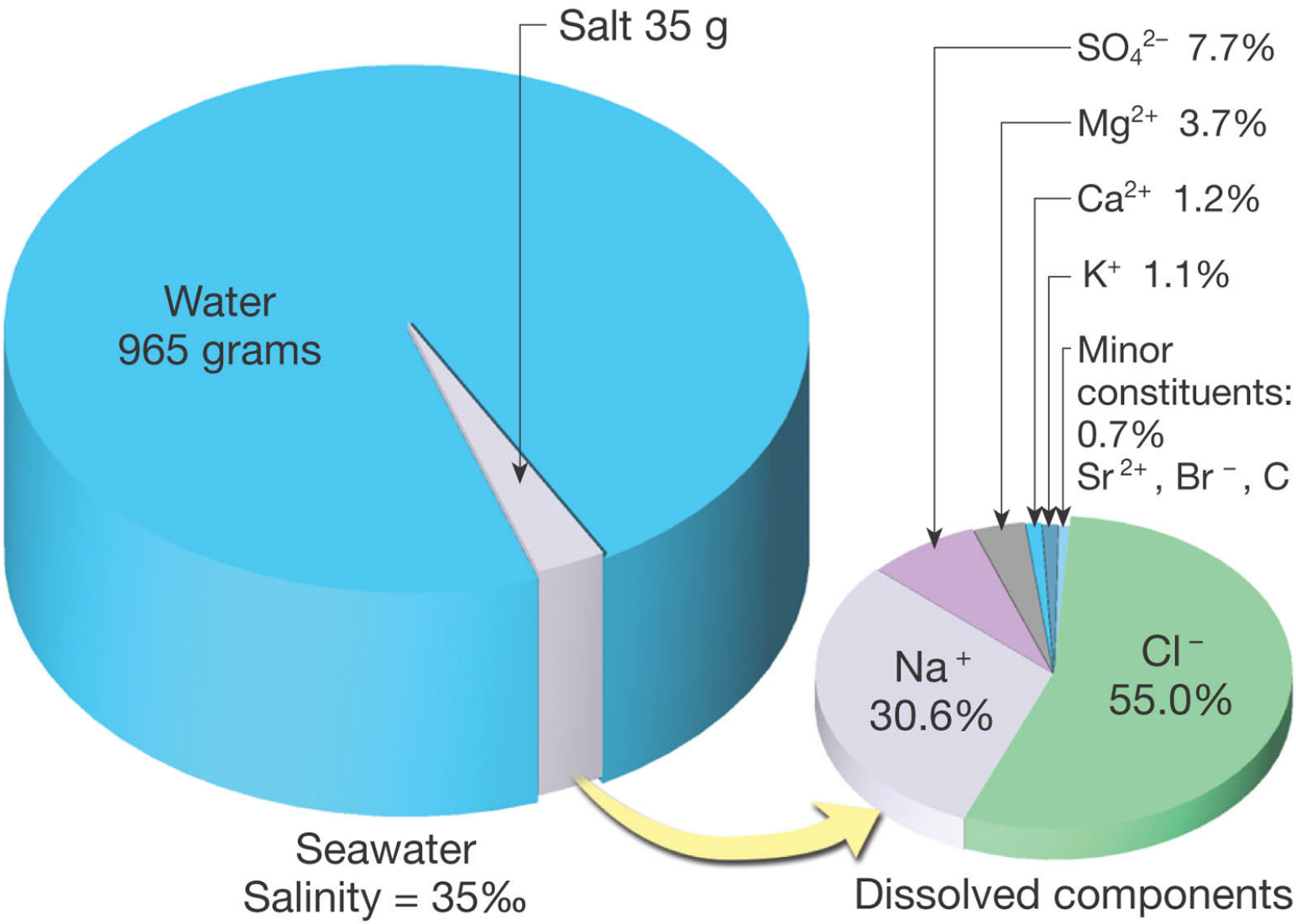
Chemistry of the Ocean

Liz Kujawinski
Woods Hole Oceanographic Institution

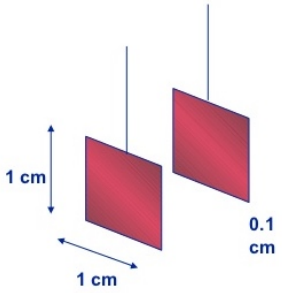
Chemicals in Seawater

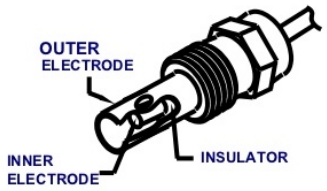
- Salt
- Nutrients
- Land-derived (trees, grasses, dirt)
- Ocean-derived (phytoplankton, shrimp, fish, whales)
- Pollution (pesticides, oil, sewage)

SALT

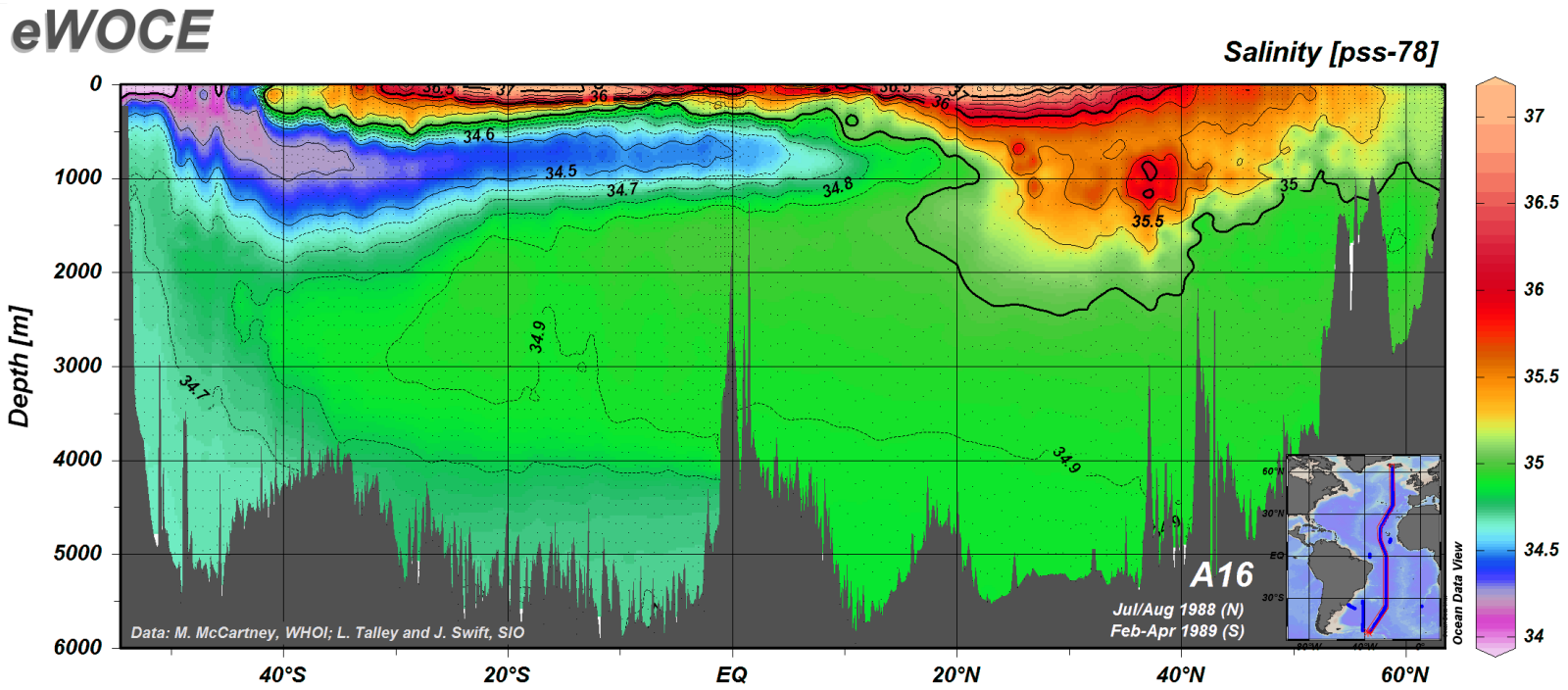


SALT

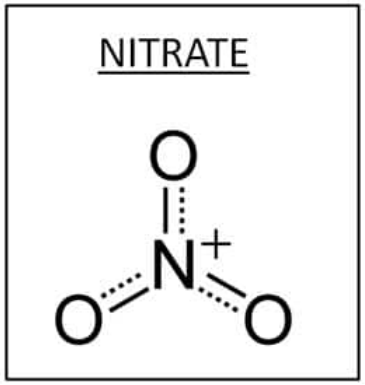


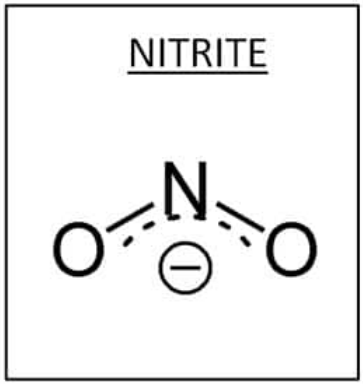


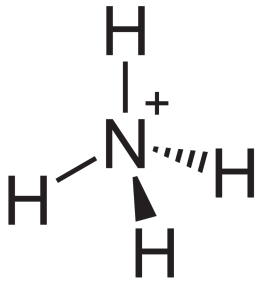
$$\text{Conductivity Cell Constant} = \frac{\text{Length}}{\text{Area}} = \frac{0.1}{\text{cm}} = 0.1\ \text{cm}^{-1}$$



