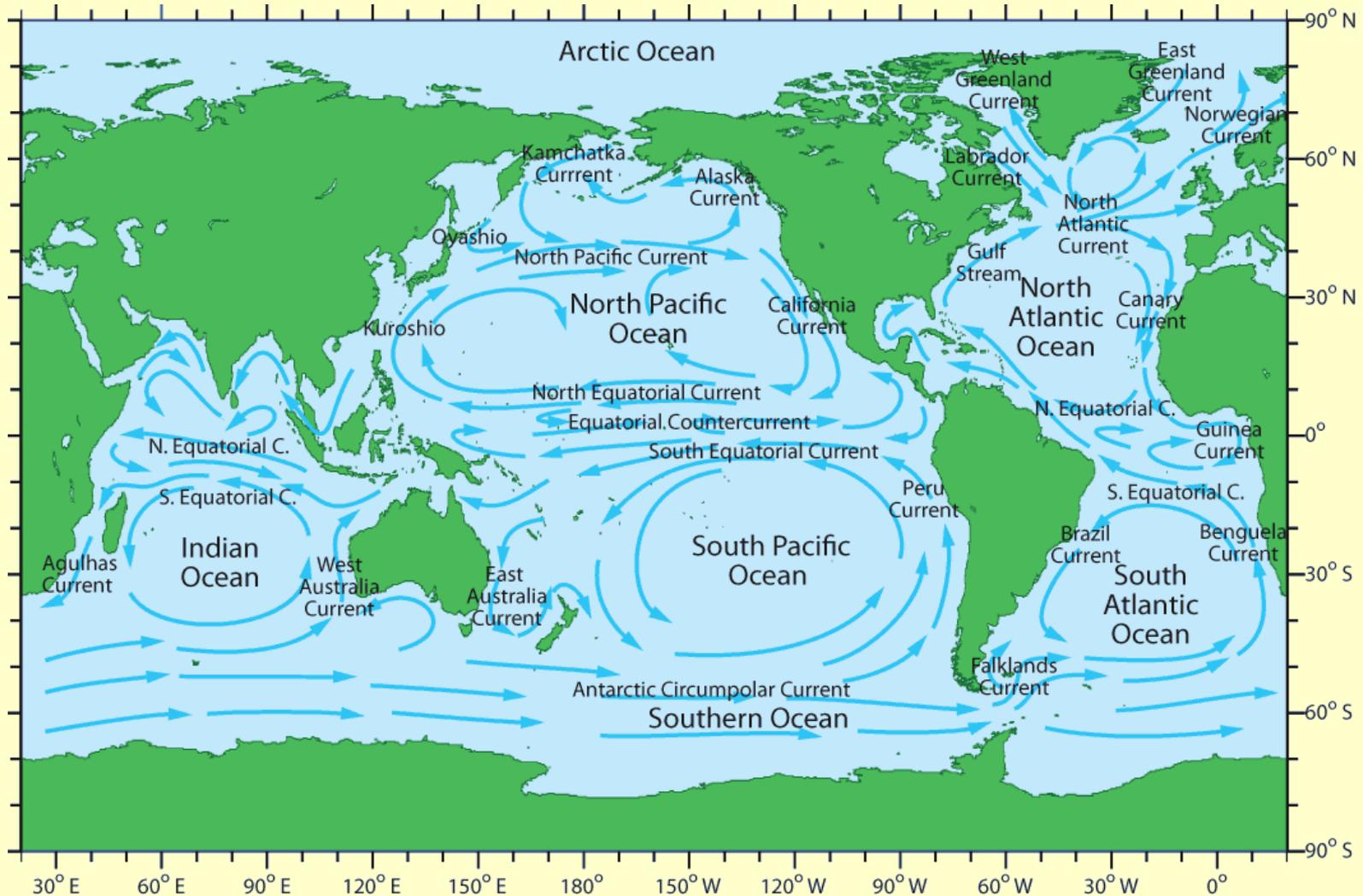
OSCURS Model With Windage



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

Ocean Surface Currents and Gyres

Ocean currents driven by: **WIND + DENSITY**



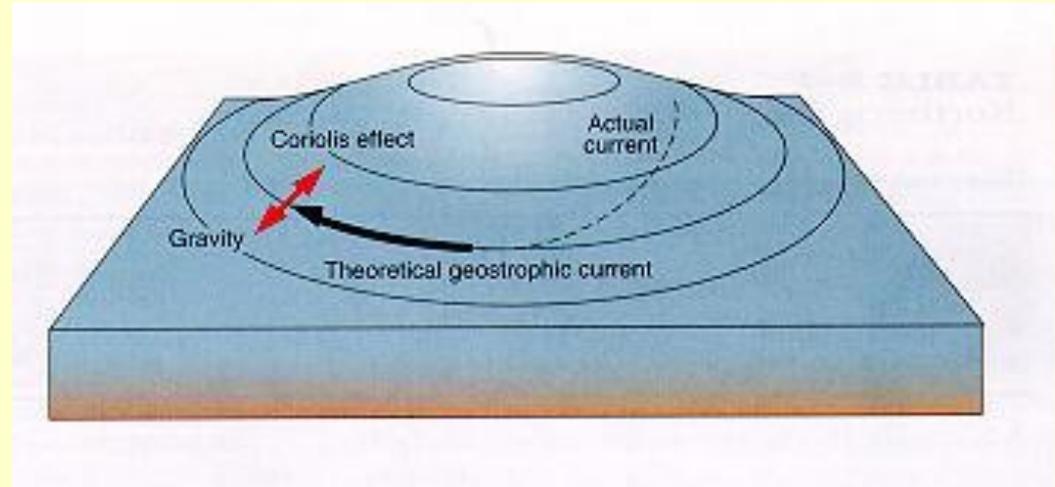
