"....the blue heart of the planet"

"Next Generation Ocean Exploration: Why the Time-Domain is so Crucial"

John R. Delaney University of Washington Seattle, WA 98103 - jdelaney@uw.edu

9TH OCEAN EXPLORATION ADVISORY BOARD MEETING 30-31 January 2018 Seattle, Washington



9TH OCEAN EXPLORATION ADVISORY "....the blue heart BOARD MEETING of the planet" 30-31 January 2018 Seattle, Washington

"Next Generation Ocean Exploration: Understanding Planetary Life Support Systems"

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CONCEPTUAL APPROACH TO EXPLORING OCEANS IN THE TIME DOMAIN

- Protect Planetary Life Support System The Global Ocean Basin;
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- Search for life beyond earth Planning/Testing to Explore Off-Planet Oceans.
 - J.R.Delaney-UW







"THE SYSTEM"

Our Challenge: To optimize the benefits and mitigate the risks of living on a planet driven by two basic energy sources





SOLAR ENERGY

CAUSES:

Winds, Waves, Tides, Ocean Currents, Cloud Formation, Rainfall, Storms, Erosion, Drought, Hurricanes, Photosynthesis, and Carbon Cycling





INTERNAL ENERGY

Drives Plate Tectonics,
Moves Continents,

• Builds Mountain Ranges,

- Molten Rock for Volcanoes,
- Causes Major Earthquakes,

Concentrates Metal Deposits,
Framework for Energy Deposits,
Major 'Source' of Chemosynthesis.



THE HUMAN ELEMENT

• Human activities alter Earth systems, increasing the ocean's vulnerability to stresses and perturbations. perturbations.

 SOLUTION: requires deep understanding of the organization and function of MARINE ECOSYSTEMS



The Global Ocean is the Essential Life **Support System of the Entire Planet.** Oxygen, GH Gases, Heat.

Food, Energy, Commerce, Projection of Sea Power, Communications, Recreation -All Depend Upon, and Impact, the Health and the **Economy** of our Planetary System.

But...The Ocean Basins <u>also</u> **Underpin the Global Economy!**



As a Consequence, Balancing <u>ALL</u> Oceanic Linkages will be essential to ensure sustained well-being of our **Global Community**

THIS IS NOT SOMETHING WE ARE PARTICULARLY GOOD AT.





In the 1990's, Jeremy Jackson sounded the warning about serious Marine Ecosystem decline

He was roundly criticized by experts in the field

MAR ARINA

AL AND A HULL HAL

On May 27, 2017, the Economist ran a main story about Marine Ecosystem Devastation

<u>Their Statement: "The Ocean</u> <u>Sustains Humanity, Humanity</u> <u>treats it with contempt"</u>



The Economist/Helter Break Stractom



A crucial focus must be a deep understanding of **MARINE ECOSYSTEMS.**

This requires that we enter the ocean <u>permanently and comprehensively,</u> to study the complex interacting processes from within the ocean!!!













Oceanography the Early Years From Oscar Schofield J.R.Delaney-UW



ARGO, a global array of 3,800 free-drifting profiling floats, is measuring the temperature, salinity, and movement of the upper 2000 m of ocean.

All data being relayed by satellite and made publicly available within hours after collection.







Argo

National contributions - 3829 Operational Floats

Latest location of operational floats (data distributed within the last 30 days)

- **ARGENTINA** (2)
- BRAZIL (10) .

- CHINA (149)
- ECUADOR (2) ۲
- EUROPE (6) •
- FINLAND (5)
- **FRANCE (328)** •
- GERMANY (133)
- GREECE (7) ٠
- INDIA (124)
- IRELAND (10)
- **ITALY (46)** ۰

٠

- **JAPAN** (189) .
- KENYA(1) .
- KOREA, REPUBLIC OF (52)
- MAURITIUS (3) .
- MEXICO (2)

- AUSTRALIA (380)
- **BULGARIA**(2)
- CANADA (58)

NETHERLANDS (12) ۲ NEW ZEALAND (12) ٠

.

- - SOUTH AFRICA (1) 0

NORWAY (10)

POLAND (3)

- SPAIN (9) ۲
- TURKEY (3)
- UK (134)
- USA (2138)

April 2016

J.R.Delaney-UW

Generated by www.jcommops.org, 09/05/2016





And then there were Gliders -**ARGO Floats with Wings and beyond!**





One Example of Launching a Different Type of Sustained Approach to Long-term *Interactive* Human "Presence' within Entire Volumes of Oceanic Ecosystems





THE FULL EXTENT OF THE AT-SEA NSF-FUNDED OCEAN **OBSERVATORIES** INITIATIVE (OOI) ASSETS

> \$386 M for Construction

\$33 M Annual Operation of All Elements







One of Many Examples of ISSUES AND QUESTIONS:

- HOW DO FUNDAMENTALLY DIFFERENT MARINE ECOSYSTEMS ACTUALLY INTERACT THROUGH TIME AND SPACE?
 - EVOLVING MID-OCEAN RIDGE (M.O.R.) SYSTEMS?
 - ERUPTIONS....WITH RESPECT TO THE OVERLYING OCEAN?
 - M.O.R. CYCLE ERUPTION-TO-ERUPTION?