NUTRIENTS



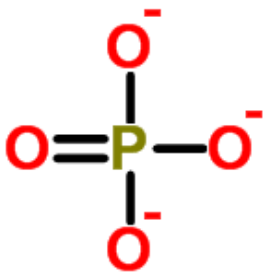




Nitrogen

In biomass, C:N = 7

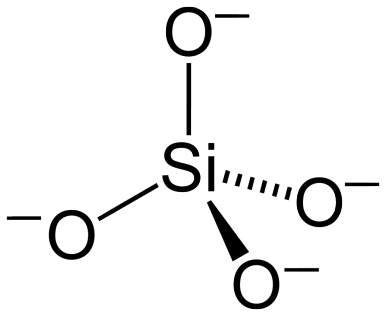
Proteins, DNA, RNA



Phosphate

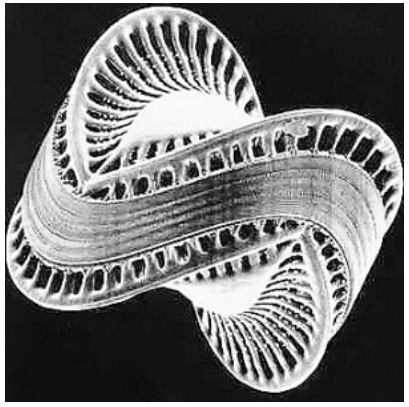
In biomass, C:N = 16

DNA, RNA

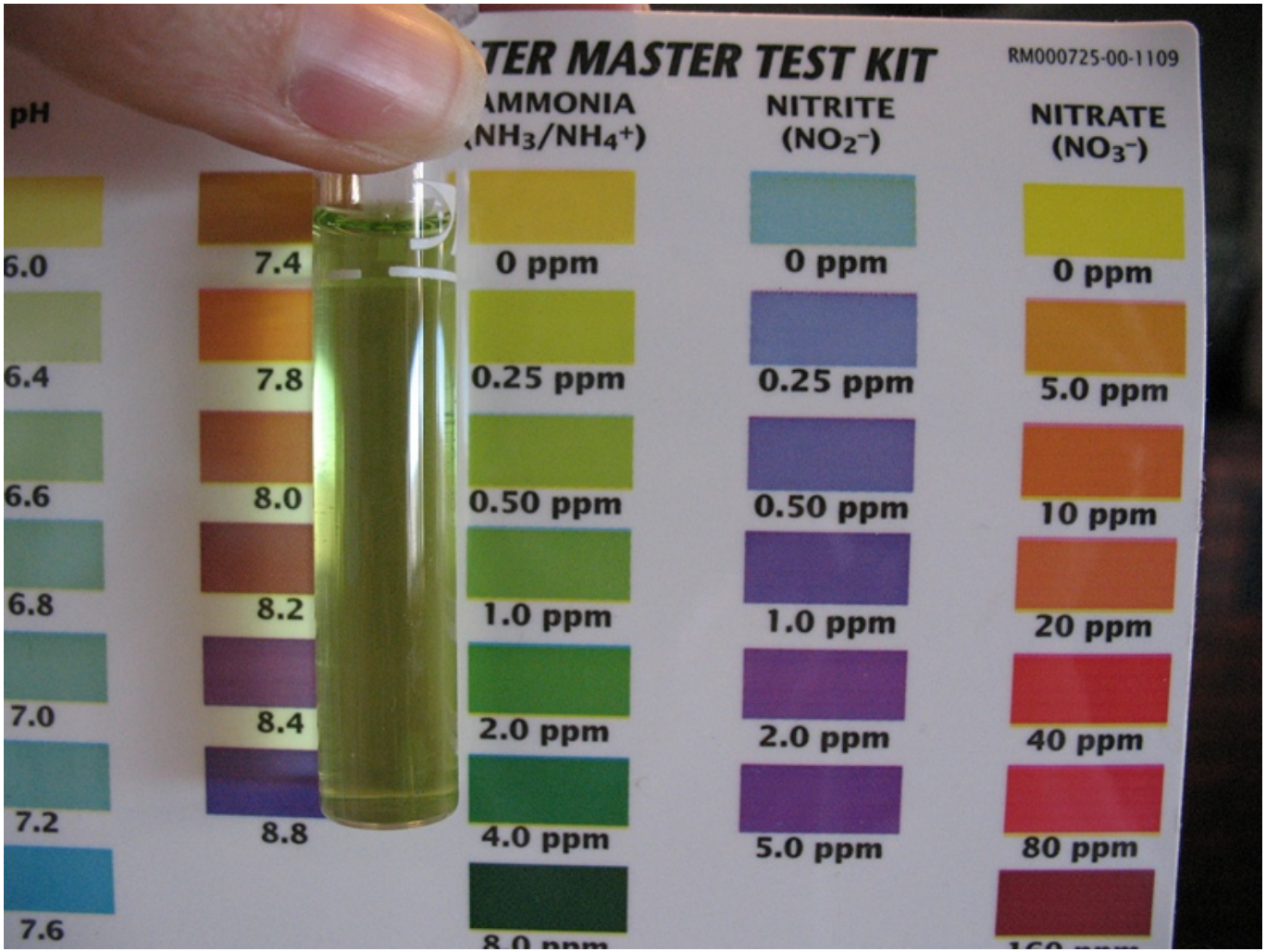


Silicate

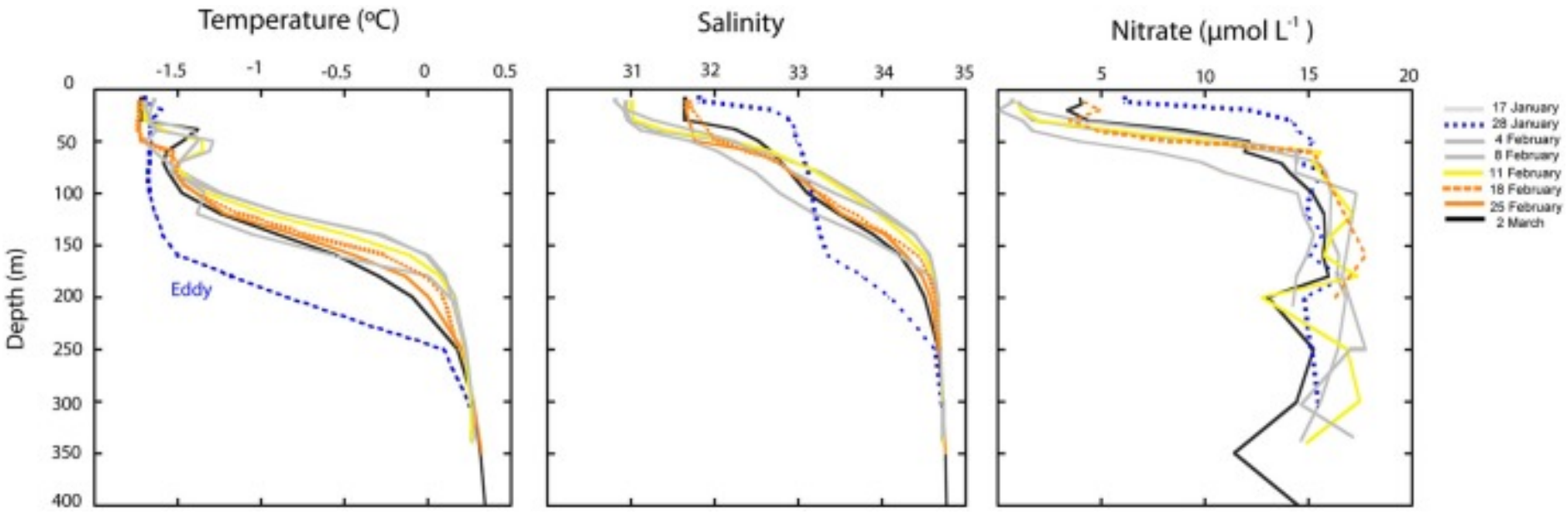
Required for diatoms



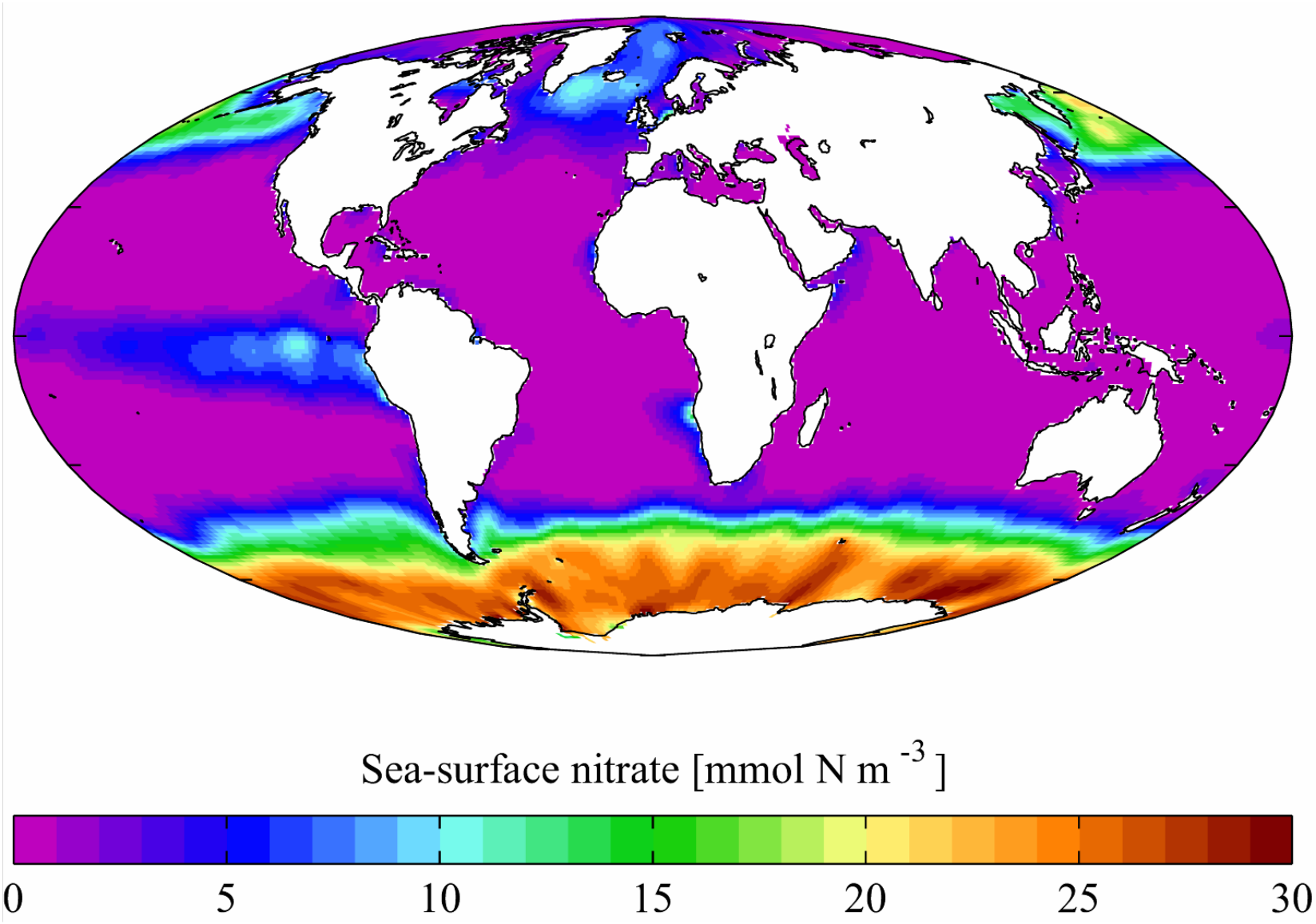
NUTRIENTS


TER MASTER TEST KIT
RM000725-00-1109
pH
6.0
6.4
6.6
6.8
7.0
7.2
7.6
7.4
7.8
8.0
8.2
8.4
8.8
AMMONIA
(NH3/NH4+)
0 ppm
0.25 ppm
0.50 ppm
1.0 ppm
2.0 ppm
4.0 ppm
NITRITE
(NO2−)
0 ppm
0.25 ppm
0.50 ppm
1.0 ppm
2.0 ppm
5.0 ppm
NITRATE
(NO3−)
0 ppm
5.0 ppm
10 ppm
20 ppm
40 ppm
80 ppm

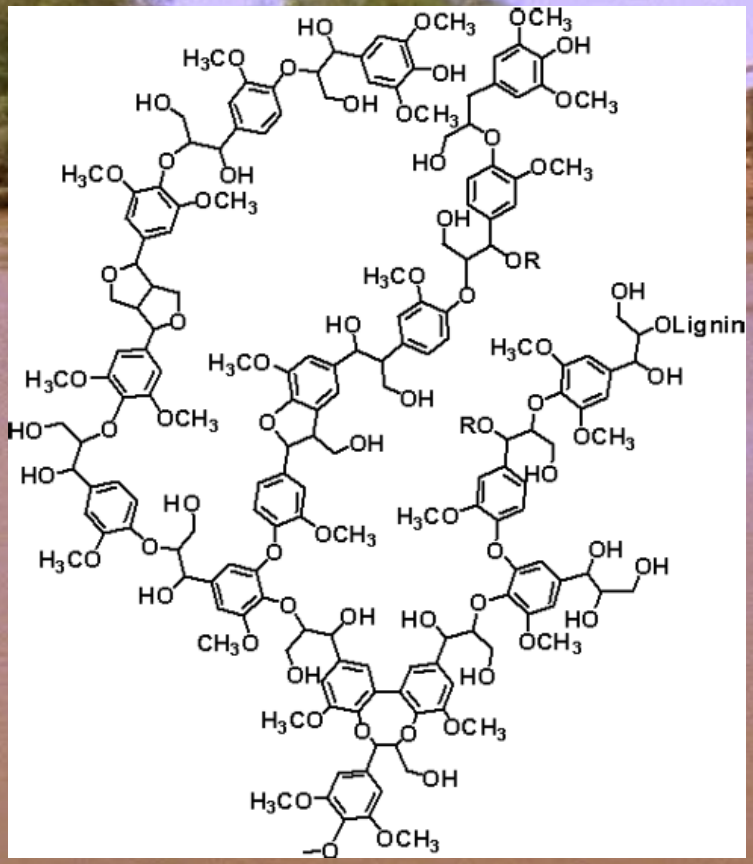
NUTRIENTS (nitrate)



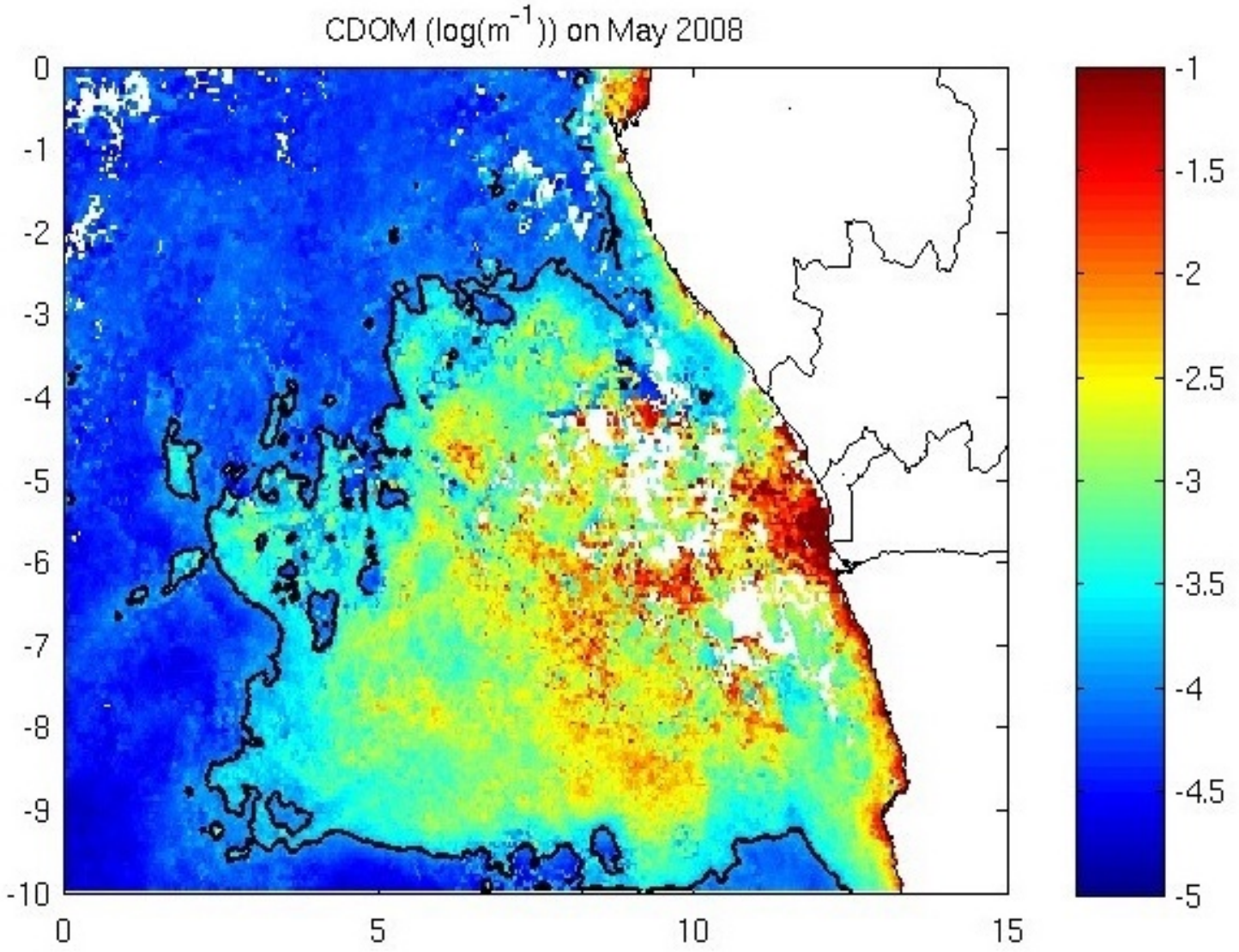
NUTRIENTS (nitrate)



