東京大学
THE UNIVERSITY OF TOKYO

AORI

PICES-2011

Science Board Symposium
Mechanisms of Marine Ecosystem Reorganization in the North Pacific Ocean

Potential importance of volcanic emissions on marine biogeochemical cycles and clouds over the North Pacific

Mitsuo UEMATSU[1], Shigenobu Takeda[2], Hiroshi Furutani[1] and Itsushi Uno[3]

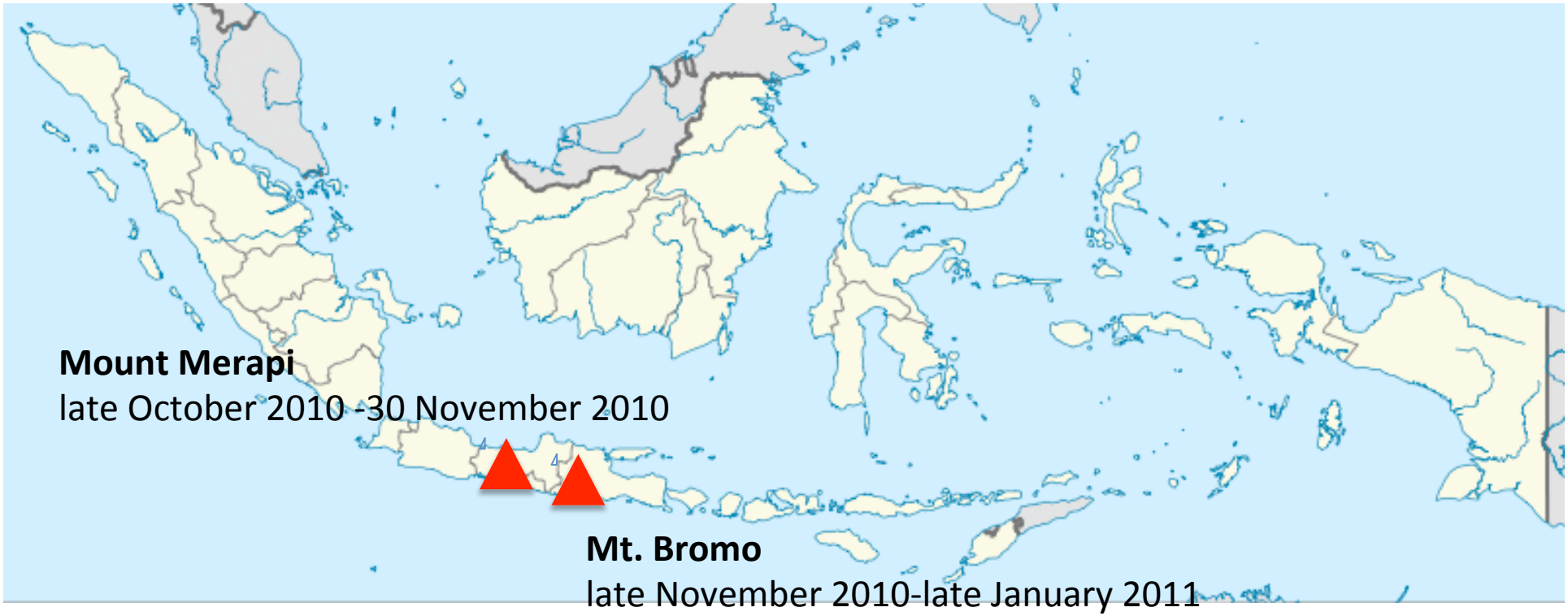
1:The University of Tokyo,
2: Nagasaki University, and 3:Kyushu University

PICES

Khabarovsk, Russia
17 October 2011

Eyjafjallajökull, Iceland

エイヤフィヤトラヨークトル火山　　April 14, 2010


Mount Merapi
late October 2010 -30 November 2010
Mt. Bromo
late November 2010-late January 2011

2010 Eruption

Merapi volcano was raised to level 3 alert (out of a maximum 4) due to inflation and volcanic earthquakes on 21st October 2010. Sand miners were asked to stop all activity, and people advised not to climb the volcano.

Merapi volcano erupted on 26th October 2010 killing 13 people.

Mount Bromo eruption 22 January 2011

Shinmoedake

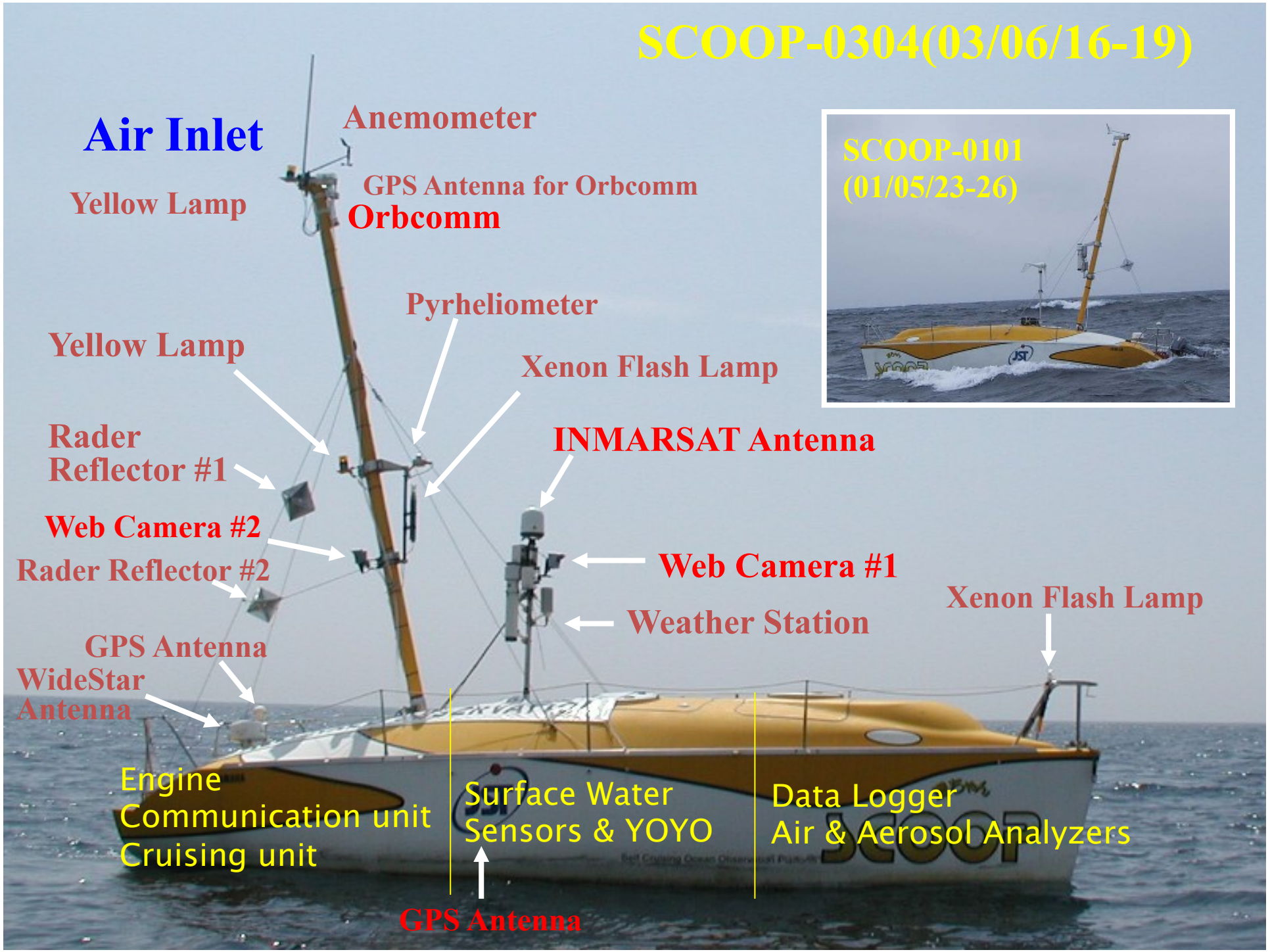
The latest eruptions began on January 19, 2011

Hunga Tonga

March 2009

Tonga

eruption of an underwater volcano in the South Pacific
Six miles off Tonga's main island of Tongatapu


SCOOP-0304(03/06/16-19)
Air Inlet
Anemometer
GPS Antenna for Orbcomm
Orbcomm
Yellow Lamp
Pyrheliometer
Yellow Lamp
Xenon Flash Lamp
Rader
Reflector #1
INMARSAT Antenna
Web Camera #2
Rader Reflector #2
Web Camera #1
Weather Station
Xenon Flash Lamp
GPS Antenna
WideStar
Antenna
Engine
Communication unit
Cruising unit
Surface Water
Sensors & YOYO
Data Logger
Air & Aerosol Analyzers
GPS Antenna
SCOOP-0101
(01/05/23-26)


