

EqPOS

Jan 29, 2012 – Feb 19, 2012 (22 days)

**Equatorial Pacific Ocean and
Stratospheric/Tropospheric Atmosphere Study**

Sky, Ocean, and In-Between

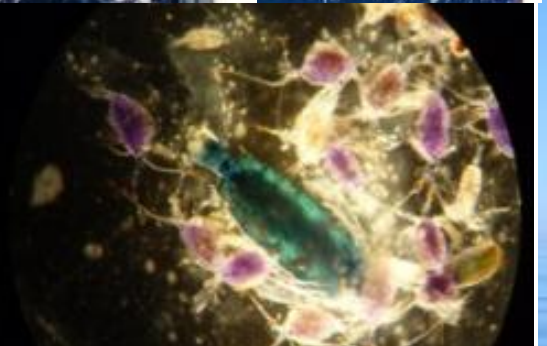
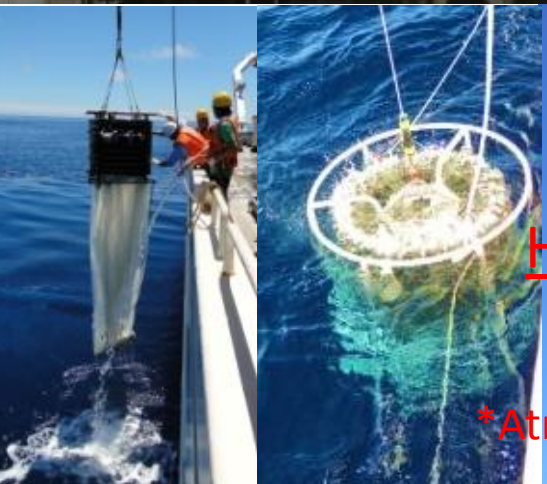
Overview and Science Objectives

Hiroshi Furutani*, Mitsuo Uematsu*
and EqPOS Science Team

*Atmosphere and Ocean Research Institute (AORI)
Univ. of Tokyo



東京大学
THE UNIVERSITY OF TOKYO



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Equatorial Pacific Ocean and

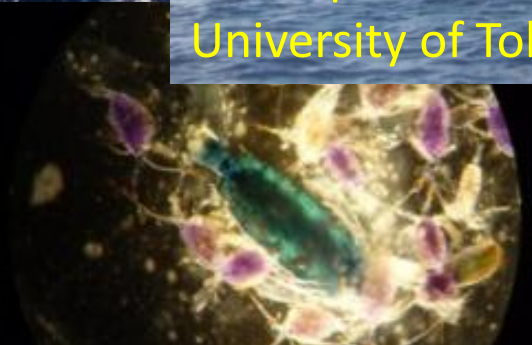
Stratospheric/Tropospheric Atmosphere Study

Length: 100 m
Displacement: 3991 t
Cruise Speed: 16 knot



R/V Hakuho-maru

Atmosphere and Ocean Research Institute (AORI),
University of Tokyo

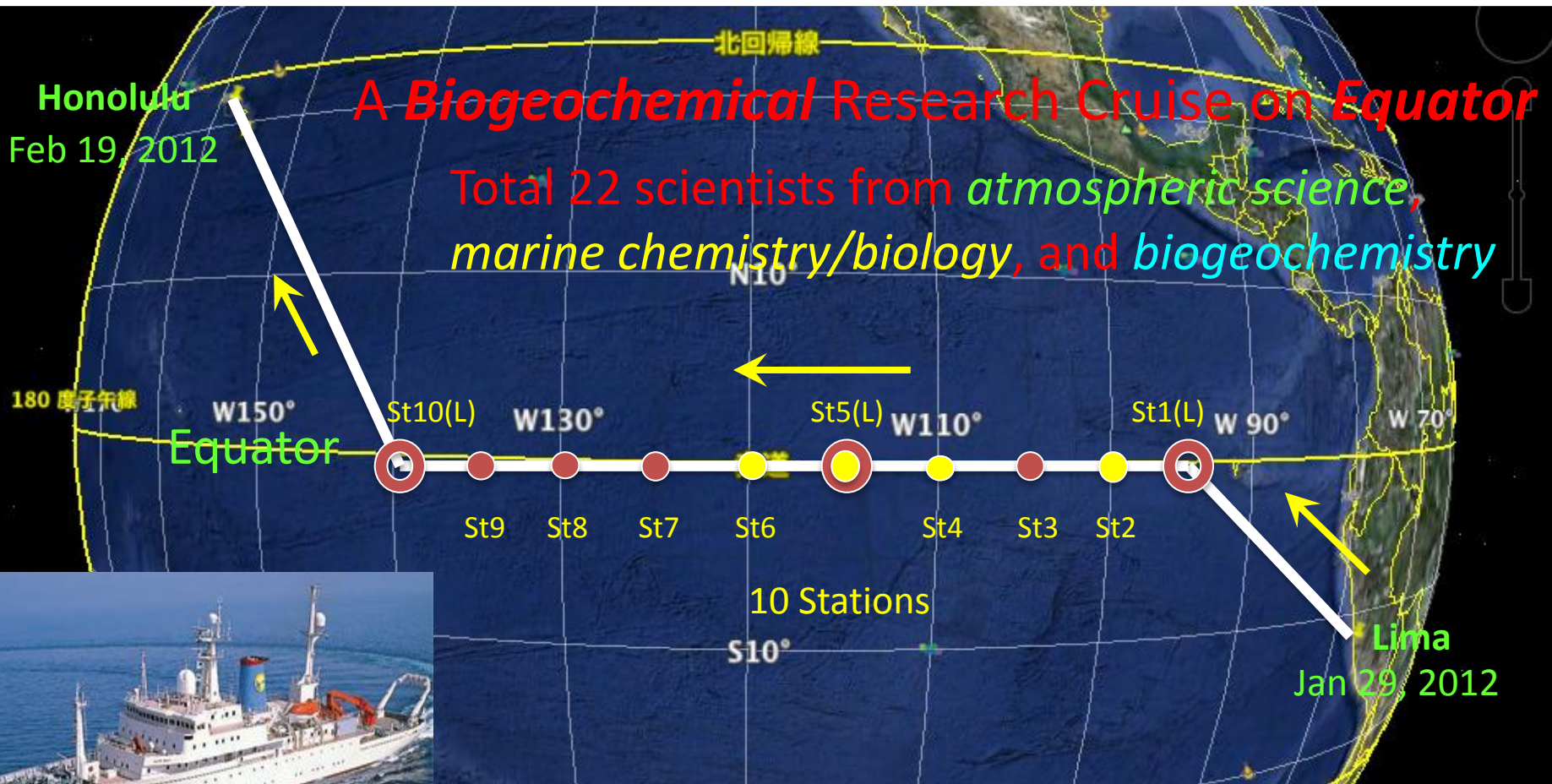


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Tropospheric Atmosphere Study**

PI: Prof. Uematsu (AORI)

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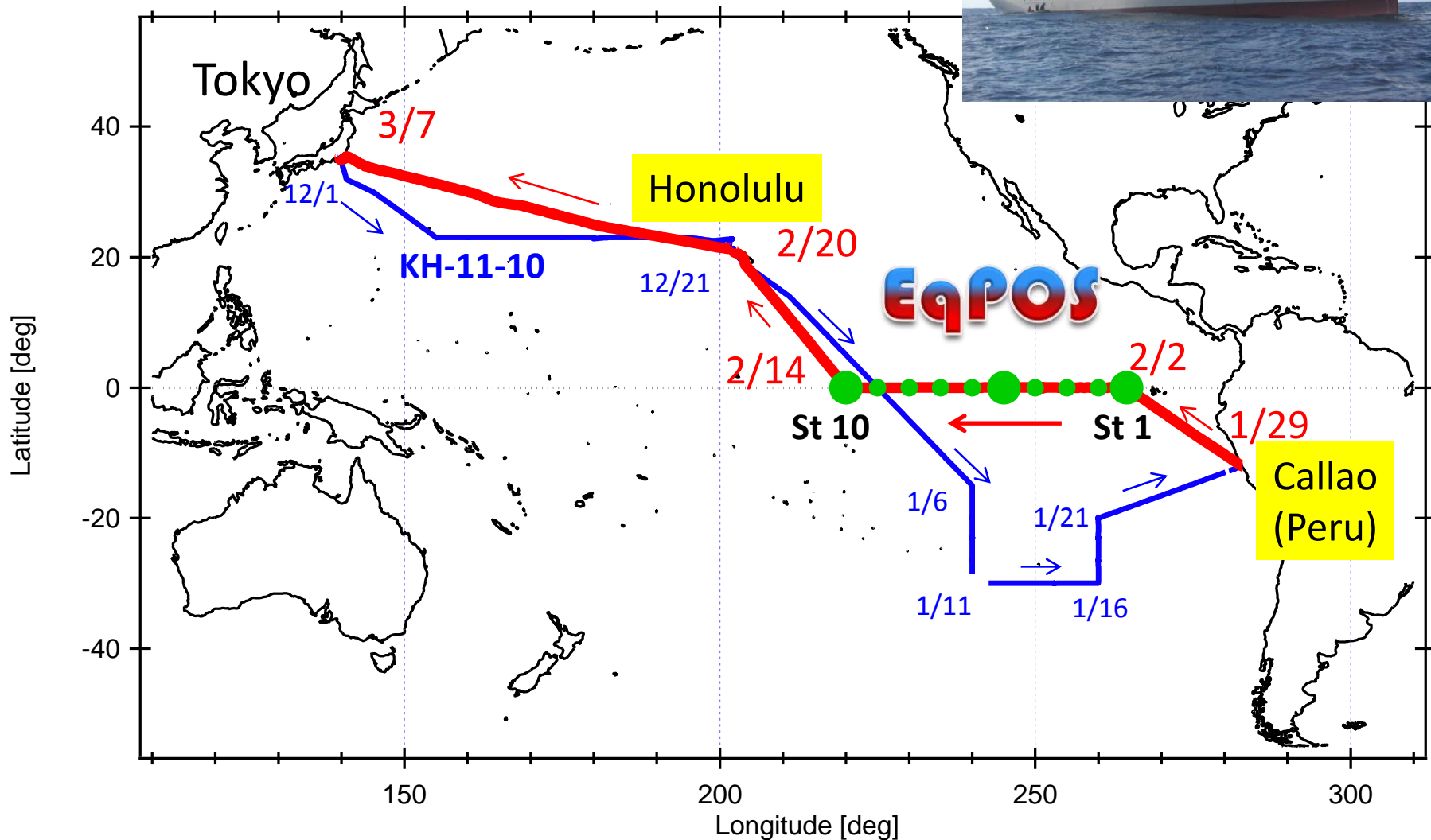


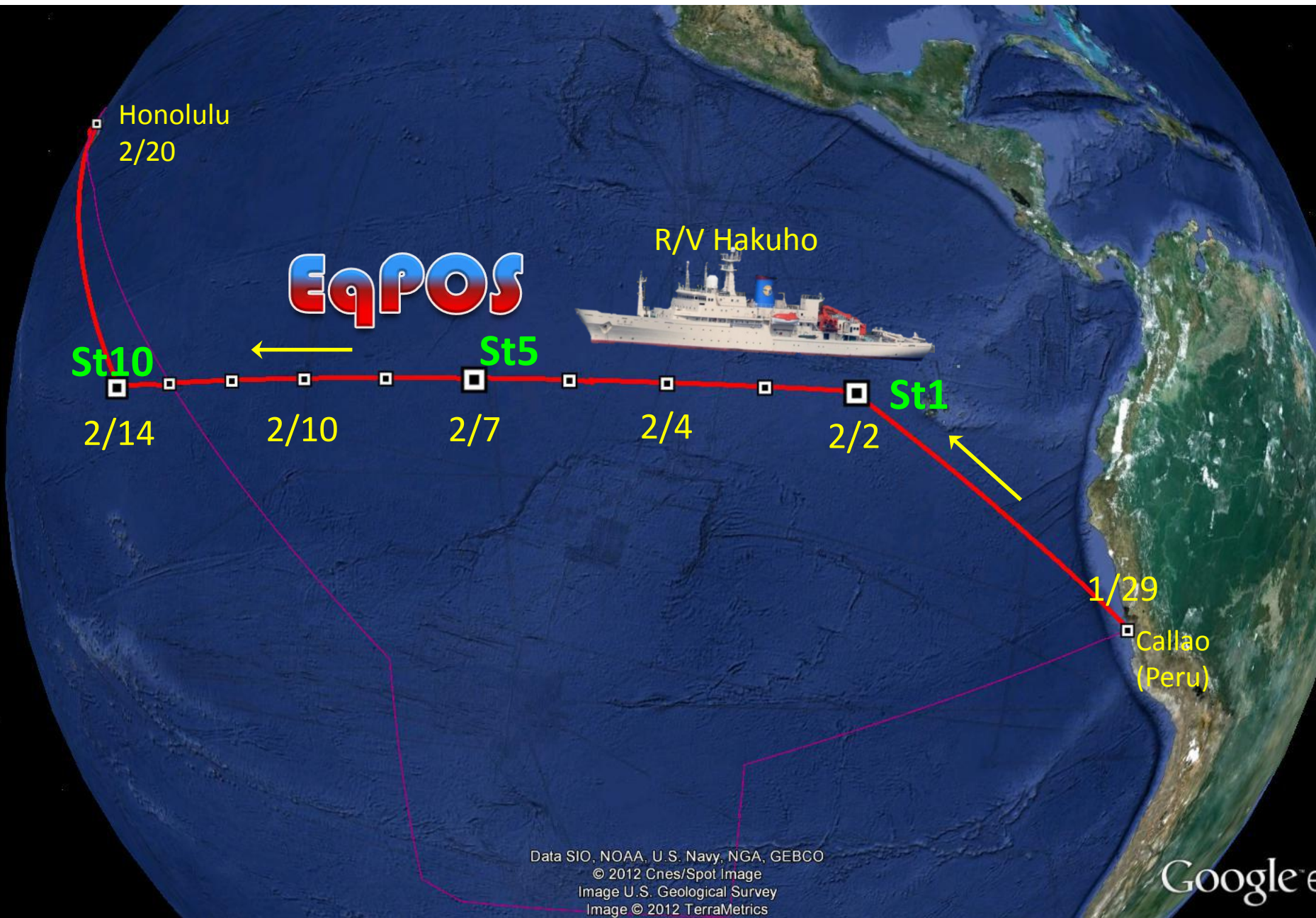
KH-11-10 and EqPOS

白鳳丸



12/1/2011 – 3/7/2012 (98 days)





Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image
Image U.S. Geological Survey
Image © 2012 TerraMetrics

Google

R/V Kaimimoana

TORERO

Honolulu
2/20



R/V Hakuho

EqPOS



St10

2/14

2/10

2/7

St5

2/4

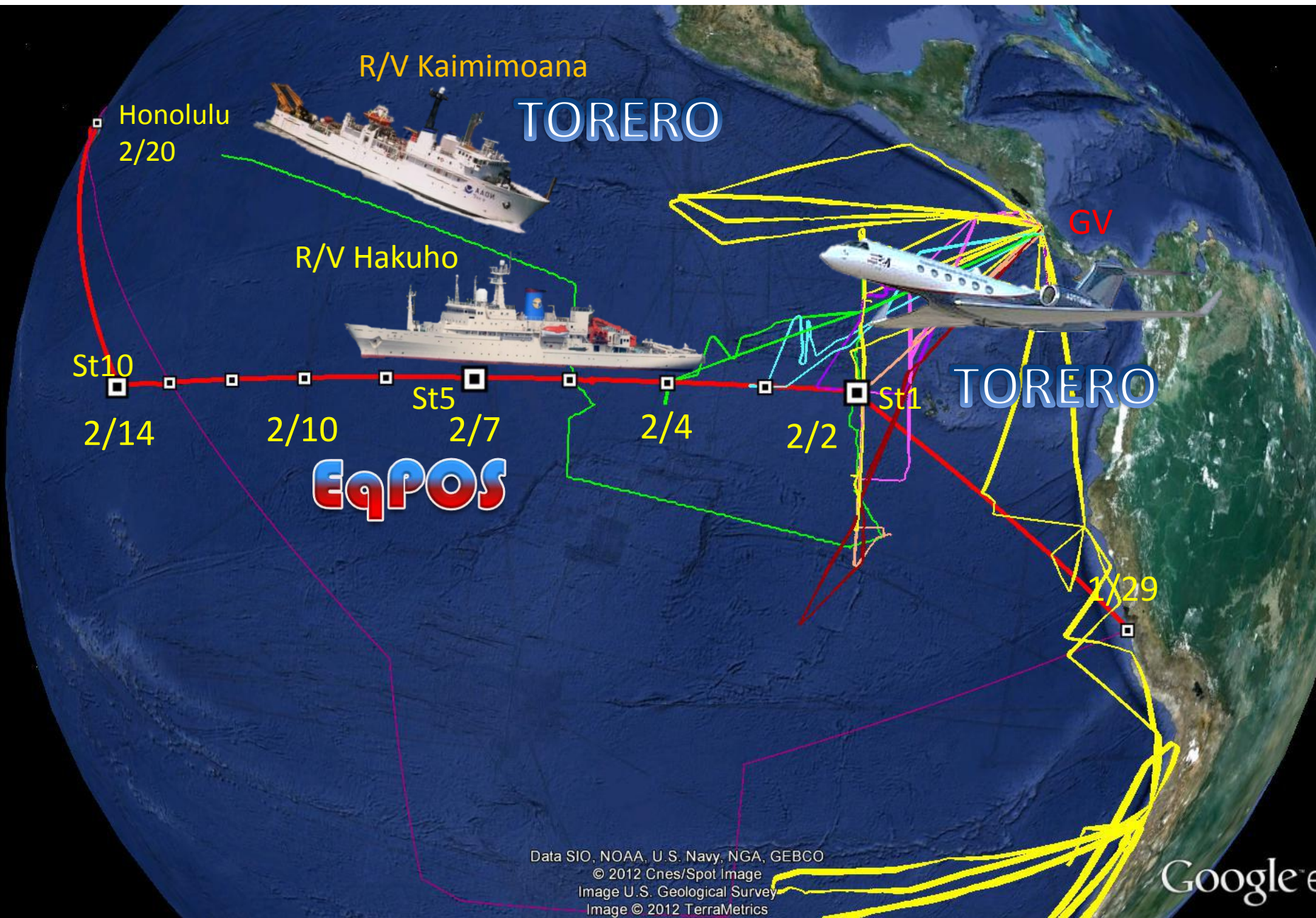
2/2

St1

1/29

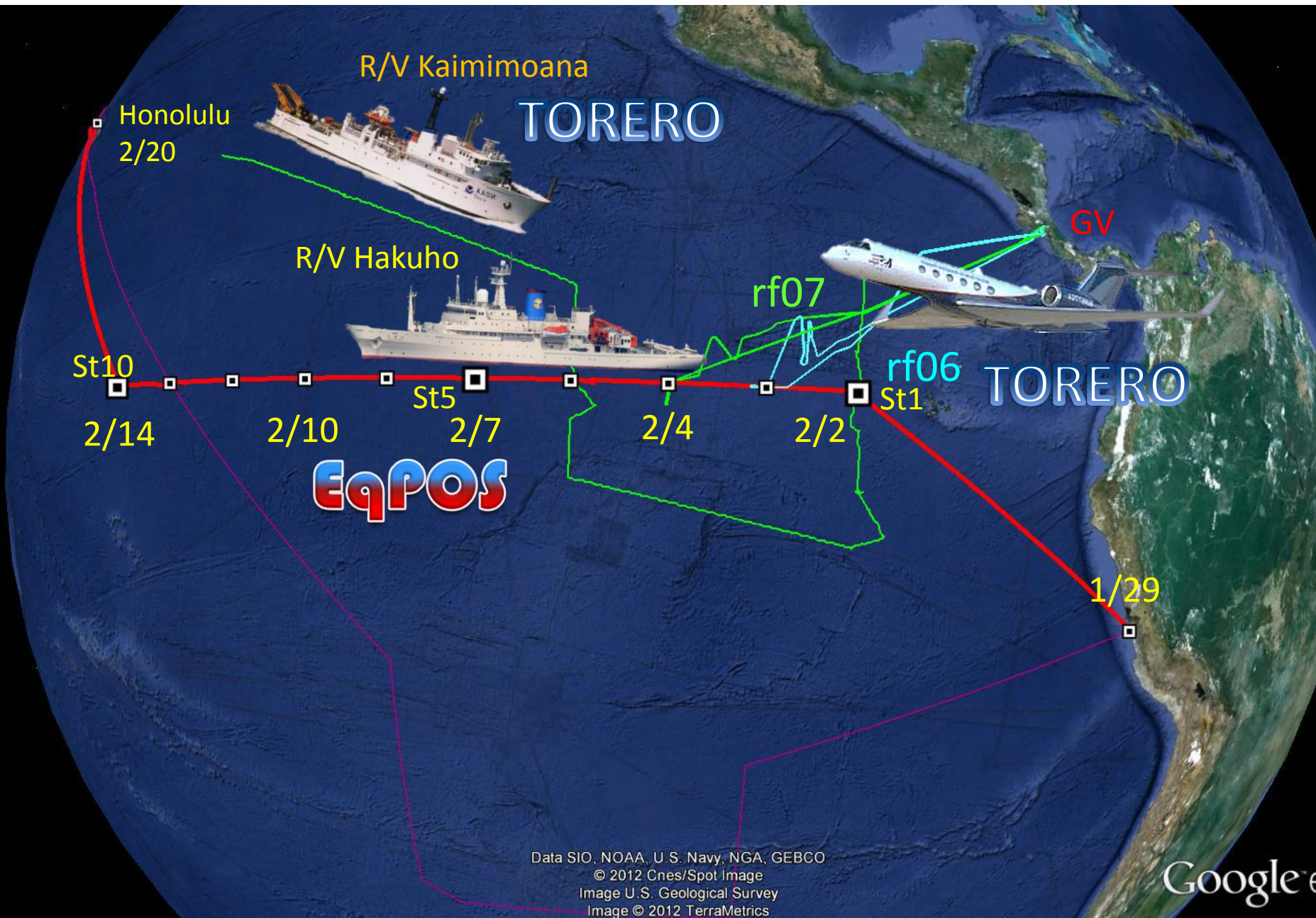
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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Image U.S. Geological Survey
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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Google

R/V Kaimimoana

TORERO

Honolulu
2/20

R/V Hakuho

GV

rf07

rf06

TORERO

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2/14

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EqPOS



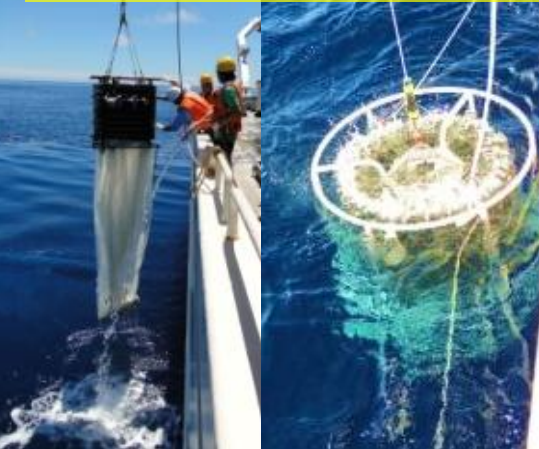
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To understand *biogeochemical interaction/link/flux* between *ocean* (marine biota) and *atmosphere* (aerosols, trace gases) through their *interface (sea surface microlayer)* in the equator.



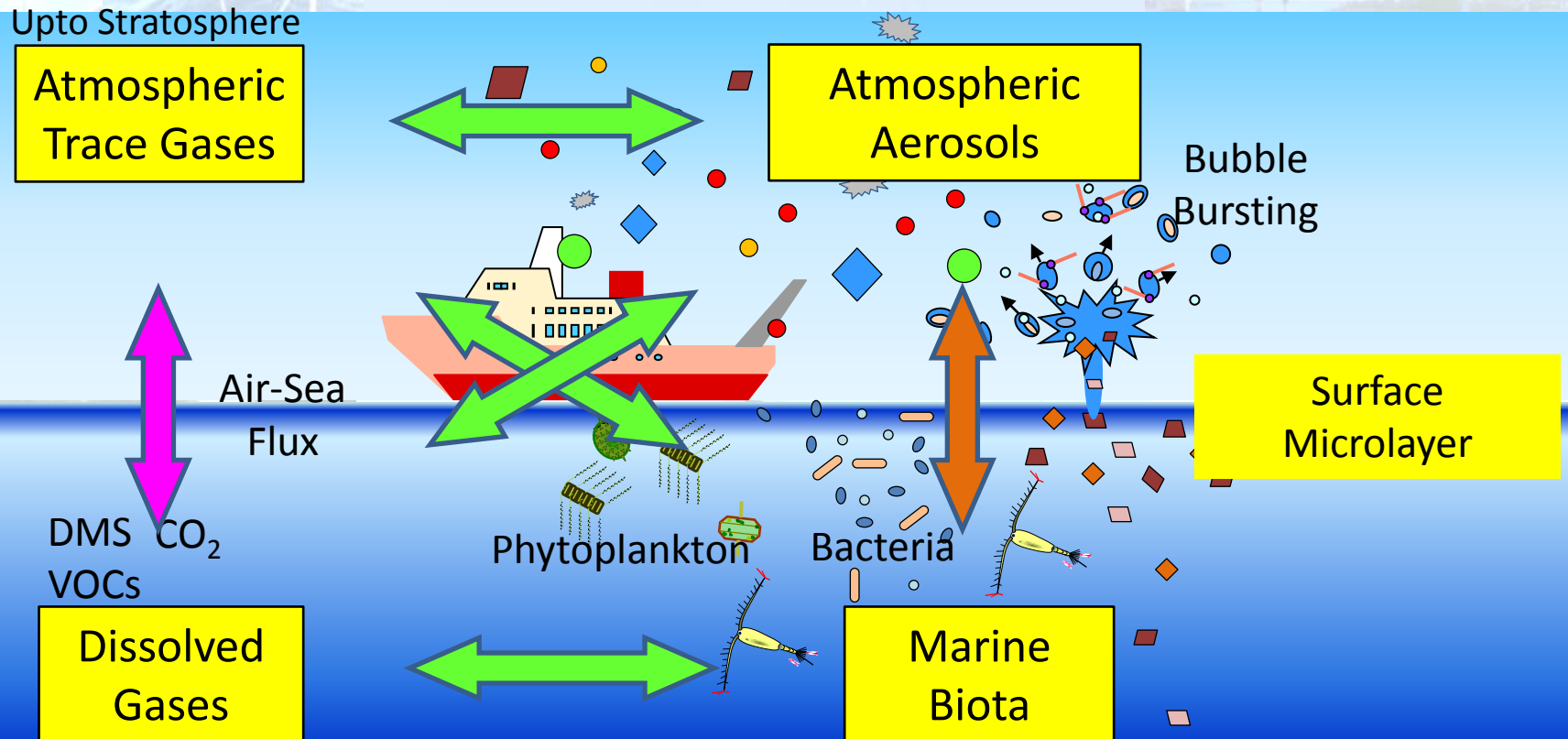
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Stratosphere (30 km)



EqPOS

O₃, CO₂, H₂O
Profiling



Stratospheric
Air Sampling
(Alt = 19-30 Km)

Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)

Eddy
Covariance

Gradient
Profile

Trace Gas
(DMS, VOCs, CO₂,
CO, O₃)

Bubble Bursting

Air-Sea
Flux

CO₂

Surface
Microlayer
Sampling

DMS VOCs
CO₂

Dissolved Gas
(DMS, DMSP, VOCs,
pCO₂, O₂)