LAND PLANTS

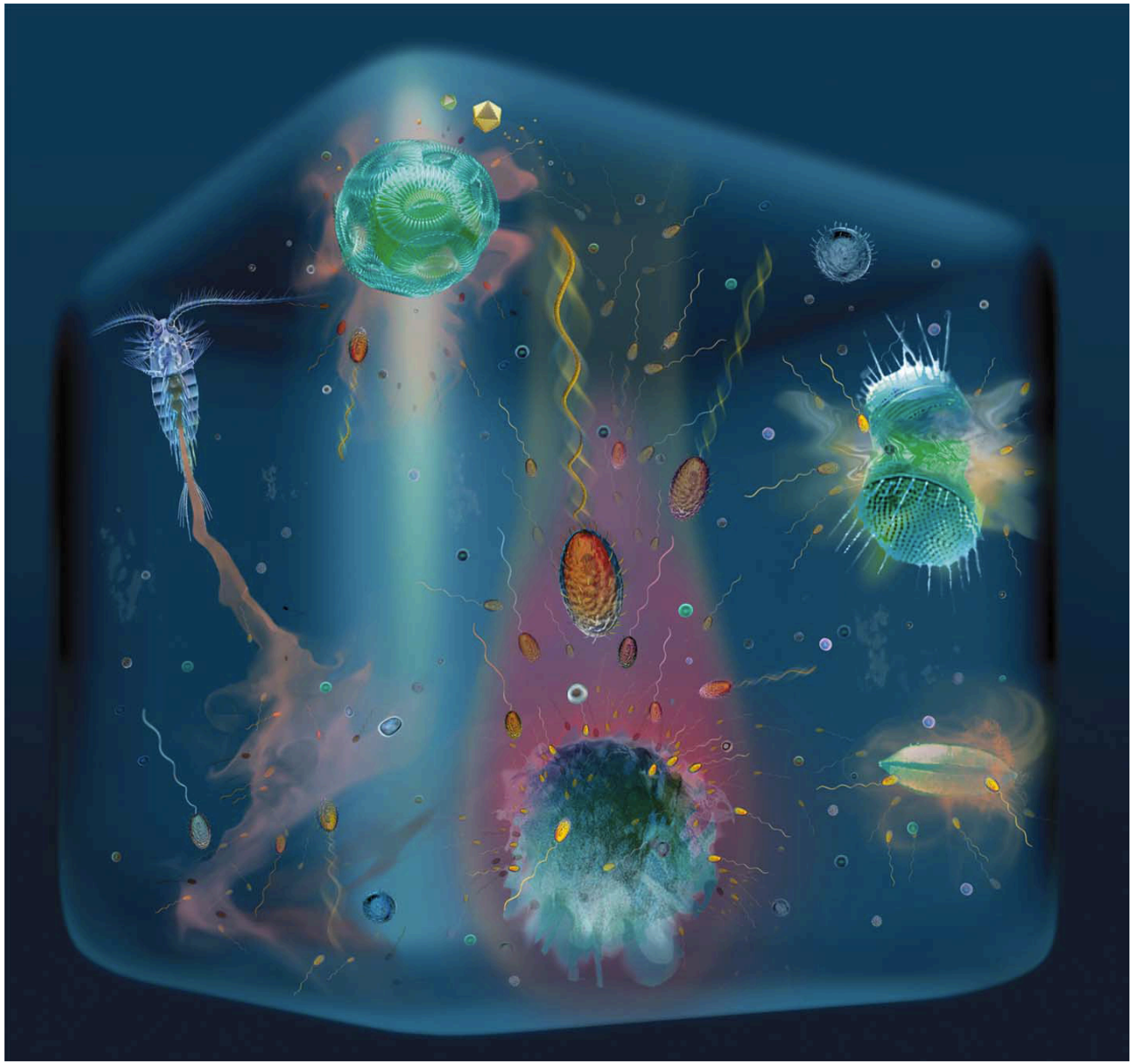


LAND PLANTS



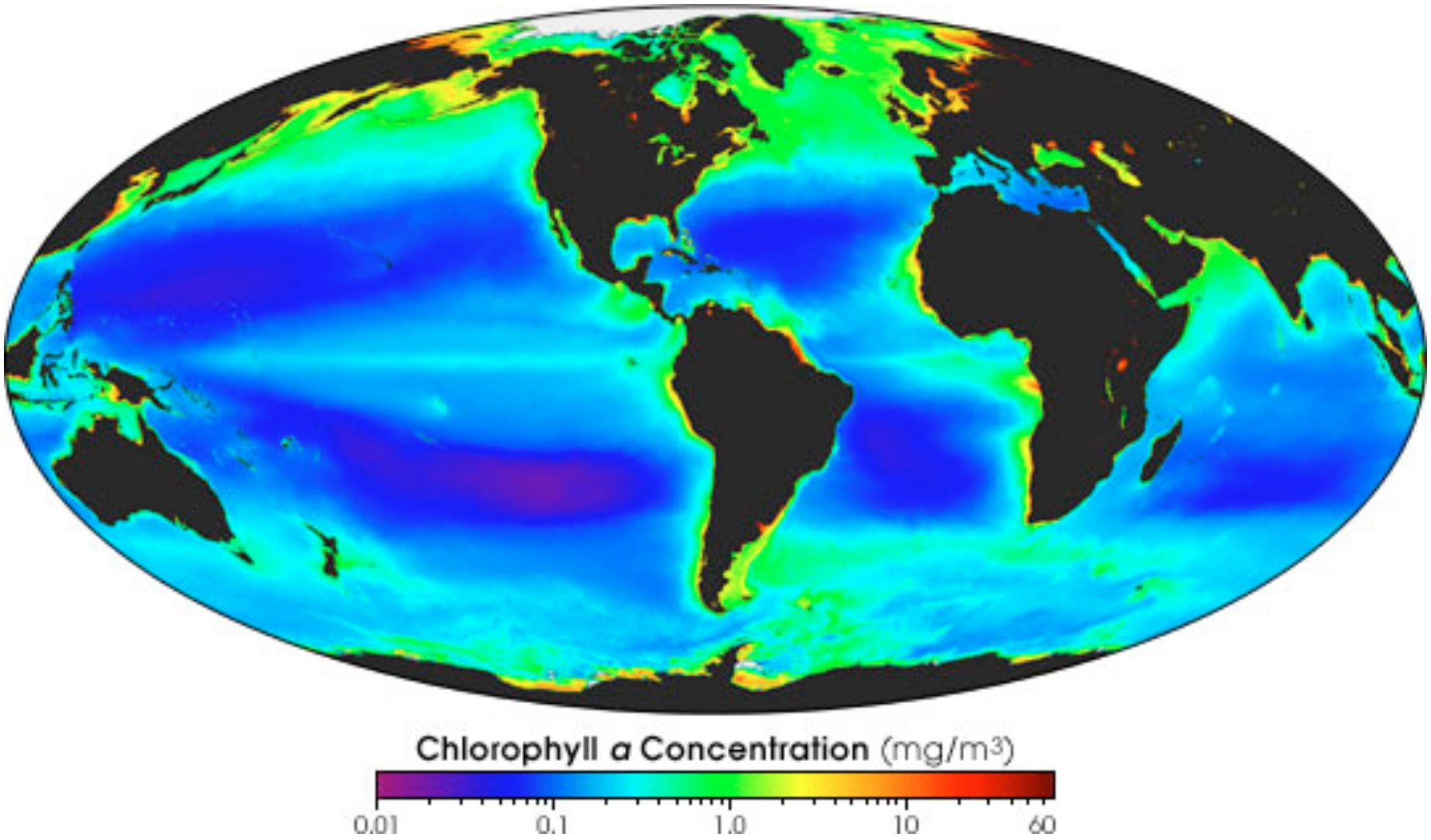
Congo River

OCEAN PLANTS

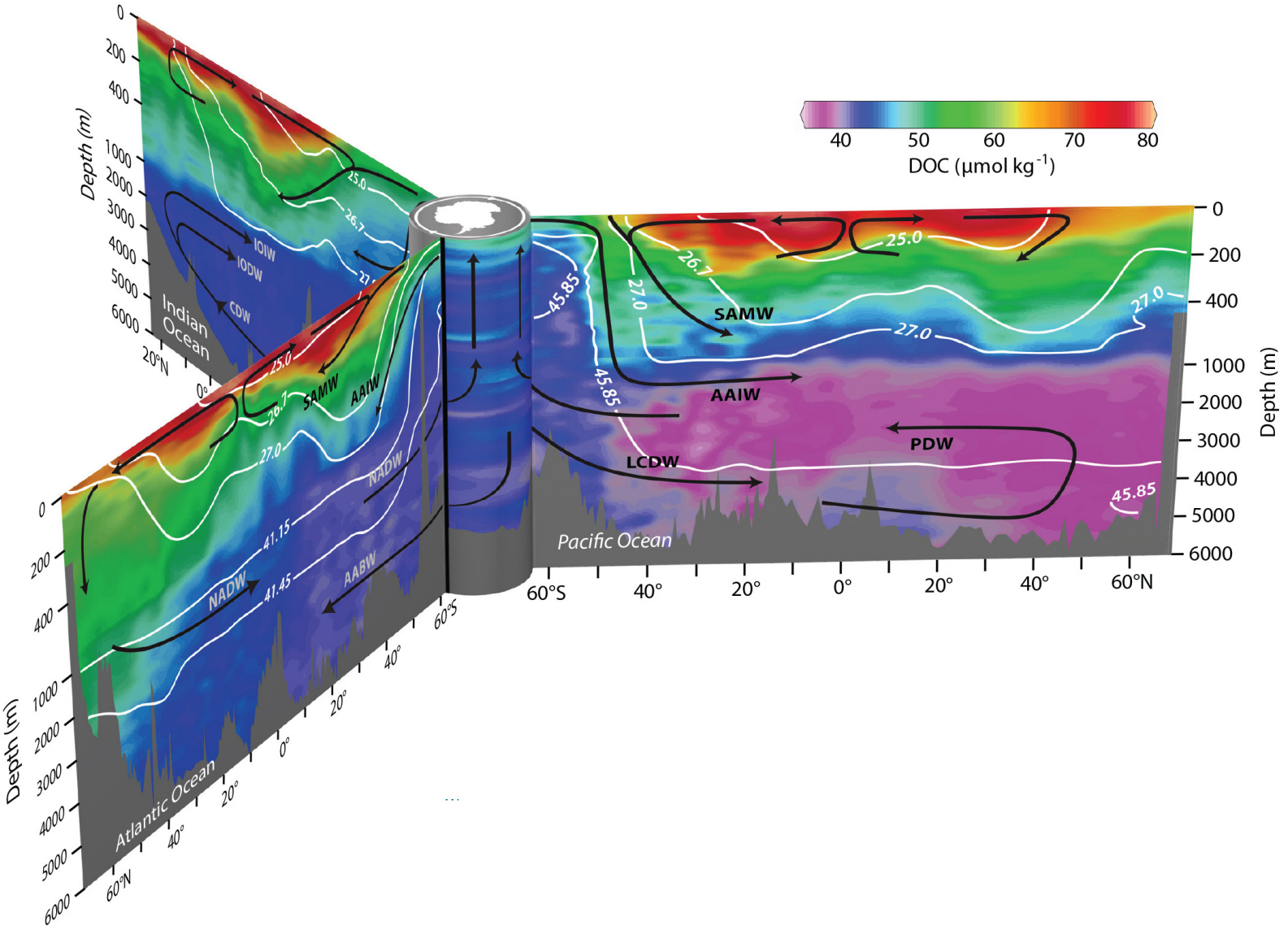


Roman Stocker, 2012 Science

OCEAN PLANTS

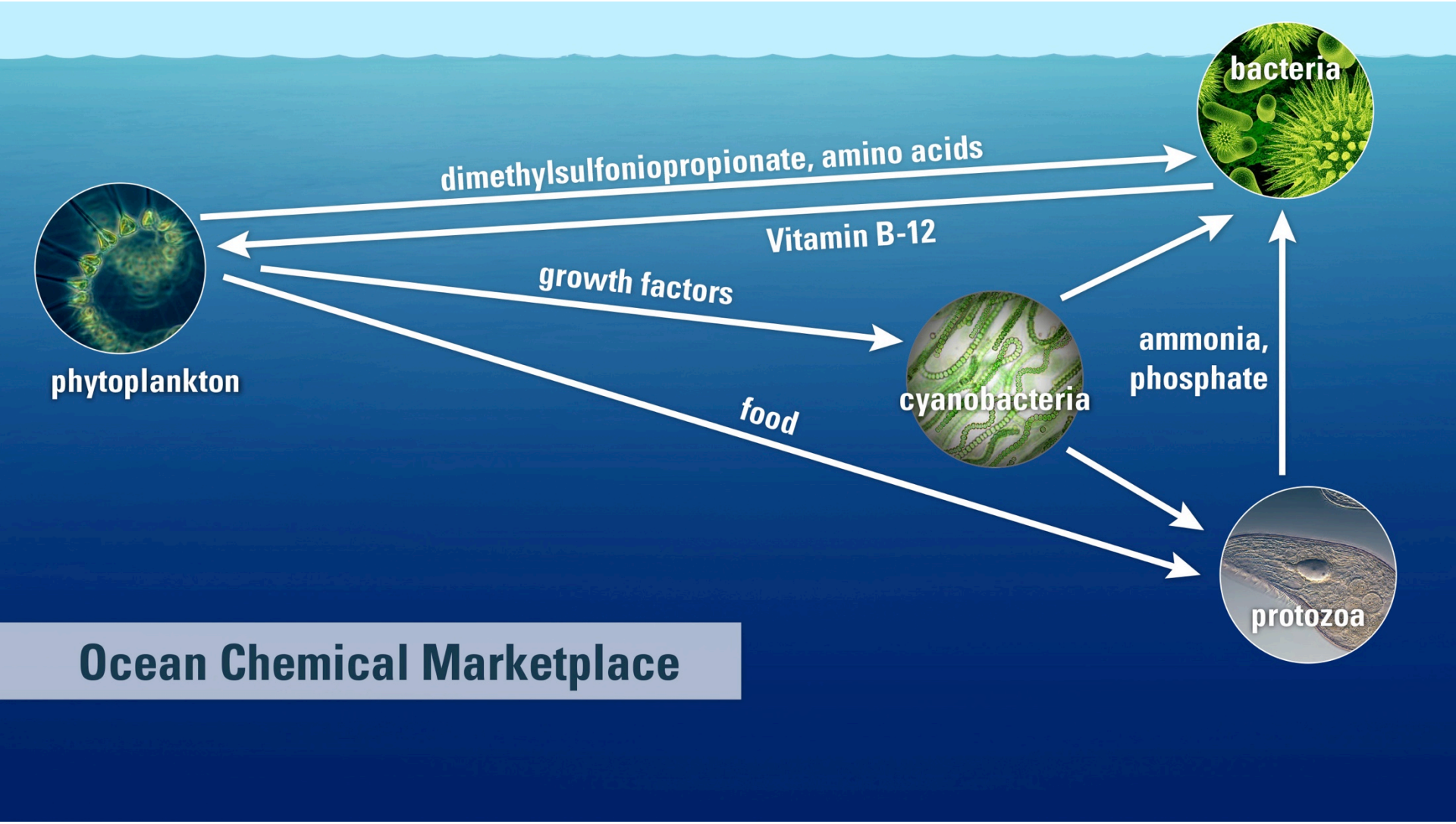


OCEAN PLANTS (dissolved impact)

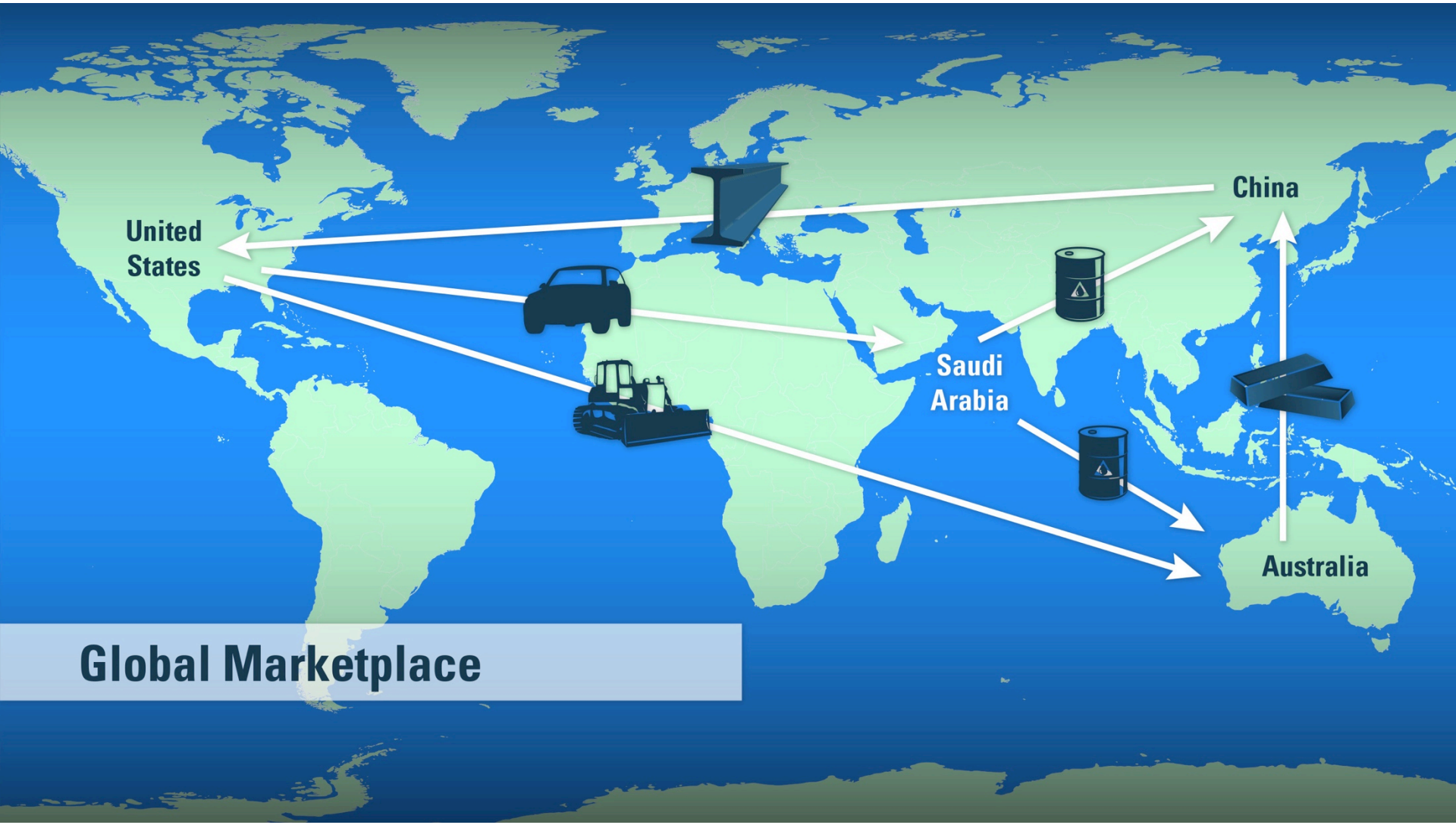


Dennis Hansell, Univ of Miami

OCEAN PLANTS (exchange!)



