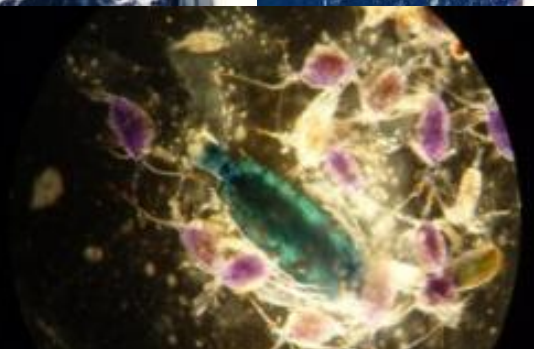
EqPOS

Jan 29, 2012 – Feb 19, 2012 (22 days)

Equatorial **P**acific **O**cean and **S**tratospheric/Tropospheric Atmosphere Study

Sky, Ocean, and In-Between



Preliminary Results

Hiroshi Furutani*, Mitsuo Uematsu* and EqPOS Science Team

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

AORI

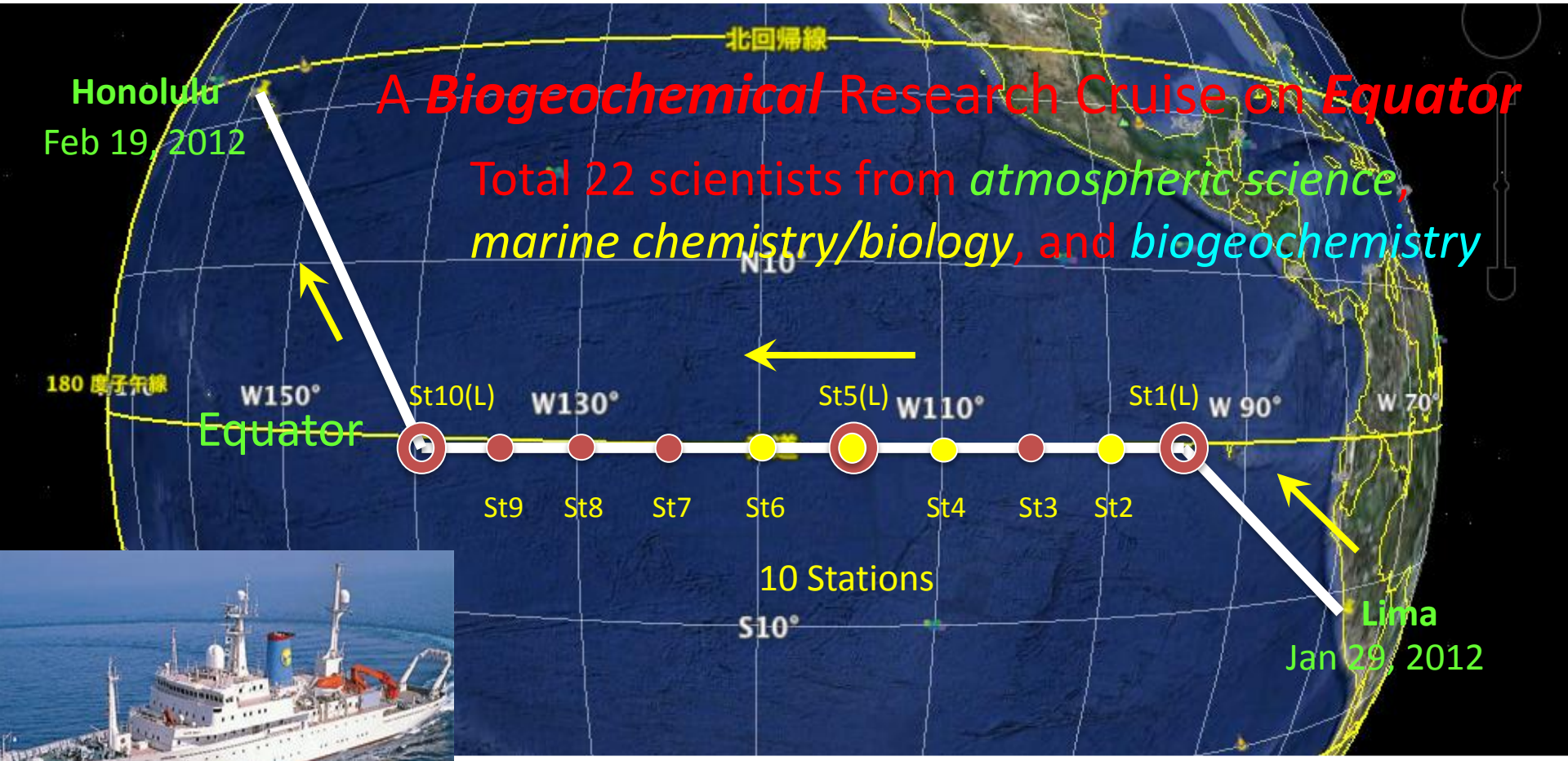
東京大学 THE UNIVERSITY OF TOKYO

EqPOS

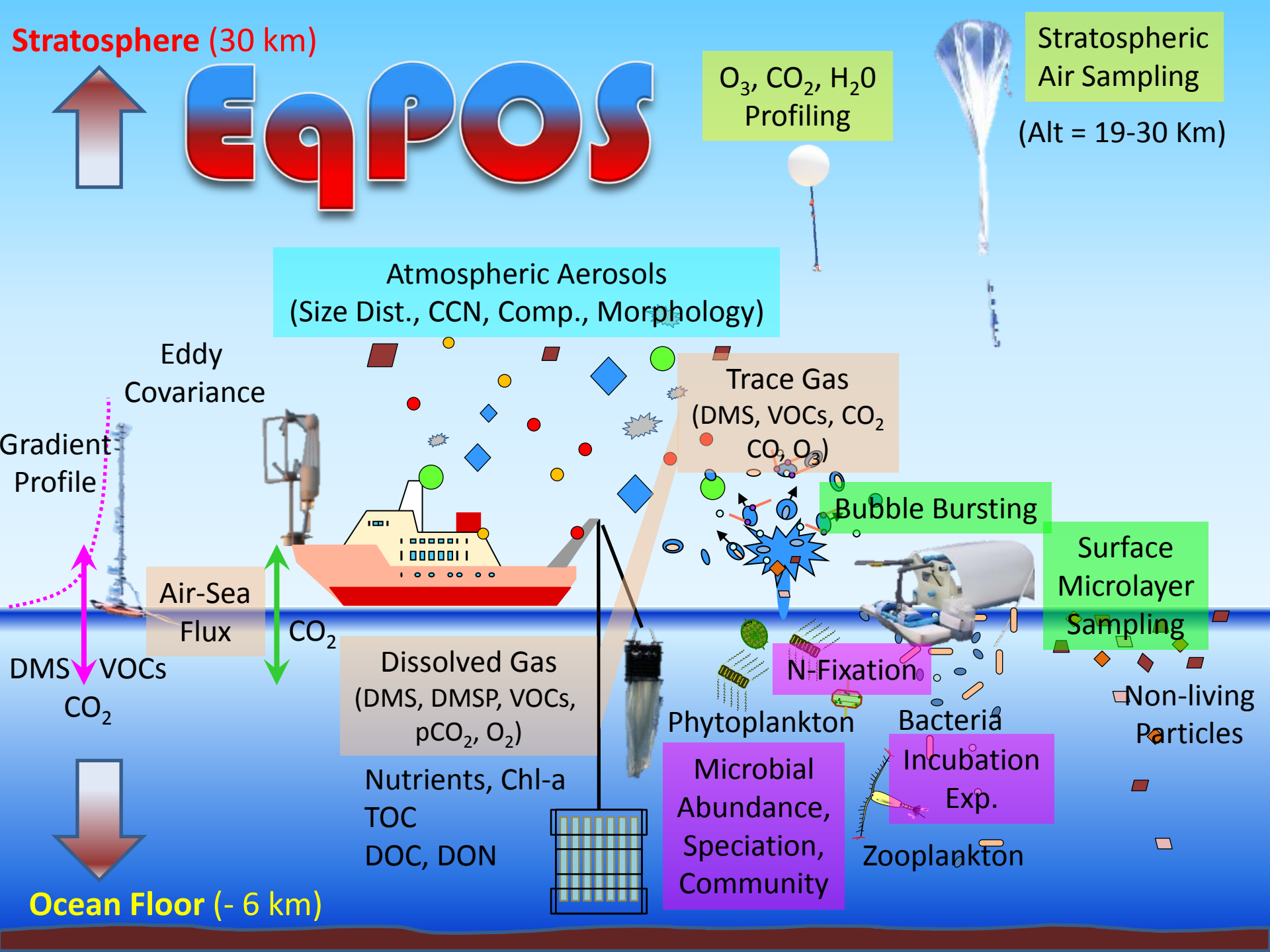
Equatorial Pacific Ocean and Stratospheric/ Tropospheric Atmosphere Study