YOYO


Salinity•Temp.
Sensors
Chlorophyll•Turbidity
Sensors
YOYO
Storage Hole

GPS

Observation Data
Cruising
Parameters

Start / Stop
Destination Location

MOBOTIX

CCD
Camera

Wireless
LAN

Wind Speed
& Direction

Compass

Inclinometer

Speed Meter

Cruising
Control
Unit

Cruising
Parameters

Destination
Location
Command

Communication Unit

Atmospheric
Measurements

NO_2, SO_2, NH_3, O_3
Aerosol, BC, Mass,
Size, Number

Current

Motor Speed

Propulsive Motor

Speed

Start/Stop
Speed Control

Diesel Engine

AC&DC dynamos

Power Unit

Rudder Angle

Rudder

Steerage Control

Oceanic Measurements

Sal., Temp, Turbidity, Chlorophyll

Yoyo System

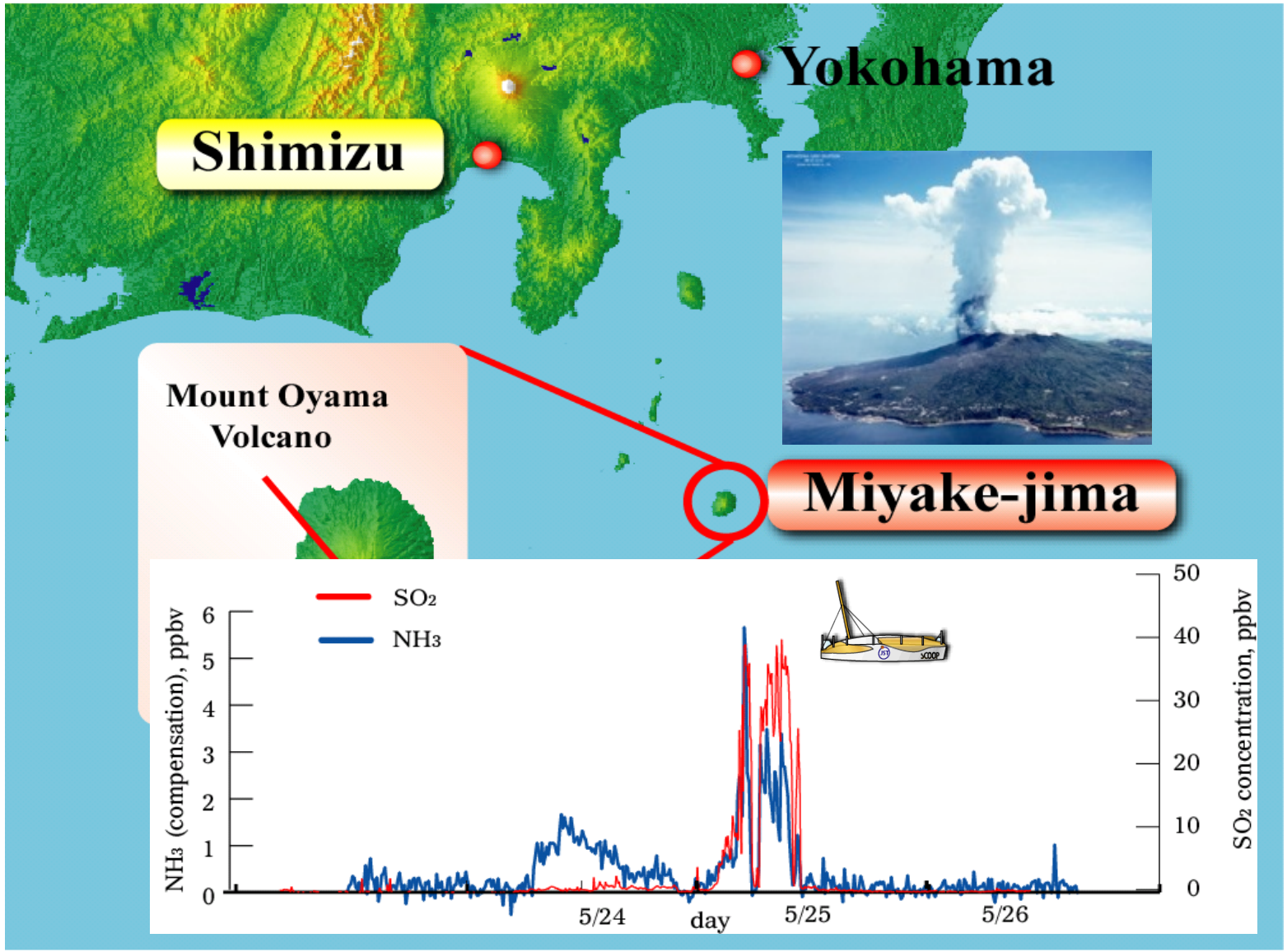
Functional Block Diagram of SCOOP

LAN (TCP/IP)

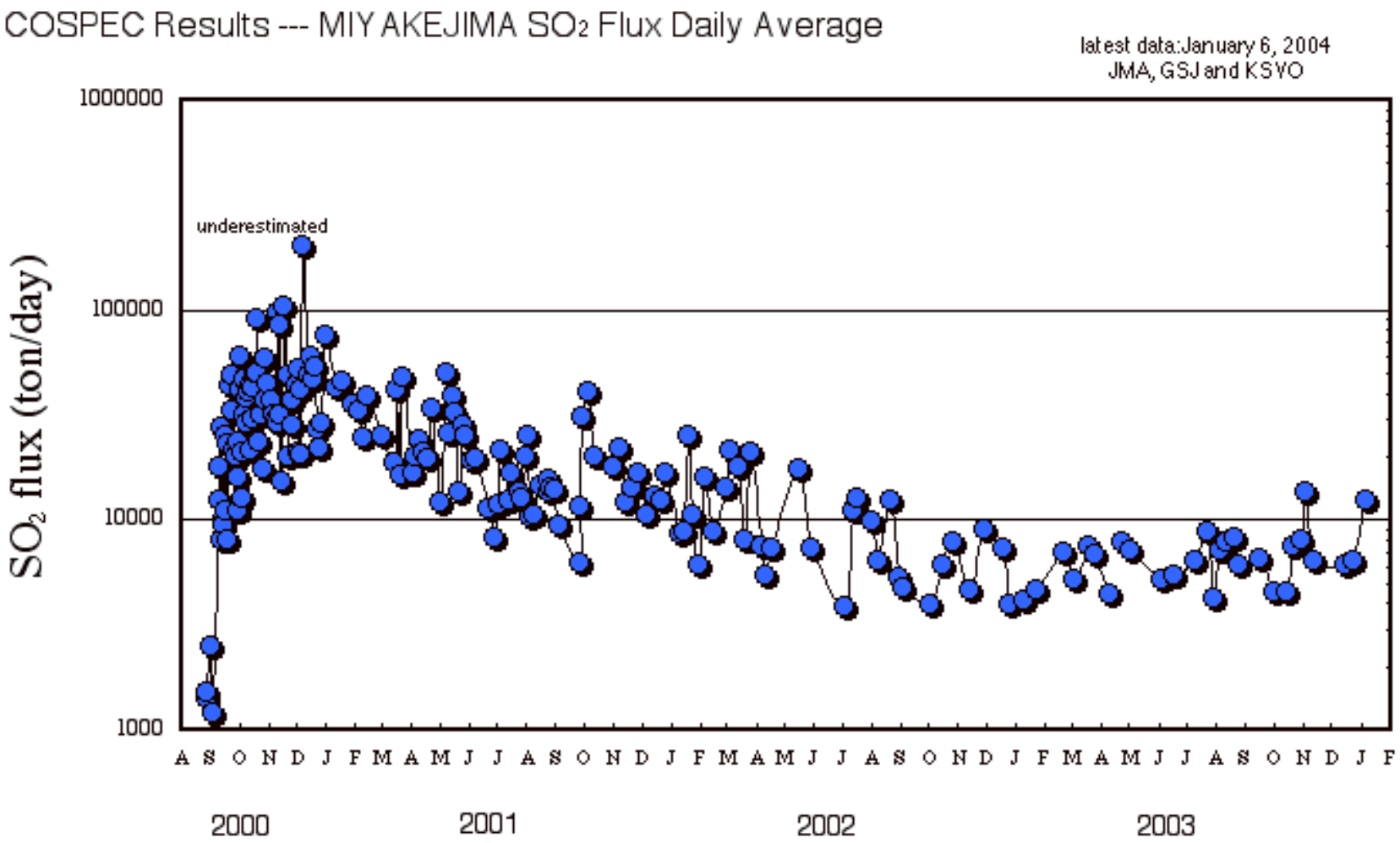
RS232C


VMAP project team
SCOOP

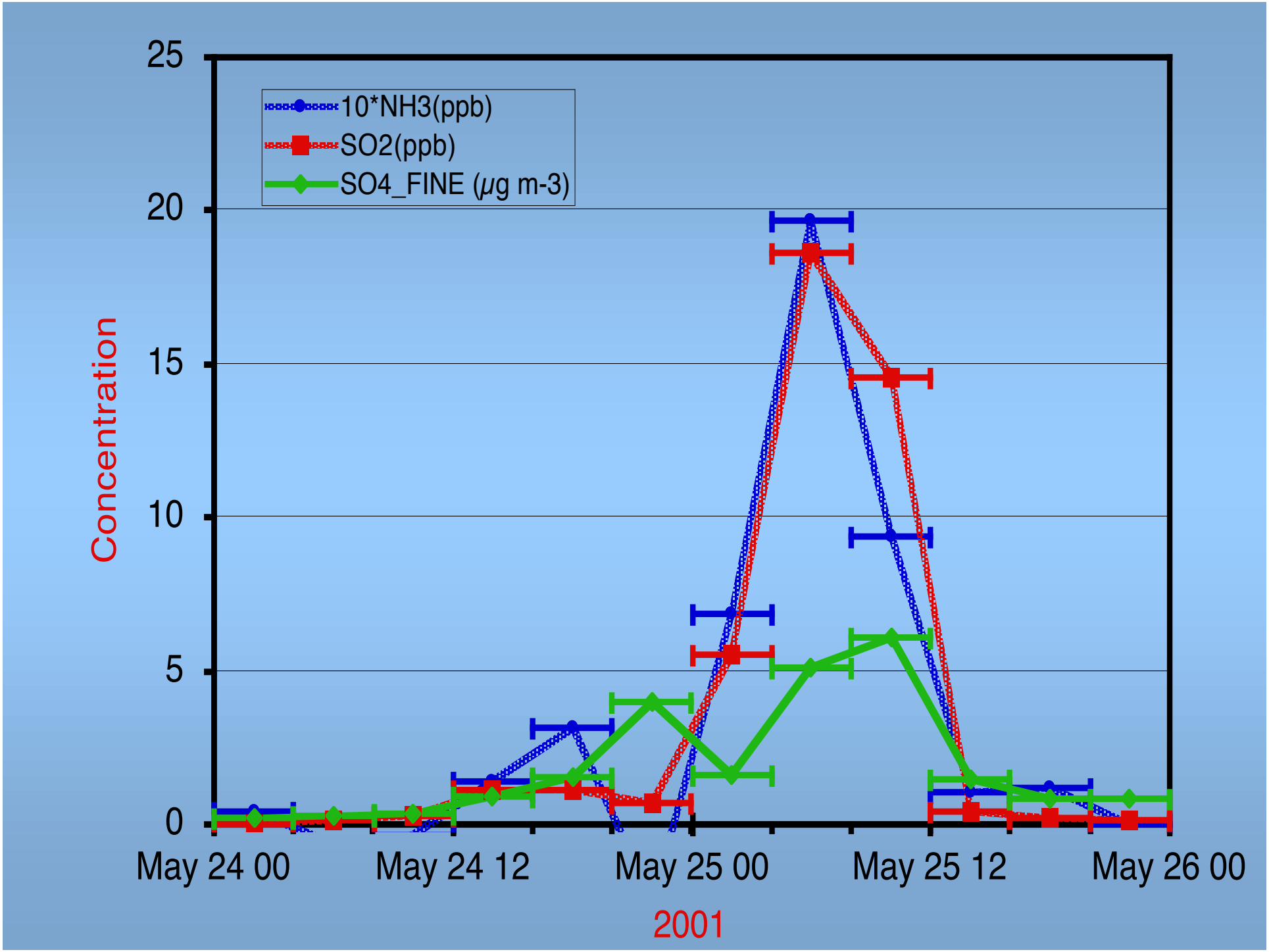
SCOOP (Self Cruising Ocean Observation Platform)
Observation for SCOOP-0101 in 2001



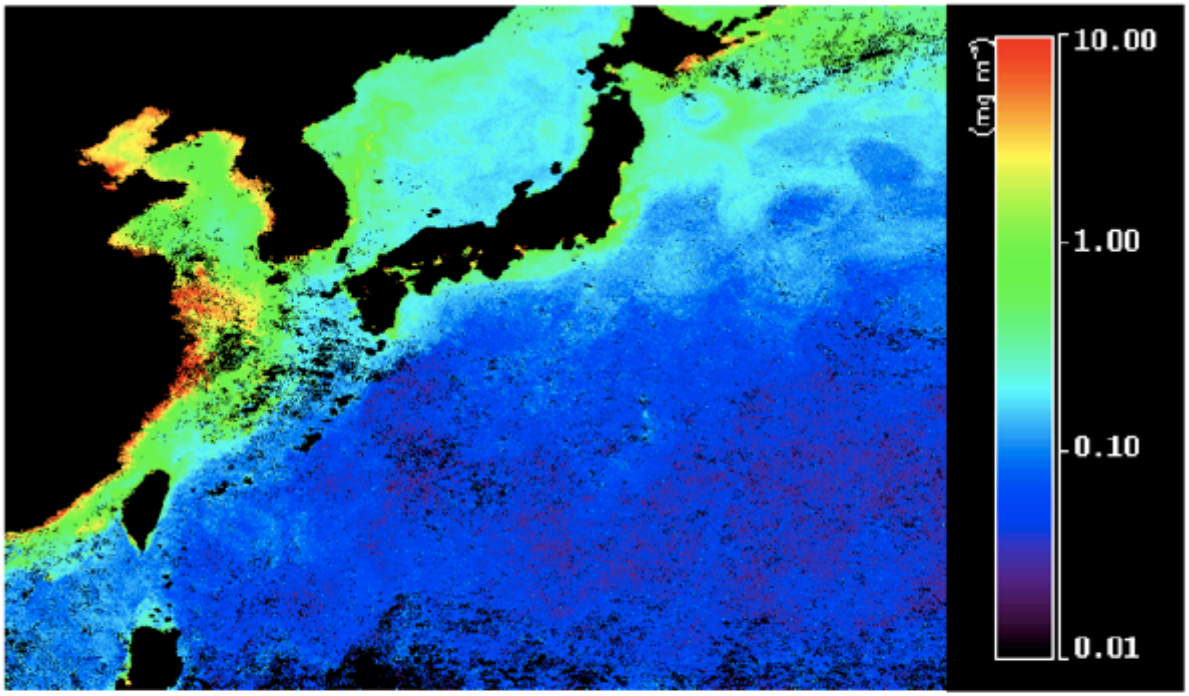
http://staff.aist.go.jp/kazahaya-k/miyakegas/COSPEC.html