OCEAN PLANTS (exchange!)

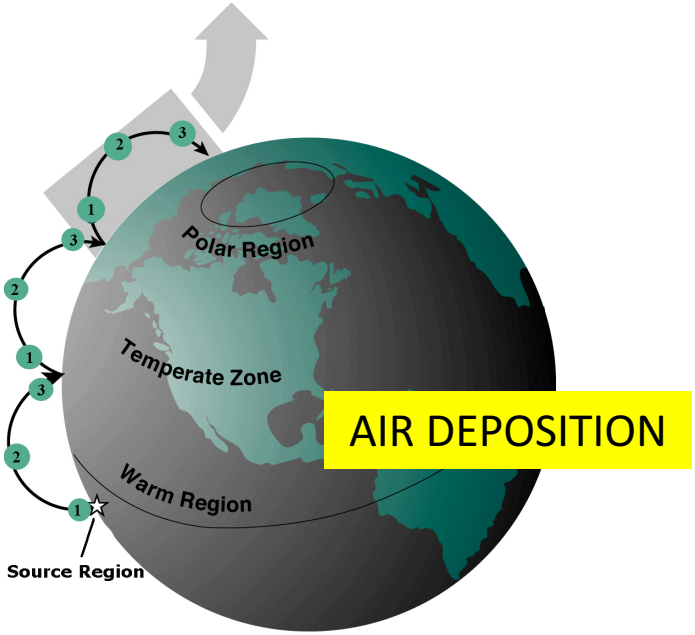


POLLUTION

CONTAMINATED RUNOFF

OIL SPILLS

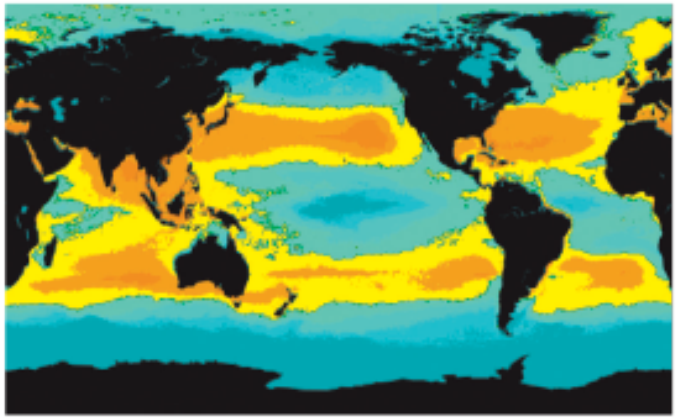
PLASTICS



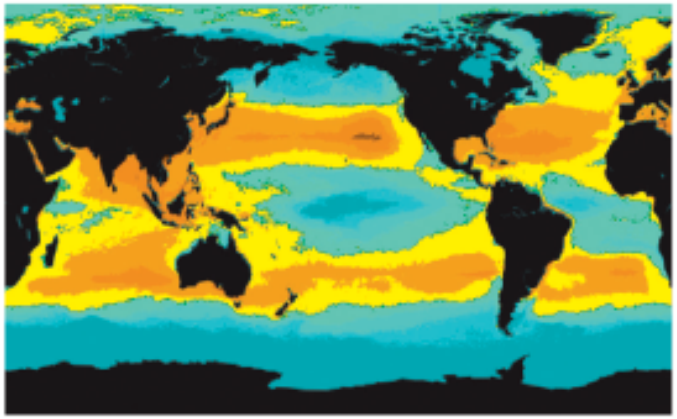
AIR DEPOSITION

POLLUTION

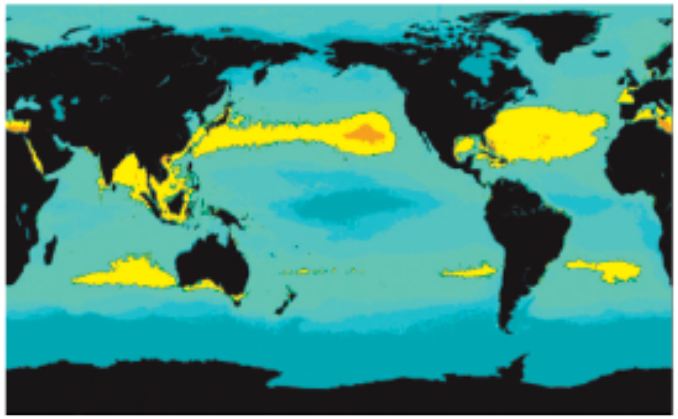
0.33–1.00 mm



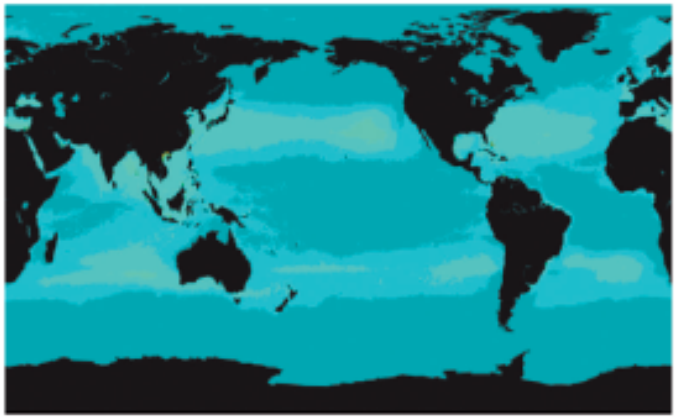
1.01–4.75 mm



4.76–200 mm



>200 mm



Plastic pieces per km²

1,000,000

100,000

10,000

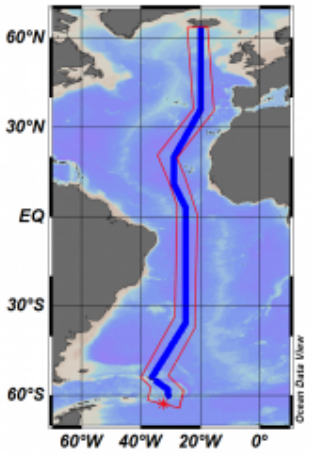
1,000

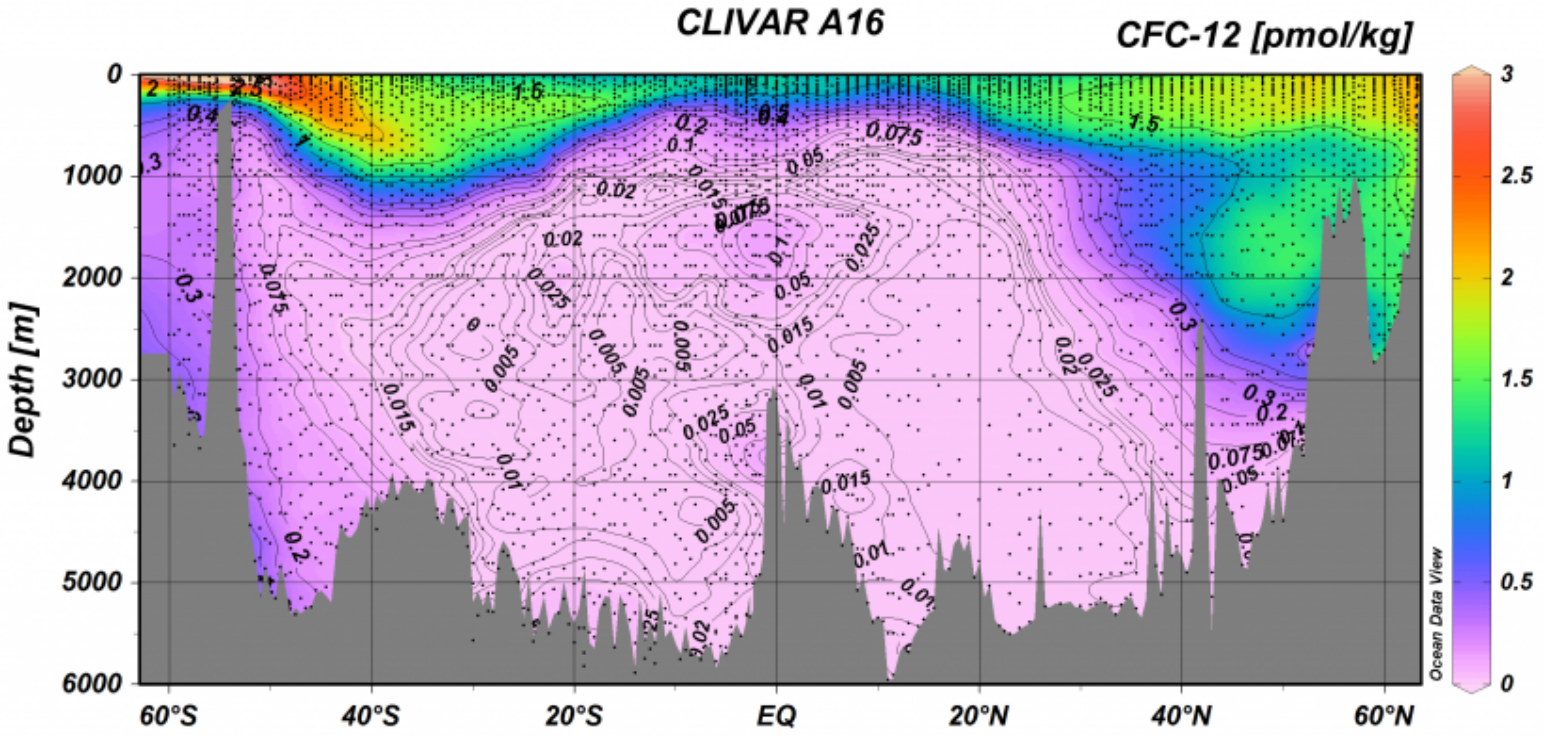
100

10

1

POLLUTION


60°N
30°N
EQ
30°S
60°S
60°W
40°W
20°W
0°
Ocean Data View


CLIVAR A16
CFC-12 [pmol/kg]
Depth [m]
0
1000
2000
3000
4000
5000
6000
60°S
40°S
20°S
EQ
20°N
40°N
60°N
3
2.5
2
1.5
1
0.5
0
Ocean Data View

Chemical Oceanography can solve problems

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, mostly sunny, high 72. Tonight, increasing clouds, a shower or thunderstorm, low 59. Tomorrow, windy, a shower or thunderstorm, high 73. Details, Page B16.

VOL. CLIX . . No. 55,033 © 2010 The New York Times NEW YORK, FRIDAY, MAY 7, 2010 $2.00

TORIES HEADING FOR BIG GAINS AS LABOUR SAGS

BRITISH ELECTION LEAD

But Party May of Majority, L Prospects Ur

By JOHN F. BU

LONDON — After most passionately co tions in decades, th tive Party was hea big, though not nece sive, gains in Britain day.

Incomplete result House of Commons cics across the countr a strong performanc day by the opposition by David Cameron, size of the increase servative vote rai about the party's ab the majority needed t regaining power afte Labour control.

What seemed sure Conservatives woul

DOW FALLS 1,000, THEN REBOUNDS, SHAKING MARKET

DEBT WORRIES EXPAND

A Stee Is A te

By

A bad turned i fying m tory on 1,000-po the pani It lasted Wall Str investor come to pened markets At lea peared ror, per routed tion's ec tracks m ors do t tionable But th

was prepared. Page A18.

OIL SPILL IN THE GULF DAY 54

BIG TEN CONFERENCE

NEBRASKA JOINS BIG TEN IN CONFERENCE SHAKEUP

OTHER TEAMS REPORTED IN MASS EXODUS FROM BIG 12/16

PRESS-REGISTER

SATURDAY

SERVING SOUTH ALABAMA SINCE

Saving the birds

Theodore center helps avian oil victims recover/ 2A

AJM ACTIVITIES STILL ON DESPITE OIL SPILL/5A

OIL ANSWERS: ABOUT THE DEEPWATER HORIZON/5A

WAVES OF OIL

BLACK TIDE INTRUDES ALONG ALABAMA BEACHES

WORLD CUP U.S. takes on England for the first time since 1950. SPORTS 1D

SUPER REGIONALS Florida tops Miami in Game 1. SPORTS 1D

PENSACOLA News Journal

SATURDAY, JUNE 12, 2010

2 MILES WIDE, 6 MILES AWAY

Large and colorful oil plumes can be seen floating near the surface of the Gulf about six miles south of Pensacola Pass on Friday afternoon.

Officials block Pensacola Pass

Travis Griggs

Beach closures counties' call

Jamie Page

OIL SPILL ON RAMPING UP IN THE GULF

INSIDE

BIRD'S-EYE VIEW

ONLINE: PNJ.COM

Heat sends swimmers looking for oil-free spot

Louis Cooper

INSIDE // 7A

Quick Read

HABITAT

In Local

In Business

In the Nation

INSIDE

MAY 17, 2010

Special Report: The Times Square Bomber

Faisal Shahzad's double life + Why Pakistan is terror's new source

TIME

Big Spill

the Gulf means for the future of energy

BY BRYAN WALSH

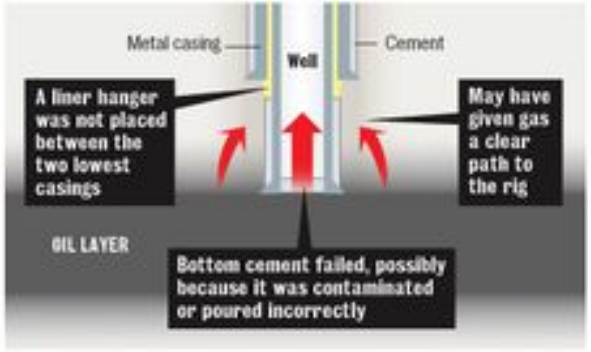
www.time.com

DEEPWATER HORIZON OIL SPILL - 2010

SIX STEPS THAT DOOMED THE RIG

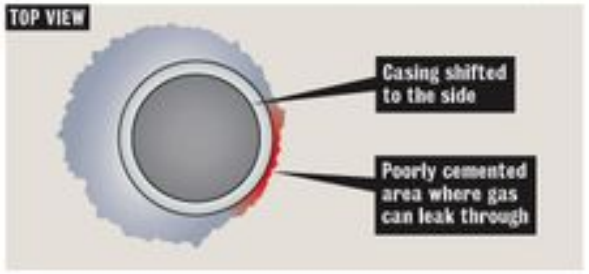
1 FEWER BARRIERS TO GAS FLOW AT WELL BOTTOM

BP used a single, long string of casing in the middle of the drill hole, one designed for later use in extracting oil.



2 FEWER CENTRALIZERS TO KEEP CEMENT EVEN

BP used six of the devices for keeping tubes centered, ignoring models calling for 21. It's important to have the casings centered in the well hole for the cement pumped in around it to set evenly.