PI: Prof. Uematsu (AORI)

Jan 29, 2012 – Feb 19, 2012 (22 days)



R/V Hakuho-maru


Stratosphere (30 km)
EqPOS
O_3, CO_2, H_2O Profiling
Stratospheric Air Sampling
(Alt = 19-30 Km)
Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)
Eddy Covariance
Gradient Profile
Trace Gas
(DMS, VOCs, CO_2 CO, O_3)
Bubble Bursting
Surface Microlayer Sampling
Air-Sea Flux
CO_2
DMS VOCs
CO_2
Dissolved Gas
(DMS, DMSP, VOCs, pCO_2, O_2)
N-Fixation
Phytoplankton
Bacteria
Non-living Particles
Nutrients, Chl-a
TOC
DOC, DON
Microbial Abundance, Speciation, Community
Incubation Exp.
Zooplankton
Ocean Floor (- 6 km)

EqPOS

Equatorial Pacific Ocean and Stratospheric/ Tropospheric Atmosphere Study

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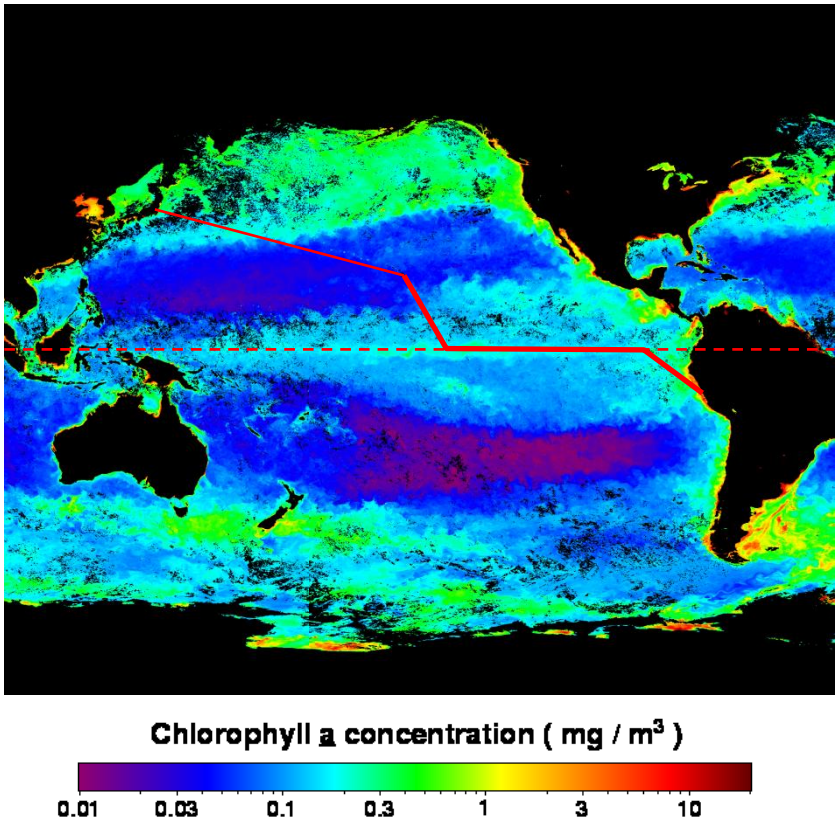
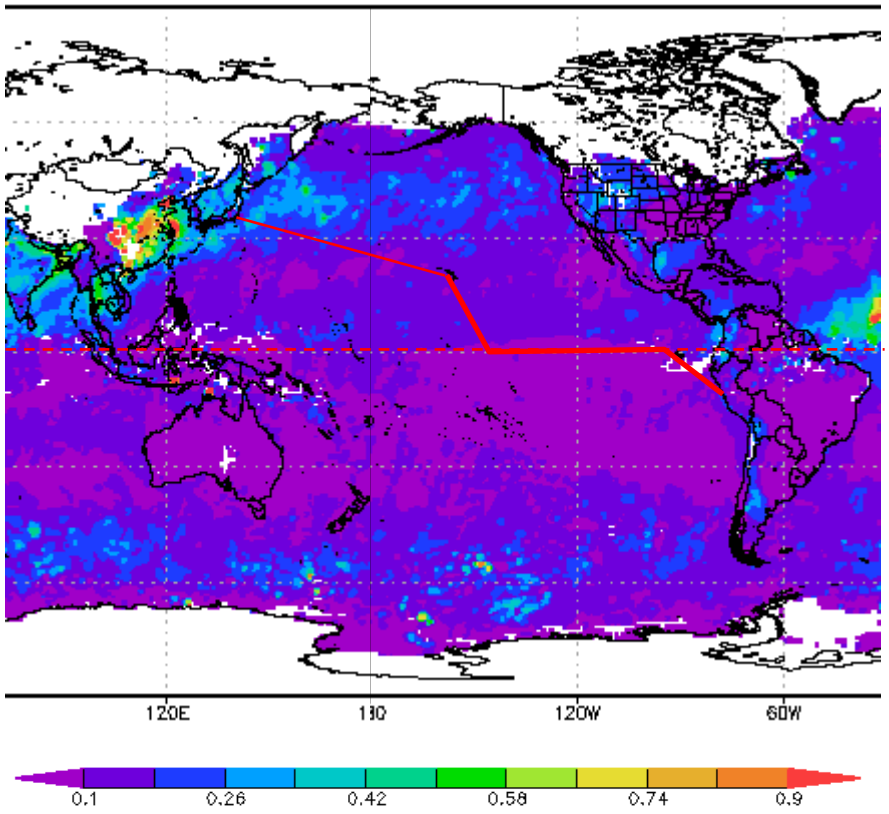
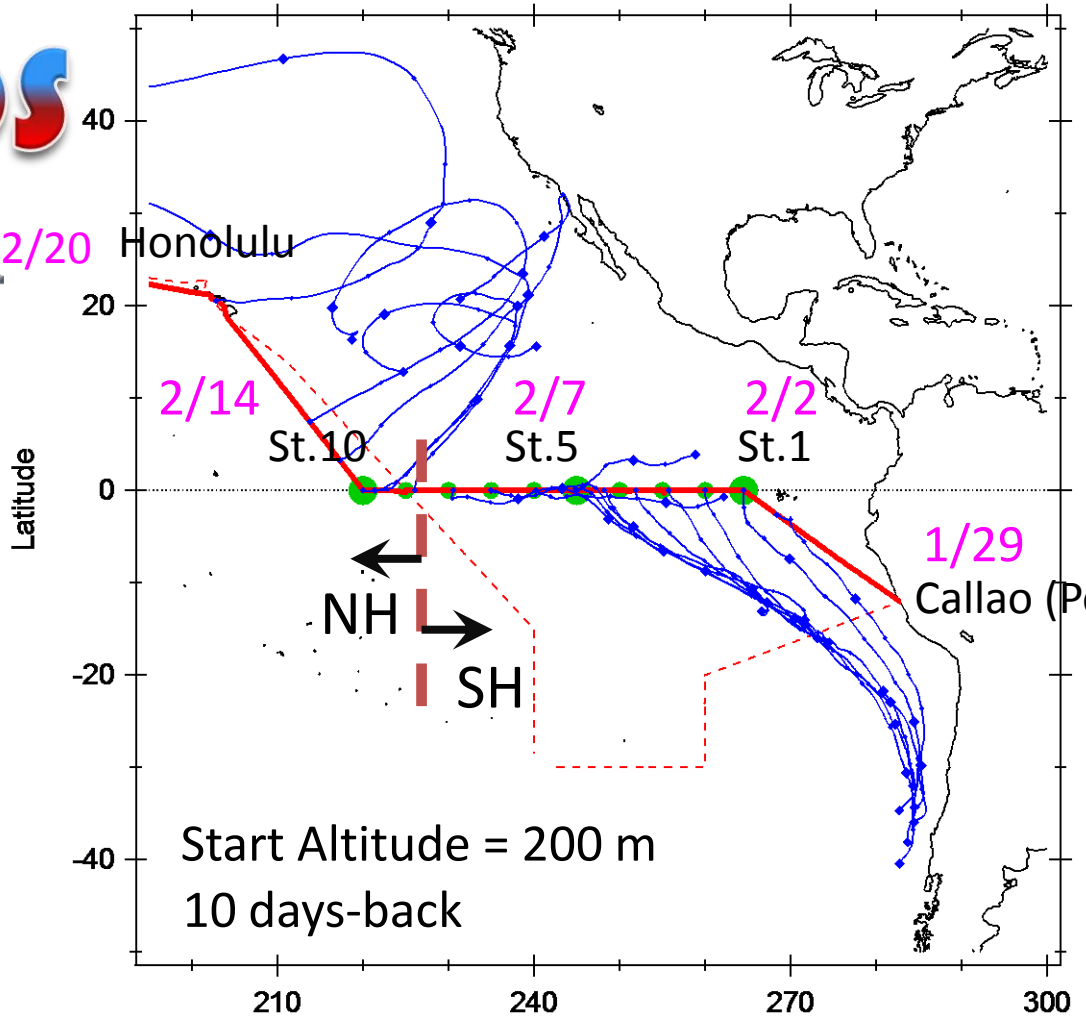
MODIS Surface Chl-a (Feb 2012)