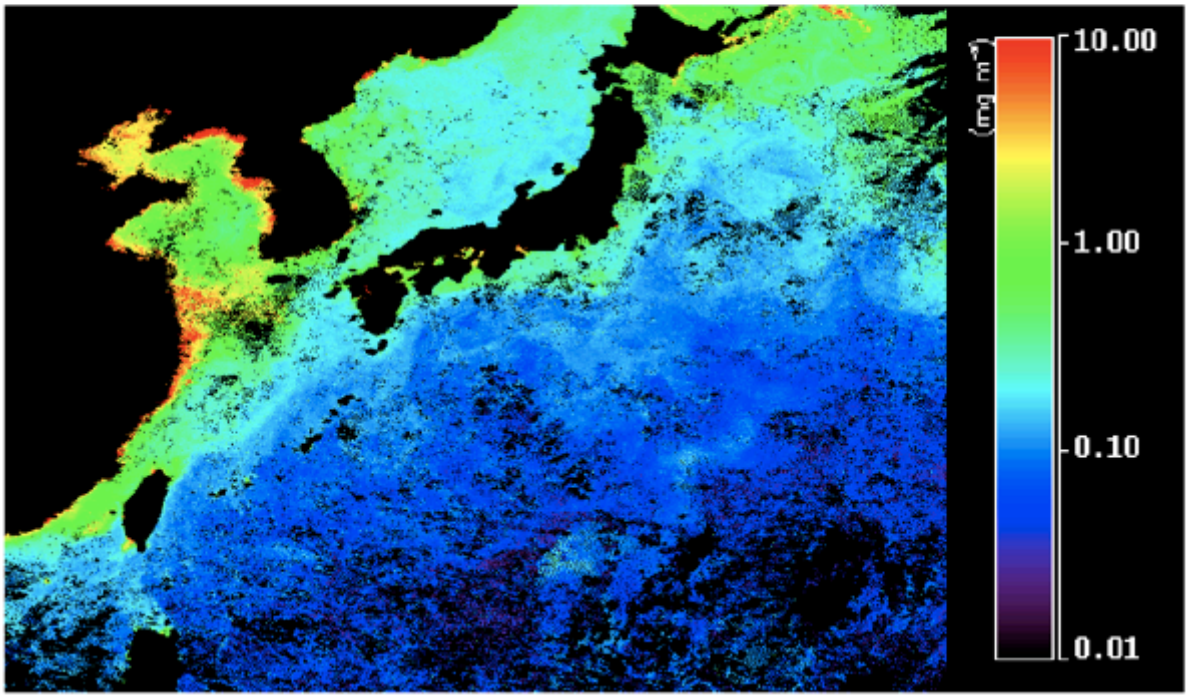
25% of the emission of SO_2 from China and more than 10 times as that from Japan [*Streets et al.*, 2000]


10*NH3(ppb)
SO2(ppb)
SO4_FINE (μg m-3)
Concentration
25
20
15
10
5
0
May 24 00
May 24 12
May 25 00
May 25 12
May 26 00
2001

Before Eruption
August 1998

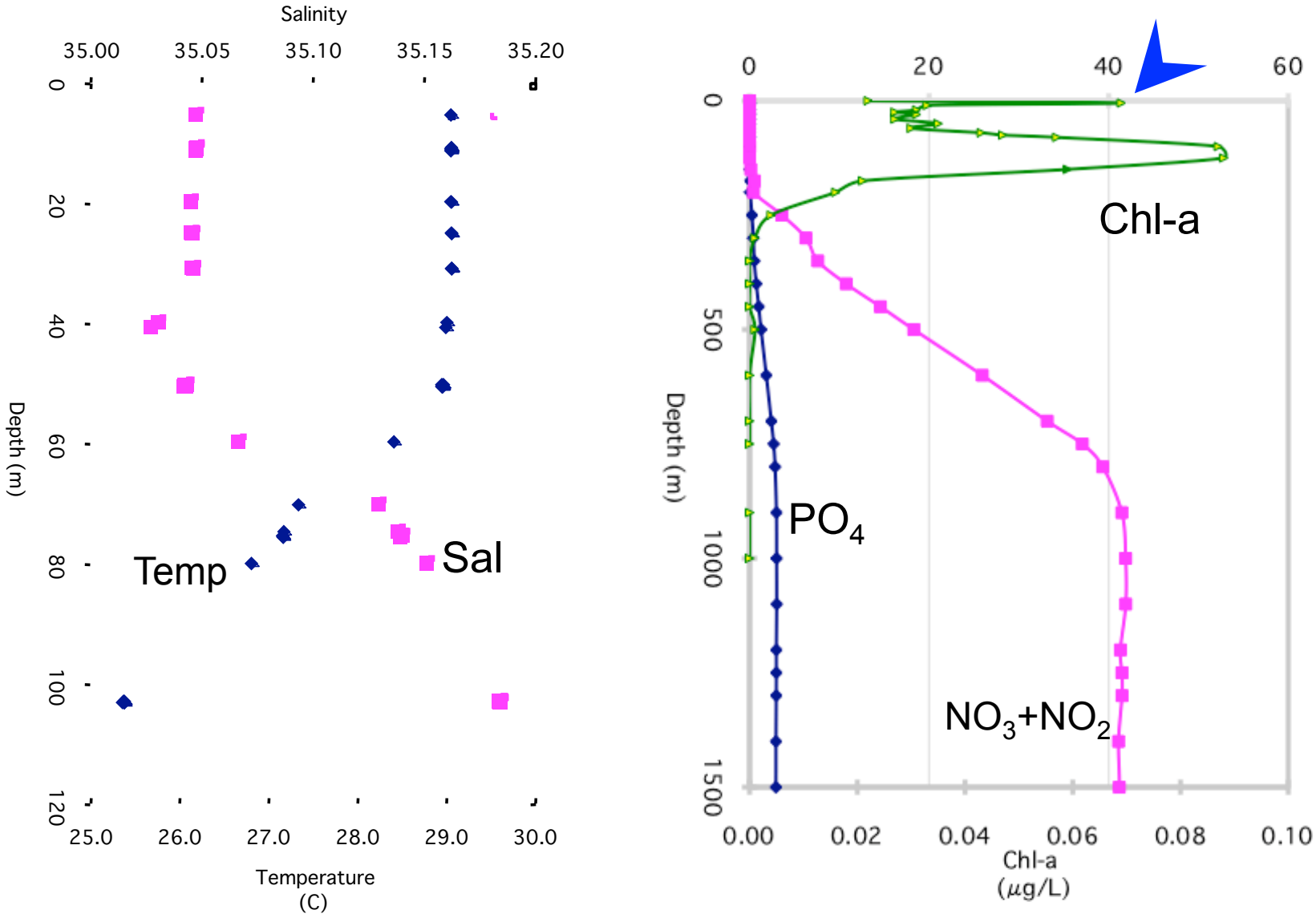


After Eruption
August 2001



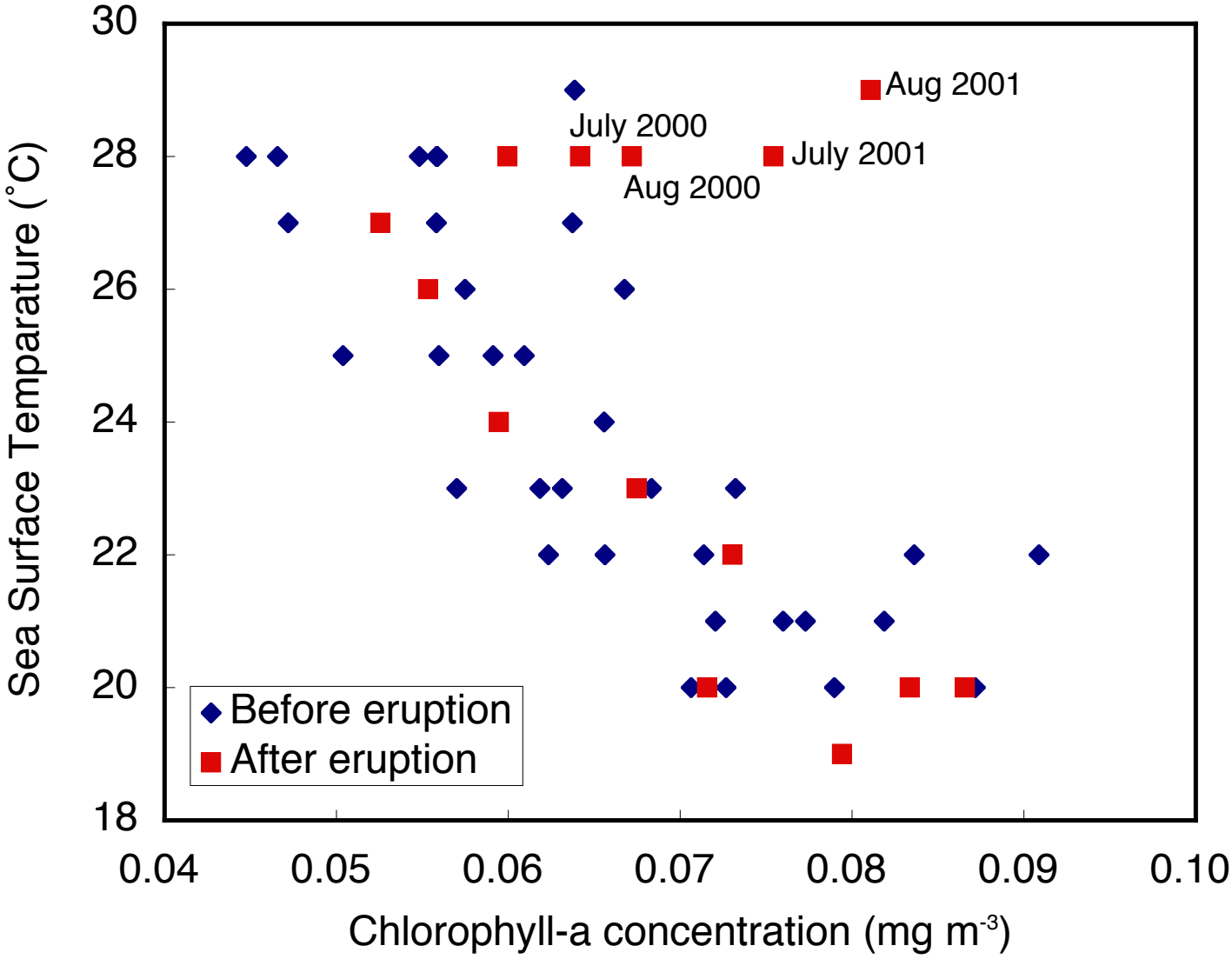
Vertical Profiles at 21N, 151E,
July 2000

KH-00-3 Stn BO-07 (22˚N, 151˚E) 21-23 July 2000



From Preliminary Report of the Hakuho Maru Cruises KH-00-3

High Chlorophyll-a in the surface water stratified during the summer season after the eruption