3 NO BOND LOG TO TEST CEMENT INTEGRITY

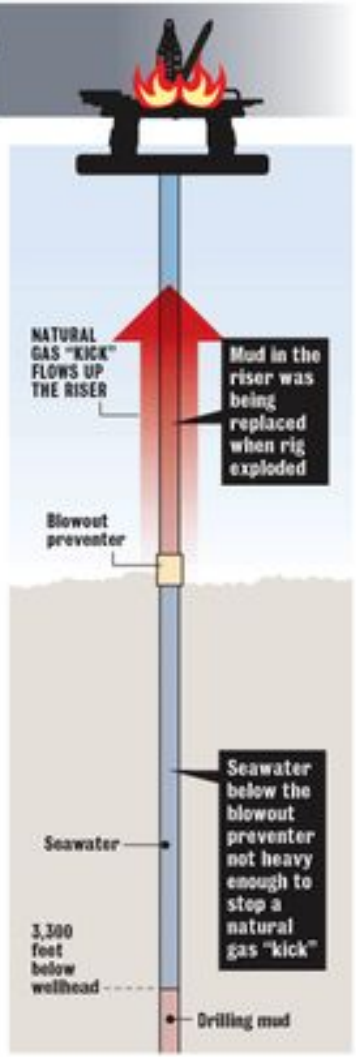
BP had hired contractor Schlumberger to run tests on the newly cemented well. But BP sent Schlumberger's crew home on a helicopter without having it run the test, called a cement bond log.

4 PRESSURE TEST MISINTERPRETED

Rig workers reported confusion over the negative test, which measures upward pressure from the shut-in well. It is a key test of whether the well is stable.

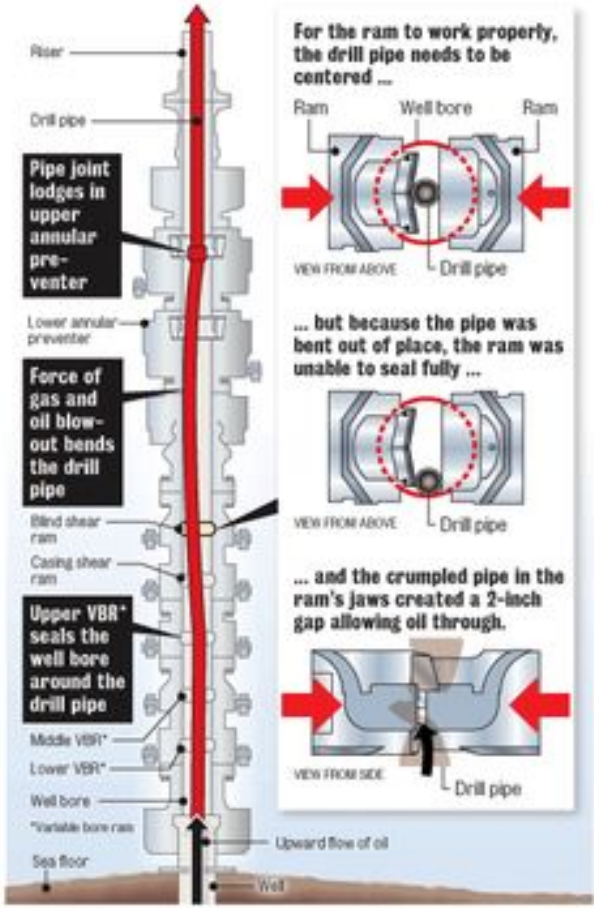
5 MUD BARRIER REMOVED EARLY

BP decided to take heavy drilling mud out of the system, to 3,000 feet below the normal point, and earlier than usual. The barrier wasn't there to stem the gas kick that destroyed the rig. The mud is used to keep any upward pressure under control.



6 BLOWOUT PREVENTER FAILED

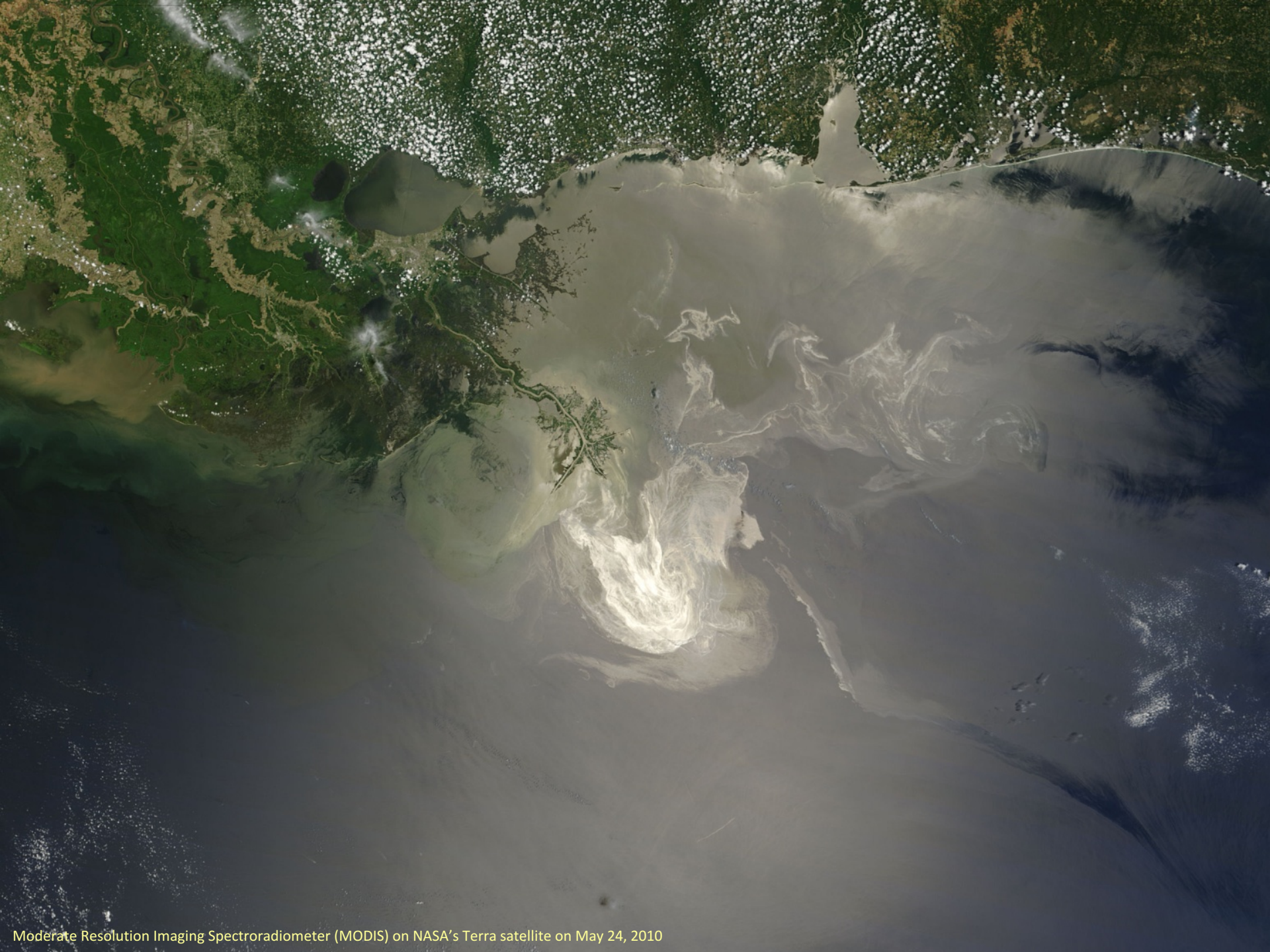
A stuck drill pipe and intense pressures from the blowout cause a section of pipe to bend and get lodged inside the blowout preventer. The blind shear rams cannot cut the bent pipe completely and fail to seal the well.



Source: Det Norske Veritas, Halliburton, BP e-mails, testimony, Times-Picayune investigation

NOLA.com | The Times-Picayune

DEEPWATER HORIZON OIL SPILL - 2010

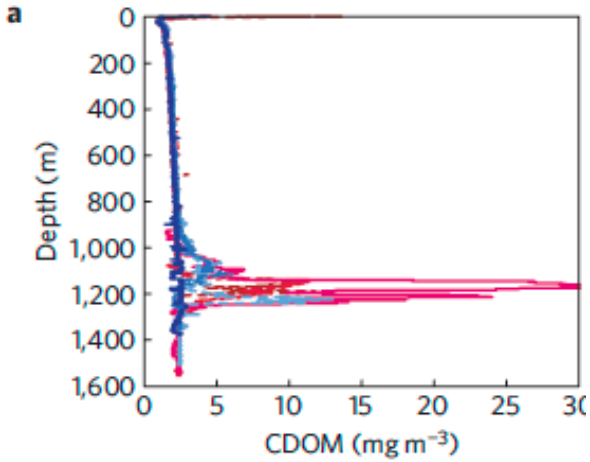


Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on May 24, 2010

DEEPWATER HORIZON OIL SPILL - 2010

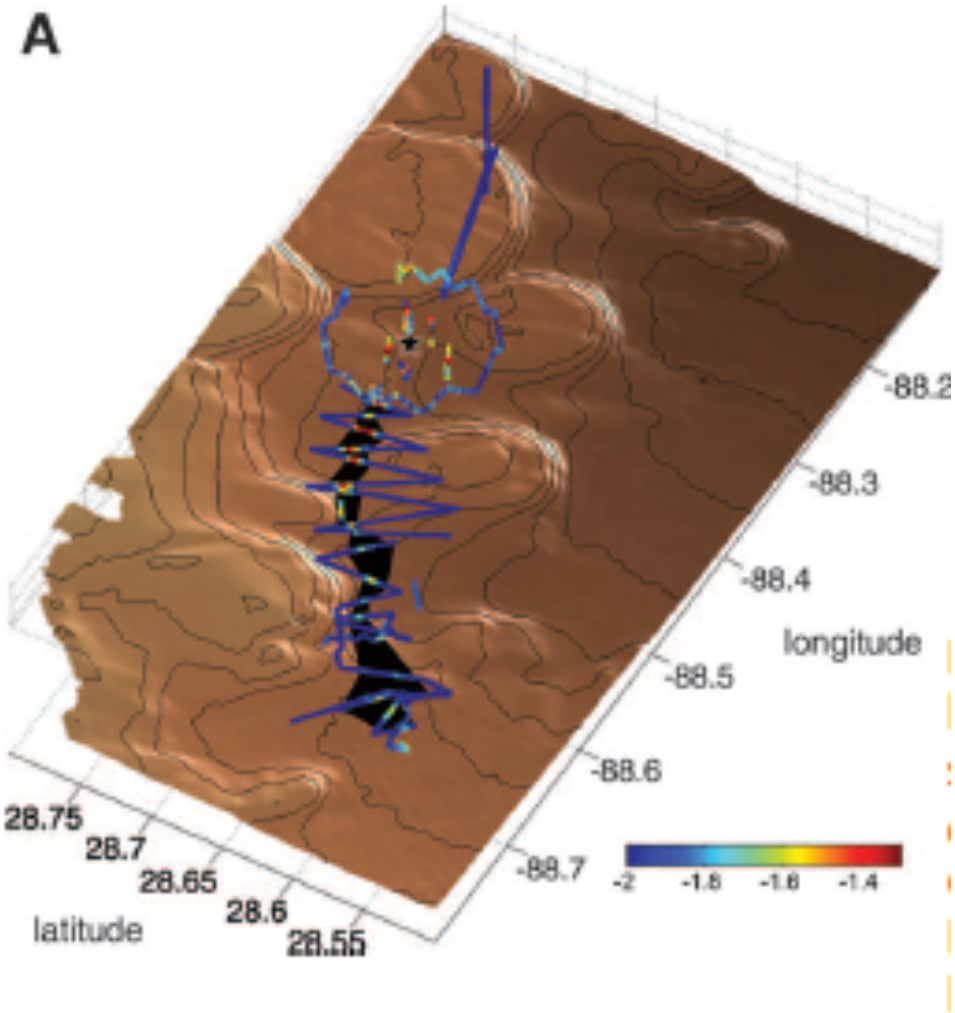
Near the wellhead… Evidence of an underwater plume