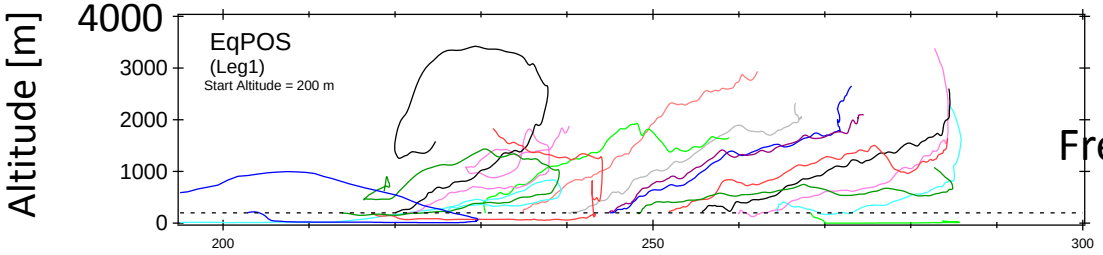


MODIS AOD (Feb 2012)



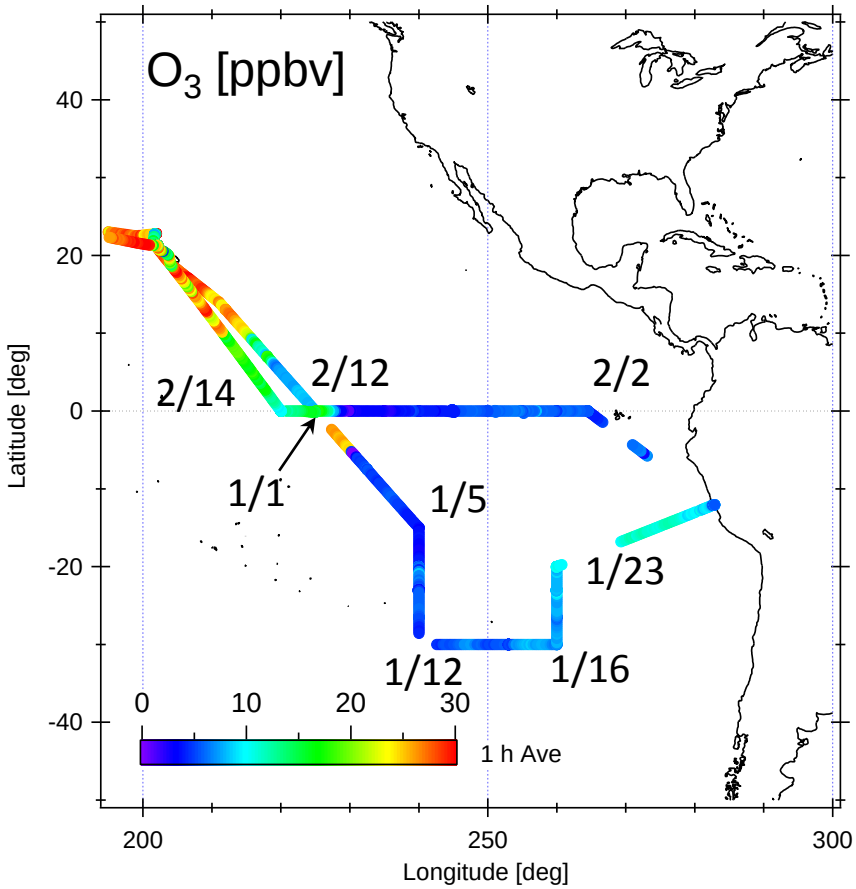
Back Air Trajectories (10 days back)