Uematsu et al., Geophys. Res. Lett., 2004

Simple Estimation of Nitrogen Flux From Miyake Eruption

Mole ratios of N and S in the plume of Miyake eruption:

NH_4:SO_4: NH_3: SO_2 = 1: 1: 1: 12

Approx. 15% of SO_2 is equivalent to the amount of reduced Nitrogen (NH_4 + NH_3)

From Sep. 2000 to Aug. 2001

SO_2 emission: **10×10^{12} g SO_2 period^{-1}**

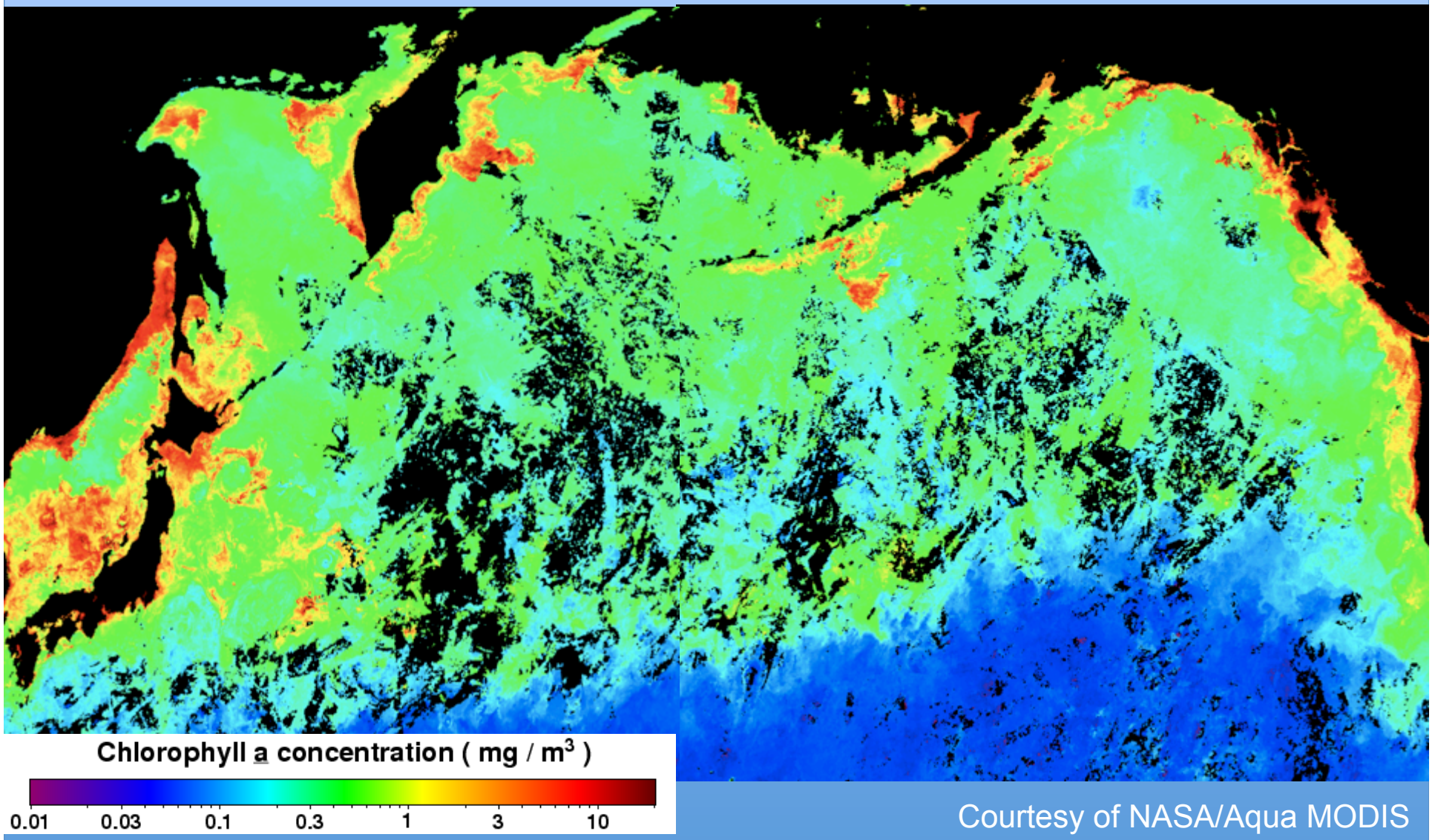
N emission: **40×10^{10} g N period^{-1}**

Total Deposition of Reduced Nitrogen over the North Pacific

600×10^{10} gN yr^{-1} (Duce et al., 1991)

If all reduced nitrogen emitted from Miyake eruption deposited to the vicinity of Miyake Island, additional 7% of nitrogen deposition to the entire North Pacific may affect to marine biological activity in this limited region.

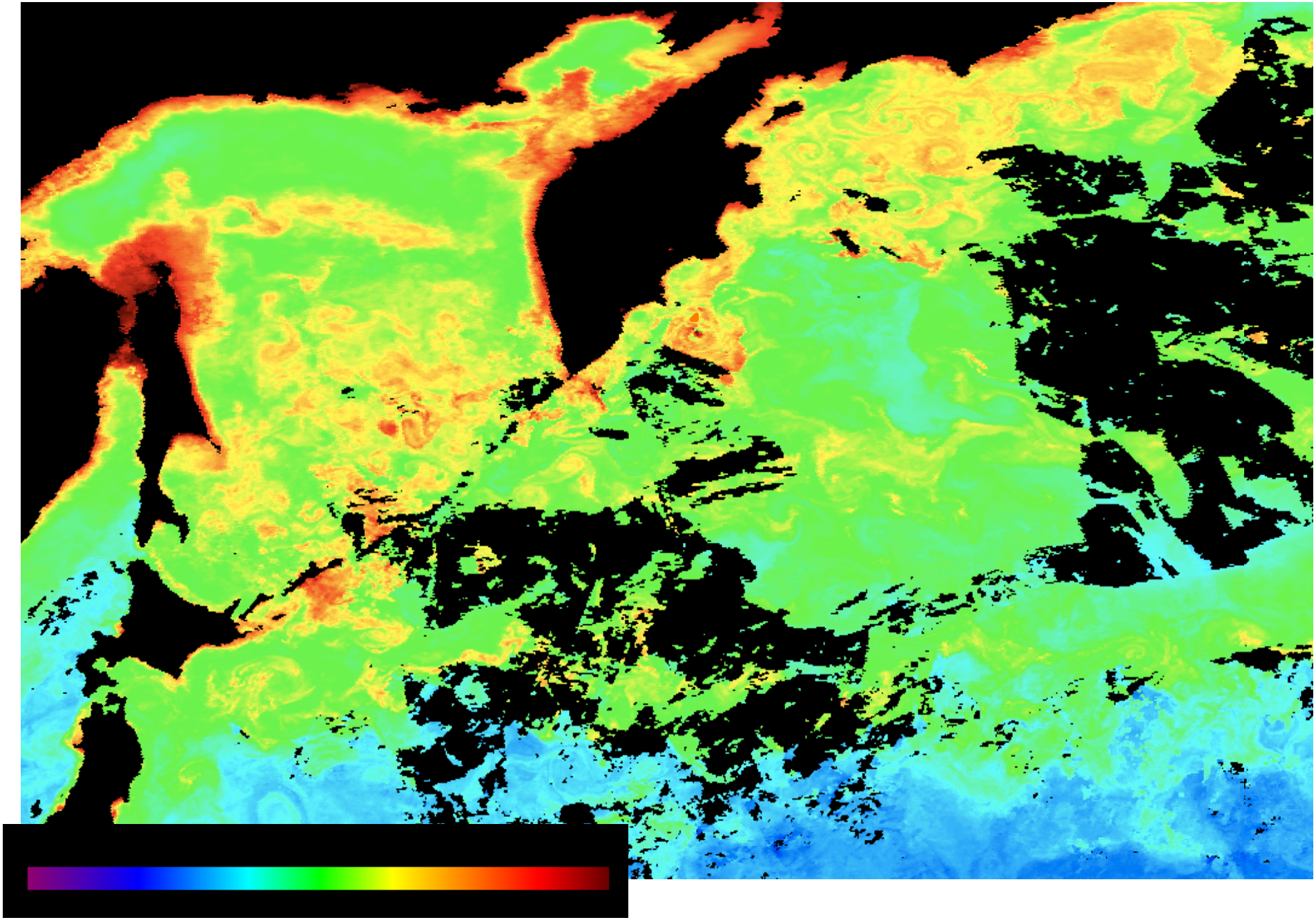
Sea-surface Chlorophyll *a* [April 2009]



Courtesy of NASA/Aqua MODIS

Light limitation by deep surface mixing may prevent phytoplankton blooming in spring when most of the Asian dust deposition events occur.

Sea-surface Chlorophyll *a* [July 2004]



Questions

- How do atmospheric depositions influence dissolved iron distributions in the subarctic western North Pacific during summer?

- How do phytoplankton communities respond to the atmospheric iron depositions in these high-nitrate, low-chlorophyll (HNLC) waters?

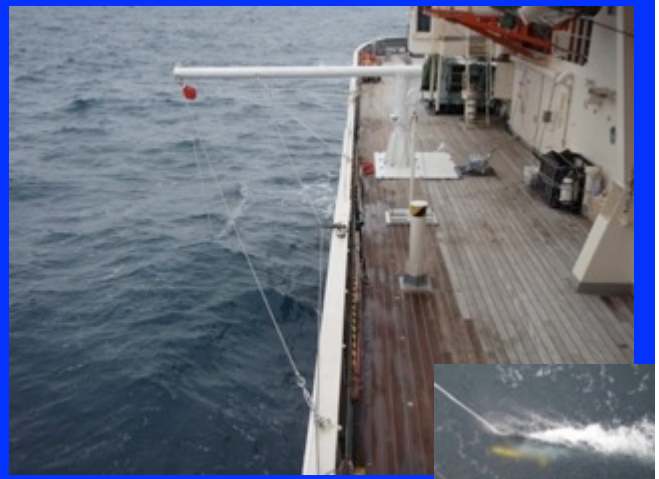
What needs to be done to address the questions?

Surface water transect surveys

Spatial variability of trace metals, nutrients, phytoplankton activity and community composition in large regions encompassing gradients of atmospheric deposition and water properties.