Ocean Surface Currents and Gyres

Ocean currents are influenced by: **CORIOLIS**

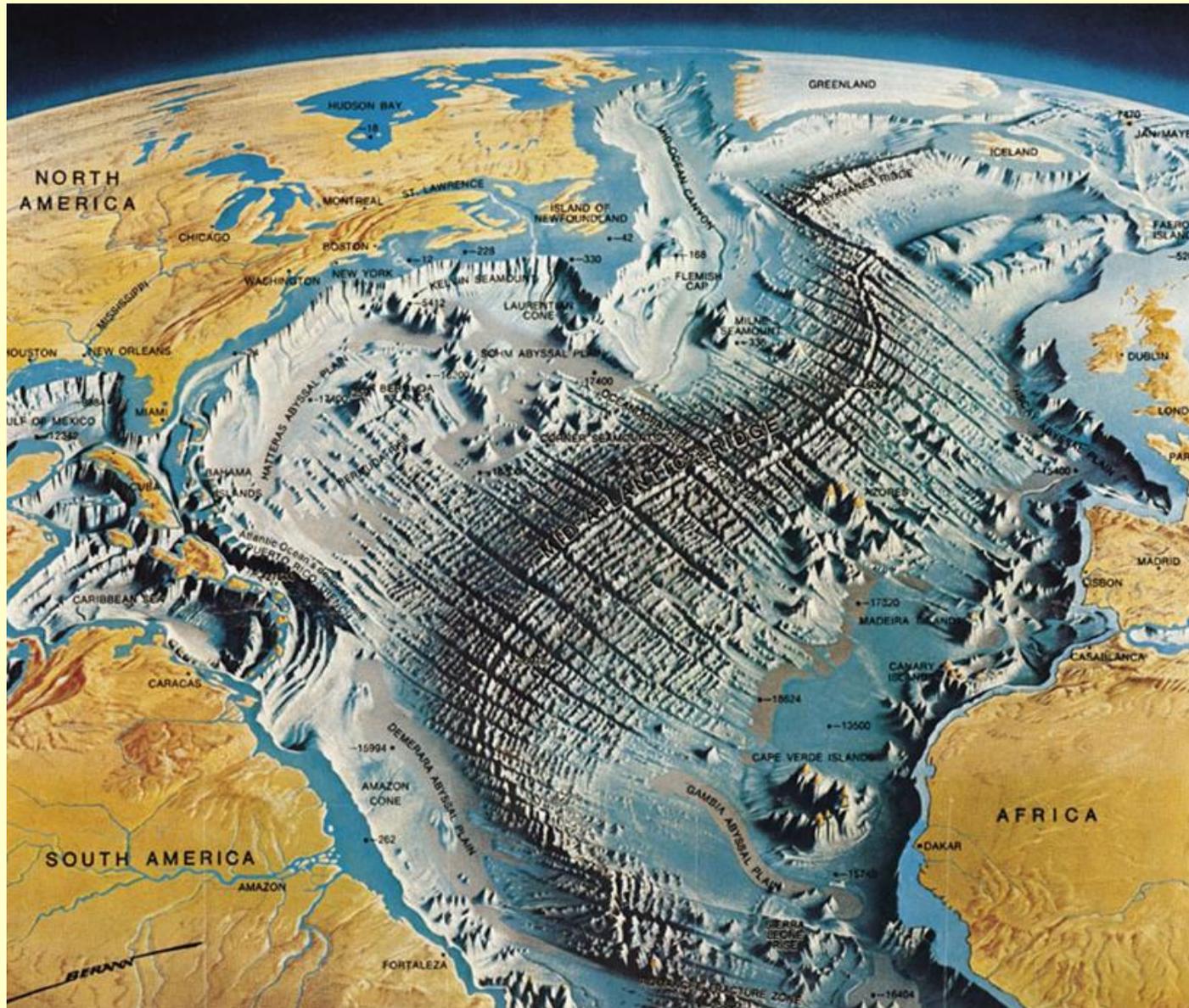
Coriolis Effect makes objects (planes, water parcels) traveling long distances around Earth appear to move along a curve as opposed to a straight line.