N-Fixation

Phytoplankton

Bacteria

Non-living
Particles

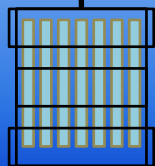
Nutrients, Chl-a
TOC
DOC, DON

Microbial
Abundance,
Speciation,
Community

Micro-nutrient
condition.
Zooplankton



Ocean Floor (- 6 km)



EqPOS

**Equatorial Pacific Ocean and Stratospheric/
Tropospheric Atmosphere Study**

PI: Prof. Uematsu (AORI)

Jan 29, 2012 – Feb 19, 2012 (22 days)

Honolulu
Feb 19, 2012

北回帰線

**Why *eastern equatorial* Pacific Ocean?
from biogeochemical point of view**

180 度子午線

W150° St10(L) W130° St5(L) W110° St1(L) W 90° W 70°
Equator
St9 St8 St7 St6 St4 St3 St2

10 Stations

S10°

Lima
Jan 29, 2012

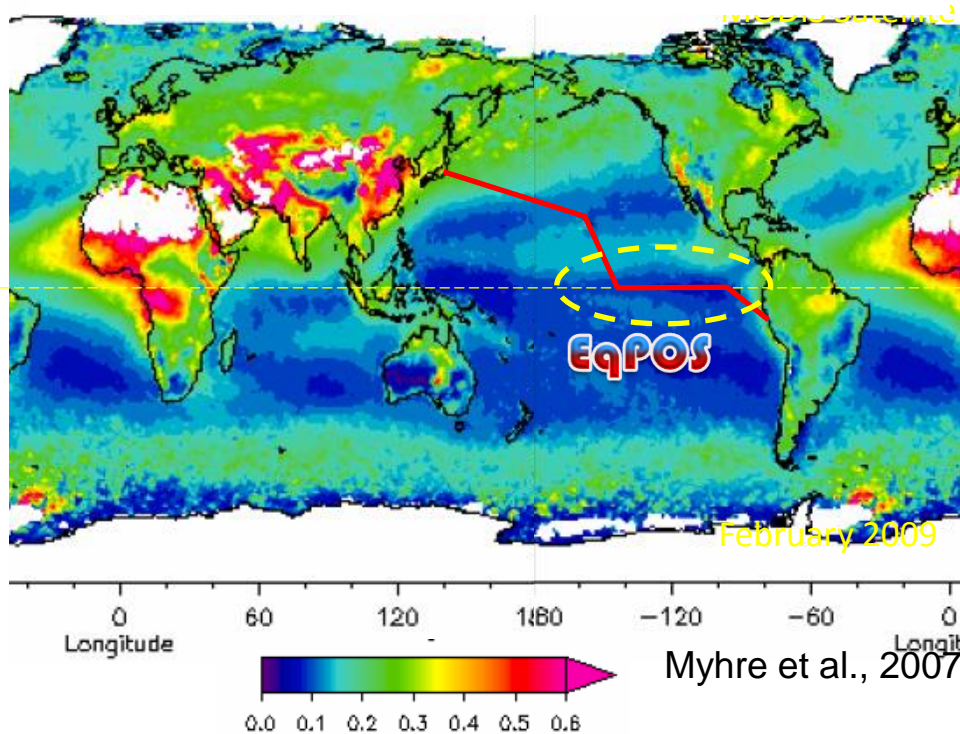


R/V Hakuho-maru

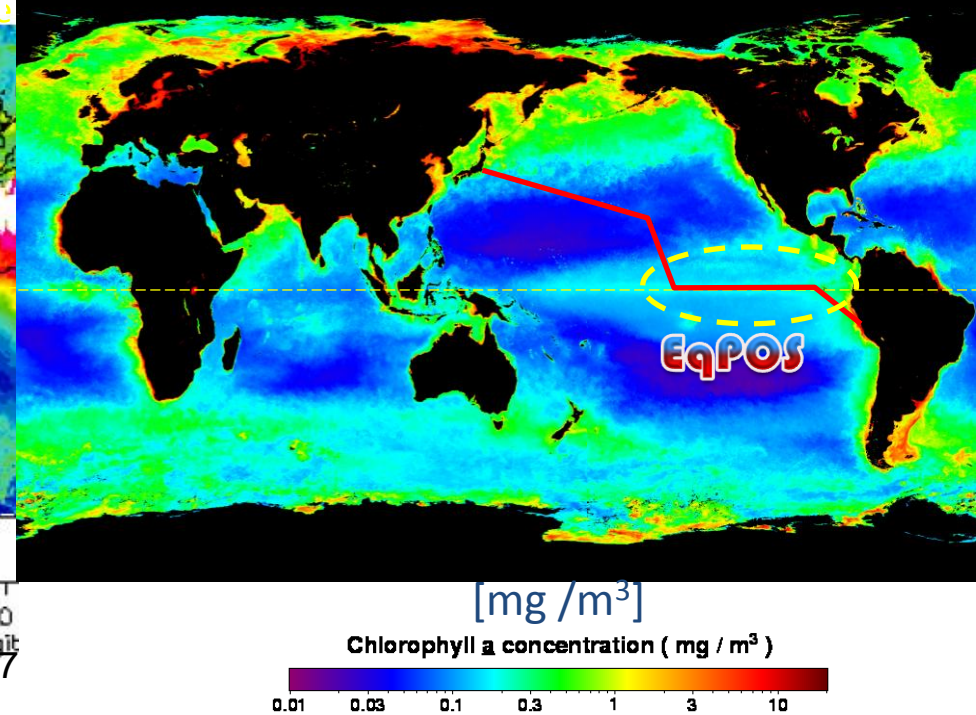
Why *eastern equatorial Pacific Ocean*? (1)

- Remote Ocean
- Low Aerosol Loading
- Relatively High Chl-a and

Aerosol Optical Depth (AOD)



Surface Chlorophyll-a



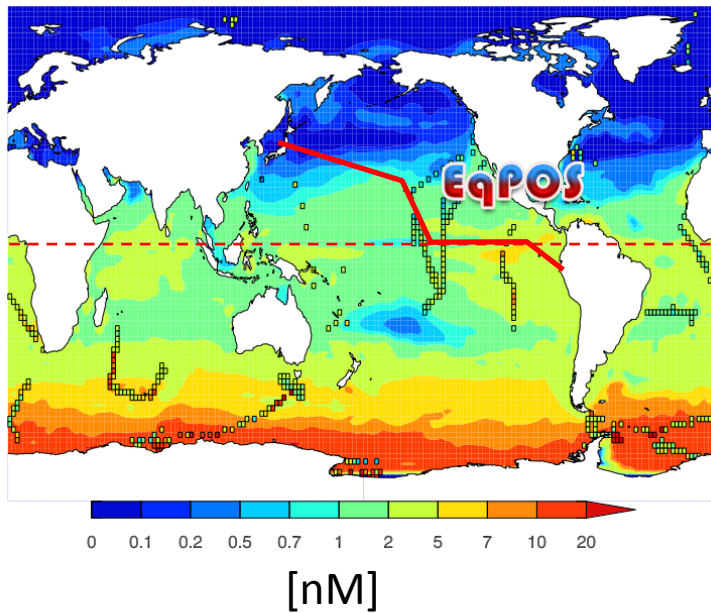
- Reduced effect of anthropogenic activity

- Clear effect of natural marine biota on atmosphere

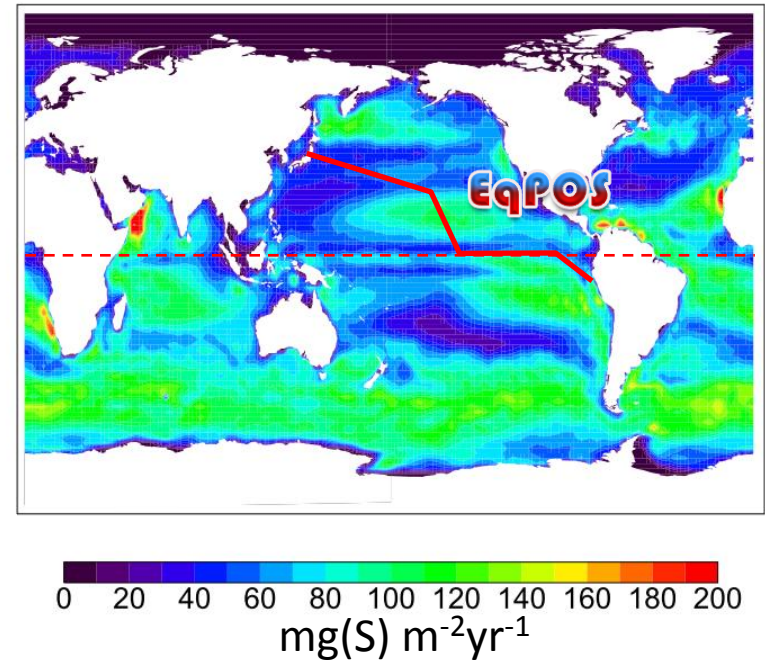
Why eastern equatorial Pacific Ocean? (1)

Relatively high sea surface DMS conc. and flux to atmosphere

Modeled DMS sea surface conc. (Dec-Feb)

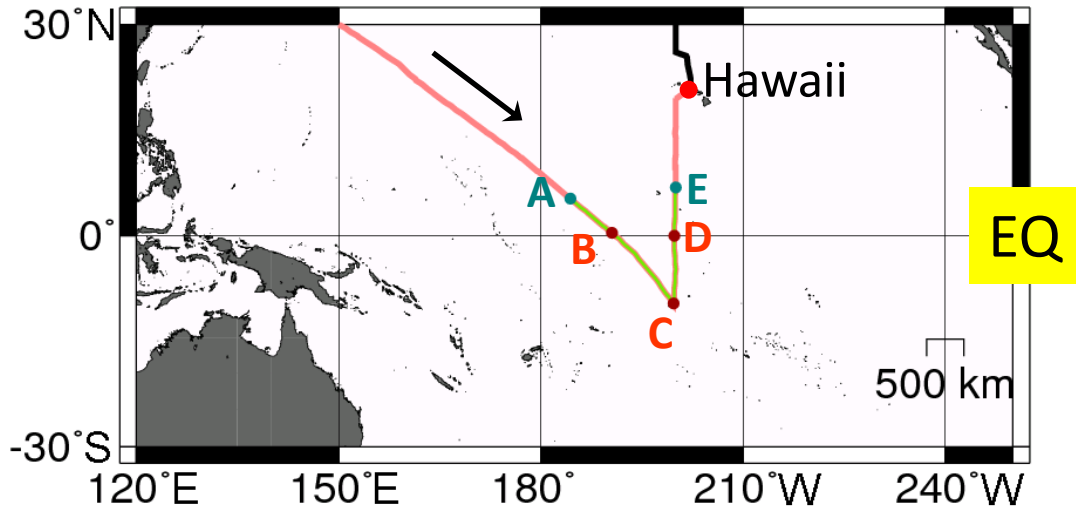


Modeled annual mean DMS flux to atmosphere

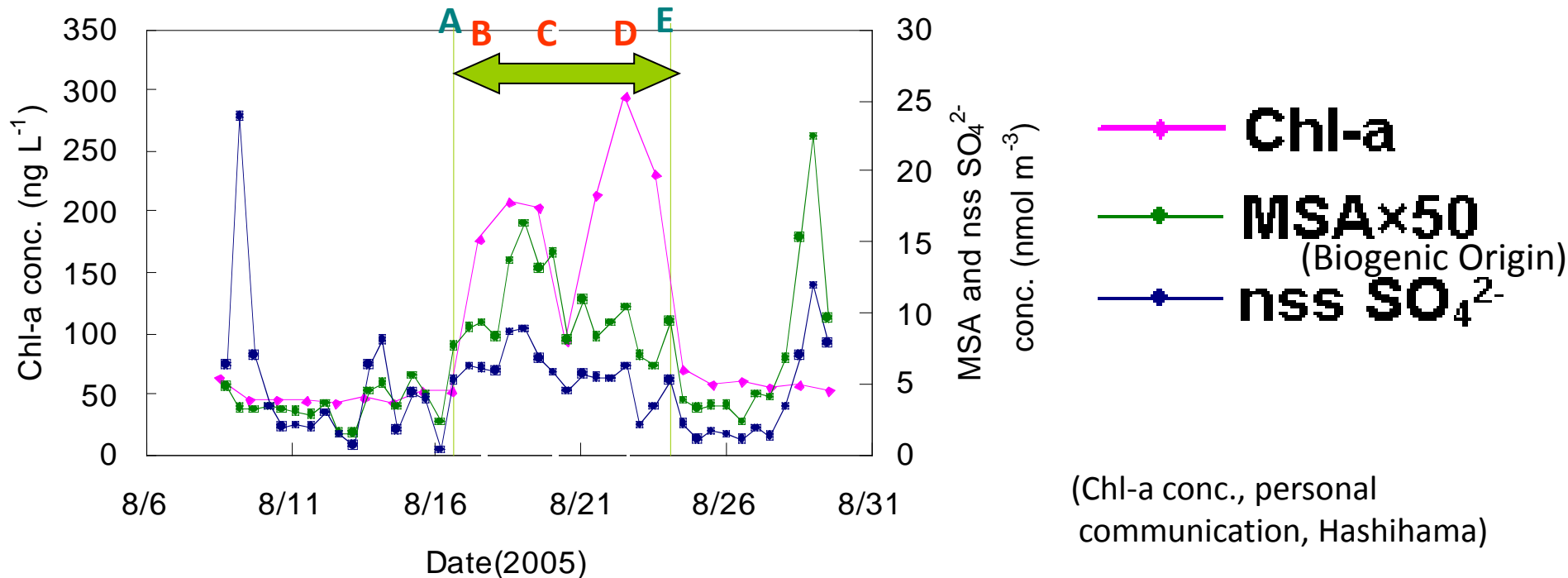


Kloster et al., (2006)

Increased Chl-a, MSA, and nss SO₄²⁻ in Equator



KH-05-2 Cruise (2005)