Epoxy-coated fish
(10.2 cmφ×120 cm, 75 kg)

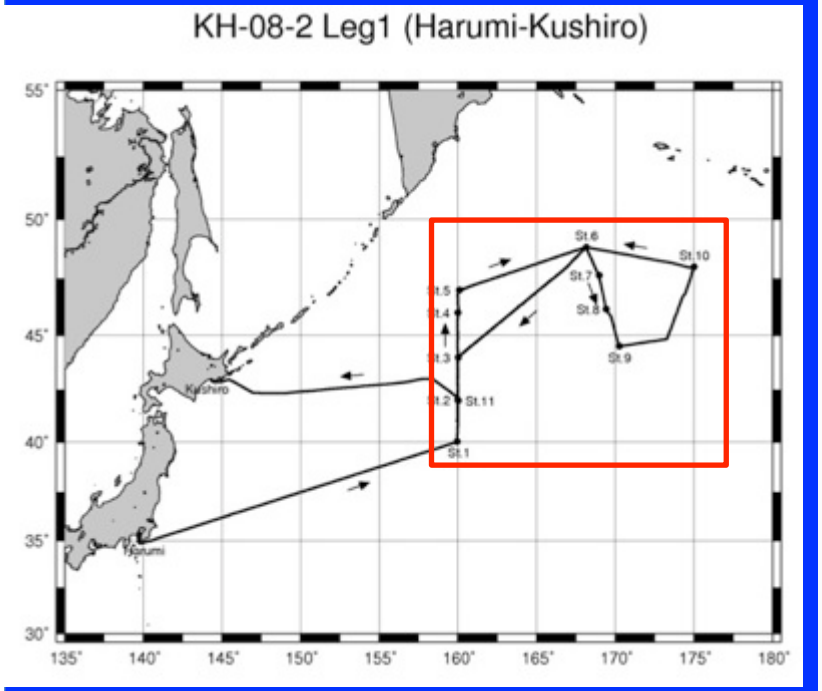
AstiPure PFD2 pump
with AMC Pulsation
Damper (Saint-Gobain)



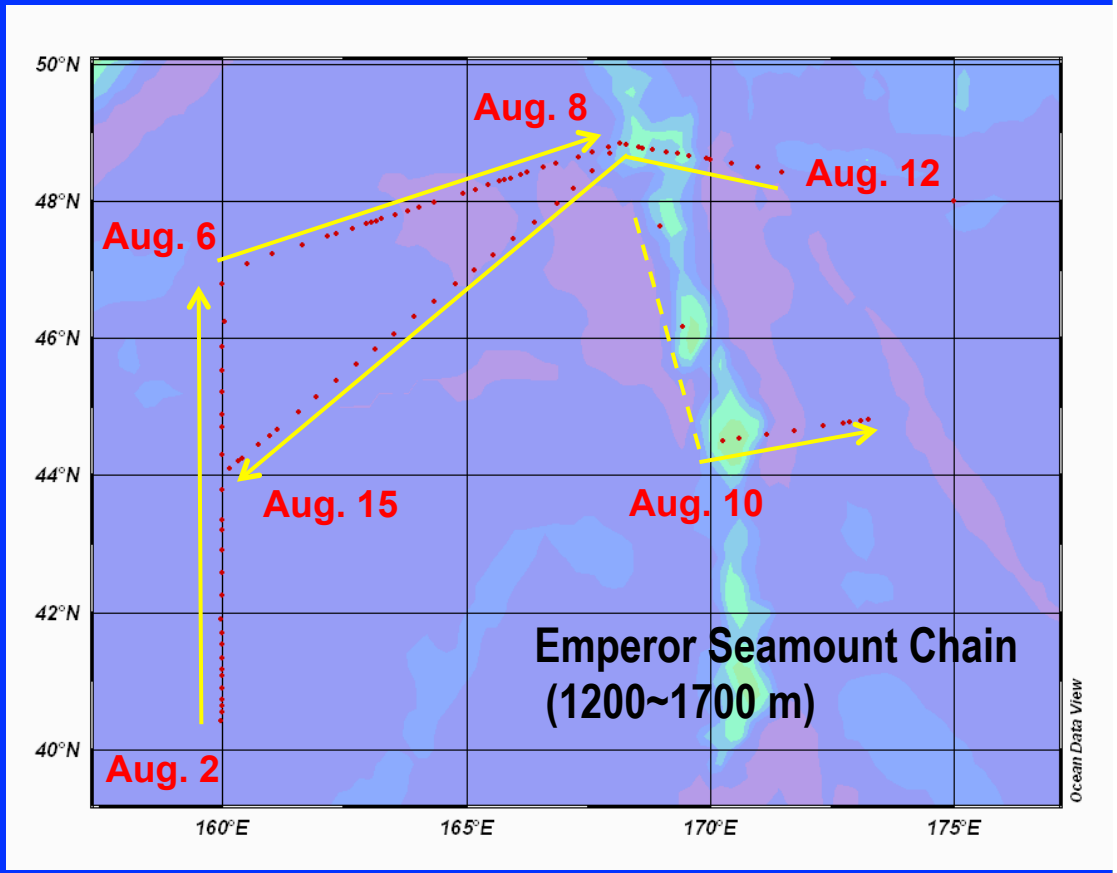
R/V Hakuho-maru
Surface water (~1 m)

13 knots

Surface transect surveys in the subarctic NW Pacific



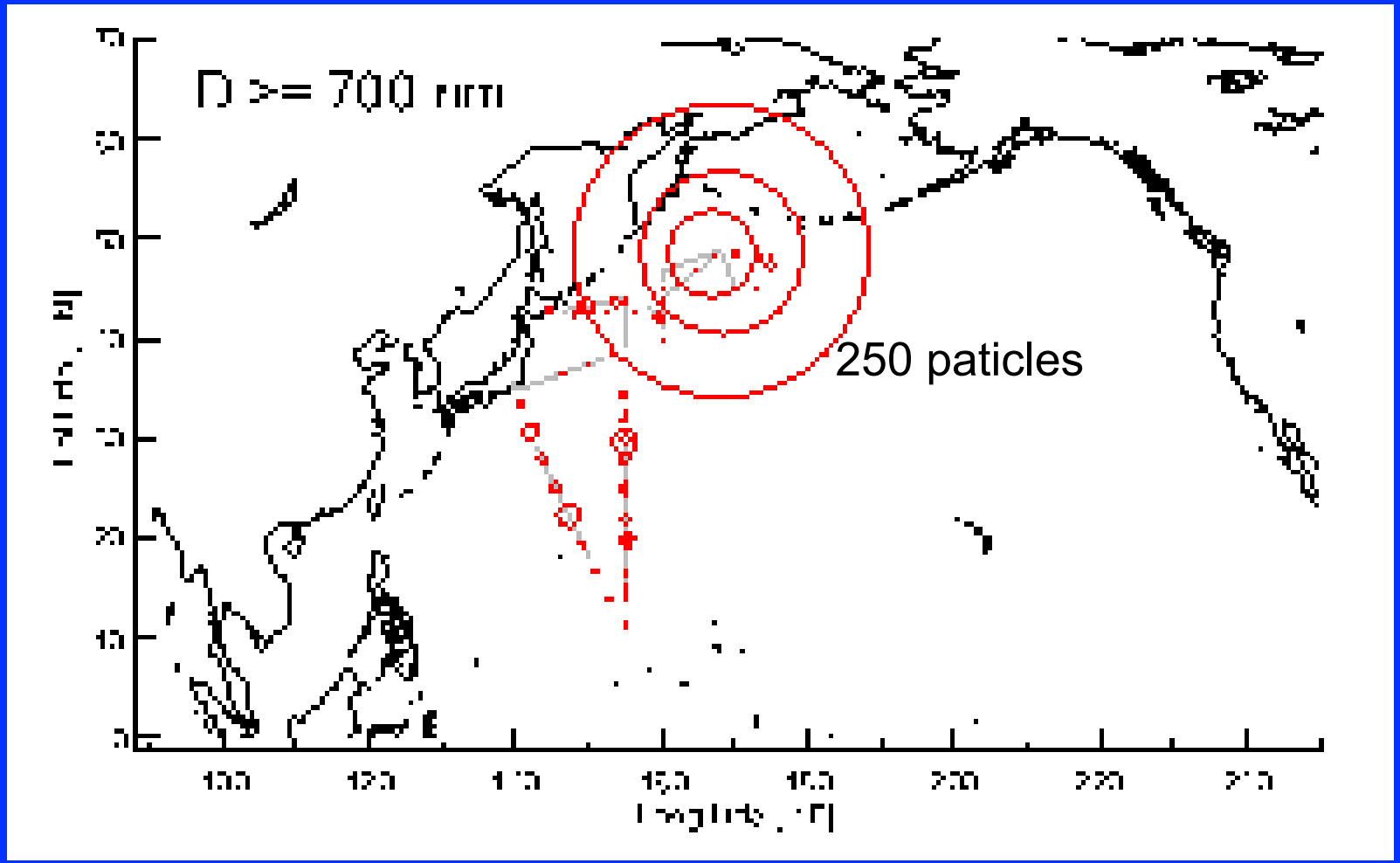
R/V Hakuho-maru
KH-08-2 cruise Leg.1
July 29 -August 19, 2008



101 samples
Dissolved iron (<0.22 μm, pH<1.7)
Nutrients, Chlorophyll *a*
Algal photosynthetic activity (Fv/Fm)
Community composition (HPLC pigments)

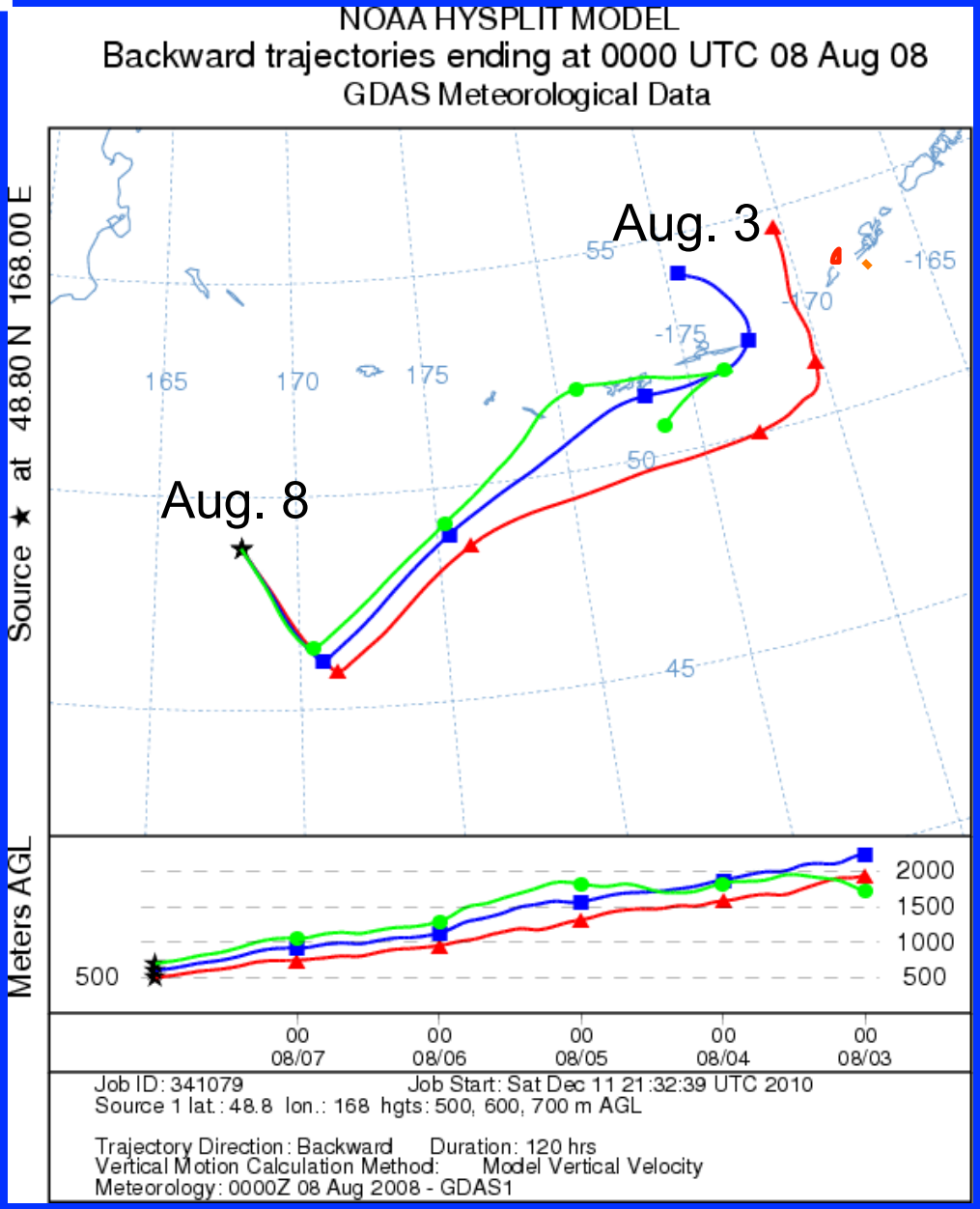
Iron-containing Aerosols (D > 700 nm) measured by Aerosol Time-Of-Flight Mass Spectrometry: ATOFMS