Geostrophic:

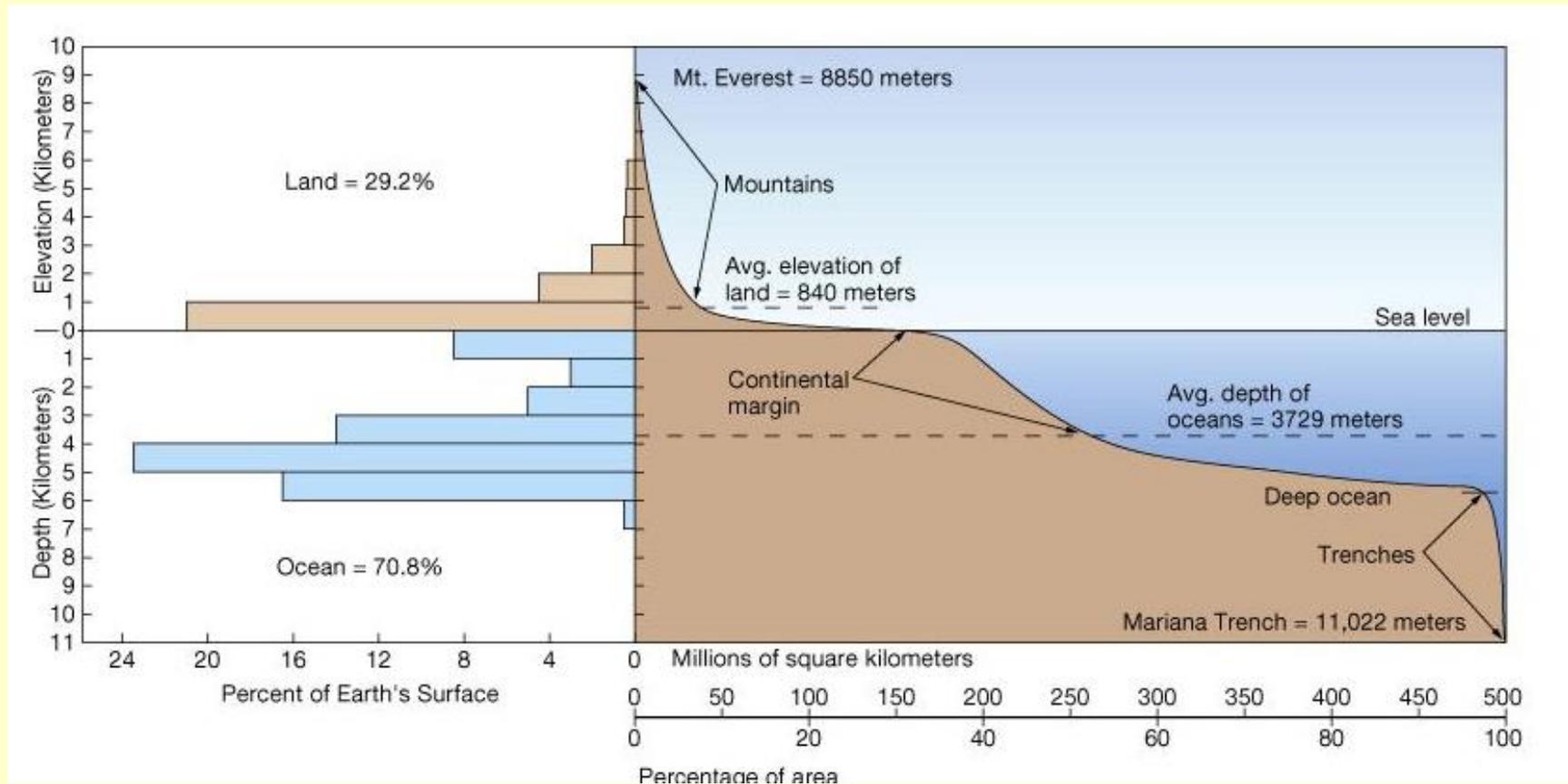
Component of a current from a balance of pressure gradients (density) and coriolis force.