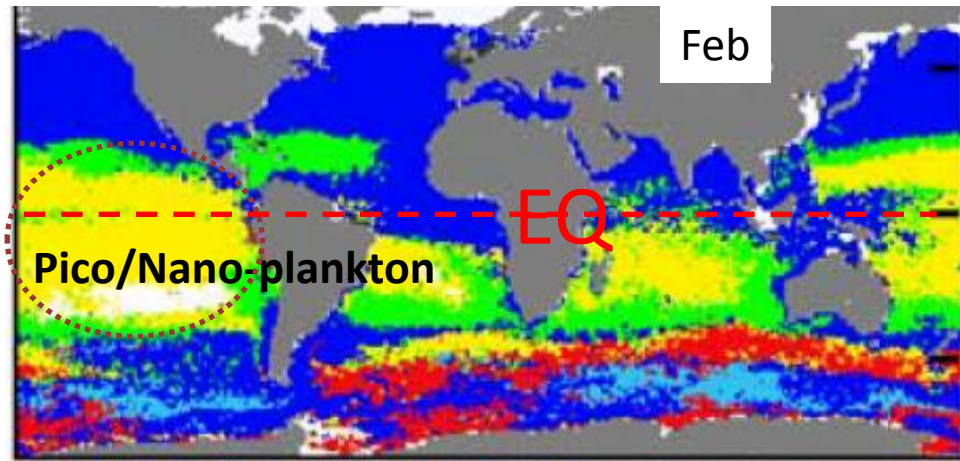


(Chl-a conc., personal communication, Hashihama)

Why eastern equatorial Pacific Ocean? (2)

Different Phytoplankton Group

(Dominant phytoplankton group retrieved from satellite ocean color image)

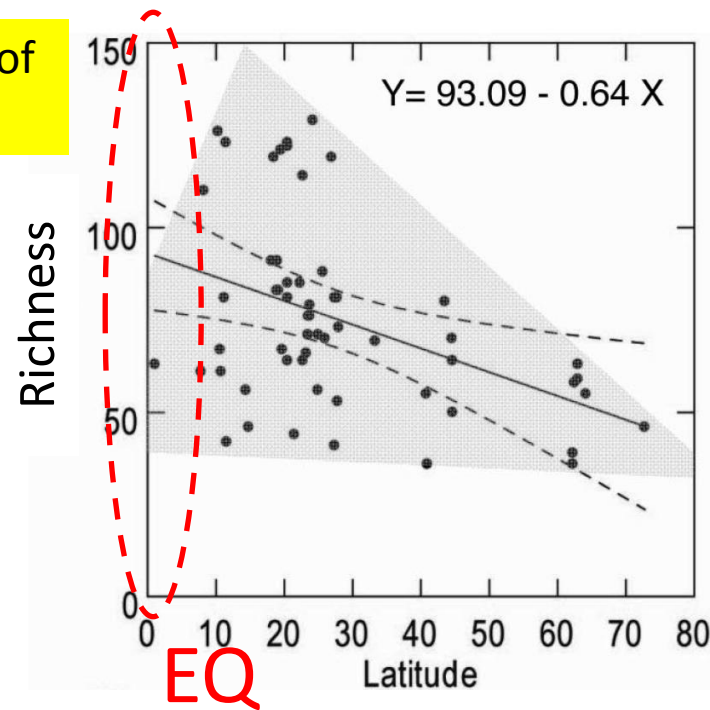


Alvain et al., GBC (2008)

- Prochlorococcus
- Synecochoccus
- Nanoecaryotes
- Diatom
- Phaeocystis-like

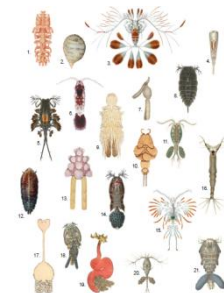
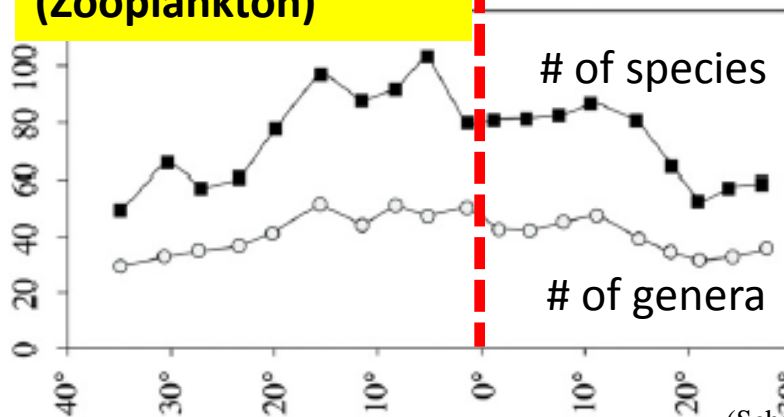
Pico/Nano-plankton

Diversity of Bacteria



Fuhrman et al, PNAS (2008)

Diversity of Copepod (Zooplankton)



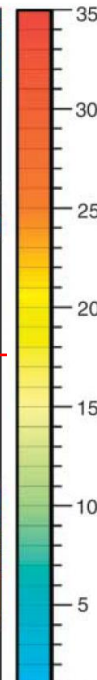
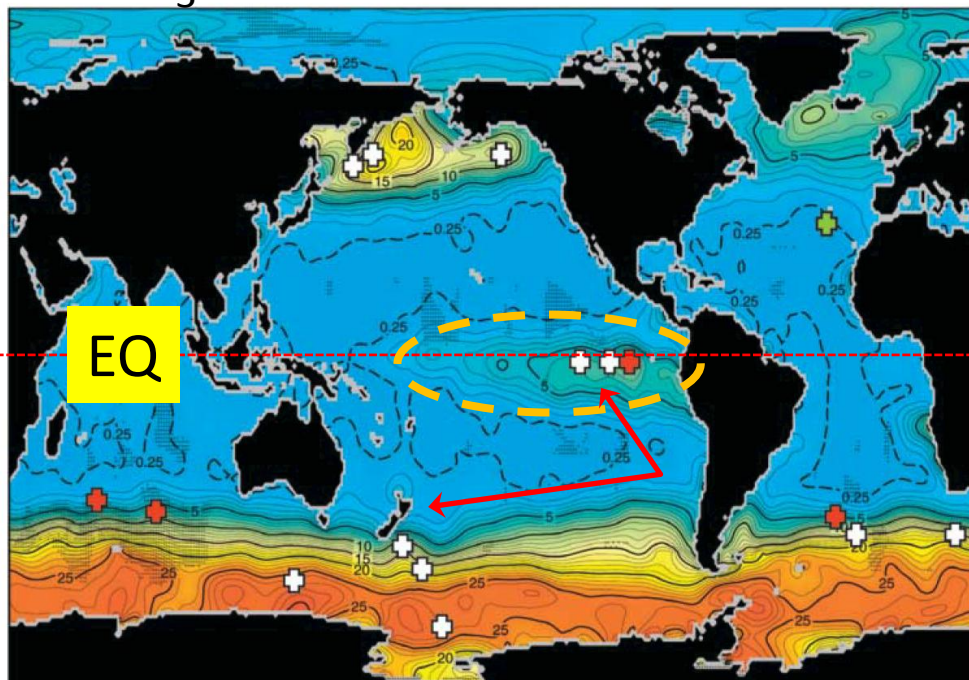
(Schnack-Schiel et al. 2010)

Why eastern equatorial Pacific Ocean? (3)

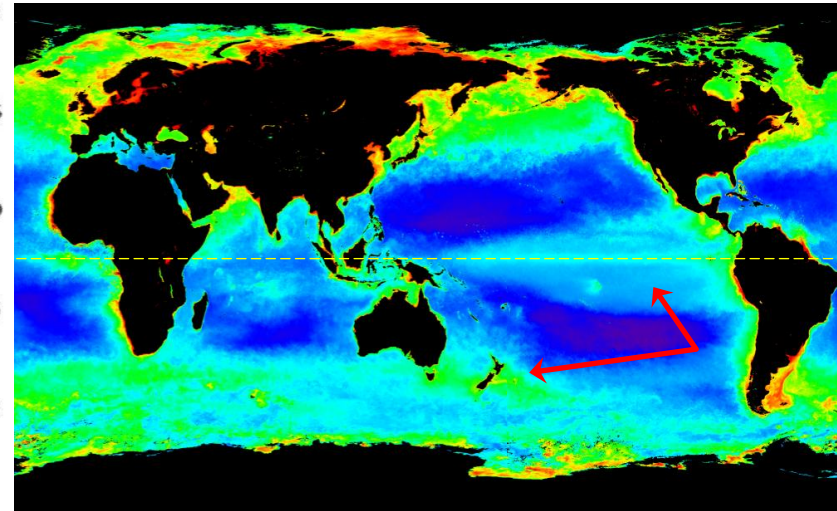
Eastern Equatorial Pacific Ocean is **HNLC** Ocean
(High Nutrient Low Chlorophyll)

Limited availability of **trace metals** limits marine primary production
(e.g., Fe, Zn, Cu, Ni)

NO₃- conc. in surface seawater



Chl-a conc.

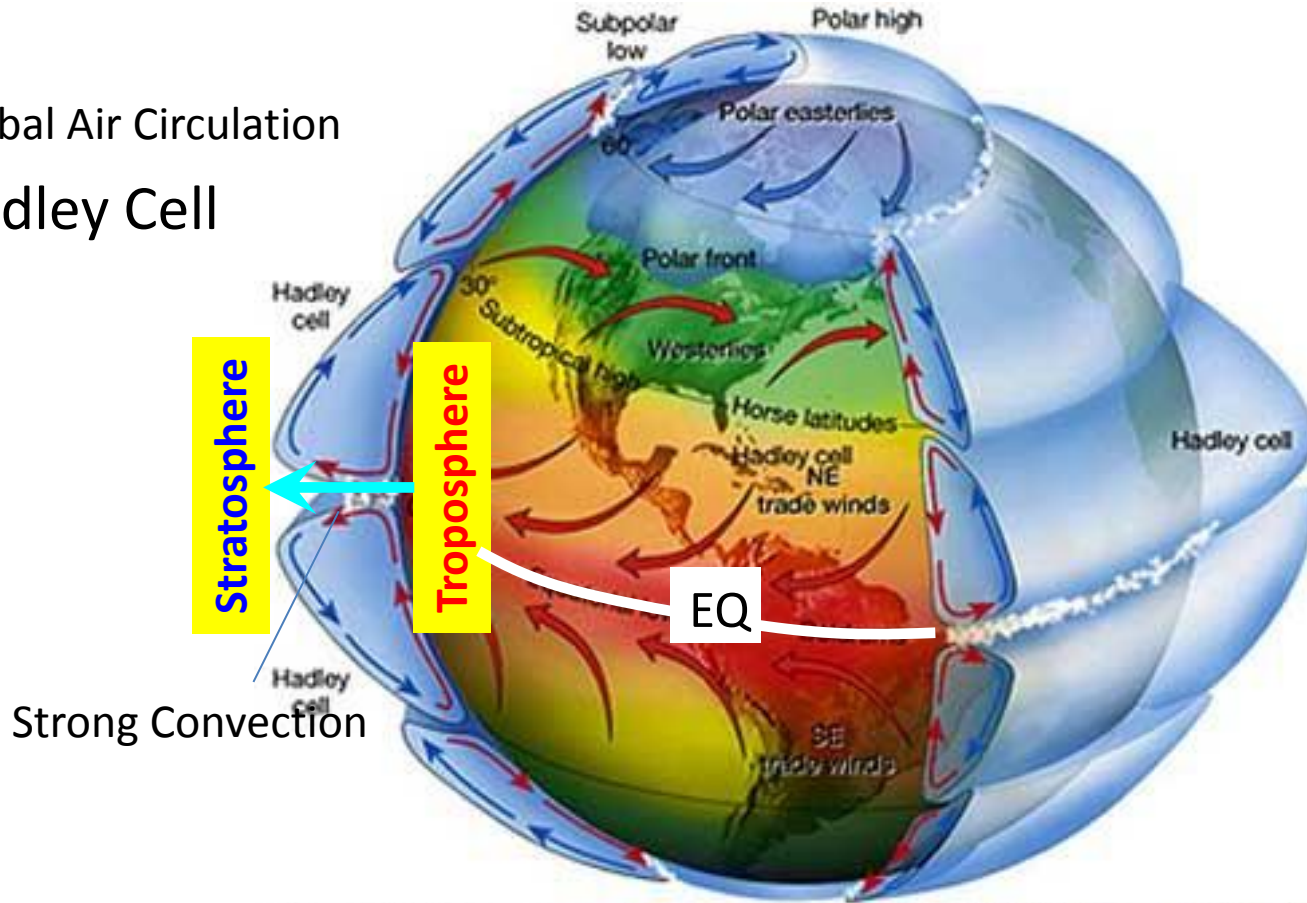


Importance of **atmospheric deposition** as a source of trace metals for marine phytoplankton

Why eastern equatorial Pacific Ocean? (4)

High Sea Surface Temperature => Strong Convection
=> Strong **Troposphere**-to-**Stratosphere** Chemical Transportation

Global Air Circulation
Hadley Cell



Equatorial Tropopause:

Global window of troposphere-to-stratosphere chemical transportation

Stratospheric O₃ Loss

Decreased O₃ through catalysis involving BrO + ClO and BrO + HO₂

Longer-lived bromocarbons and decomposition products of shorter-lived bromocarbons + sunlight + OH → BrO

Lowermost stratosphere

Tropopause

Decomposition of shorter-lived bromocarbons

Troposphere

Decreased O₃ by direct and indirect effects

Bromocarbons + sunlight + OH → BrO

Heterogeneous recycling of inorganic bromine on cloud and aerosol surfaces

Convective outflow

Deep convection

Bromocarbons produced by marine algae

Marine Biogenic Organic Halogen

Tropical ocean

Among other effects, bromine released by biological processes in the oceans apparently reduces ozone levels in the troposphere. This source may be a link between atmospheric composition and climate change.