CDOM



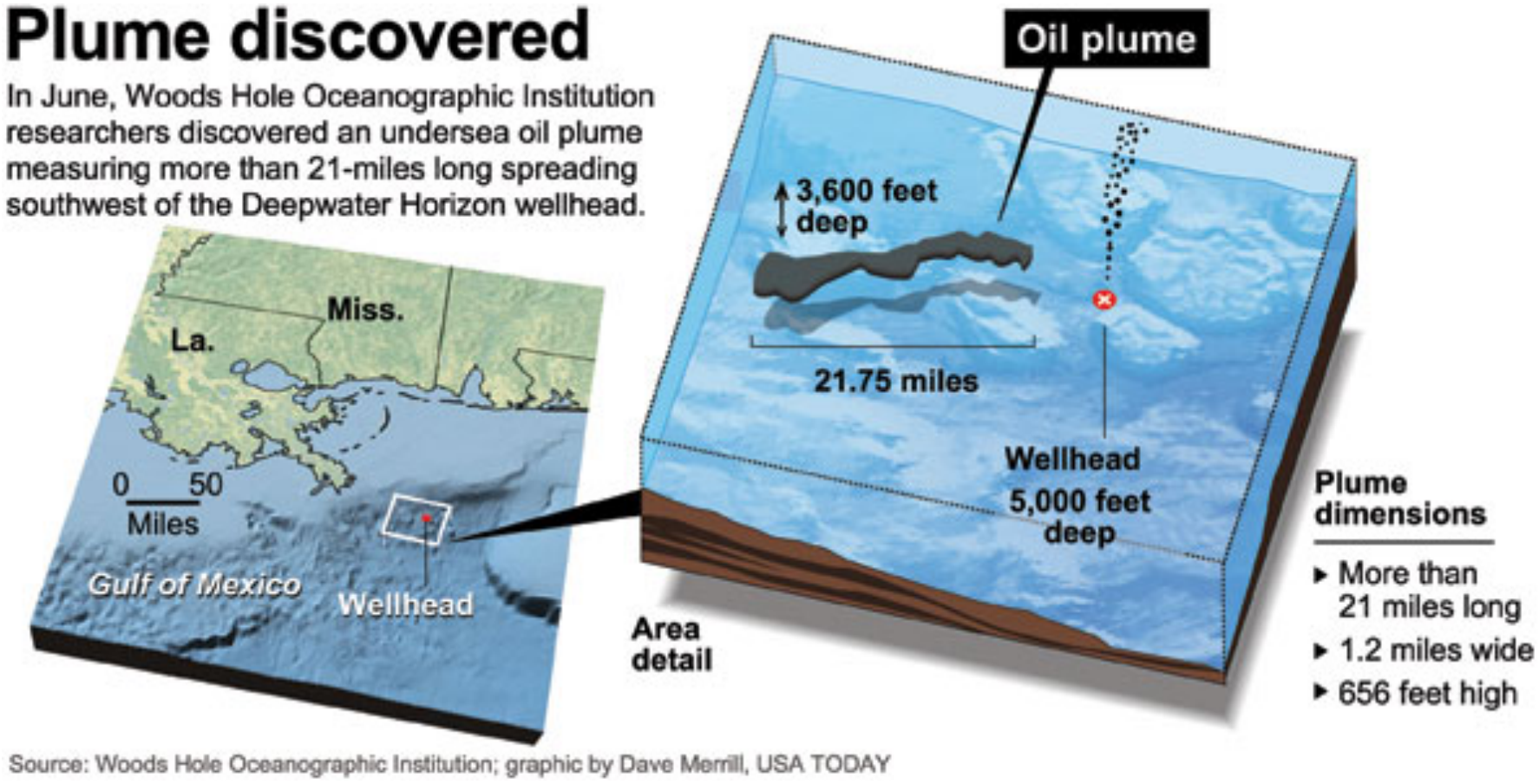
Mandy Joye, Univ of Georgia

DEEPWATER HORIZON OIL SPILL - 2010



Rich Camilli, WHOI

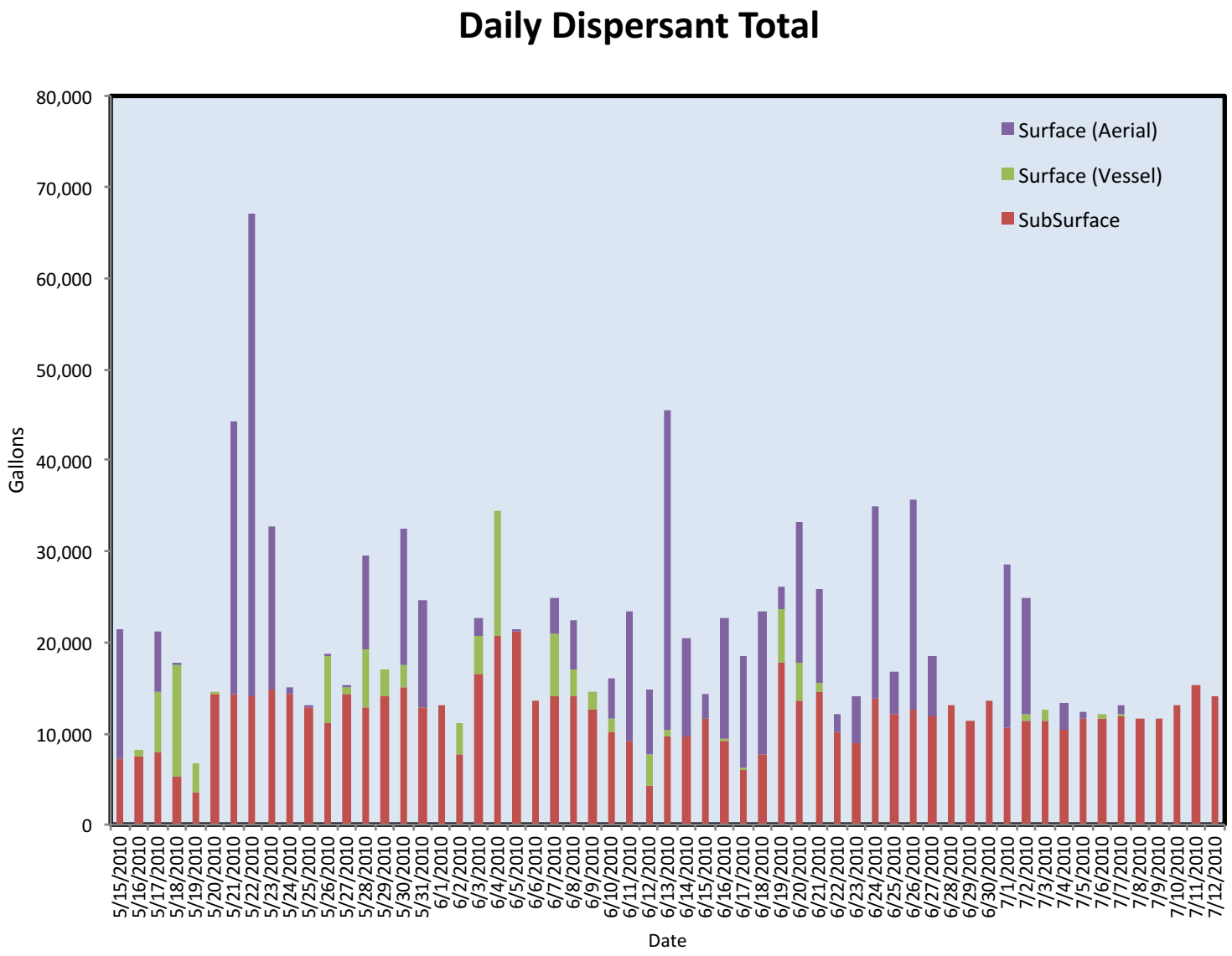
DEEPWATER HORIZON OIL SPILL - 2010



Rich Camilli, WHOI

DEEPWATER HORIZON OIL SPILL - 2010

DEEPWATER HORIZON OIL SPILL - 2010

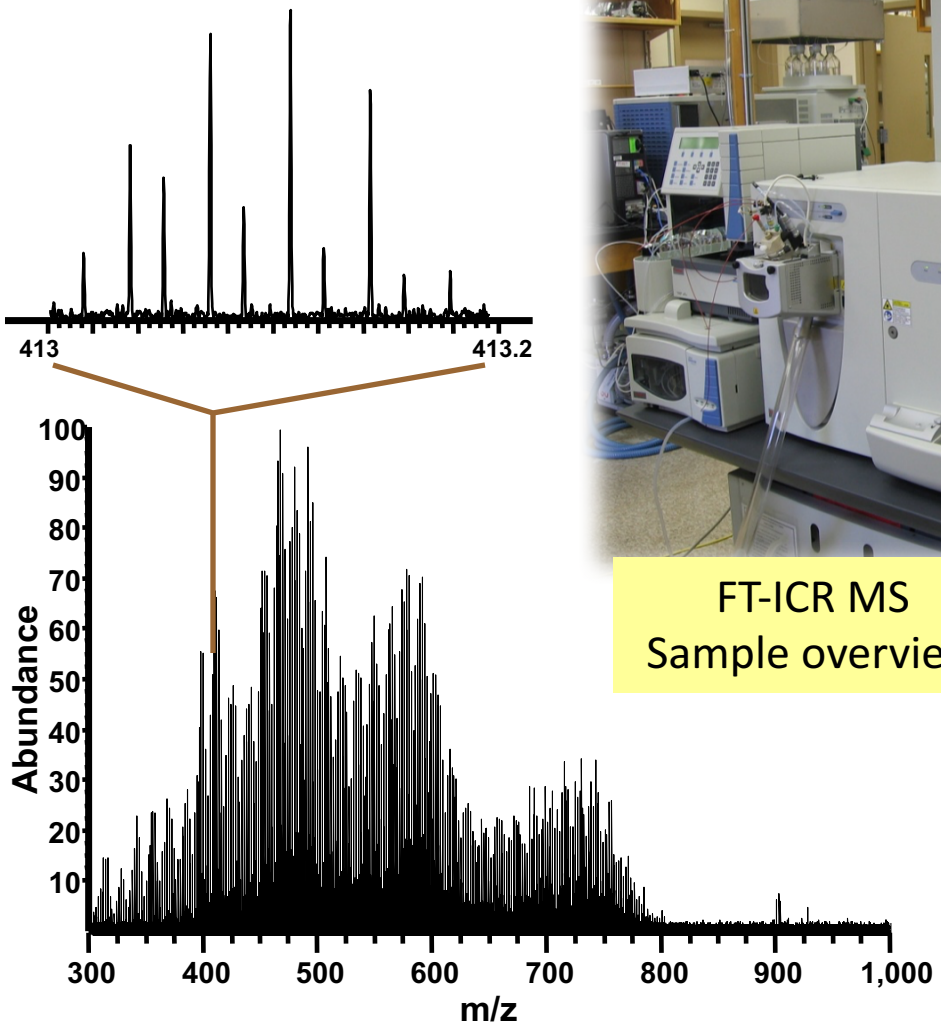


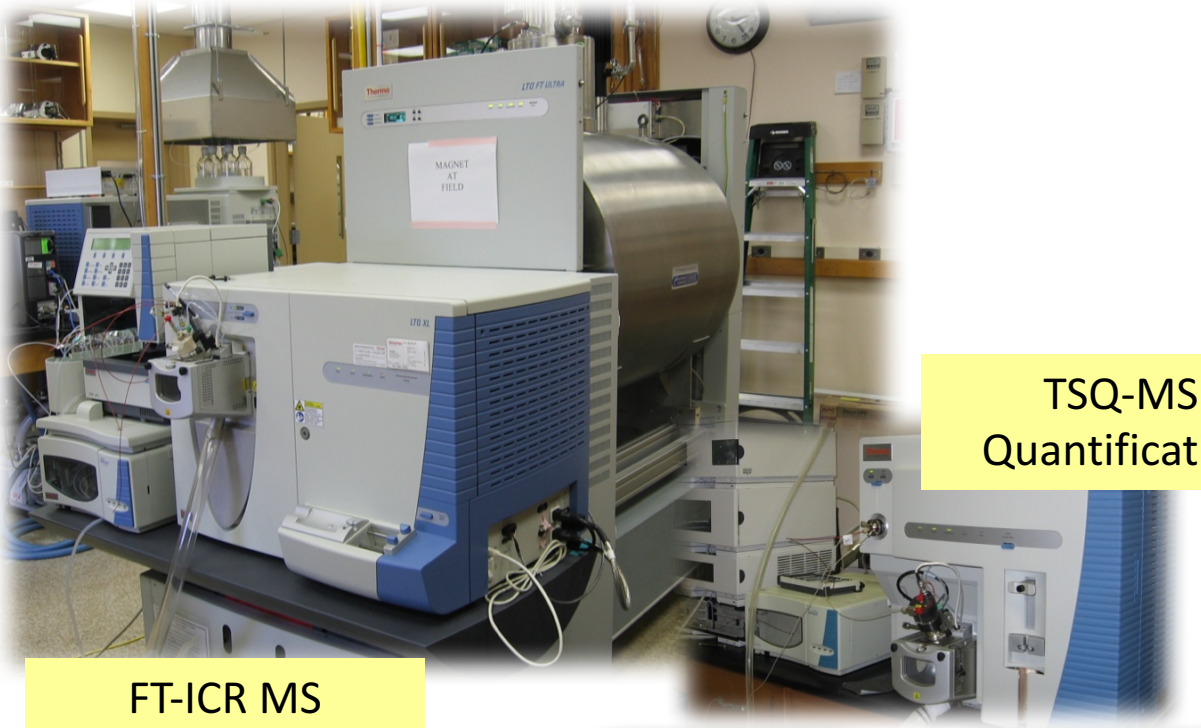
DEEPWATER HORIZON OIL SPILL - 2010

Photo by David Valentine

1 tanker truck = 8000 gallons; daily total = 23,000 gal; ~3 tanker trucks per day; ~300 total!!