Calculated using HySPLIT

Free Troposphere Origin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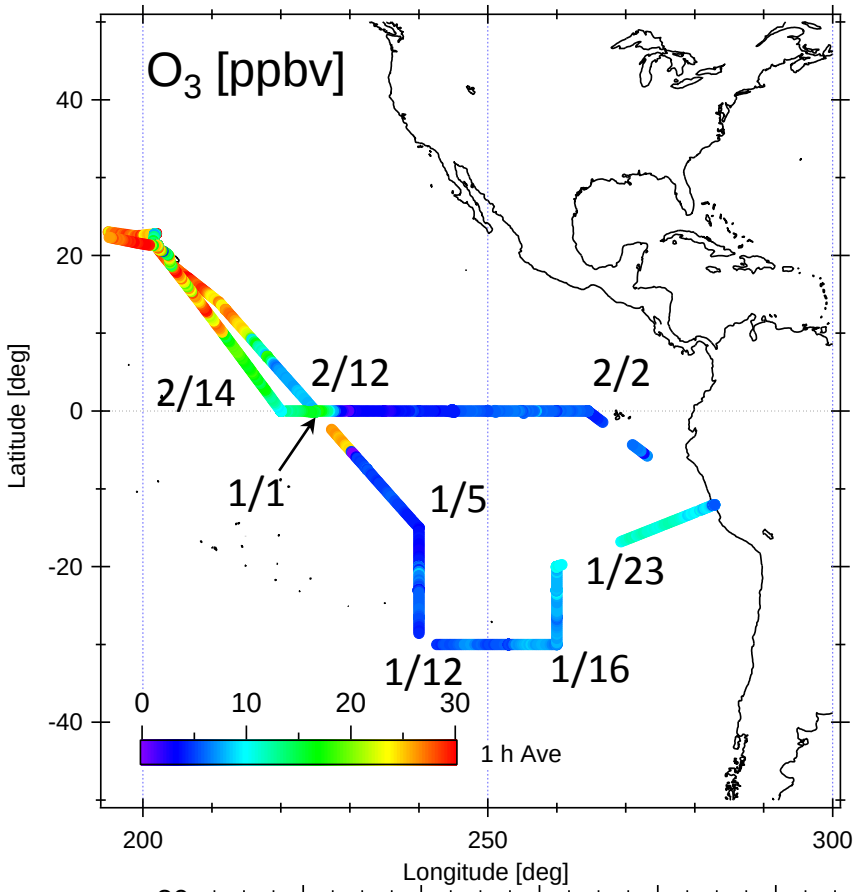
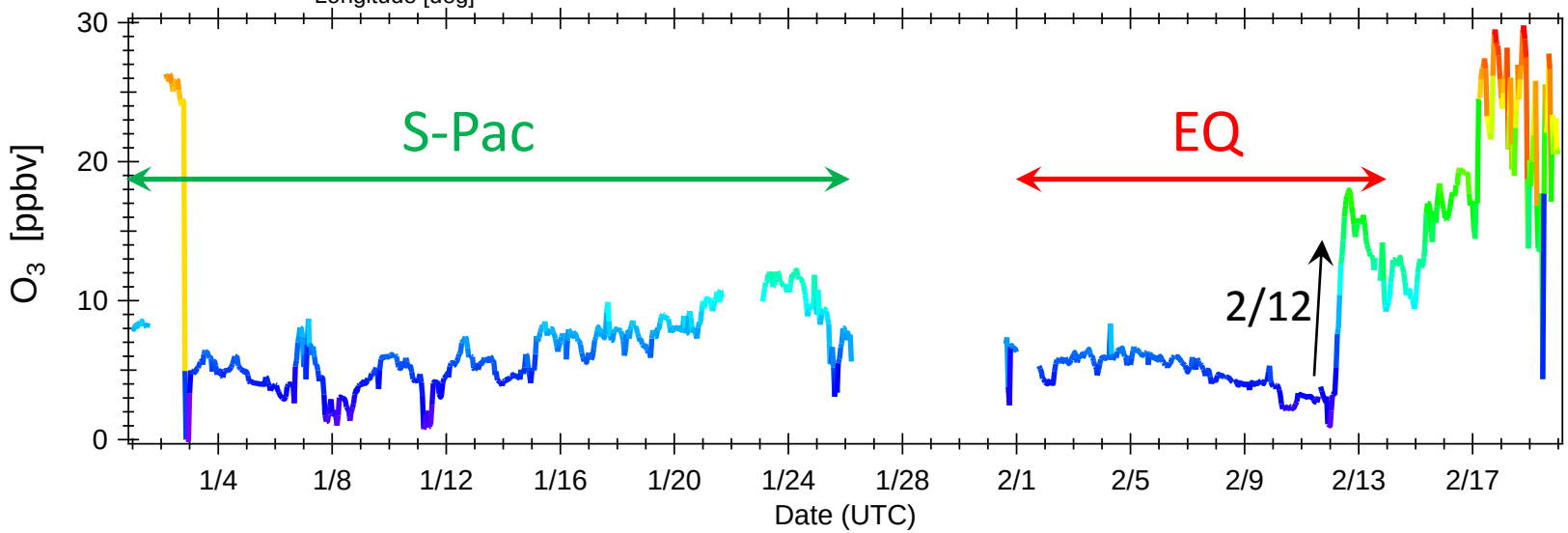
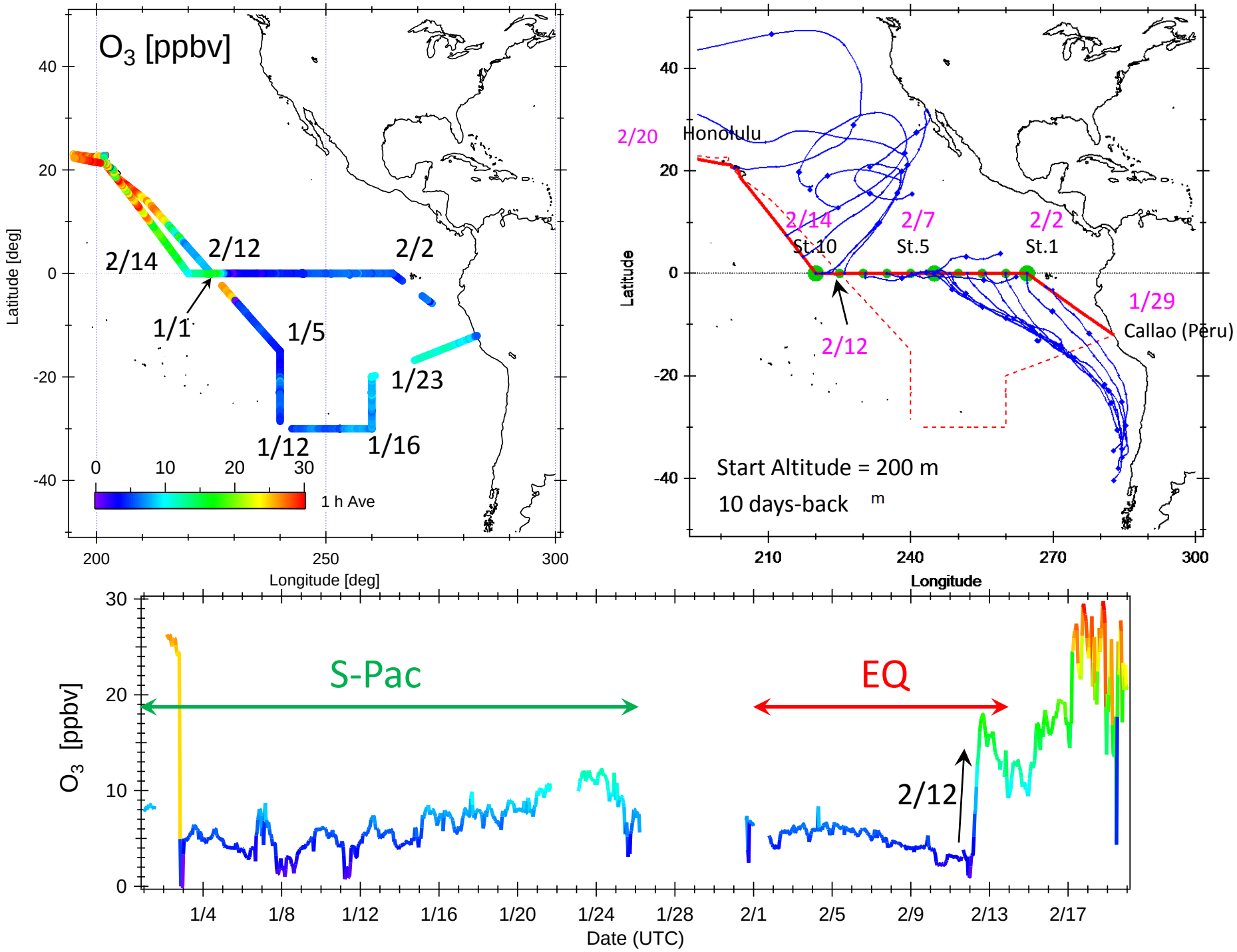
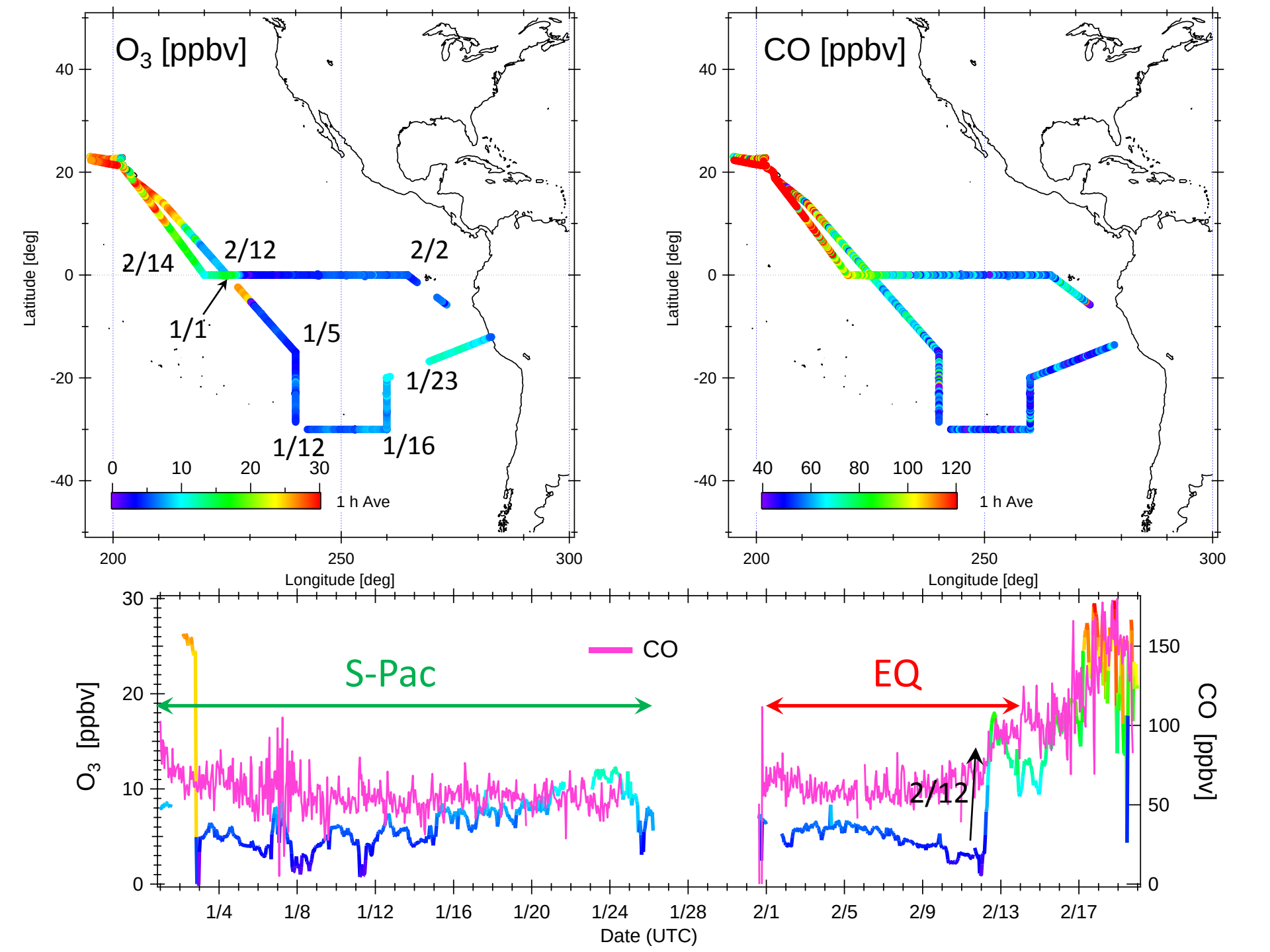
20
0
-20
-40
Latitude [deg]
200
250
300
Longitude [deg]
2/14
2/12
2/2
1/1
1/5
1/23
1/12
1/16
0
10
20
30
1 h Ave