Salawitch, Nature, 2006

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Stratosphere

Troposphere

O₃ Loss
by Halogen

Tropical
Deep Convection

Marine Biogenic
Trace Gases

VOC

Org C

Nanoparticles
(secondary
aerosol
formation)

SO₂

H₂SO₄

(NH₄)₂SO₄

DMS

MSA

NH₃

Sea Salt
Aerosol

Coarse
Aerosols

Sea Surface Microlayer

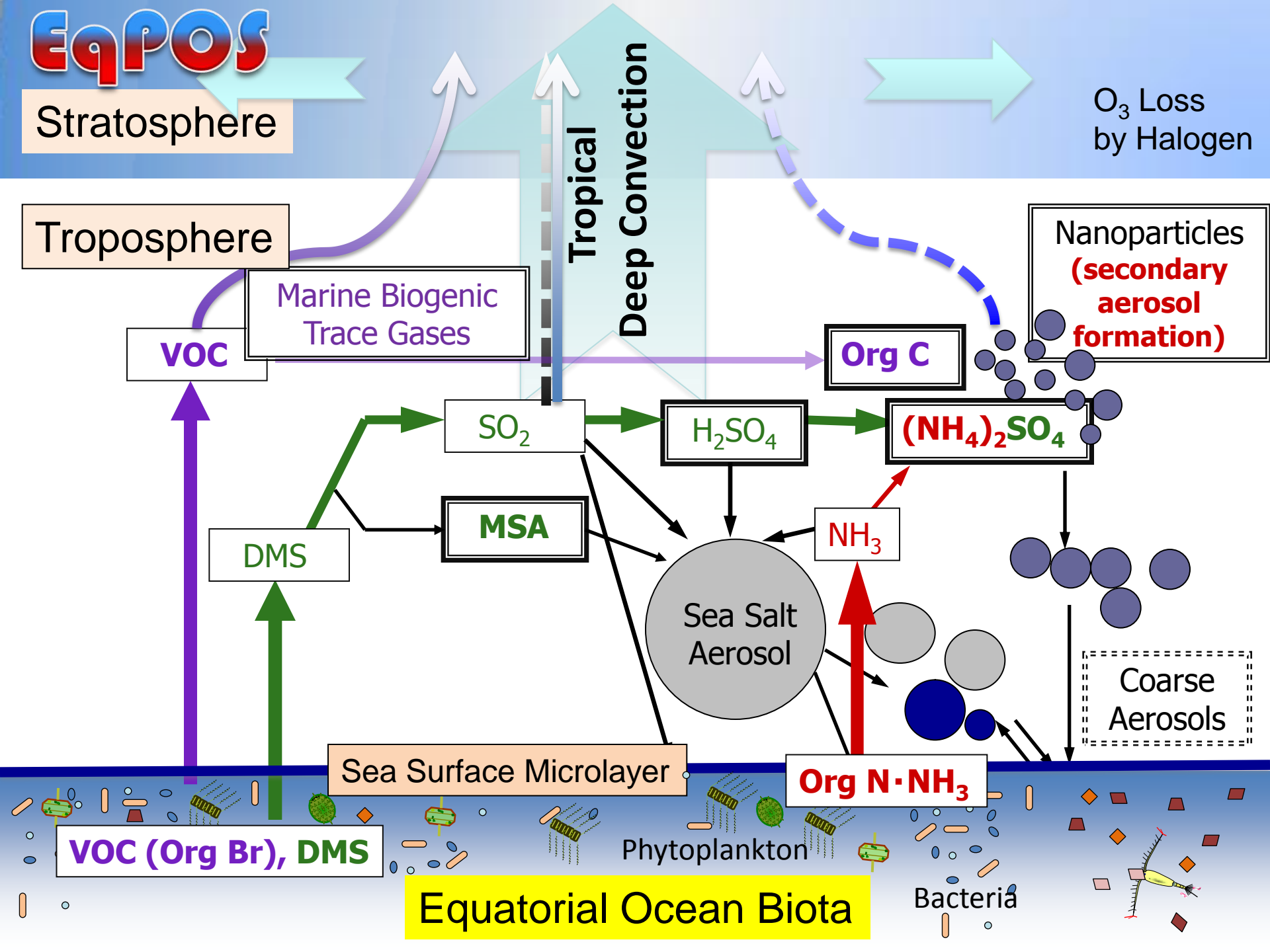
Org N-NH₃

VOC (Org Br), DMS

Phytoplankton

Equatorial Ocean Biota

Bacteria



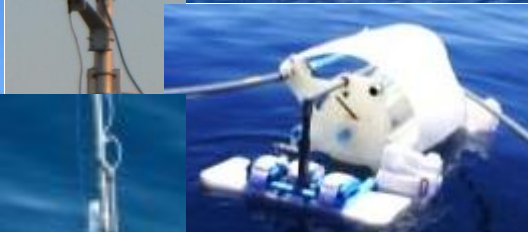
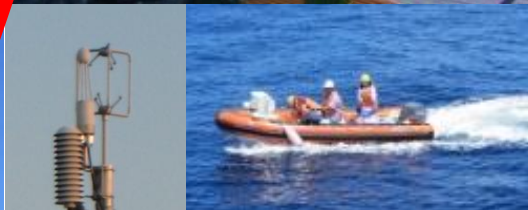
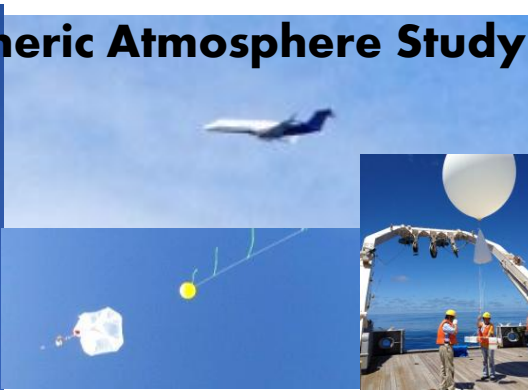
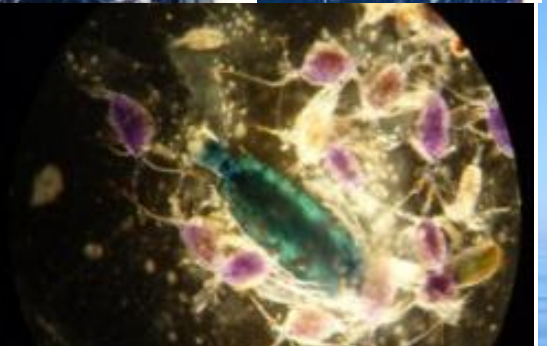
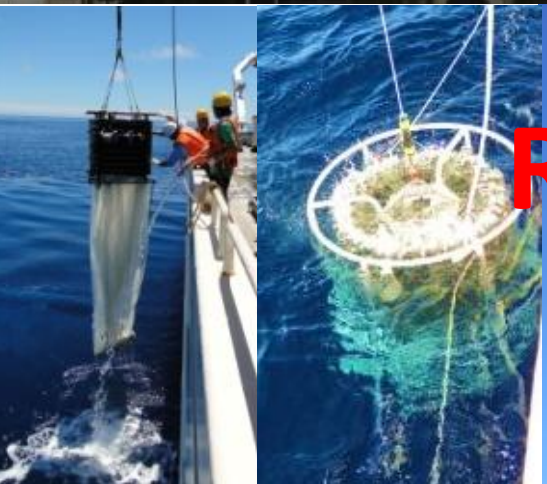
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Equatorial **P**acific **O**cean and
Stratospheric/Tropospheric Atmosphere Study

Sky, Ocean, and In-Between

Research Activity



Stratosphere (30 km)



EqPOS

O₃, CO₂, H₂O
Profiling



Stratospheric
Air Sampling
(Alt = 19-30 Km)

Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)

Eddy
Covariance

Trace Gas
(DMS, VOCs, CO₂,
CO, O₃)

Bubble Bursting

Gradient
Profile

Air-Sea
Flux

Surface
Microlayer
Sampling

DMS VOCs
CO₂

Dissolved Gas
(DMS, DMSP, VOCs,
pCO₂, O₂)

N-Fixation

Non-living
Particles

Phytoplankton

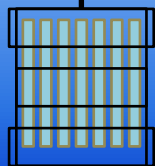
Bacteria

Microbial
Abundance,
Speciation,
Community

Micro-nutrient
condition

Zooplankton

Nutrients, Chl-a
TOC
DOC, DON



Ocean Floor (- 6 km)



Stratosphere (30 km)



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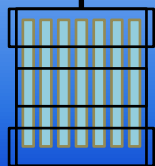
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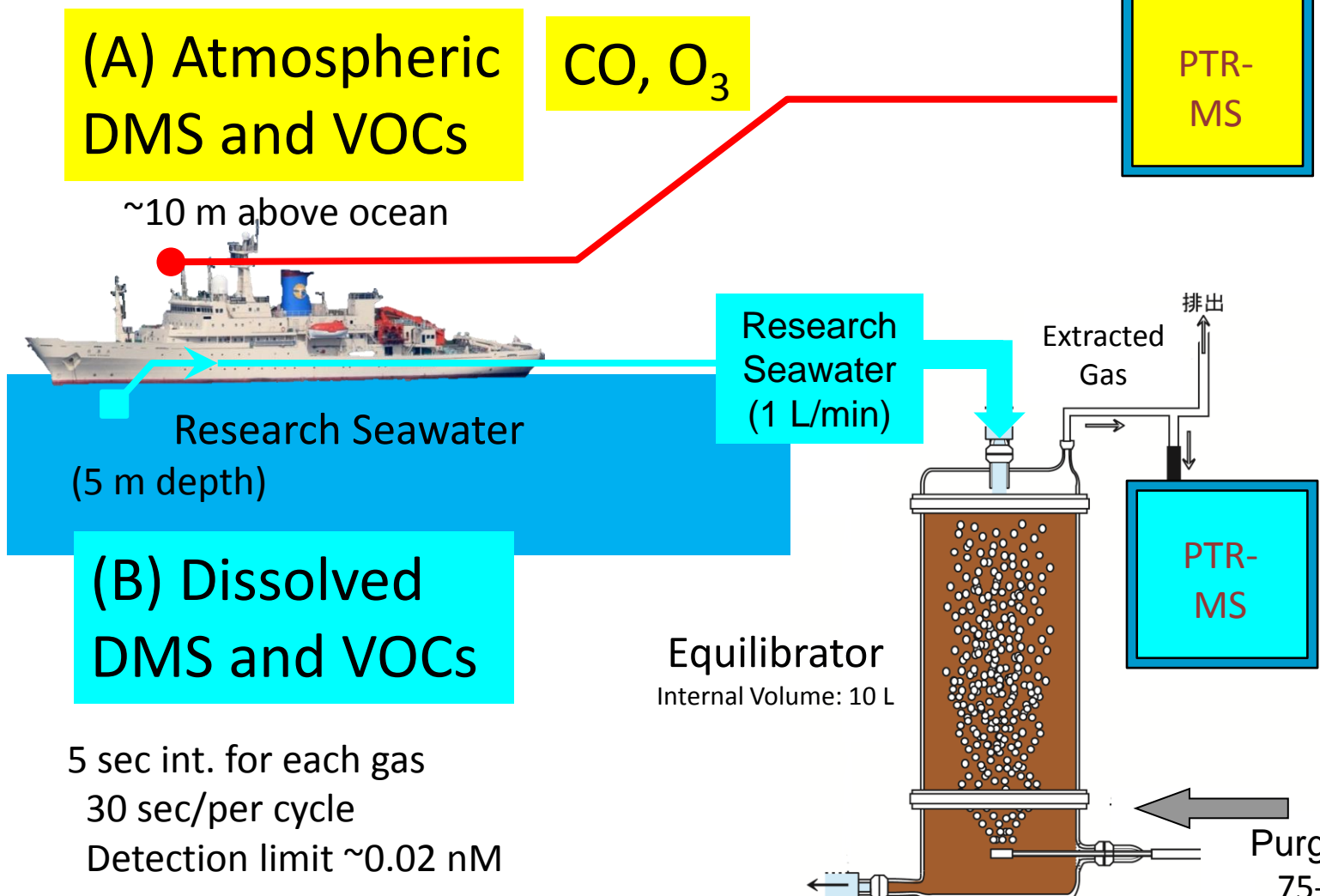
Ocean Floor (- 6 km)



Simultaneous and Continuous Measurement of Dissolved and Atmospheric DMS and VOCs with two PTR-MSs

Tanimoto Group (NIES)

DMS, Isoprene, Acetone, Methanol, Propene, Acetaldehyde



5 sec int. for each gas
30 sec/per cycle
Detection limit ~0.02 nM

Simultaneous and Continuous Measurement of

Dissolved and *Atmospheric* DMS and VOCs

Tanimoto Group
(NIES)

with two PTR-MSs

DMS, Isoprene, Acetone, Methanol, Propene, Acetaldehyde

(A) Atmospheric DMS and VOCs

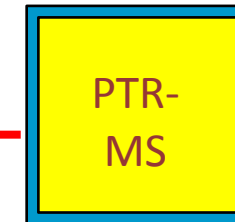
~10 m above ocean



Research Seawater
(5 m depth)

(B) Dissolved DMS and VOCs

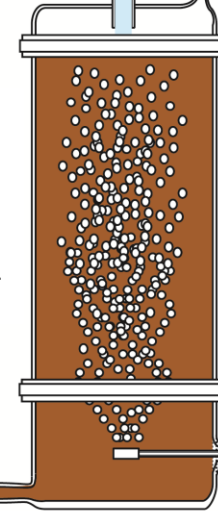
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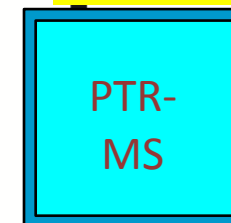
- Mapping of the gases
- Flux estimate
- Mapping of Flux
- Relationship to Marine Organisms

Research
Seawater
(1 L/min)