MASS SPECTROMETRY TO FIND TRACE MOLECULES



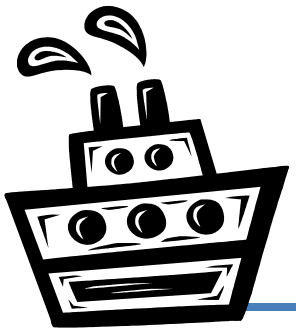


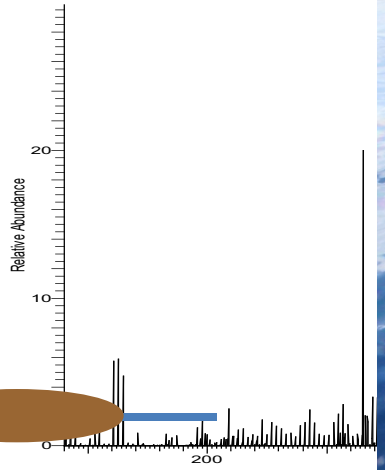
FT-ICR MS
Sample overview

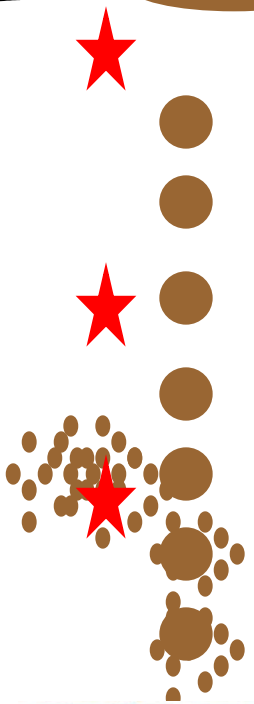
TSQ-MS
Quantification

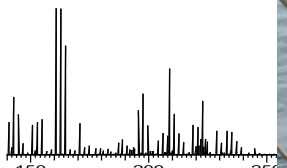
Dr. Melissa Soule

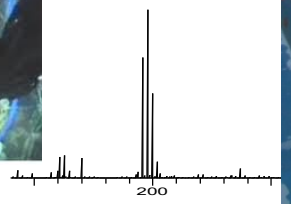
Dr. Krista Longnecker

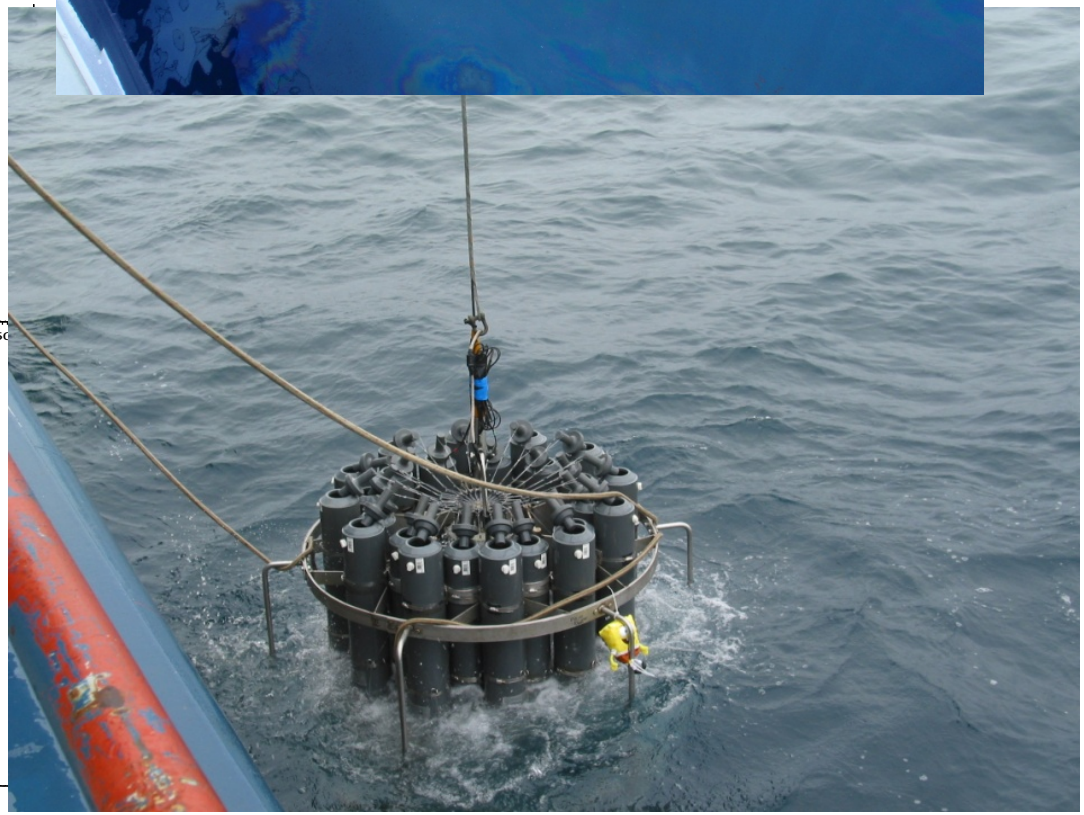


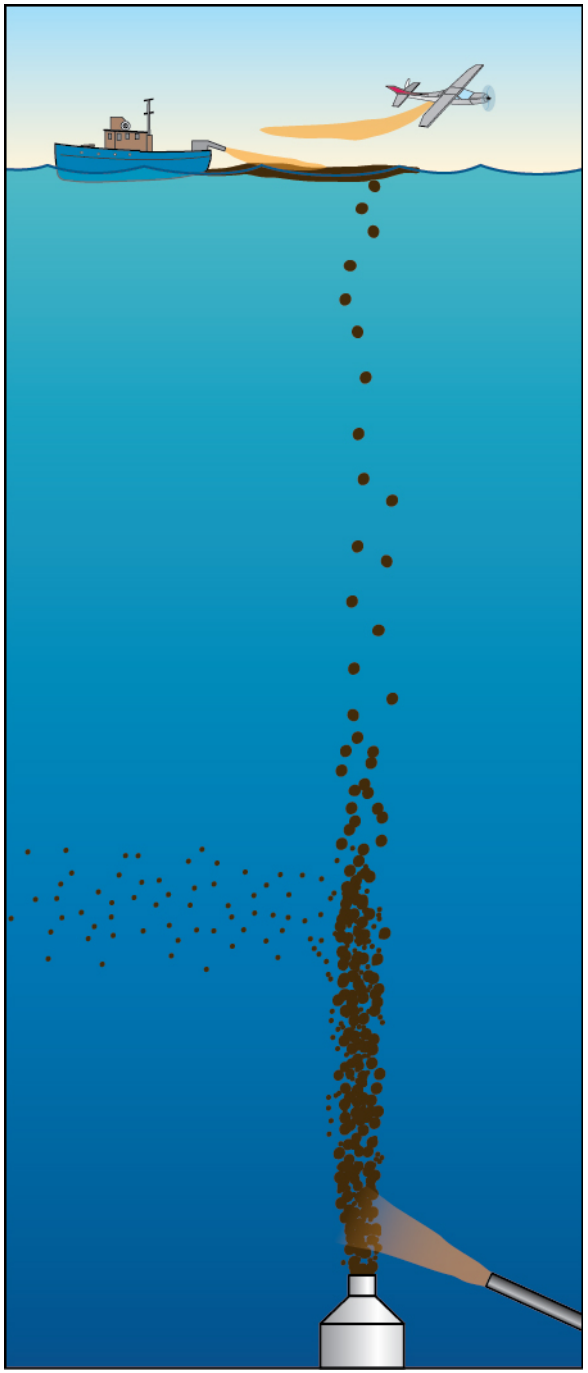

Relative Abundance
20
10
0
200

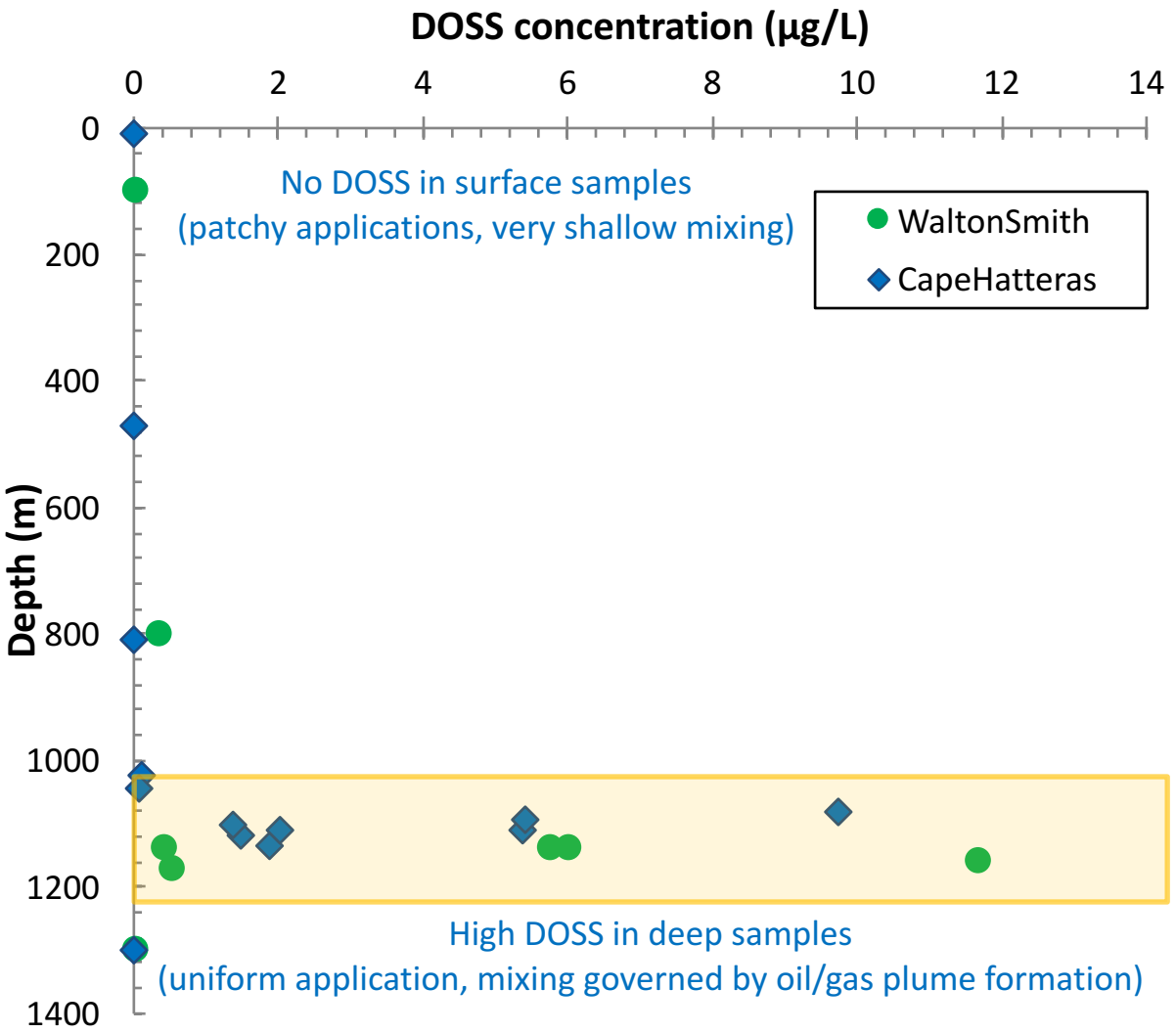



150
200
250


200

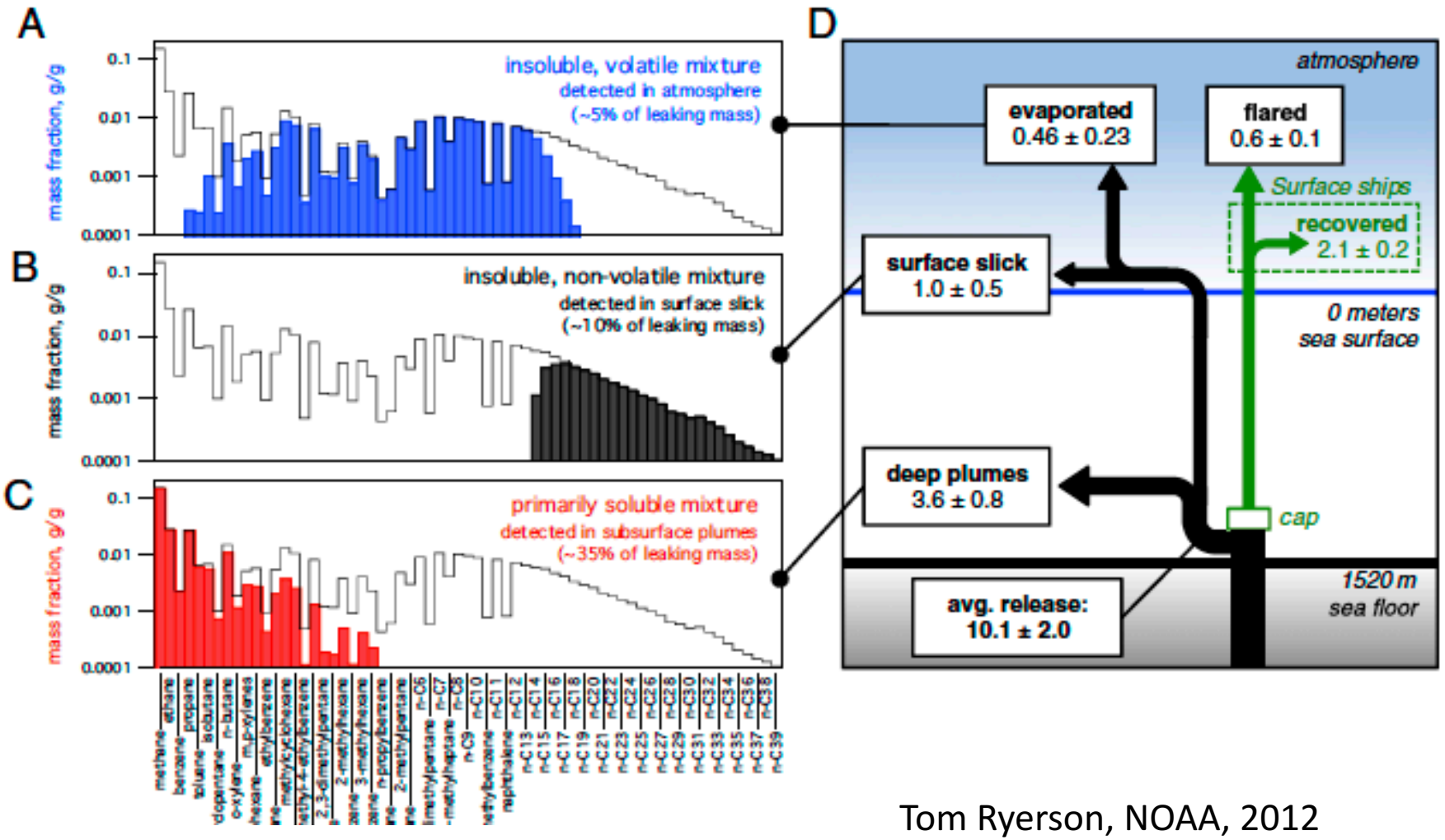






Kujawinski, et al. 2011. *Env. Science & Tech.*

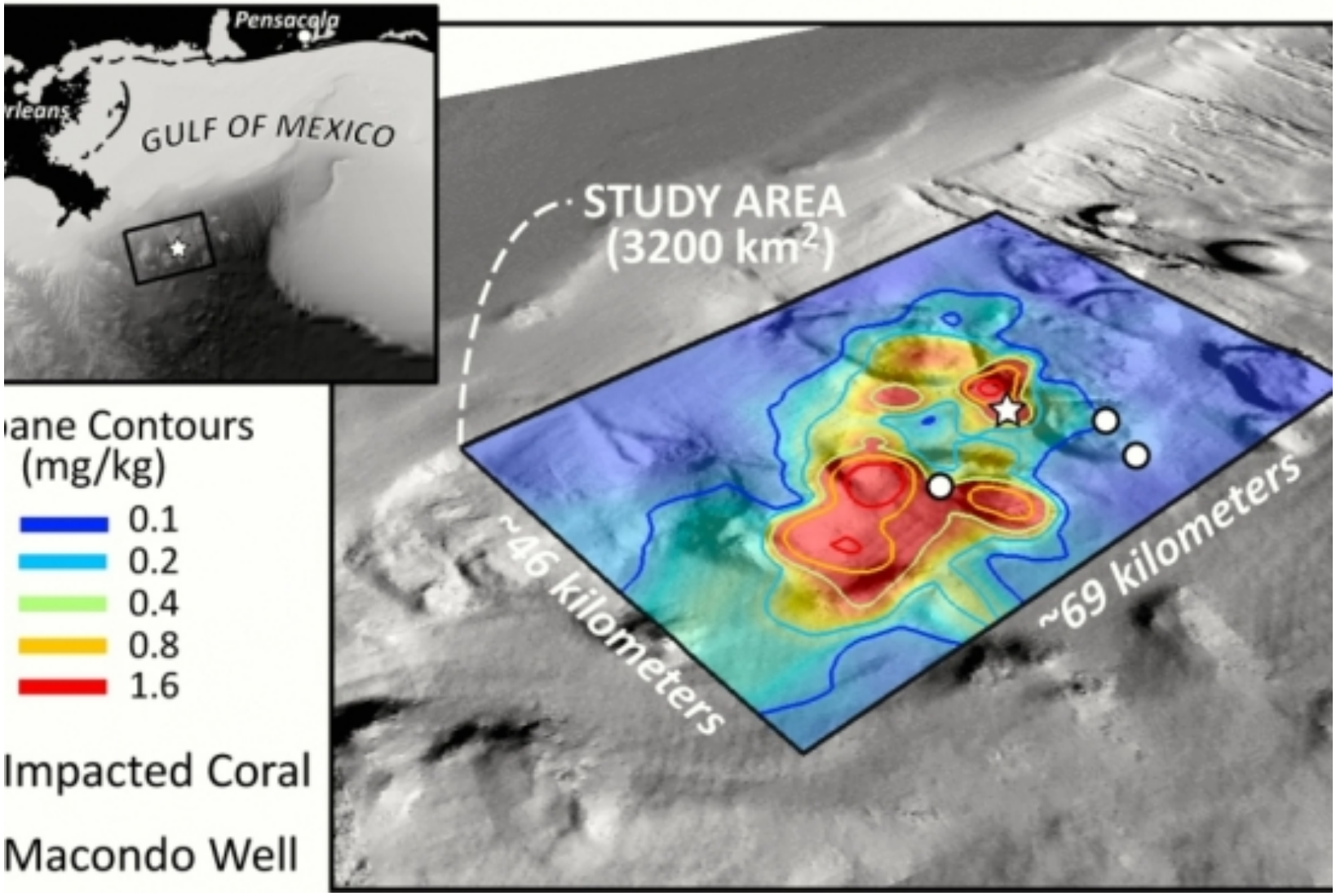
DEEPWATER HORIZON OIL SPILL - 2010



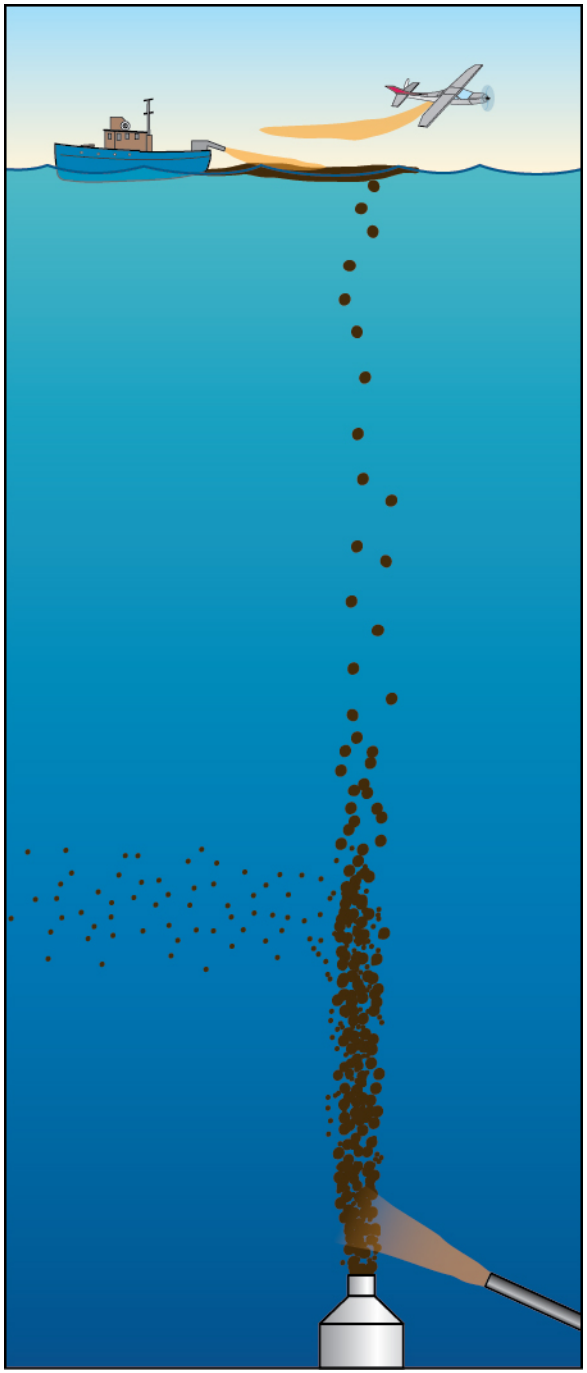
Tom Ryerson, NOAA, 2012

DEEPWATER HORIZON OIL SPILL - 2010

DEEPWATER HORIZON OIL SPILL - 2010



OCEANOGRAPHY = A COMMUNITY OF RESEARCHERS



Air measurements
Surface samplers
Mass spectrometry

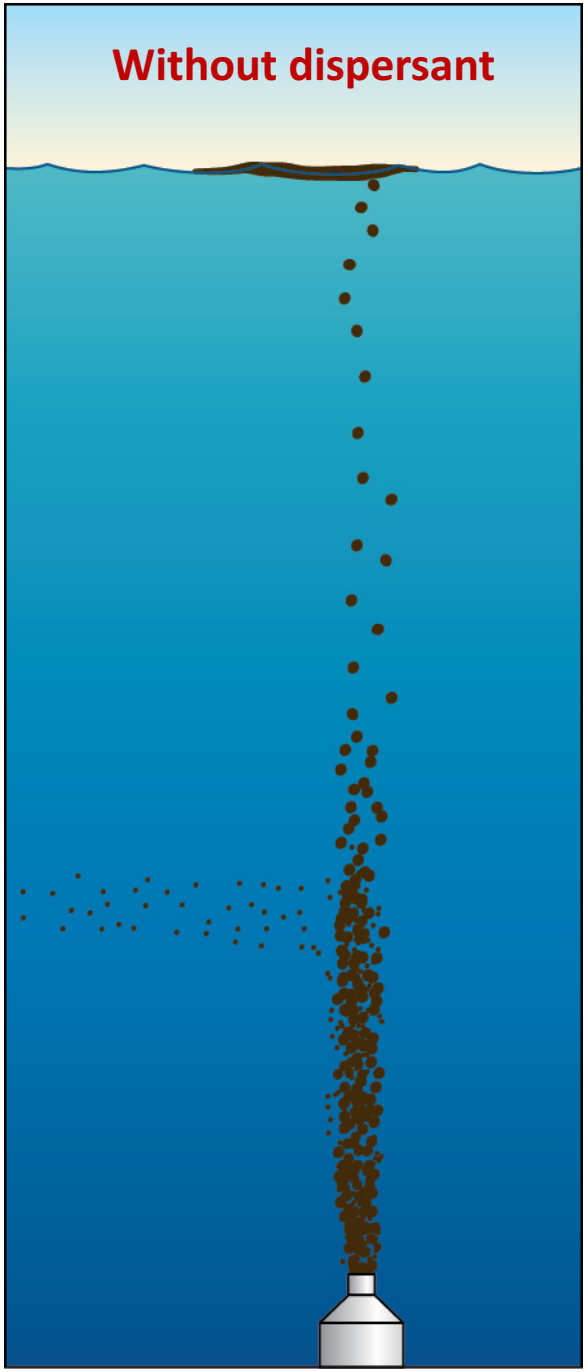
CDOM, oxygen sensors
Methane measurements
Mass spectrometry for oil and dispersants

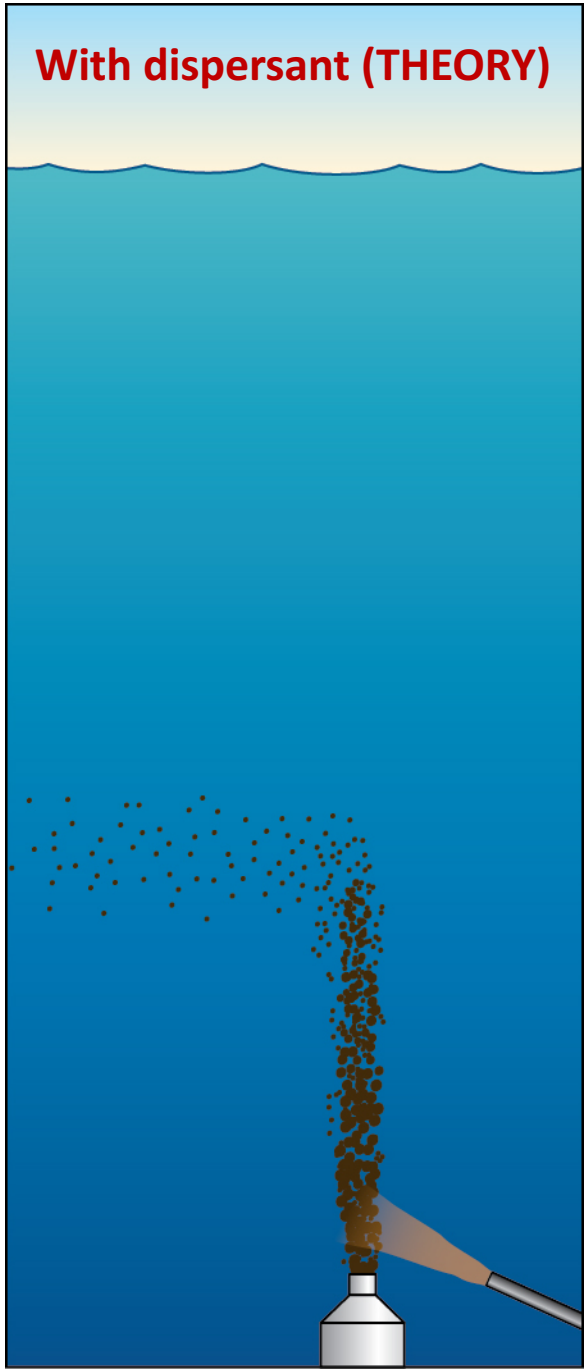
Deep-sea sampling
Modelling of flow and bubbles
Sediment analysis

QUESTIONS?

Photos by Rich Camilli, WHOI

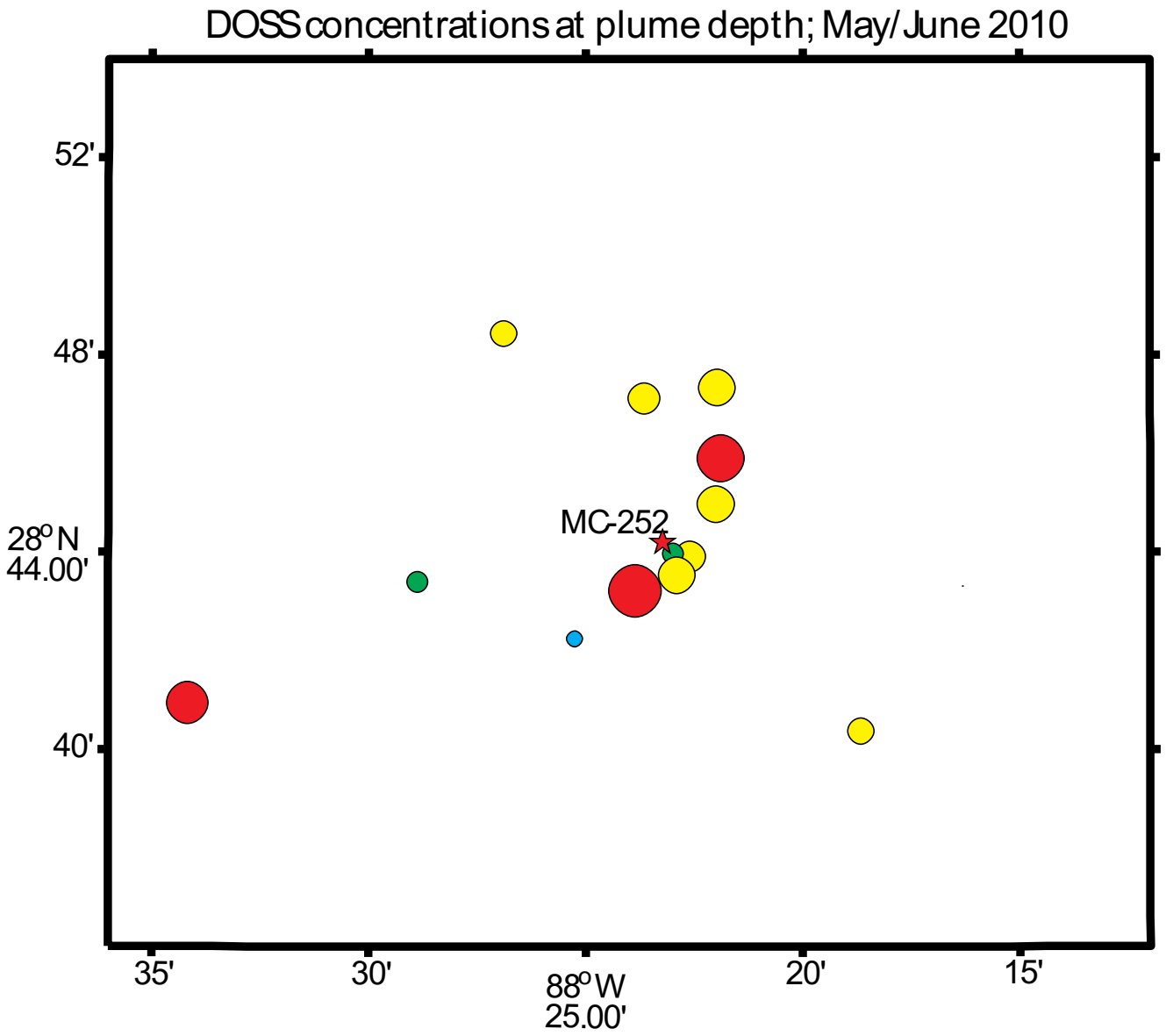
1. **What is a dispersant and how does it work?**