O3 [ppbv]
Latitude [deg]
Longitude [deg]
2/14
2/12
2/2
1/1
1/5
1/23
1/12
1/16
0
10
20
30
1 h Ave

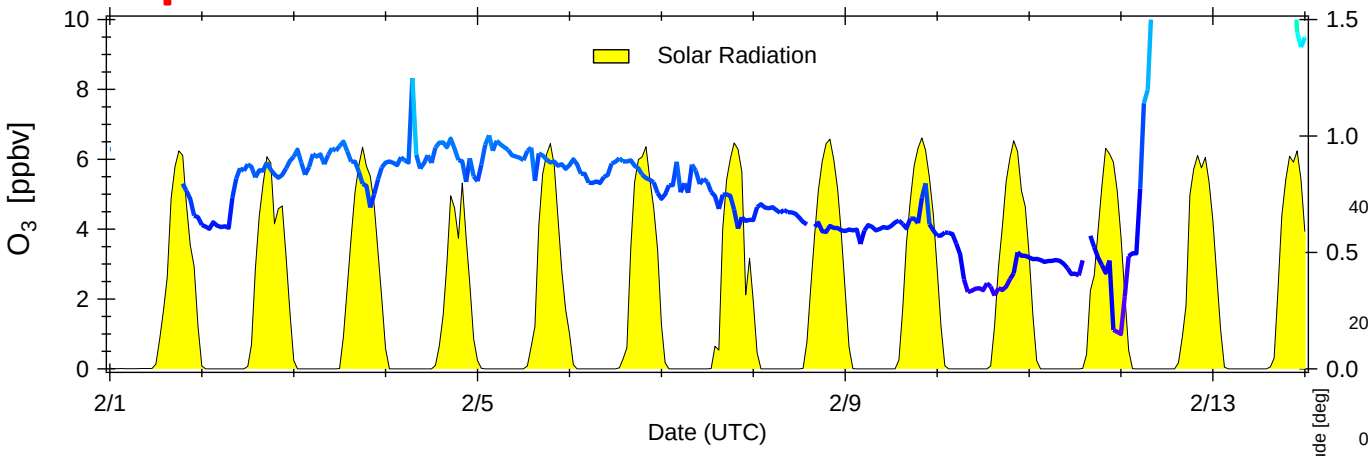

O3 [ppbv]
S-Pac
EQ
2/12
Date (UTC)

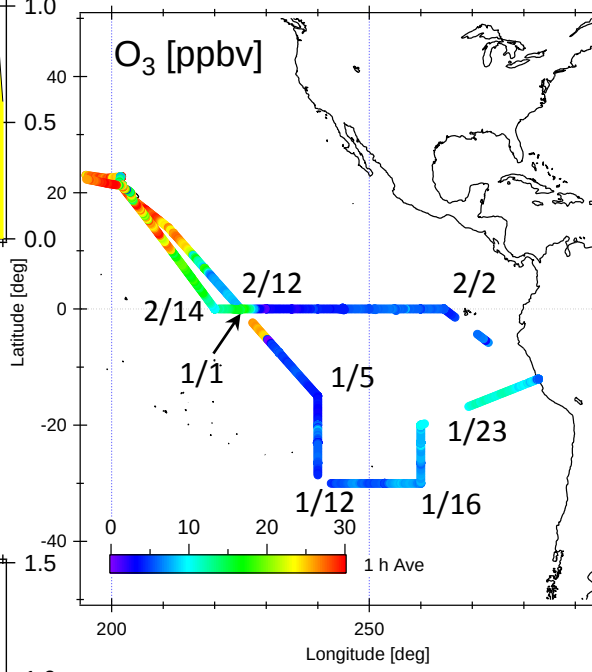

O3 [ppbv]
Latitude [deg]
Longitude [deg]
2/14
2/12
2/2
1/1
1/5
1/23
1/12
1/16
0
10
20
30
1 h Ave
2/20
Honolulu
2/14
St.10
2/7
St.5
2/2
St.1
1/29
Callao (Peru)
2/12
Start Altitude = 200 m
10 days-back
Latitude
Longitude
S-Pac
EQ
2/12
O3 [ppbv]
Date (UTC)


O3 [ppbv]
CO [ppbv]
Latitude [deg]
Longitude [deg]
2/14
2/12
2/2
1/1
1/5
1/23
1/12
1/16
1 h Ave
S-Pac
EQ
CO
O3 [ppbv]
CO [ppbv]
Date (UTC)