Extracted
Gas



Equilibrator
Internal Volume: 10 L



Purge Gas (N₂)
75-1000 sccm

Air-Sea Gas Flux Meas. (1/2)

CO₂-Eddy-Covariance



Top of Foremast

- Sonic Anemometer (Young 81000)
- CO₂/H₂O Analyzer for WEBB-correction (LiCor7500)
- Motion Sensing System (BEI, Motionpak2)

Kondo and Uematsu (AORI)

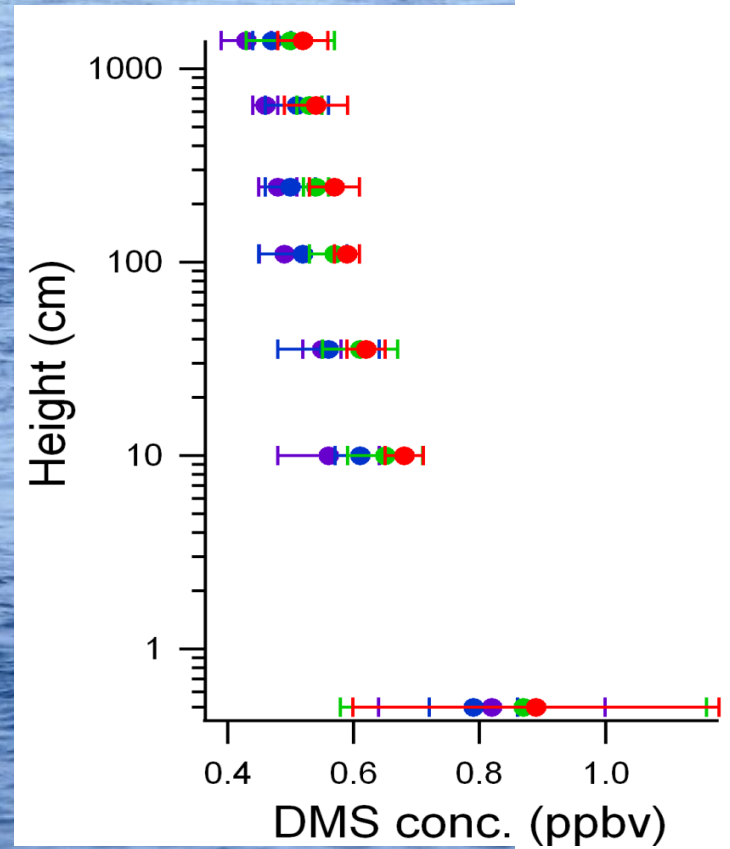
Air-Sea Gas Flux Meas. (2/2)

Aerodynamic Gradient Method

“Profiling Buoy”

DMS, VOCs, CO₂

Iwata Group (Okayama Unvi.)
Tanimoto Group (NIES)



- PTR-MS (DMS, VOCs)
- NDIR (CO₂)

Stratosphere (30 km)



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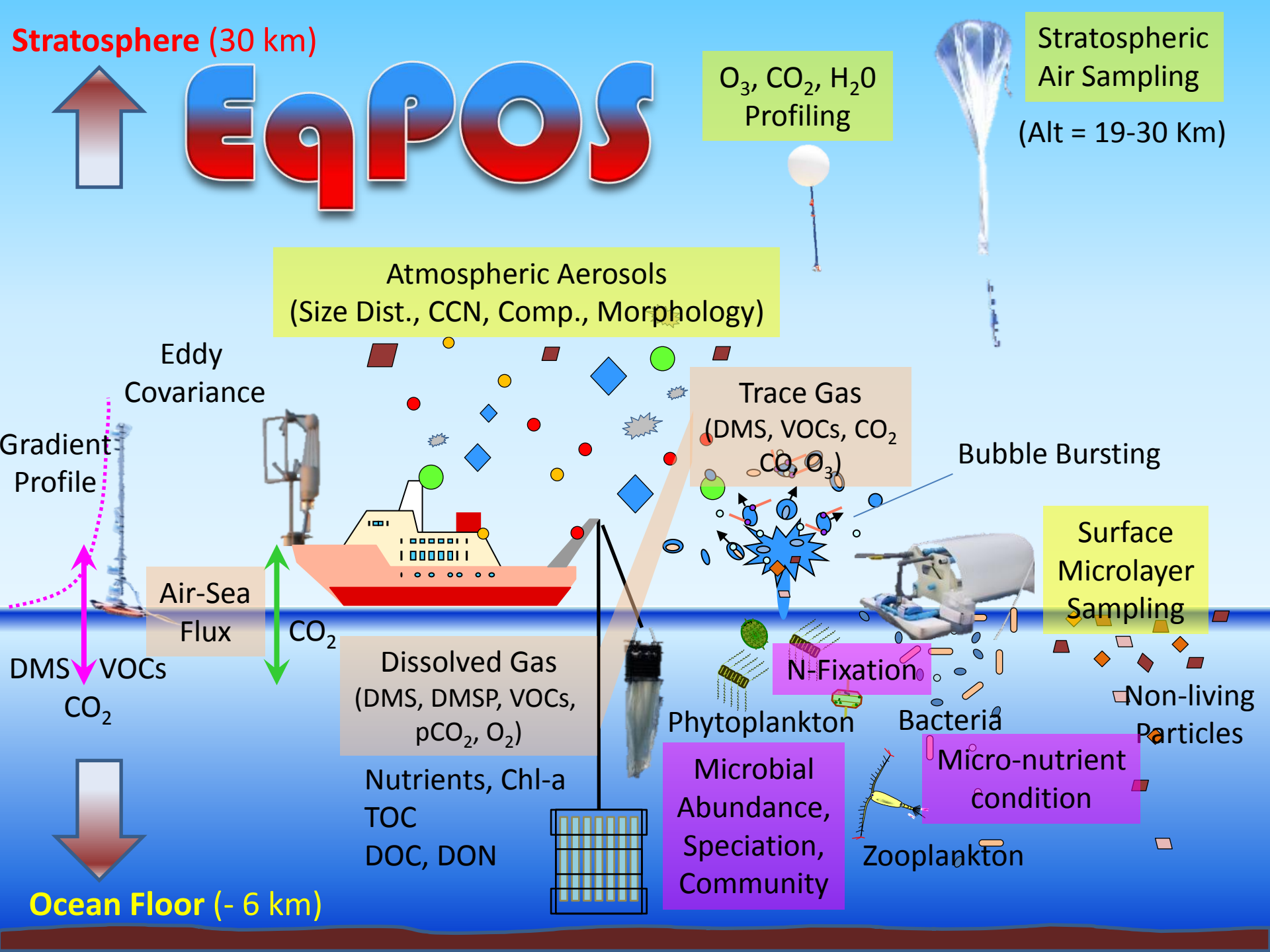
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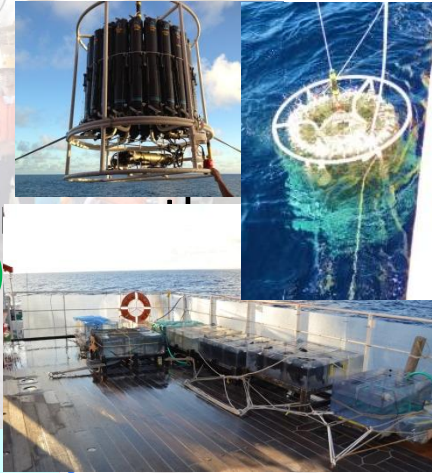
Zooplankton

Ocean Floor (- 6 km)



Marine Biological and Biogeochemical Observation

Eastern equatorial Pacific is a **HNLC ocean**



- **Micronutrients (Fe, Ni, Cu, Zn) co-limitation** of phytoplankton
(Prof. Takeda, Nagasaki Univ.)

Incubation with micronutrients (Fe, Ni, Cu, Zn) addition
=> Pico/nano-phytoplankton characterization by FCM
=> Chl-a, nutrient conc. measurements

- Distribution of **nitrogen fixation** and its **limitation by nutrients (Fe and Si)**
(Prof. Furuya, Univ. of Tokyo)

Incubation with Isotopically-labeled $^{15}\text{N}_2$ and $^{13}\text{CO}_3^-$
Incubation with enriched Fe and Si
Isotope ratio of marine particulate-N
Pico/nano-phytoplankton characterization by FCM

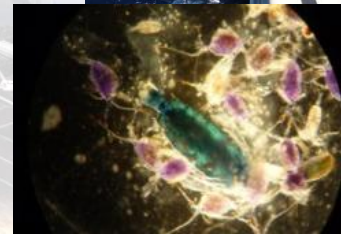
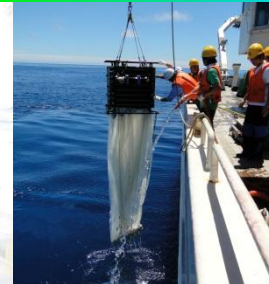
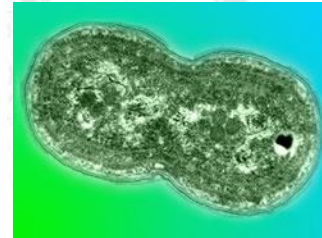
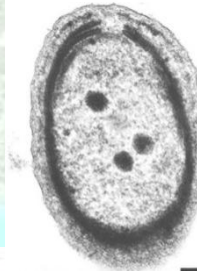
- **Microbial diversity** and **ecological functioning**

(Prof. Hamazaki, Univ. of Tokyo)

Bacterial DMSP metabolism vs. dissolved DMS conc.
Photoheterotrophic bacteria
Microbial community structure and its geographical distribution

- **Diversity** and **distribution** of **copepods** (zooplankton)

(Prof. Tsuda, Univ. of Tokyo)



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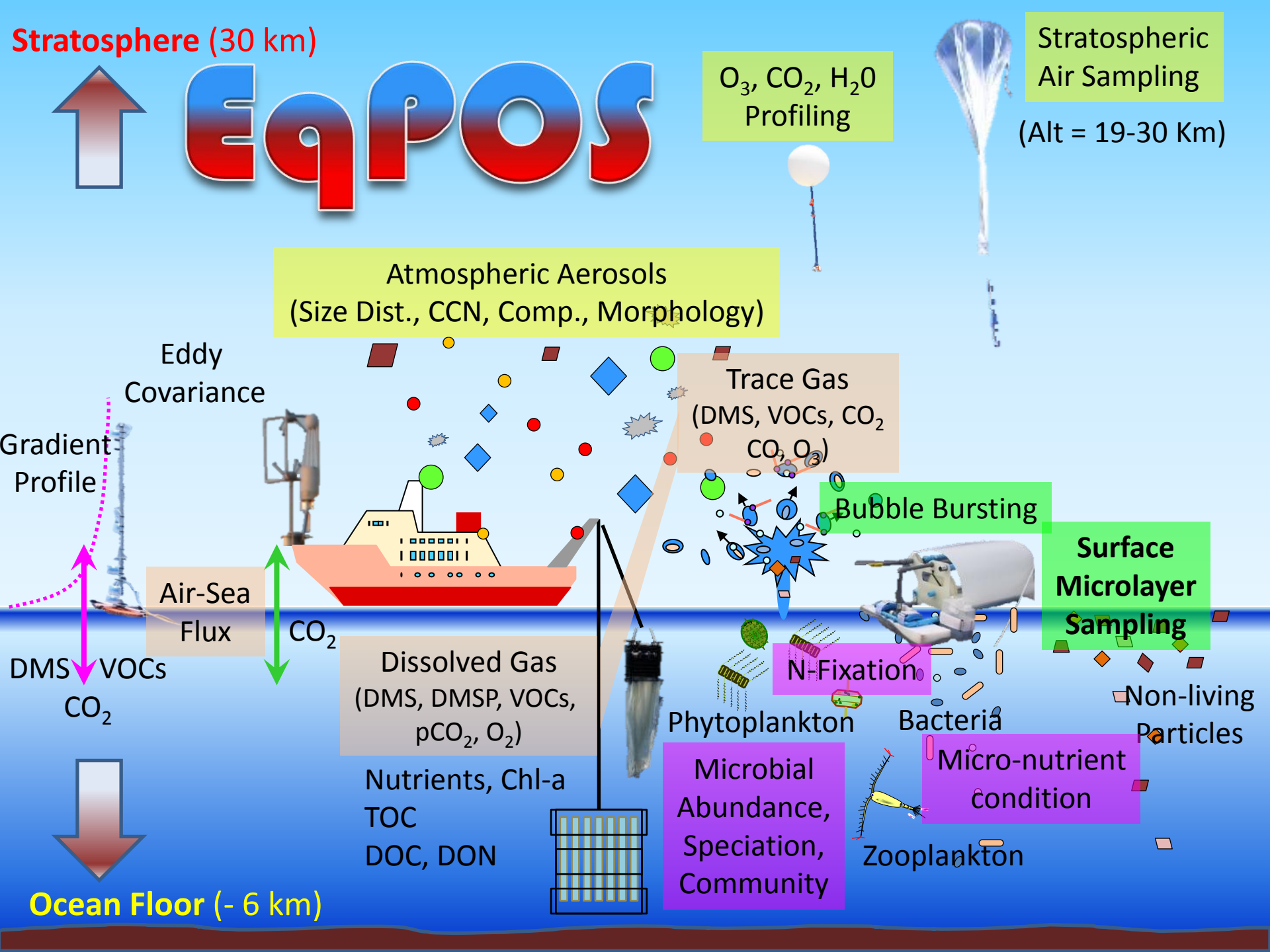
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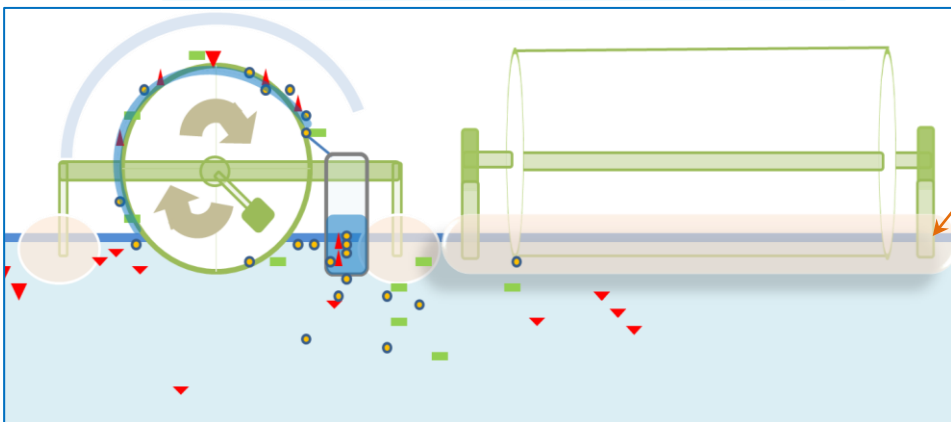
Ocean Floor (- 6 km)