   - A mixture of surfactants and solvents that break oil into small droplets
   - In theory, these small droplets make oil more available for biotic and abiotic weathering
2. **Why do we care if it is present?**
   - Toxicity of oil may be enhanced in presence of surfactant
   - Toxicity of dispersants has not been tested on deep-water fish





Graphics by J. Cook, WHOI

Spatial distribution of DOSS – ACTIVE FLOW



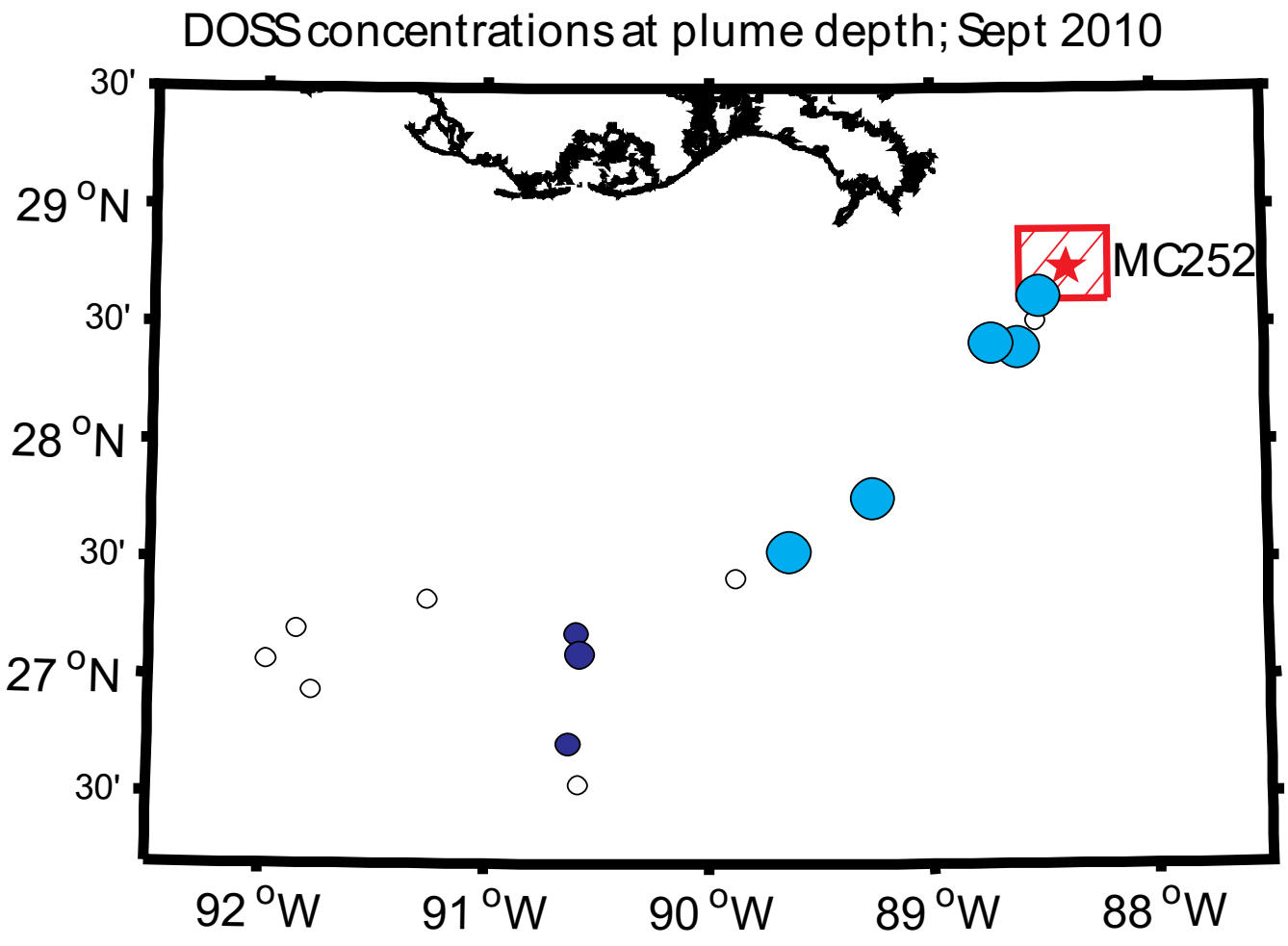
Color legend:
Red: > 9 µg/L
Yellow: 1-9 µg/L
Green: 0.1-1.0 µg/L
Cyan: 0.01-0.1 µg/L
Blue: <0.01 µg/L
White: below detection

Model assumptions:
Average DOSS rate:
4800 kg / day
No degradation
Lateral turbulent mixing

Conclusions:
DOSS is sequestered conservatively with deepwater oil & gas plume. No evidence of short-term degradation. Variable concentrations may be due to variable discharge rates at well-head.

Kujawinski, et al. 2011. *Env. Science & Tech.*

Spatial distribution of DOSS – NO FLOW



Color legend:
Red: > 9 µg/L
Yellow: 1-9 µg/L
Green: 0.1-1.0 µg/L
Cyan: 0.01-0.1 µg/L
Blue: <0.01 µg/L
White: below detection

Model assumptions:
Average DOSS rate:
4800 kg / day
No degradation
Lateral turbulent mixing

Conclusions:

DOSS is transported conservatively with deepwater oil & gas plume.
No evidence of long-term degradation.

Kujawinski, et al. 2011. *Env. Science & Tech.*