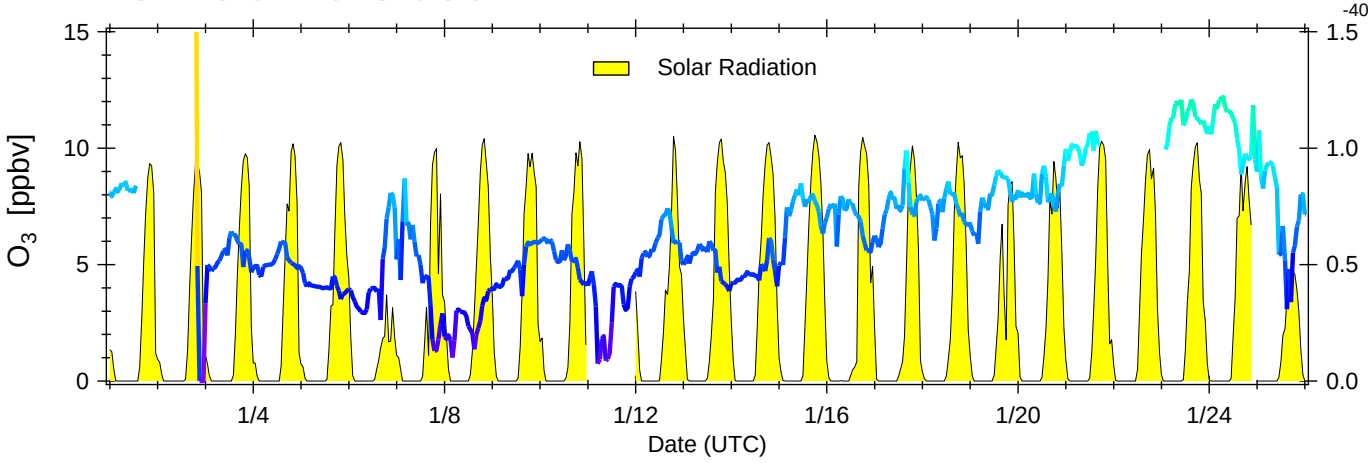
Diurnal Variation of O_3

Equator

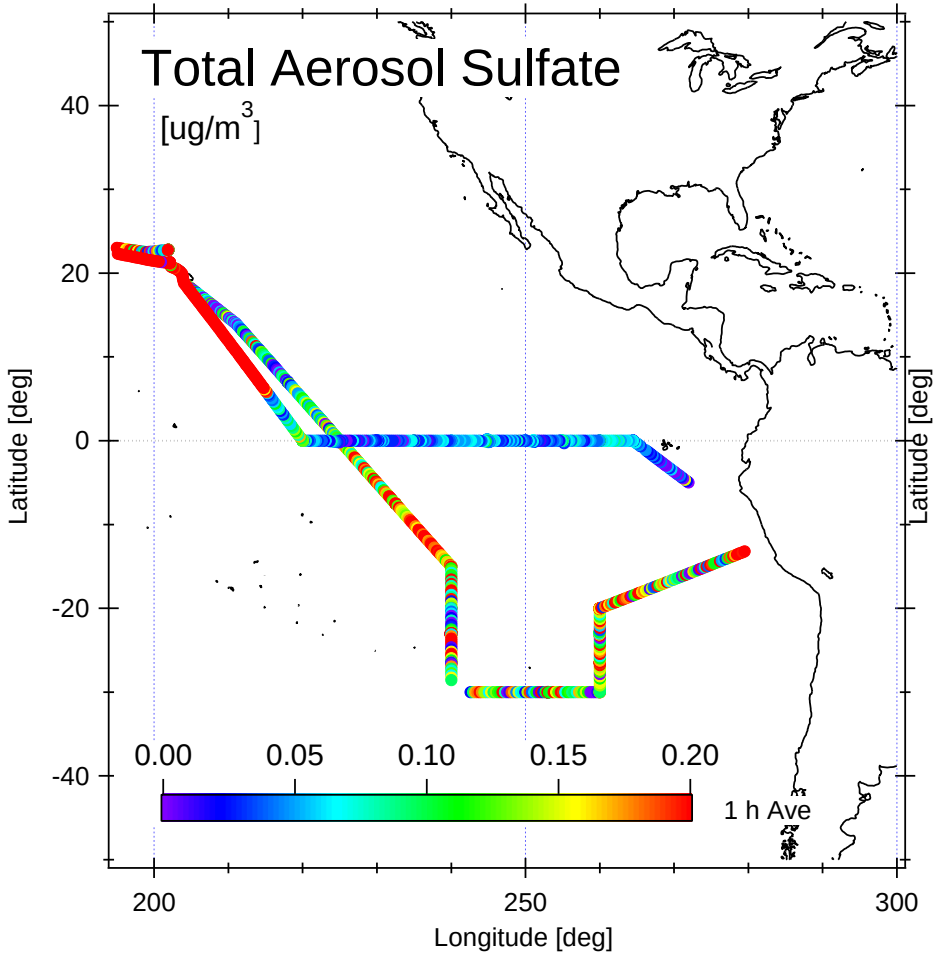


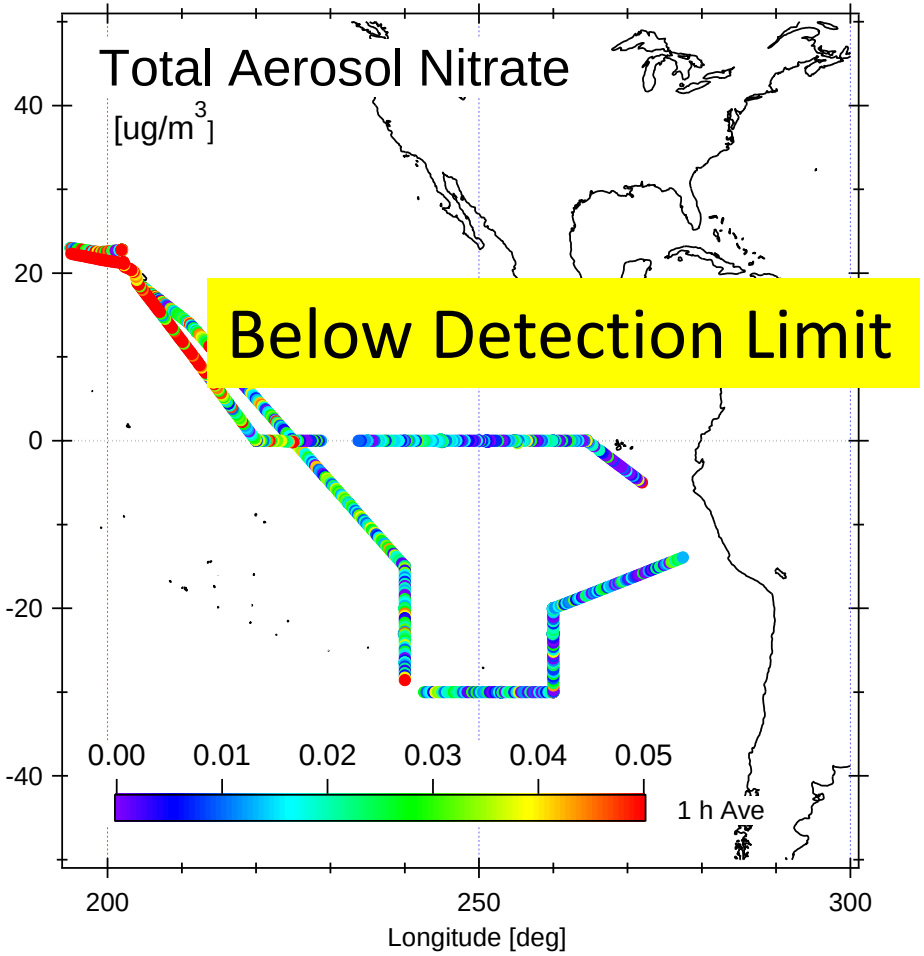


S-Pacific Ocean



Measured with Particulate Sulfate and Nitrate Monitor (R&P)





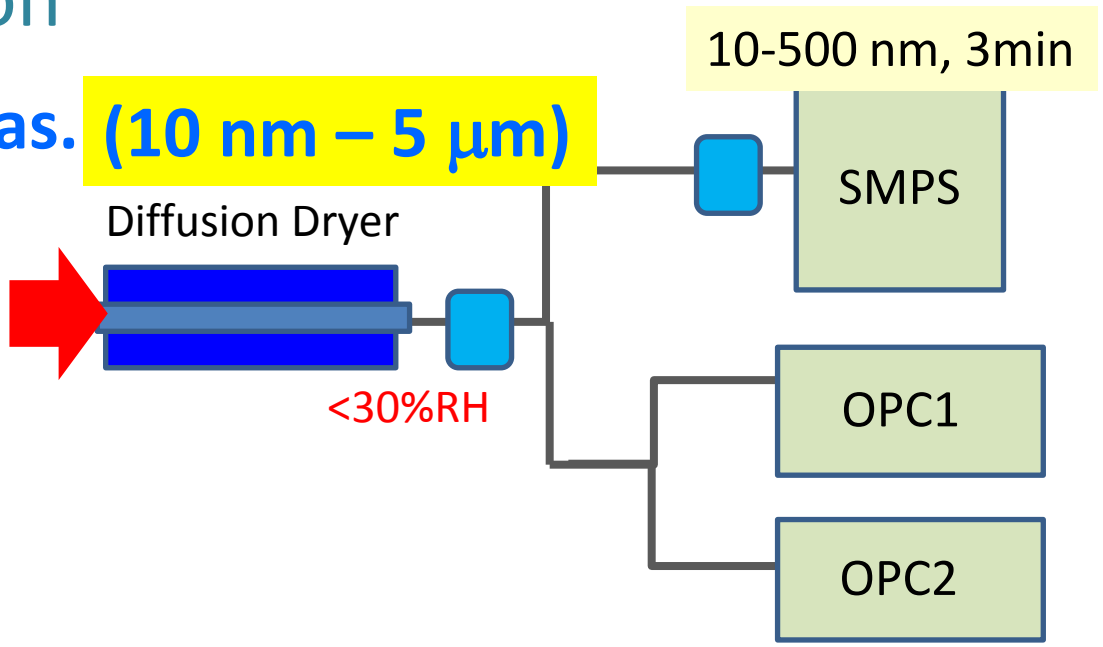
Filter samples (daily) will provide accurate MSA, nss-SO_4^{2-}, NO_3^- concentrations (coming soon..)

Aerosol Size Distribution

Small Ion (+/-) Counting
TEM Sample Collection

Miura Group
(Tokyo Univ of Sci)

(1) Size Distribution Meas. (10 nm – 5 μm)