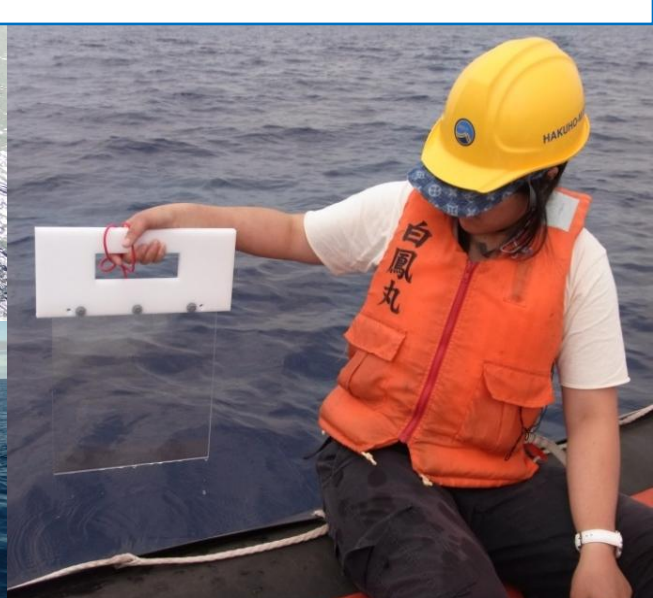
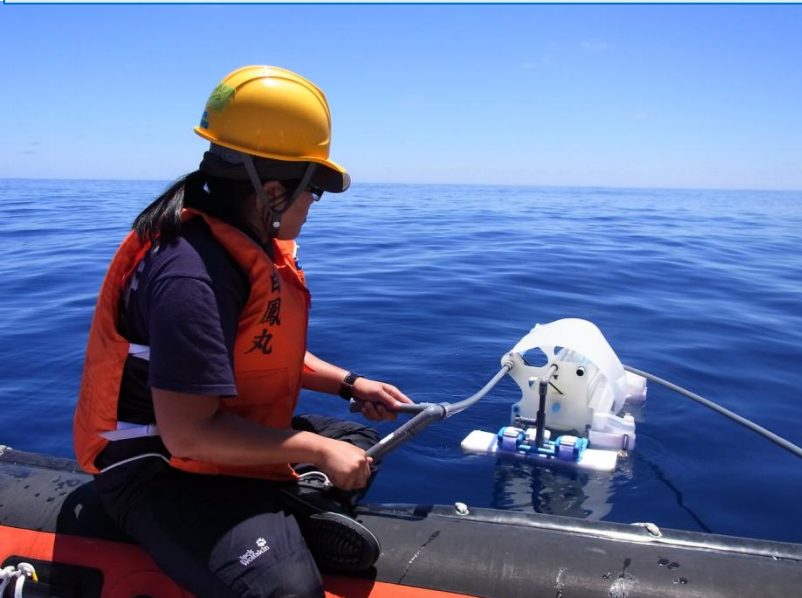
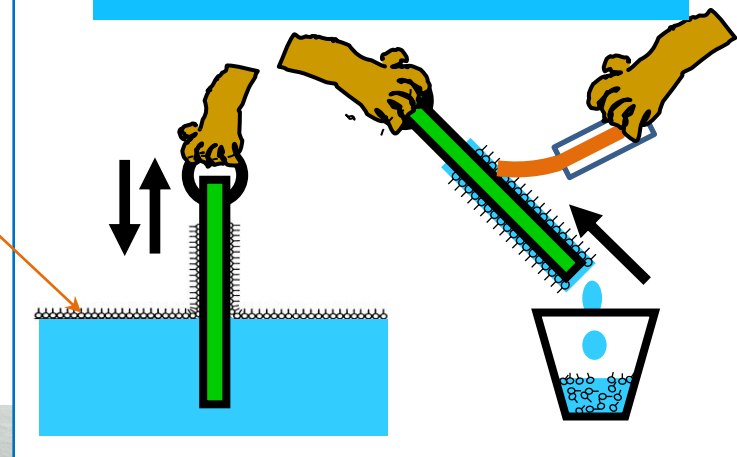
Sampling *Sea-Surface Microlayer (SML)*

Top thin layer of ocean surface (air-liquid interface)

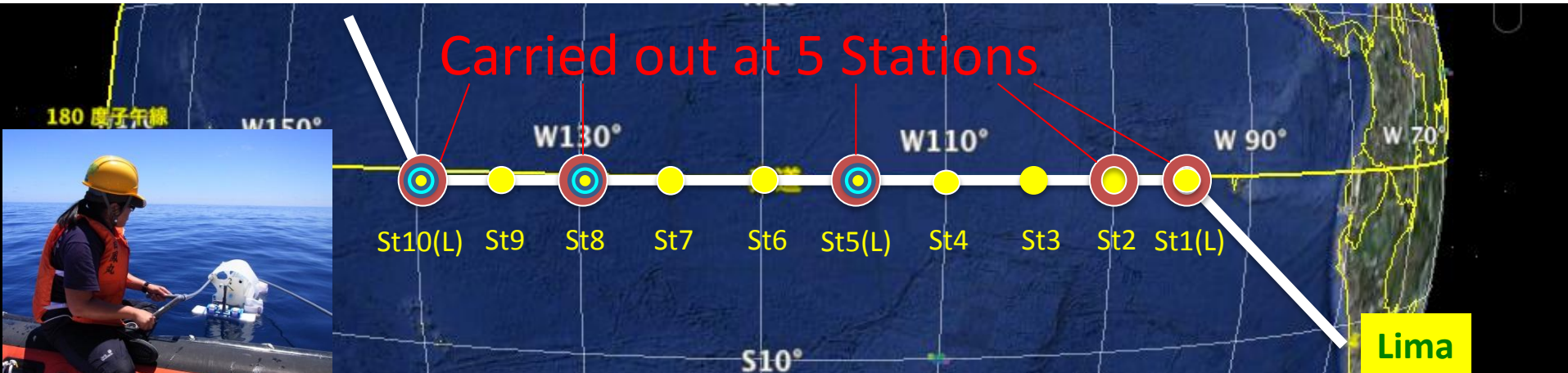
Rotating Drum Method



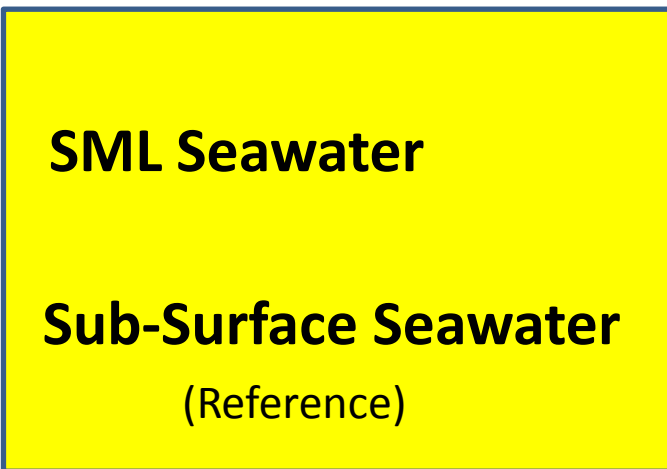
Glass Plate Method



Sea-Surface Microlayer (SML) Sampling



Further Analysis



Chemical Analysis

- Phosphorus
Total
Particulate vs. Dissolved
Organic vs. Inorganic
- Trace Metals
- Ionic Species

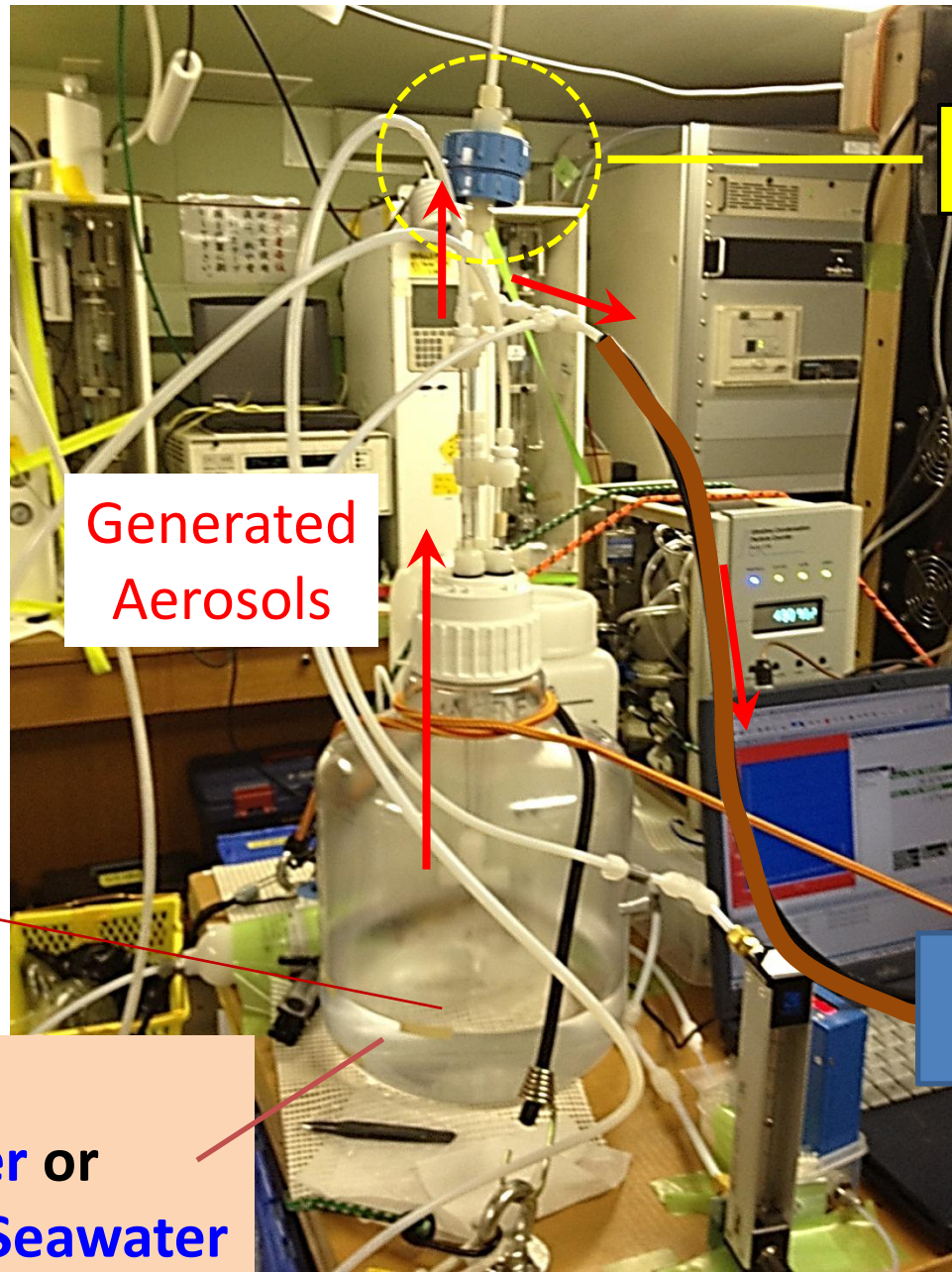
Generated Aerosols

Laboratory
Air Bubble Bursting



SML samples (St. 10, 8, 5) were provided for lab experiment by TORERO

Laboratory Bubble Bursting Aerosol Generation Exp.