 WHAT ARE THE LINKAGES AND INTERDEPENDENCIES AMONG THE PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES IN

• WHAT ARE THE MECHANISMS AND CONSEQUENCES OF M.O.R.

WHAT IS THE COMPLETE DEFORMATIONAL HISTORY OF THE





Mark and Nick Stoermer





Pacific Plate

Juan de Fuca Plate

Mark and Nick Stoermer



Axial Volcano

N



Axial Erupted in 1998 and again in 2011, and again in 2015





NSF's Ocean Observatories

.

A 900 km network of electrooptical cables supplies 10 Gbps of telecommunication bandwidth and **8kW** of power to each Primary Node. The system hosts ~ 40 instruments with significant expansion capabilities built into the design.

> Pacific Plate

OOI Primary Nodes

Potential Expansion Nodes NEPTUNE Canada Nodes Hi-Power Profiling Mooring Coastal Mooring Shore Stations GigaPOP

Seattle gaPop

Juan de Fuca

AXIAL Plate

Networ

Canada

SEAMOUNT MID-PLATE

PN5A

PN3A

Cabled Array

Pacific

City

Newport

SLOPE BASE

J.R.Delaney-UWv

Plate

Portland

GigaPop



North Rift Zone



Primary Node 3B

Primary Node 3A J.R.Delaney-UW



Axial Volcano Sub-seafloor

Visualization based off of:

Anatomy of an Active Submarine Volcano

A.F. Arnulf, A.J. Harding, G.M. Kent S.M. Carbotte, J.P. Canales, M.R. Nedimović

Upper Crustal Reflectivity Model 4:1 vertical exaggeration

Geology June 9 2014 gsapubs.org 10.1130/G35629.1

AXIAL CALDERA SEISMOMETER LOCATIONS

1229 m

Bottom Pressure & Tilt Meter Low-Frequency Hydrophone **Broadband Seismometer**

Bottom Pressure & Tilt Meter Low-Frequency Hydrophone Broadband Seismometer

Short-period Seismometer

Short-period Seismometer

OSMO Fluid Sampler 3-D Thermistor Array

HD Video Camera & Lights

Short-period Seismometer

-1300

-2700

Bathymetry: MBARI AUV Data from D. Caress and D. Clague EM302 Multi-beam from University of Washington 10m contour lines



ASHES 250m Vent Field 0

 \bigcirc

1200 m

Short-period Seismometer

0

Vent Fluid & Microbial Sampler **Mass Spectrometer Digital Still Camera and Lights Temperature Resistivity** pH - H₂S - Temperature

NODES and J-BOXES

Primary Node

Medium Power J-Box

CABLE TYPES



RSN Primary

Medium Power Electro-Optical

Electrical Extension

MJ03E Eastern 🔮 Caldera

0

1262m

M|03C

International **District Vent** Field

PN3B

Current Meter - 3D Single Point Short-period Seismometer Bottom Pressure Tilt



Earthquake Histogram



Slide by William



Movie





Ocean

1510.5 (m) Depth 1511.5

1509.5

1512.5 April I

Bottom pressure – tilt instrument

HYDRO PHONES!



now inflating again

Water temperatures across the caldera were elevated for several weeks

Seafloor inflation and deflation



B Chadwick & S. Nooner

Streaming data to shore showed the seafloor fell 7.4 ft and is



Axial Central Caldera Low Frequency Hydrophone (200 Hz) Speed x5

http://service.iris.edu/irisws/timeseries/1/query?net=00&sta=AXCC1&cha=HDH&start=2015-04-26T00:20:00&end=2015-04-26T00:30:00&output=audio&loc=-&audiosamplerate=1000



Earthquakes

Explosions

2015 Eruption of Axial Seamount

~10,000 earthquakes

~1,000 impulsive events

46° 5

.....

Seismometer Lava flows, 10 m difference Lava flows, approximate outline Earthquake (magnitude 0.4 - 4.0) Impulsive event

129° 55.0

What is happening now and when will Axial erupt again?

having new eyes"

"The real voyage of discovery consists not in seeking new landscapes, but in

Marcel Proust

Ashes Vent Field Axial Seamount

MUSHROOM HYDROTHERMAL VENT IN ASHES VENT FIELD

1.2 meters

High Resolution Pano image made from ~40 frame-grabs of CAMHD Imagery. Date: July, 2015

Ridgeia piscesea

Folliculinopsis sp.