But the Ocean is 3-D



Hypsographic Curve



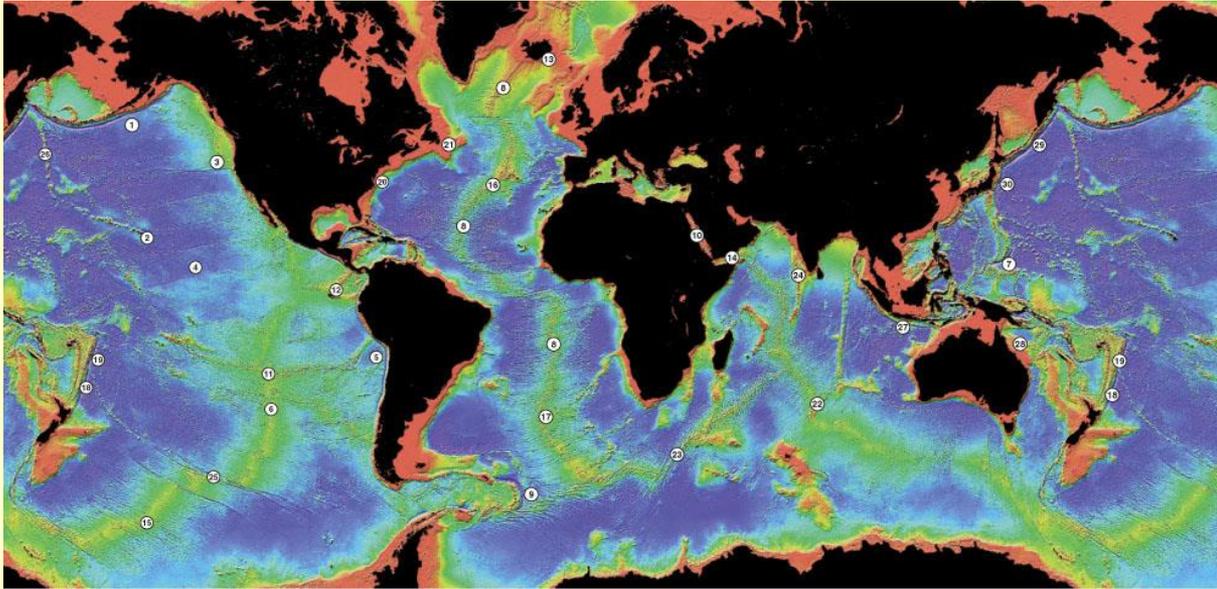
- Two modal elevations:
 - 3800 m below sea level & 800 m above sea level
- Small features important for wind and water flow