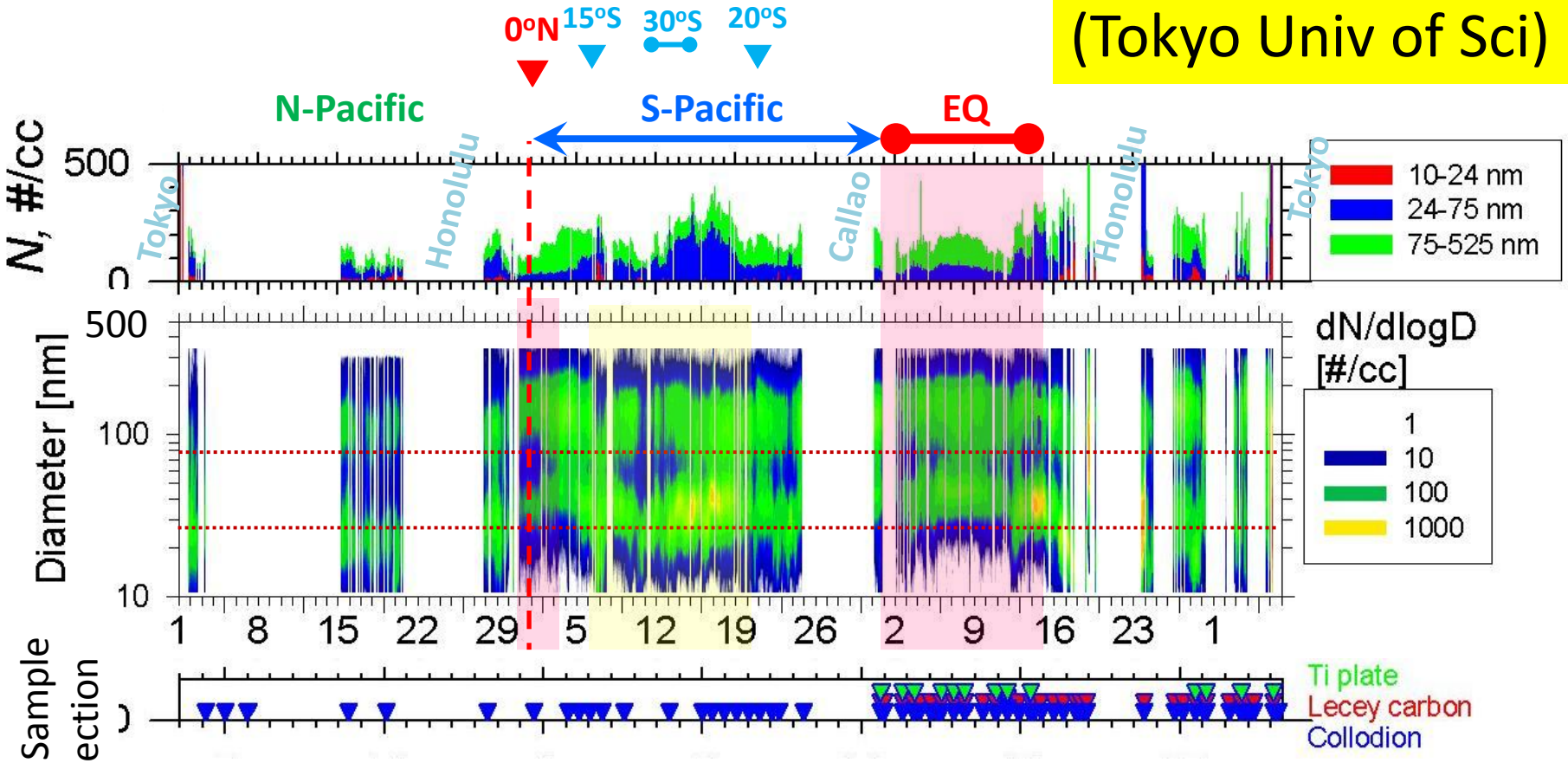
(2) Ion Counting

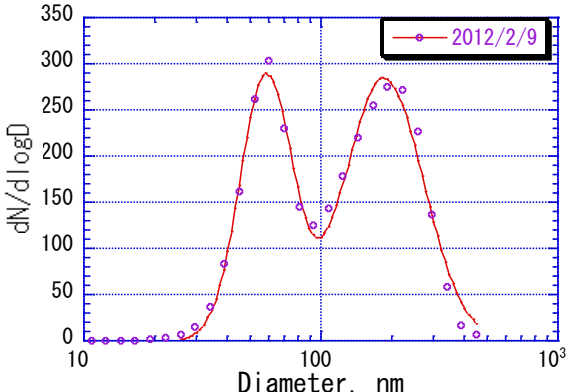
Gerdien type ion counter (+/-), 4 min

(3) TEM Sample for Individual Analysis

Collection with impactor, 1~3 per day

Miura Group (Tokyo Univ of Sci)

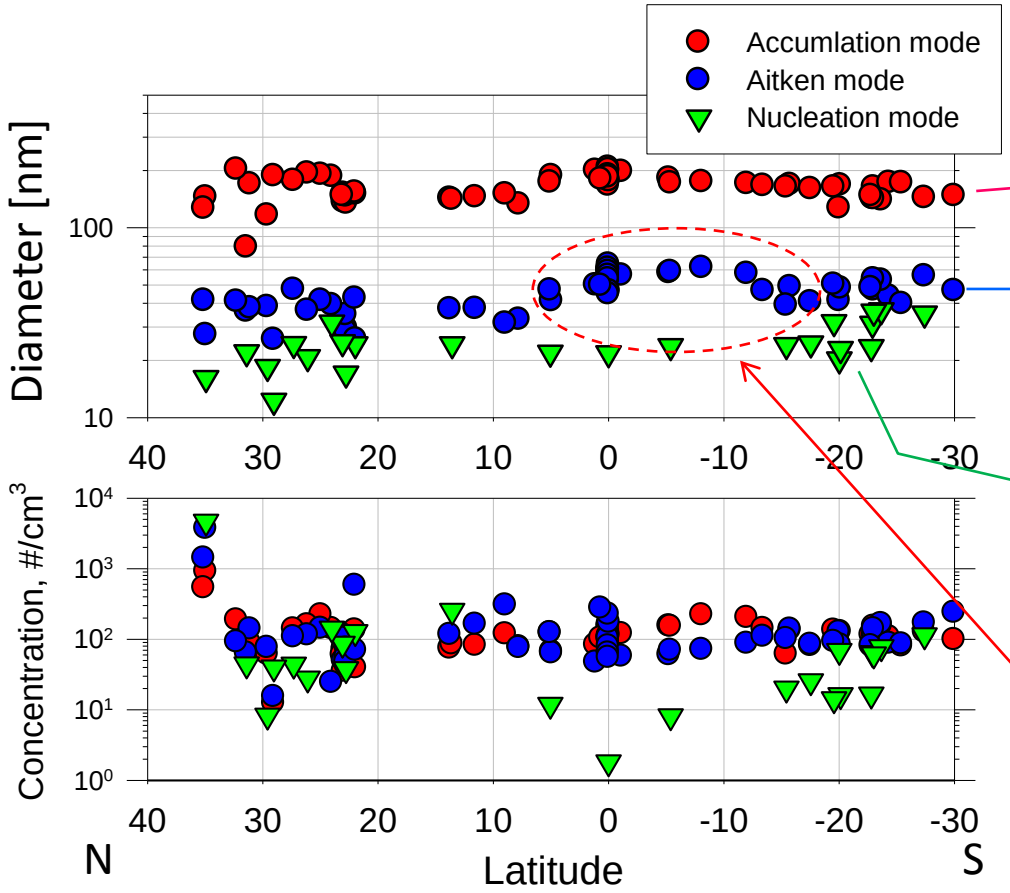


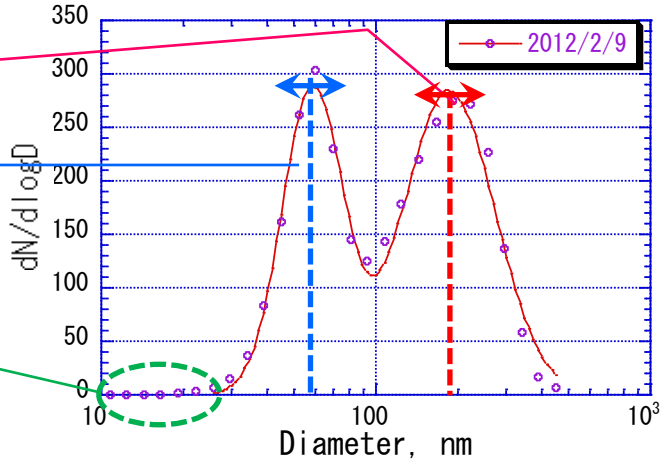


Clear **Bi-Modal**
Size Distribution
In EQ and S-Pacific

=> Indication of Cloud Processed Aerosols

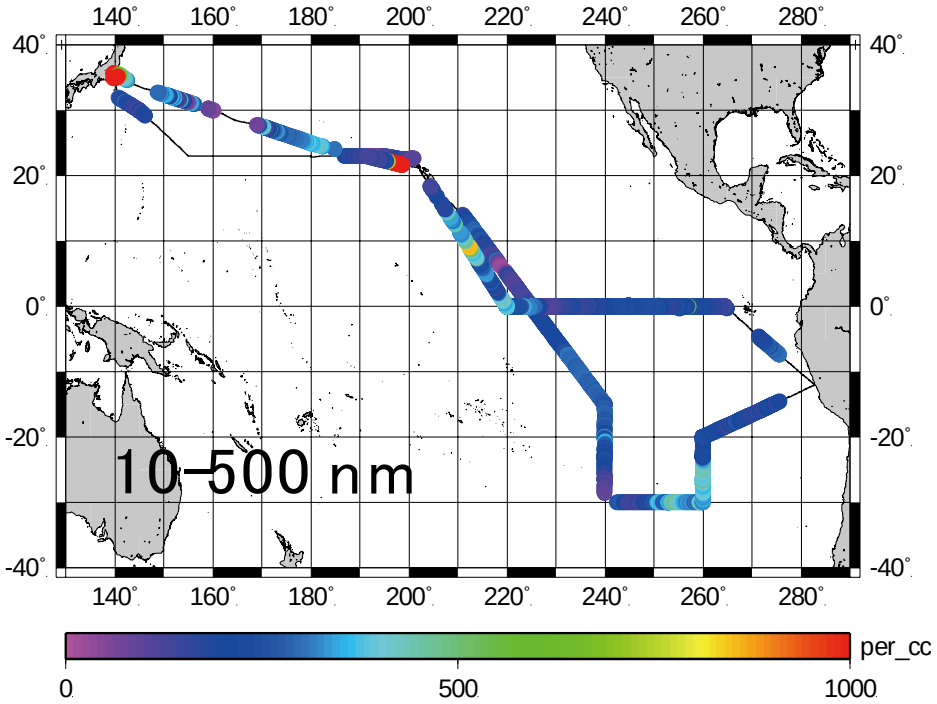
Miura Group (Tokyo Univ. of Sic.)