Paralvinella palmiformis

AXIAL VOLCANO

Ashes 🗑

Vent Field

Bathymetry: D.Caress and D.Clague, MBARI EM302 Multi-beam, UW, Image Mosaic by CEV, UW, 2015

PN3B

Lepetodrilus fucensis

Iron Sulfide-Anhydrite **Chimney venting** >200°C fluid

MHD

Paralvinella sulfincola

C'EN

Time-series High Definition Imagery of the "Mushroom" Hydrothermal Vent Structure in Ashes Field, Axial Volcano - JDF Ridge

Time interval: Nov, 2015 to July 20, 2016 - One frame every 3 hours

Video Assembled by **Tim Crone and Friedrich Knuth**

Music: Flight of the Bumblebee by Rimsky-Korsakov

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Live telepresence w/ remote control of camera inside Axial Seamount First time the HD video camera is being controlled by a user of the system. National Ocean Exploration Forum, UC San Diego at Qualcomm Institute October 23rd, 2017

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ERUPTIVE "MEGAPLUMES

- Rise heights >1000 m above seafloor
- Plume can be 20 km across
- Carries novel microbes from subsurface
 - We MUST detect and **quantitatively** characterize Mor Eruptions into the overlying oceans

RESIDENT AUV SYSTEM

Manalang and Delaney, 2016

AUV mapping water column

Acoustic Gateway

Acoustic

High bandwidth optical data link/

Docking Station

JUAN DE FUCA RIDGE NORTHEAST PACIFIC

Bathymetry: MBARI AUV Data from D. Caress and D. Clague M302 Multi-beam from University of Wa

Vehicle

Manalang and Delaney, 2016

SEAGLIDER

HYPOTHETICAL FORMATION OF A MEGA PLUME DURING AN ERUPTION AT AXIAL SEAMOUNT A portion of the Mid-Ocean Ridge System that is wired and Restless

10 - 20 km

AUV

AXIAL CALDERA

> DOCKING STATION

> > PRIMARY NODE 3B

1000m 800

1,500m

ADAPTIVE SAMPLING WITH

HIGH POWER & BANDWIDTH MOORINGS

Imagineering!

A more ambitious system for earthquake and tsunami early warning and hazards research

Concept being Driven by Will Wilcock and David Schmidt of UW

Myriad Streams of Real-time Data Flow Captured....

A **VISION OF** NEXT-GEN OCEAN SCIENCE

...into an Ever-Expanding Reservoir of Historical Data (The Globally Accessible Archive) **J.R.Delaney-UW**

Governments and big companies use exponential growth charts for predicting the future

The next slide shows the improvement level that our technology will have in the next five years

Every 12 to 18 months, computers double their capabilities,

Increase in Technological Ability Current

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Cost of Sequencing a Genome Similar Curves for Nanotech & Artificial Intelligence/Robots

Source: National Human Genome Research Institute

Peter Diamandis • www.diamandis.com/data

IF WAYNE GRETZKY WERE AN OCEANOGRAPHER, WOULD WE WIN THE STANLEY CUP?

"Skate to where the puck is going, not where it is now"

Wayne Gretzky

Quote from Klaus Schwab Re: Fourth Industrial Revolution

"The possibilities of billions of people connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge, are unlimited.

And these possibilities will be multiplied by emerging technology breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing."

What Might the Future of **Ocean Exploration Involve?**

Broad Spectrum, Evolving Sensor Capability 10's of 1000's of Highly Intelligent Adaptive Platforms **Operating at Many Different Scales Real-time Communication - Optical, Acoustic, Other? In Situ** Auto-repair & Replication

Strategy: Take Maximum Advantage of Rapid Convergence of Communications, Genomics, A.I., Nanotech, etc.

GENOMICS

NANOTECH

"ACCELERATED EVOLUTION OF OCEAN SCIENCES?"

MARINE ROBOTICS

ARTIFICIAL INTELLIGENCE

4-D Meta-Genomic "Mapping" of Ocean Space

Diatoms at Base of Food Chain

Coccolithophores -Base of Food Chain Hydrothermal-Volcanic Domain J.R.Delaney-UW

WHERE WILL THE "PUCK" BE IN A FIELD DOMINATED BY EXPONENTIALLY CHANGING TECHNOLOGIES ??

"Sometimes I think we're alone in the universe, and sometimes I think we're not. In either case the idea is quite staggering."

--Arthur C. Clark

EUROPA OCEAN & THE TIDES OF JUPITER

Janus Epimetheus

Cassini Encke Division (Pan)

D ring^C ring B ring

A ring (outer edge: Atlas)

G ring

Fring (Prometheus, Pandora) Cassini Saturn Orbit Insertion Ring Plane Crossing

Enceladus

12

• Tethys

Cassini imaging scientists used views like this one to help them identify the source locations for individual jets spurting ice particles, water vapor and trace organic compounds from the surface of Saturn's moon Enceladus. Image credit: NASA/ JPL/Space Science Institute

A Cabled Test-bed for developing and thoroughly testing off-planet "Orgobots" to explore extraterrestrial oceans for life

Acoustic Node

121

- Contraction

Turbulent the sea Stretching across to Sado The Milky Way

From Oku no Hosimichi, 1689

Stories

Turbulent the sea

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