The Earth Is Very Big

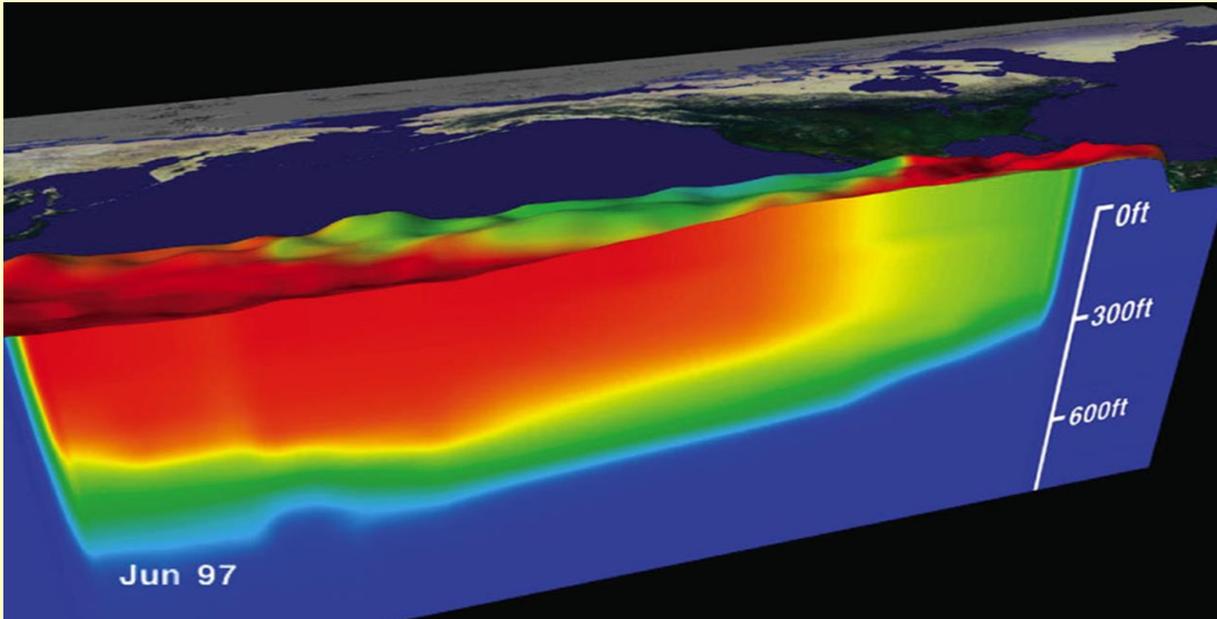
Because the Earth is flattened at poles and bulges at the Equator, it is represented as a spheroid.

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)

Typical Distortion



- Horizontal distortion from projection



- Vertical distortion from scaling

Ocean Depth in Perspective

Average ocean depth: (mode = 3.8 km)

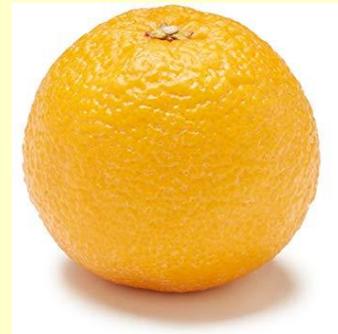
Variable estimates though the literature:

Talley et al., 3734 m

National Ocean Service 4260 m

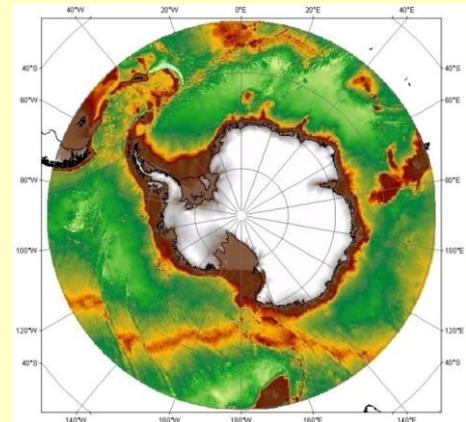
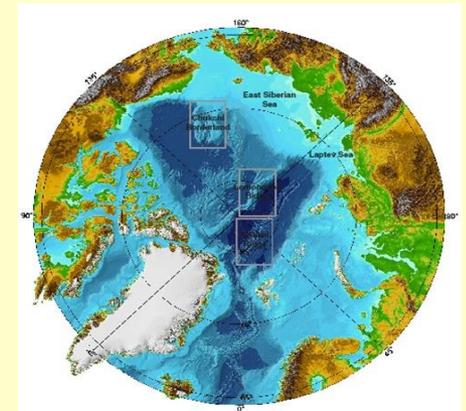
Mean Earth's diameter: 6,371 km