Volcanic ash particles (Sea Salt + Al-Si-P-Li-Sulfate) were detected in August 8, 2008; 4-5 days before the bloom observation



(Courtesy of Furutani et al., 2010, JOS Fall Meeting)

Source of Volcanic ash particles



Mt. Okmok (1073 m)
Eruption
August 2-3, 2008

(Courtesy of the AVO/UAF-GI)

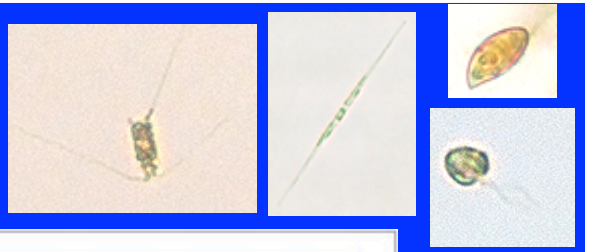
Iron-release experiments with hotspot volcanic ash and seawater (1:400)

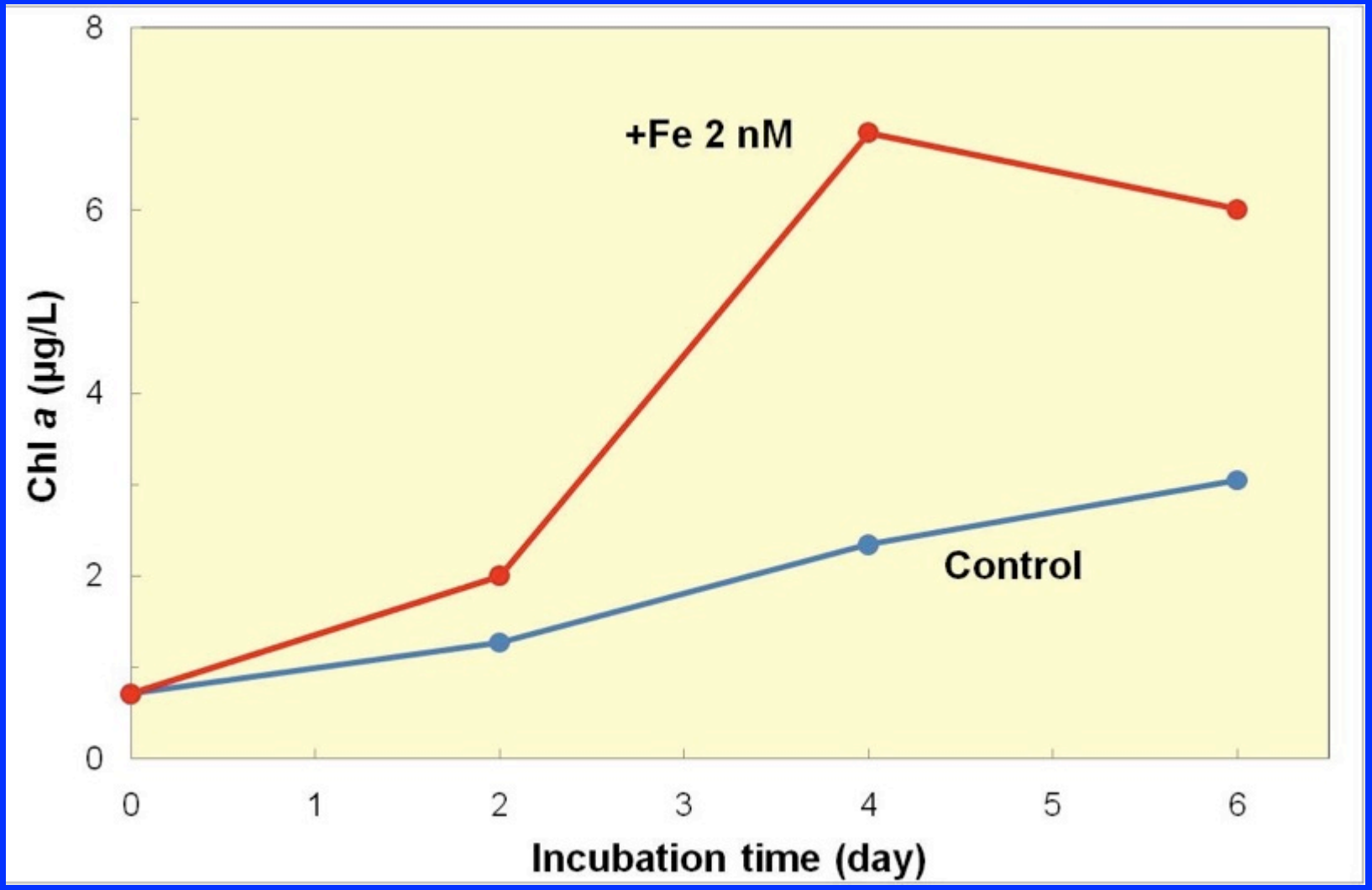
35–107 nmol Fe/g ash (in 1 hr)

(Olgun et al., 2010)

Iron-enrichment bottle incubation experiment

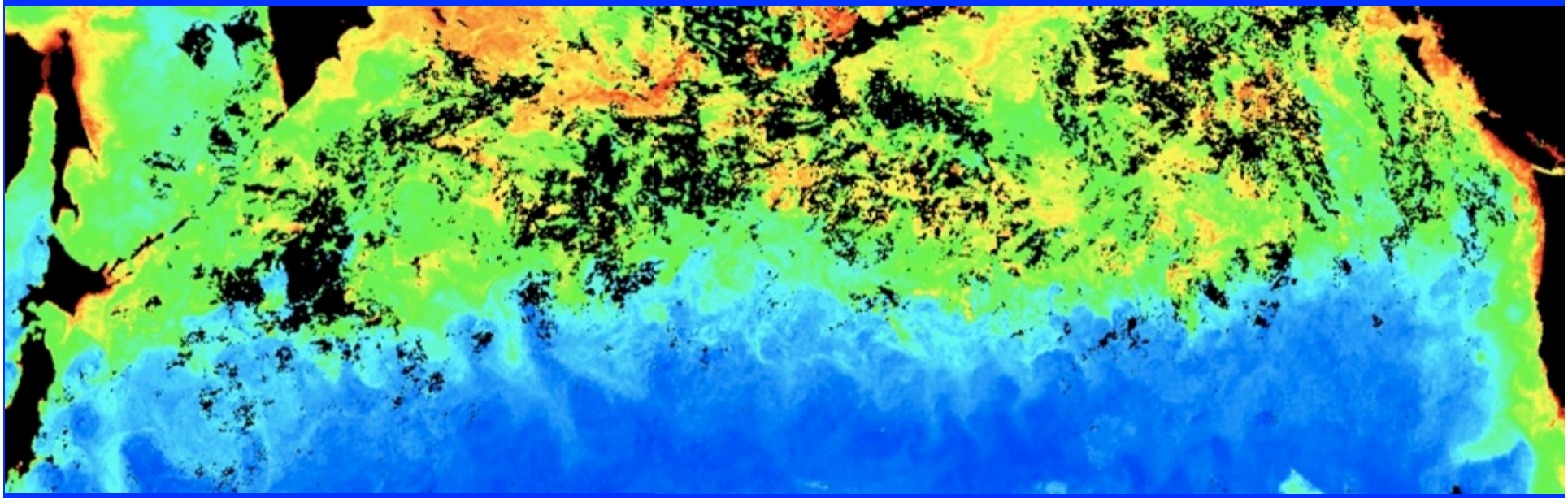
(Stn. 5, HNLC 10 m water)



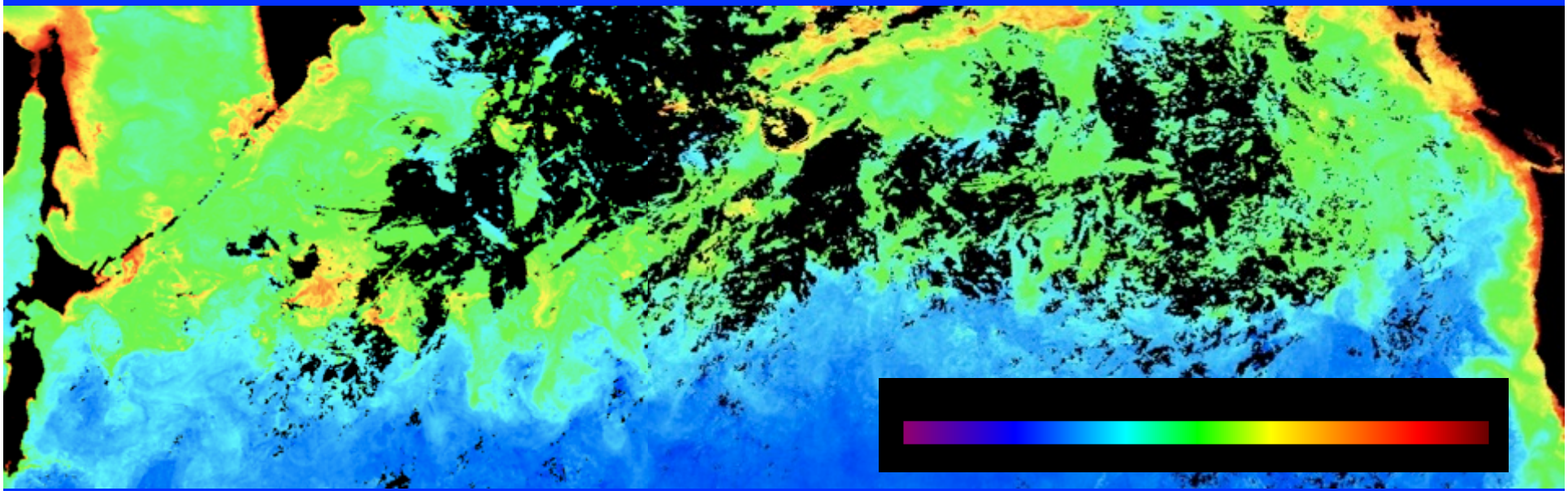


Phytoplankton could increase their chlorophyll *a* biomass within a few days if sufficient iron was available.