Teflon Filter Pack

Further Off-Line Analysis

- ⇒ Total Phosphorus
- ⇒ Water Soluble Phosphorus
- ⇒ Total Organic Carbon?
- ⇒ Trace Metals?
- ⇒ Ionic Species

Generated Aerosols

Bubbling Head



On-Line Analysis

ATOFMS

~0.1 L/min

Silica Gel
Diffusion
Dryer

Pump

Sample:
SML Seawater or
Sub-Surface Seawater

Stratosphere (30 km)



EqPOS

O₃, CO₂, H₂O
Profiling



Stratospheric
Air Sampling
(Alt = 19-30 Km)

Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)

Trace Gas
(DMS, VOCs, CO₂,
CO, O₃)

Bubble Bursting

Surface
Microlayer
Sampling

Eddy
Covariance

Gradient
Profile

Air-Sea
Flux

CO₂

Dissolved Gas
(DMS, DMSP, VOCs,
pCO₂, O₂)

N-Fixation

Phytoplankton

Bacteria

Non-living
Particles

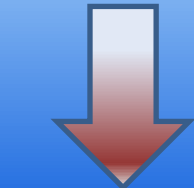
DMS VOCs
CO₂

Nutrients, Chl-a
TOC
DOC, DON

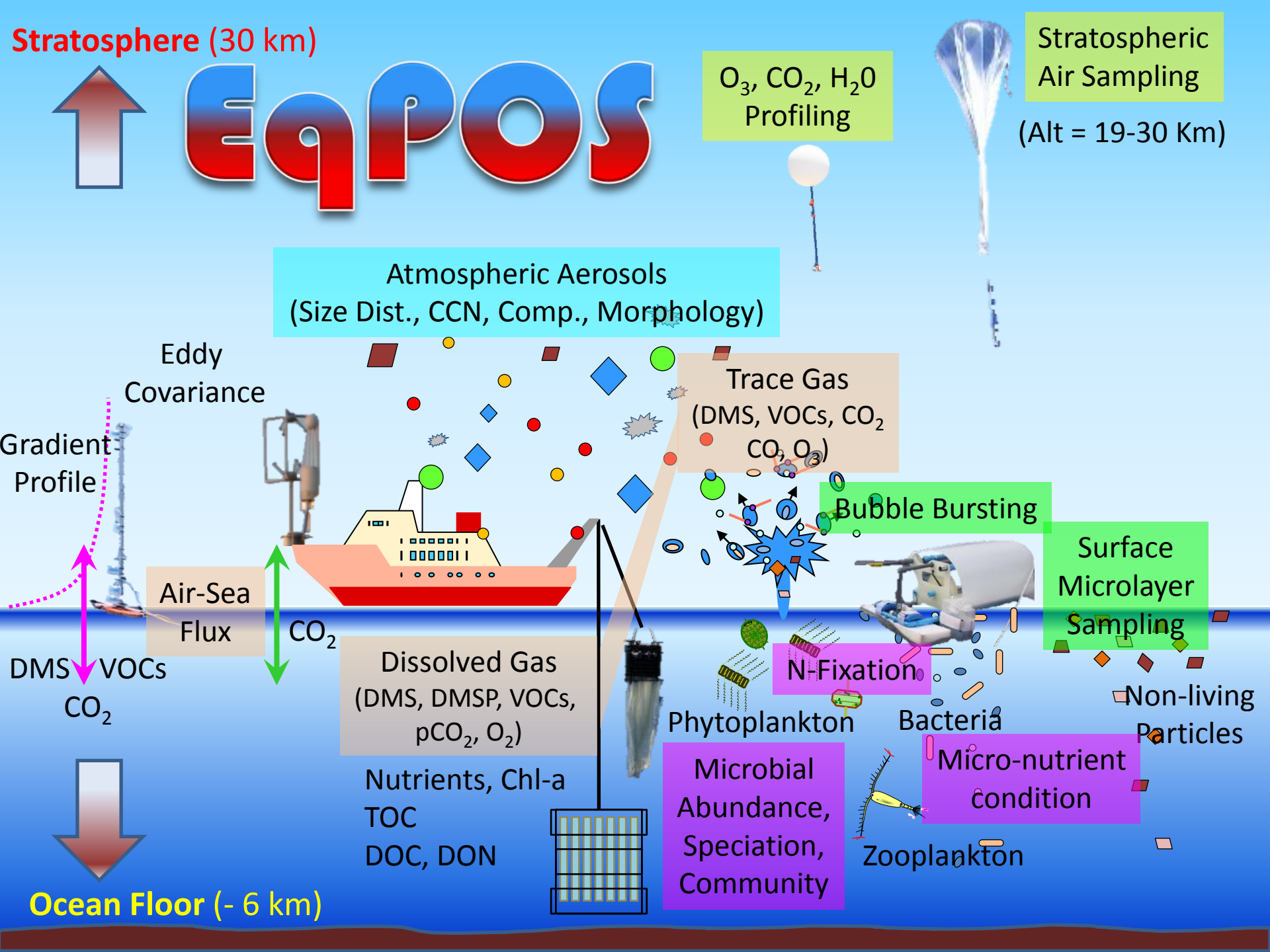
Microbial
Abundance,
Speciation,
Community

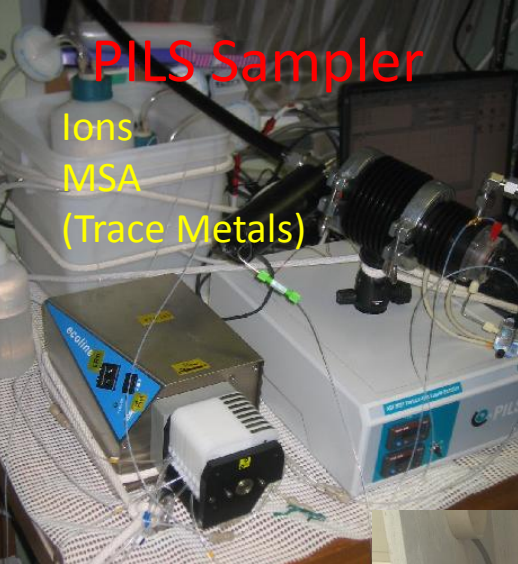
Micro-nutrient
condition

Zooplankton



Ocean Floor (- 6 km)





PILS Sampler

Ions
MSA
(Trace Metals)



Aerosol Filter Samplers (5 Units)

Ionic Species
MSA
Trace Metals
Phosphorus

TEM Sample Collection

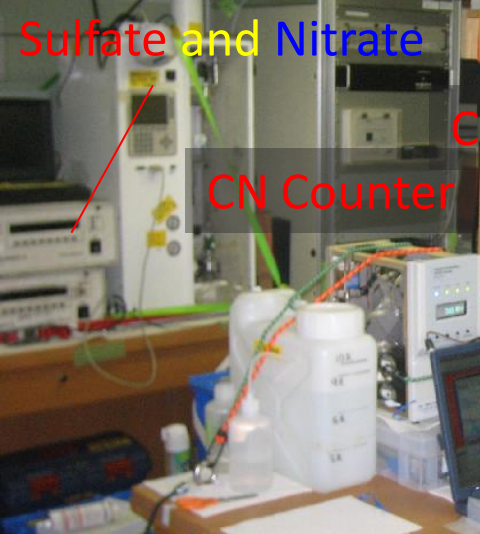
($d < 2.5 \mu\text{m}$, $d > 2.5 \mu\text{m}$)
($d = 0.06 \sim 12 \mu\text{m}$, 12stage)



Small Ion
Counter (+/-)

Size Distribution
SMPS (10-500 nm)
OPC (0.1 -10 μm)

Particulate Total
Sulfate and Nitrate



CN Counter

CCN Counter



Single Particle
Mass Spectrometer
(ATOFMS)

Stratosphere (30 km)



EqPOS

O₃, CO₂, H₂O
Profiling



Stratospheric
Air Sampling
(Alt = 19-30 Km)

Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)

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Bubble Bursting

Surface
Microlayer
Sampling

Non-living
Particles

Eddy
Covariance

Gradient
Profile

Air-Sea
Flux

CO₂

Dissolved Gas
(DMS, DMSP, VOCs,
pCO₂, O₂)

Nutrients, Chl-a
TOC
DOC, DON

N-Fixation

Phytoplankton

Microbial
Abundance,
Speciation,
Community

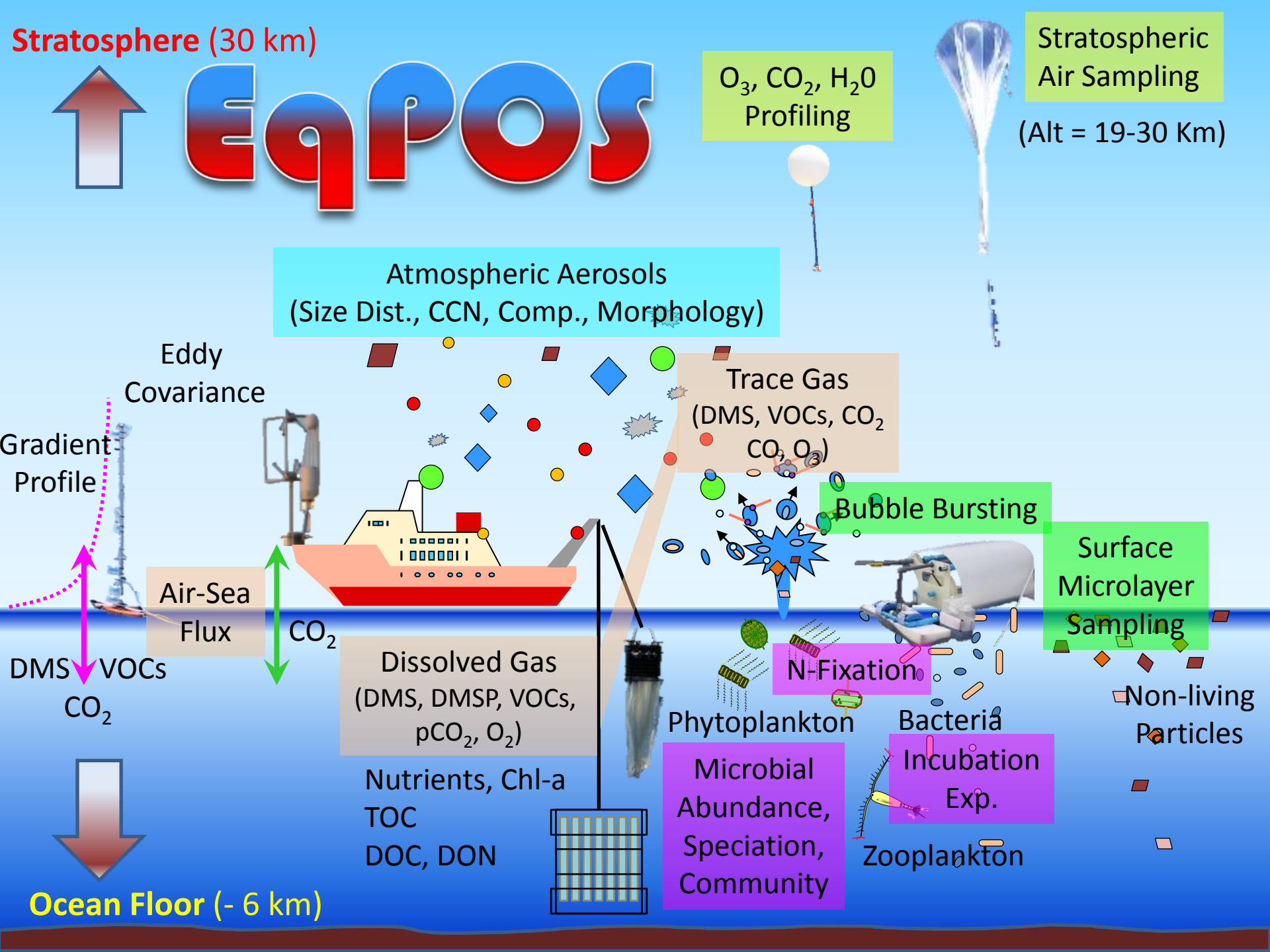
Bacteria

Incubation
Exp.

Zooplankton

DMS VOCs
CO₂

Ocean Floor (- 6 km)



Launch Large Balloons for Stratospheric Air Sampling

4 Launches (All Succeeded!)
(Alt = 19-30 km)



He Gas Cylinders



Stratospheric Air Sampling Balloon

(4 Launches)
Alt = 19-30 km

Analyzed Gas Species:

- CO₂ $\delta^{15}\text{N}$ of N₂
- CH₄ $\delta^{18}\text{O}$ of O₂
- N₂O D/H of CH₄
- SF₆
- CO
- H₂, Ar

St10

2/14



2/10



2/7

St5

2/4

2/2

St1

1/29
Callao
(Peru)



EqPOS

Stratospheric Air Sampling Balloon

(4 Launches)
Alt = 19-30 km

O₃, CO₂, H₂O Sonde

(6 Launches)
Alt = 0-30 km

St10
2/14



2/10

2/7

St5

2/4

2/2

St1

1/29
Callao (Peru)



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image
Image U.S. Geological Survey
Image © 2012 TerraMetrics

Google earth

TORERO

Stratospheric Air Sampling Balloon

(4 Launches)
Alt = 19-30 km

EqPOS

O₃, CO₂, H₂O Sonde

(6 Launches)
Alt = 0-30 km

R/V Kaimimoana

St10
2/14

2/10

St5
2/7

2/4

St2
2/2

St1

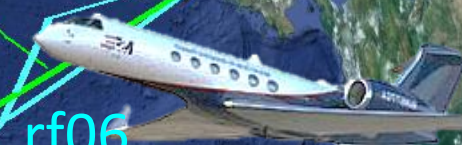
TORERO



EqPOS

Callao
(Peru)

1/29



rf07

rf06

All vertical profiles of T, RH, CO₂, H₂O, GPS data are shared with TORERO

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
© 2012 Cnes/Spot Image
Image U.S. Geological Survey

Google ea

Stratosphere (30 km)



EqPOS

O₃, CO₂, H₂O
Profiling



Stratospheric
Air Sampling
(Alt = 19-30 Km)

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Microlayer
Sampling

Eddy
Covariance

Gradient
Profile

Air-Sea
Flux

CO₂

Dissolved Gas
(DMS, DMSP, VOCs,
pCO₂, O₂)

N-Fixation

Phytoplankton

Bacteria

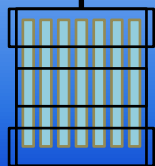
Non-living
Particles

DMS VOCs
CO₂

Microbial
Abundance,
Speciation,
Community

Incubation
Exp.
Zooplankton

Nutrients, Chl-a
TOC
DOC, DON



Ocean Floor (- 6 km)



EqPOS

**Equatorial Pacific Ocean and
Stratospheric/Tropospheric Atmosphere Study**

Summary

- **EqPOS** is a biogeochemical research cruise on eastern equatorial Pacific Ocean to investigate linkage between marine biota and atmosphere in eastern equatorial Pacific Ocean.
- EqPOS covers broad range of research field: marine biology/biogeochemistry, marine chemistry, atmospheric chemistry, atmospheric science.
- Nicely overlaps with TORERO campaign in time and space, and scientific research topics, and nicely different observations.

Acknowledgement



東京大学
THE UNIVERSITY OF TOKYO



- All participants for *more-than-planned* research activity and fun and joy together
- R/V Hakuho crew (Seino captain) for perfect support!
- TORERO (PI Prof. Volkamer) project for excellent collaboration.



PI Prof. Uematsu
(at the end of the cruise)

EqPOS

Equatorial Pacific Ocean and Stratospheric/Tropospheric Atmosphere Study