Roughness of Earth's
surface like an Orange:



Major Ocean Basins

Region	% ocean
Pacific Ocean	50.1
Atlantic Ocean	25.9
Indian Ocean	20.4
Arctic	3.6
total	100
Southern ocean	22%

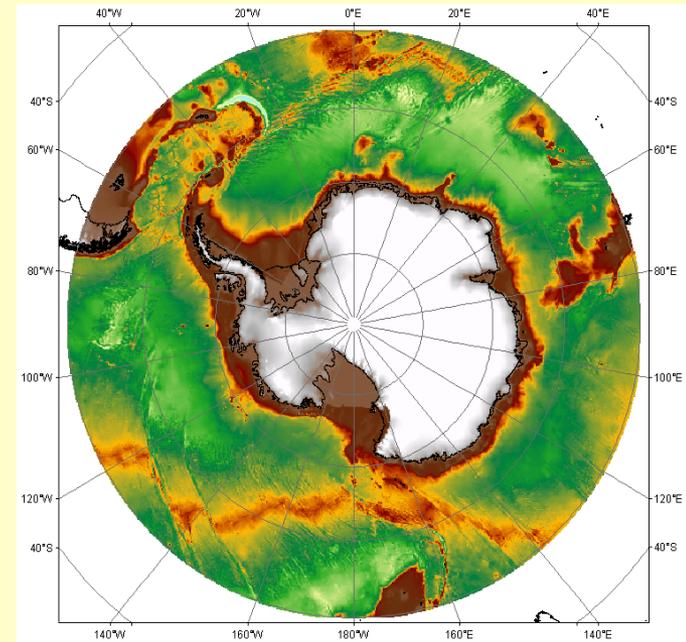


Southern Ocean

- Only ocean not bounded by continents

Northern Boundary defined by an oceanographic feature called the Subtropical Front

Extends from pole to 60° S



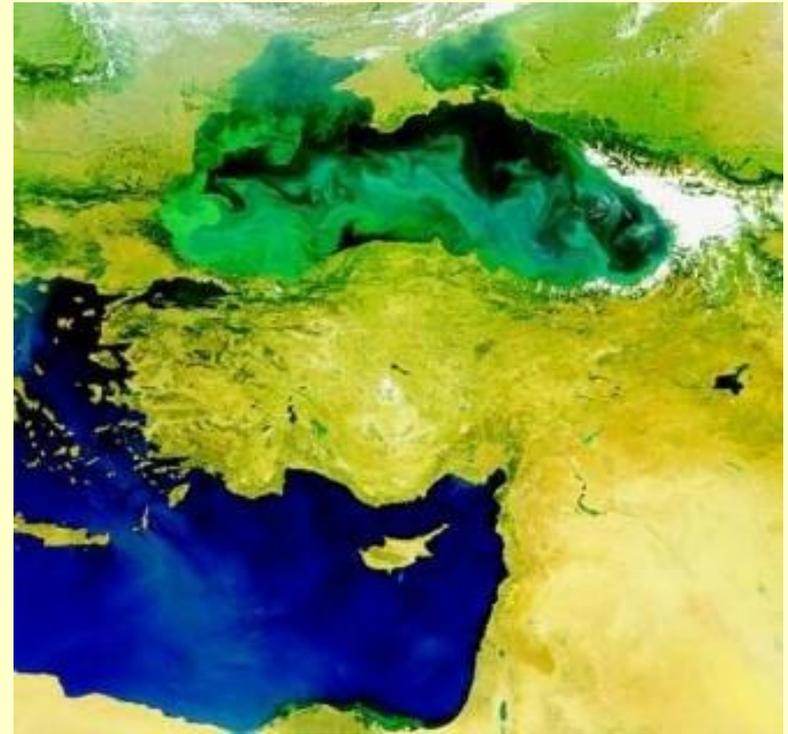
Marginal Seas

- Separated from major ocean basin by a sill (a shallow ridge 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

References



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



3:47

+ PLAYLIST

SCIENCE

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

August 19, 2019 · 5:04 AM ET

Heard on Morning Edition