Widespread bloom conditions in the subarctic North Pacific in 2008



August 2008



August 2007

Courtesy of NASA/Aqua MODIS

Volcanic eruptions in August 2008

Kamchatka Peninsula

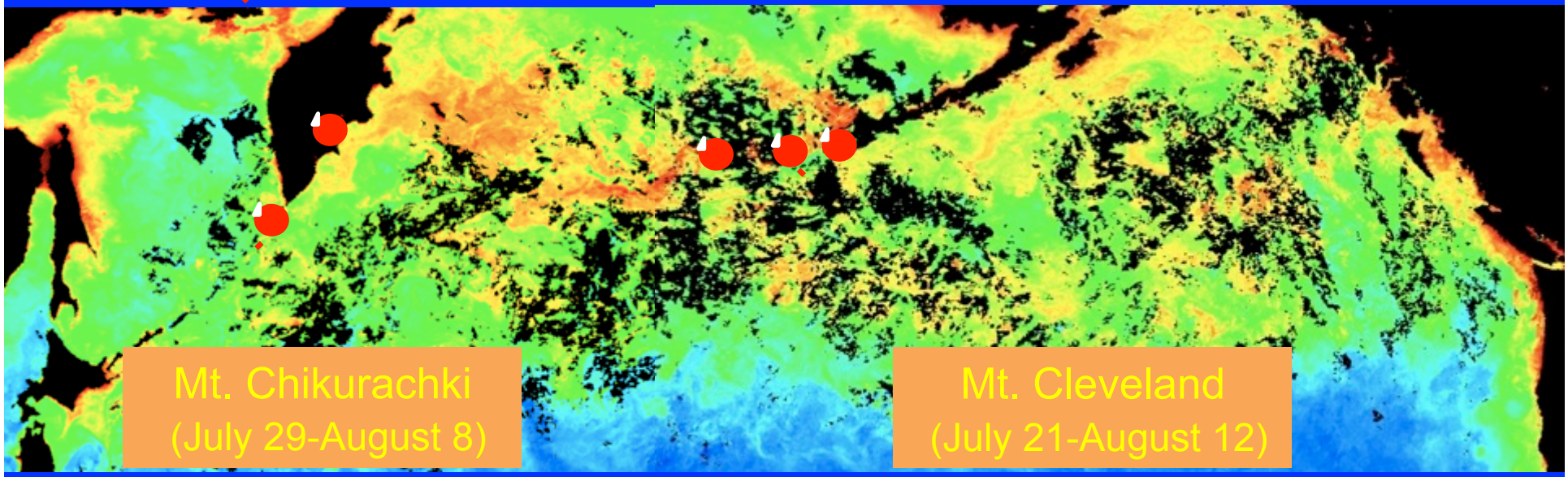
Mt. Karymsky
(continued through
June-September)

Aleutian Islands

(Courtesy of the AVO/UAF-GI)

Mt. Kasatochi
(August 7-9)

Mt. Okmok
(July 12-August 19)

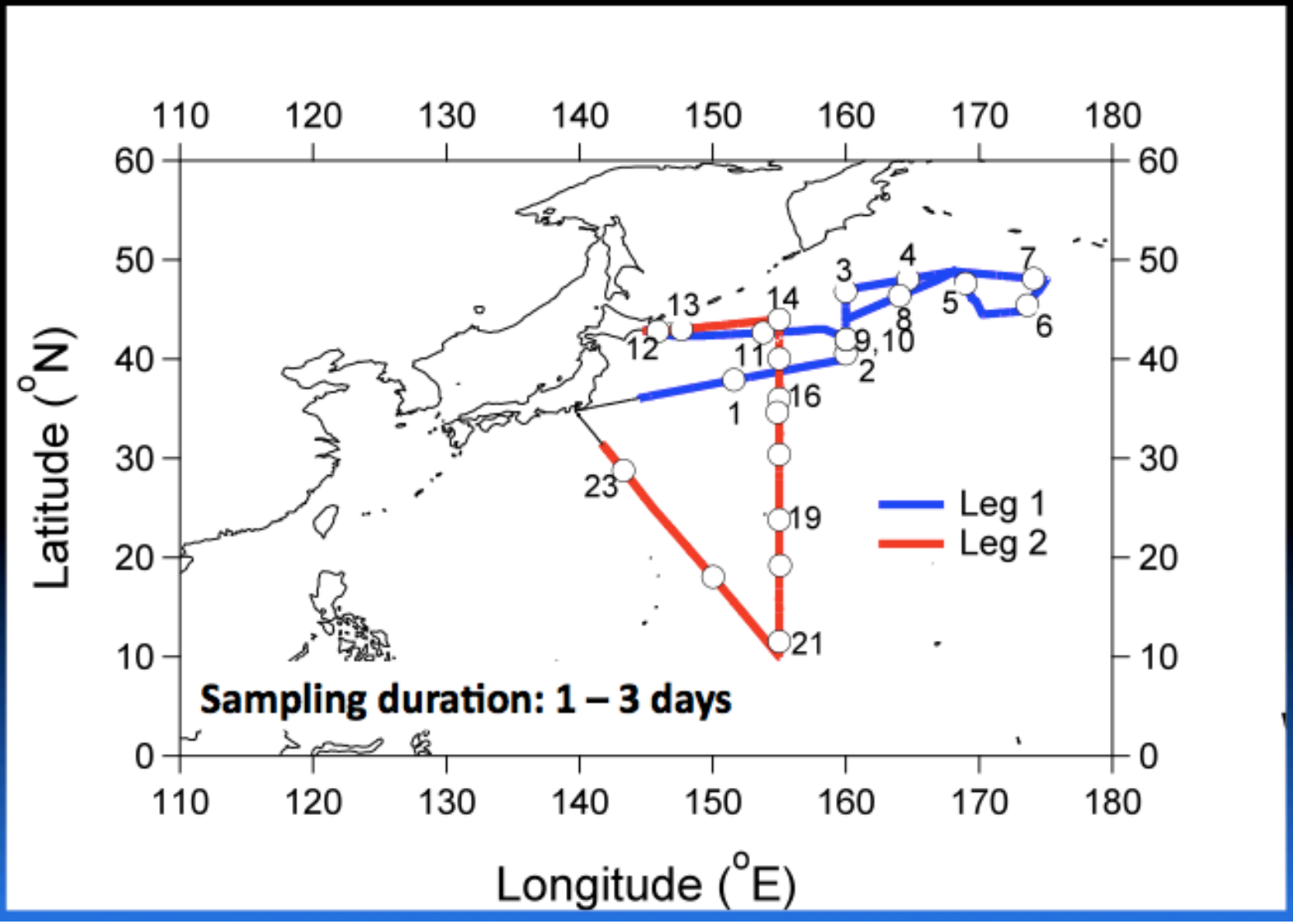


August 2008

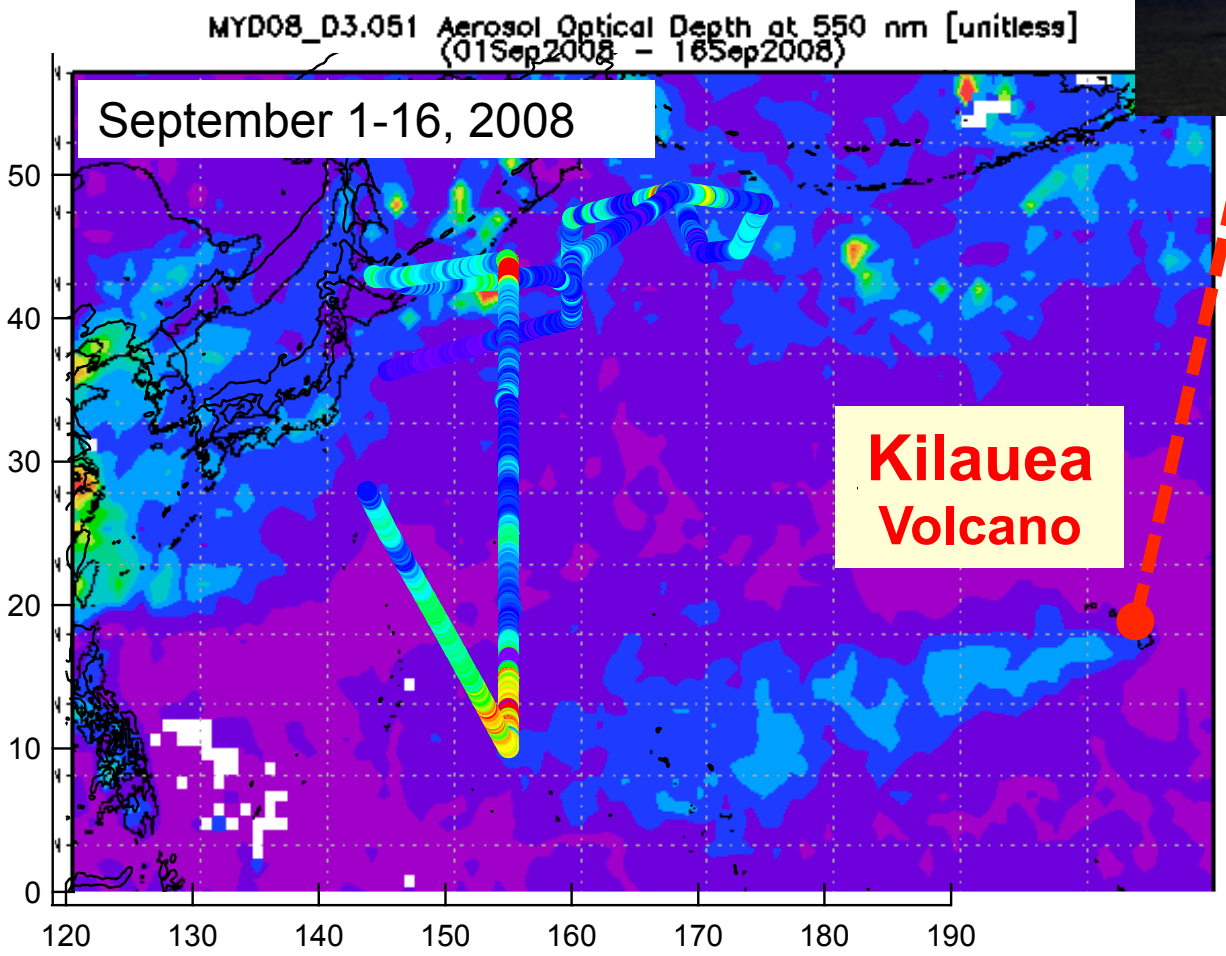
Courtesy of NASA/Aqua MODIS

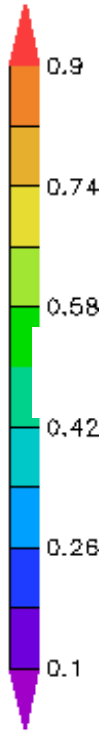
Cruise track of KH-08-2 (Leg 1 and Leg 2)

July 29, 2008 – September 17, 2008 (51 days)



Identified high sulfate aerosol origin from the Optical thickness by satellite



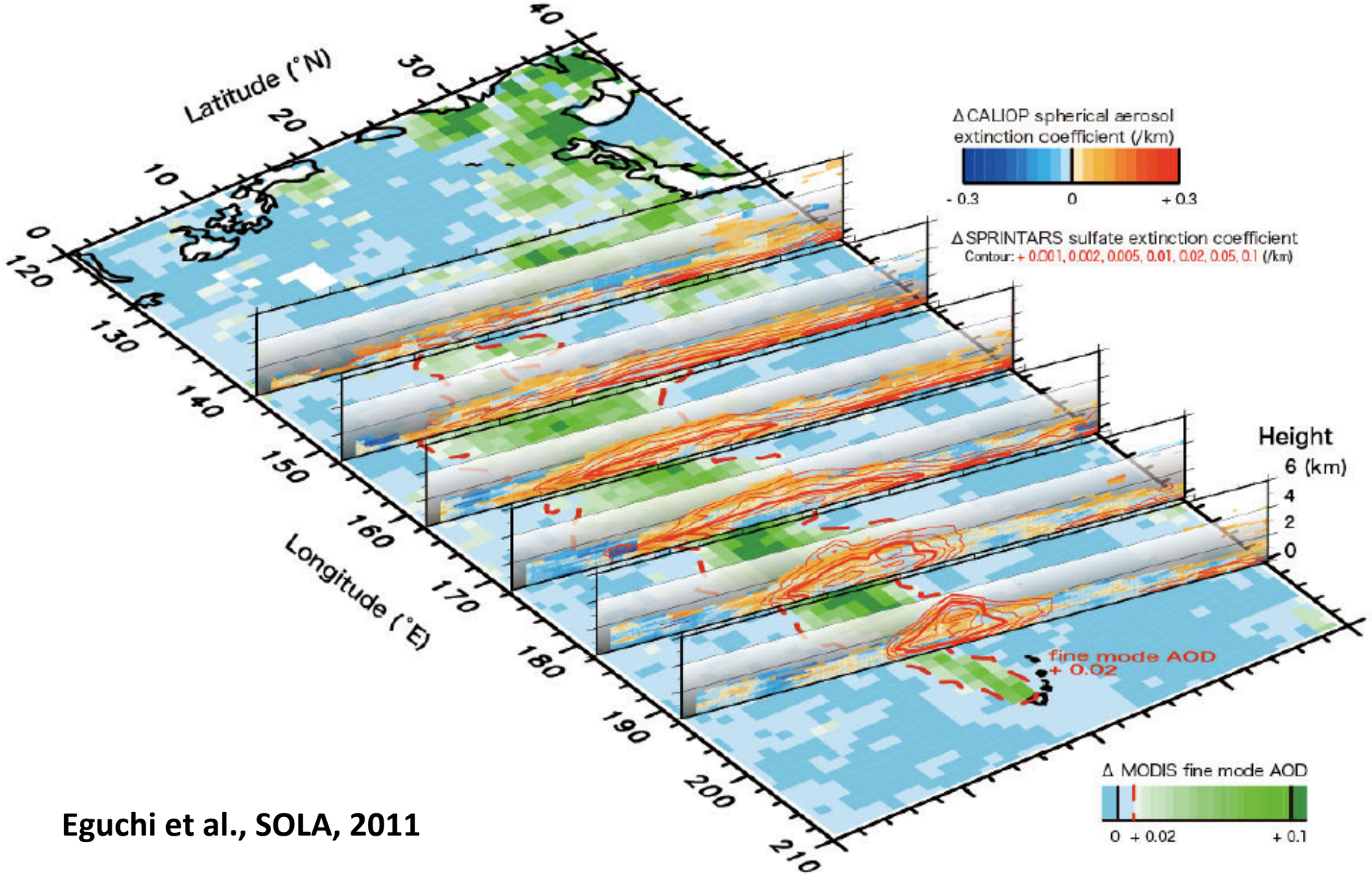


Gas to Particle

Sulfate aerosol

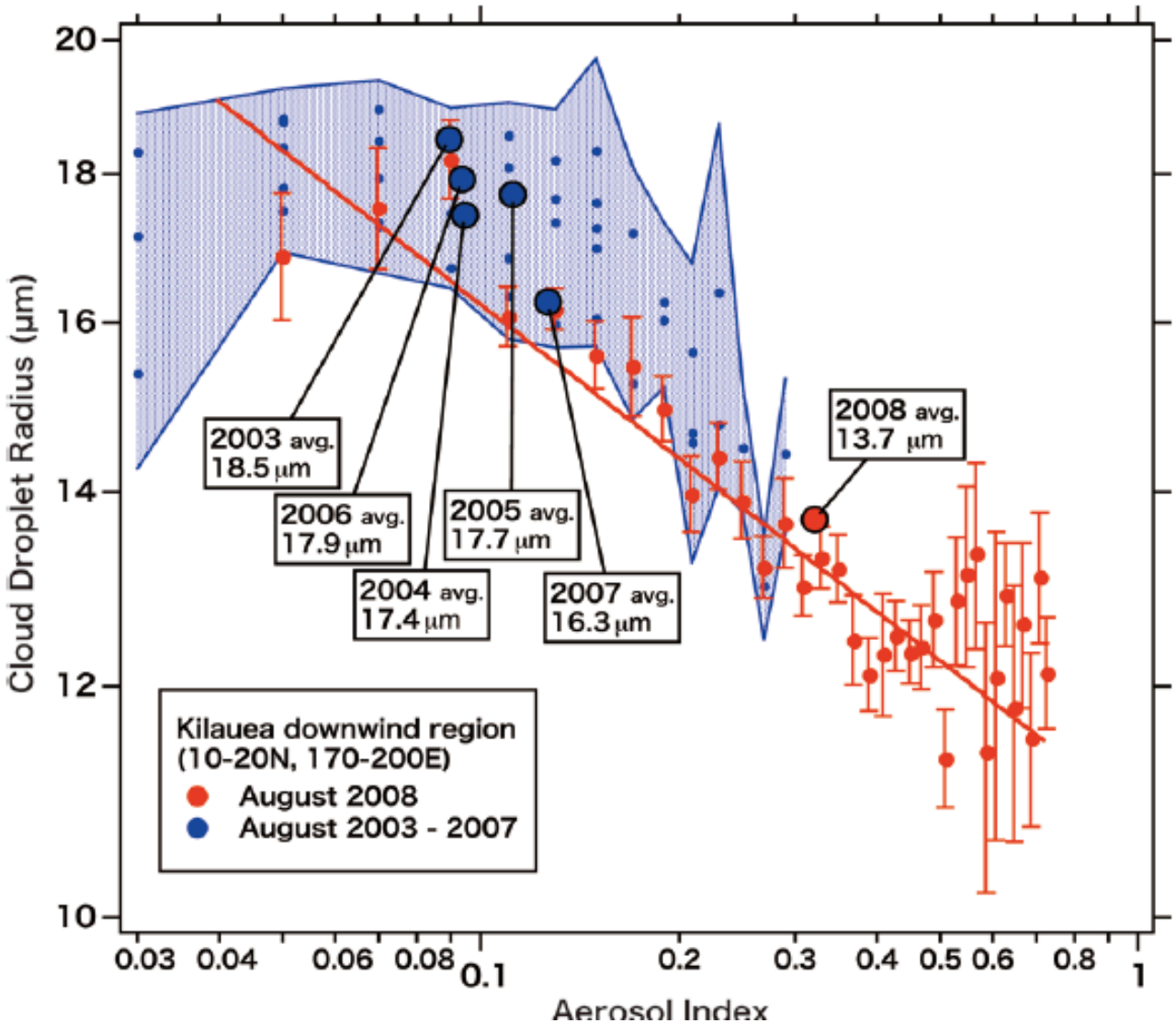
Modify cloud property ?

Aerosol distributions over the North Pacific downwind of the Hawaii Islands

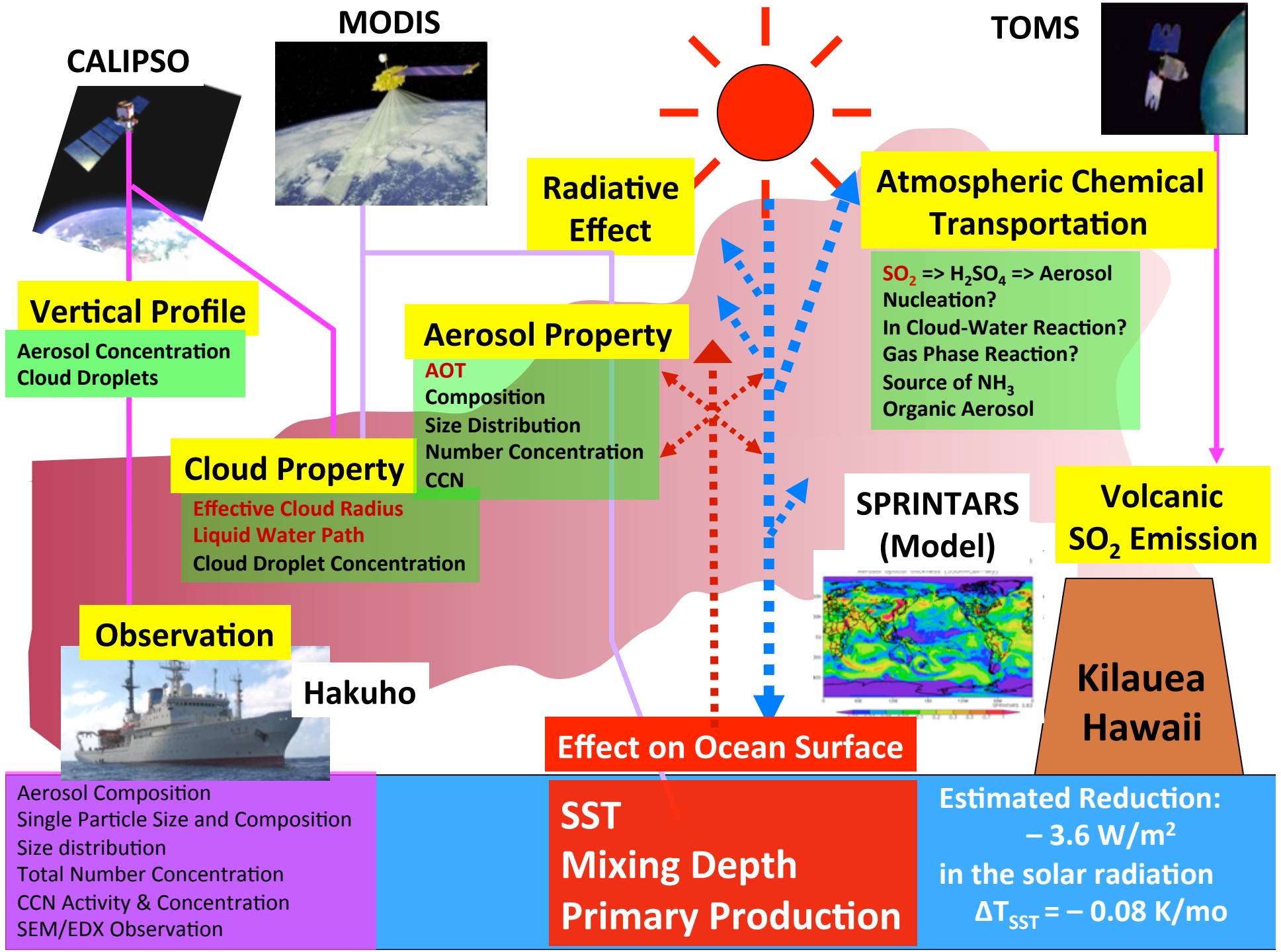


Eguchi et al., SOLA, 2011

Smaller cloud droplets make cloud whiter and its life longer over the North Pacific



Eguchi et al., SOLA, 2011


CALIPSO
MODIS
TOMS
Radiative Effect
Atmospheric Chemical Transportation
SO_2 => H_2SO_4 => Aerosol
Nucleation?
In Cloud-Water Reaction?
Gas Phase Reaction?
Source of NH_3
Organic Aerosol
Vertical Profile
Aerosol Concentration
Cloud Droplets
Aerosol Property
AOT
Composition
Size Distribution
Number Concentration
CCN
Cloud Property
Effective Cloud Radius
Liquid Water Path
Cloud Droplet Concentration
SPRINTARS (Model)
Volcanic SO_2 Emission
Observation
Hakuho
Kilauea Hawaii
Effect on Ocean Surface
Aerosol Composition
Single Particle Size and Composition
Size distribution
Total Number Concentration
CCN Activity & Concentration
SEM/EDX Observation
SST
Mixing Depth
Primary Production
Estimated Reduction:
– 3.6 W/m²
in the solar radiation
ΔT_{SST} = – 0.08 K/mo

Impacts of volcanic eruption on the marine biogeochemical cycles

From Volcanoes

- Volcanic ashes: Fe, Si, P, Al, Ca
- Gases: H_2O, CO_2, H_2S, SO_2, HCl, HF, H_2, N_2, Ar, CH_4, CO, NH_3

In the atmosphere

- Increase of gases warming
- Increase of aerosols cooling (direct and indirect)

In the ocean

- Ballast effect
- Fe supply
- N compounds supply
- Acidification by H_2SO_4, HCl vs Ca

Don’t give up, Japan
Don’t give up, Tohoku

A nation’s rallying call