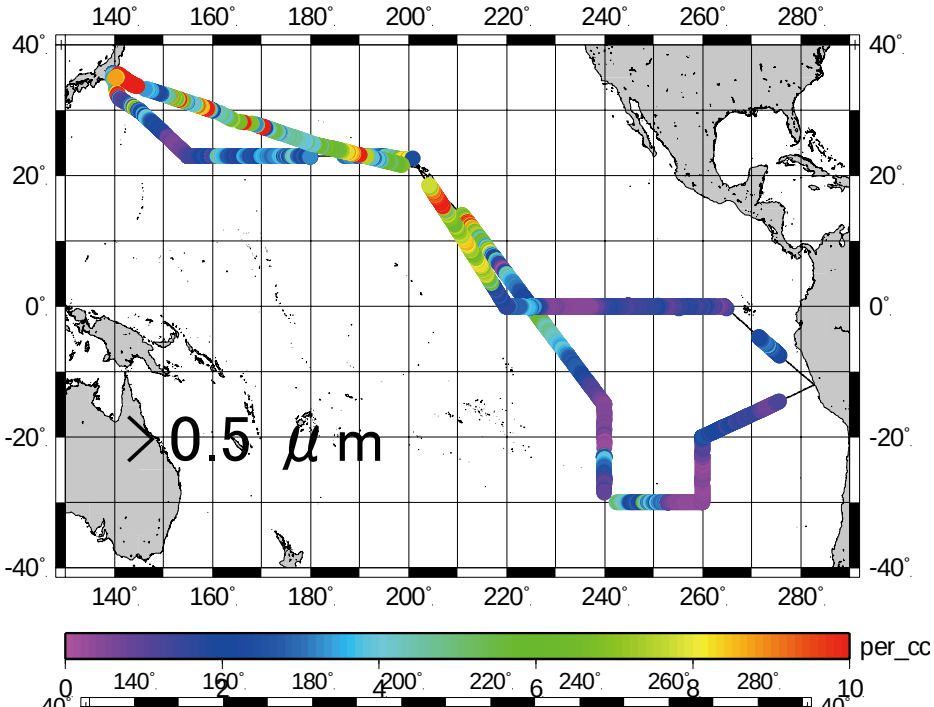




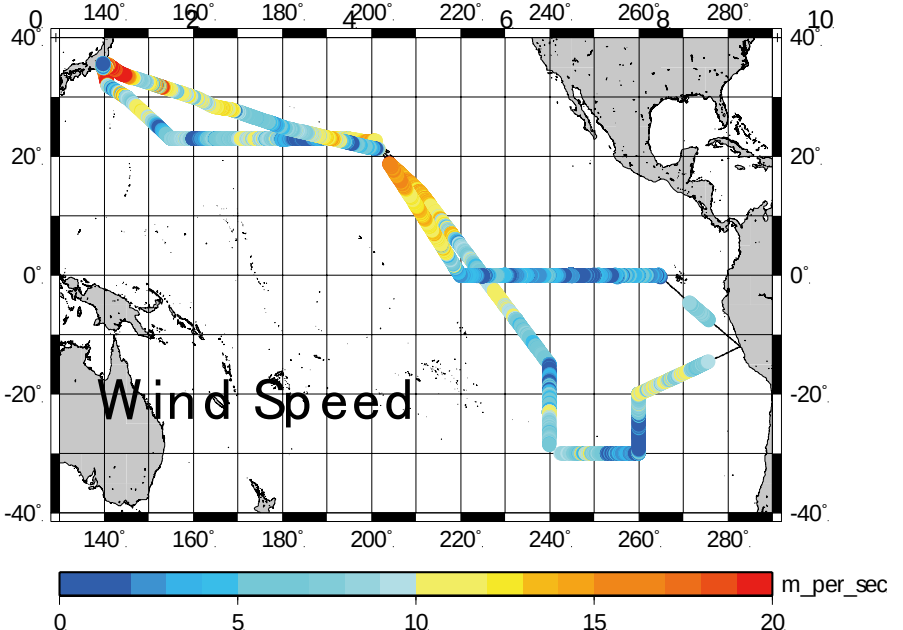
- Aitken mode diameters is large in 0° ~-15°S

Horizontal distribution of aerosol concentration

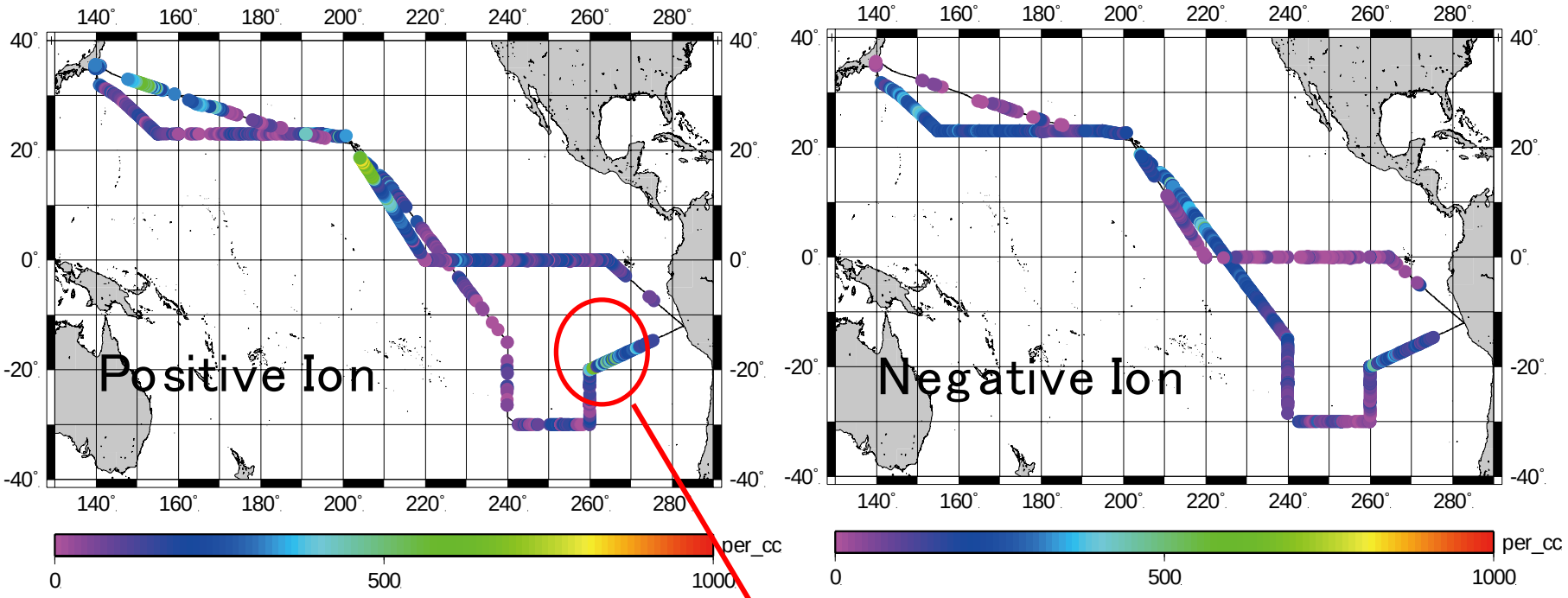




Miura Group
(Tokyo Univ. of Sic.)



Positive & Negative Ion concentrations



High concentration

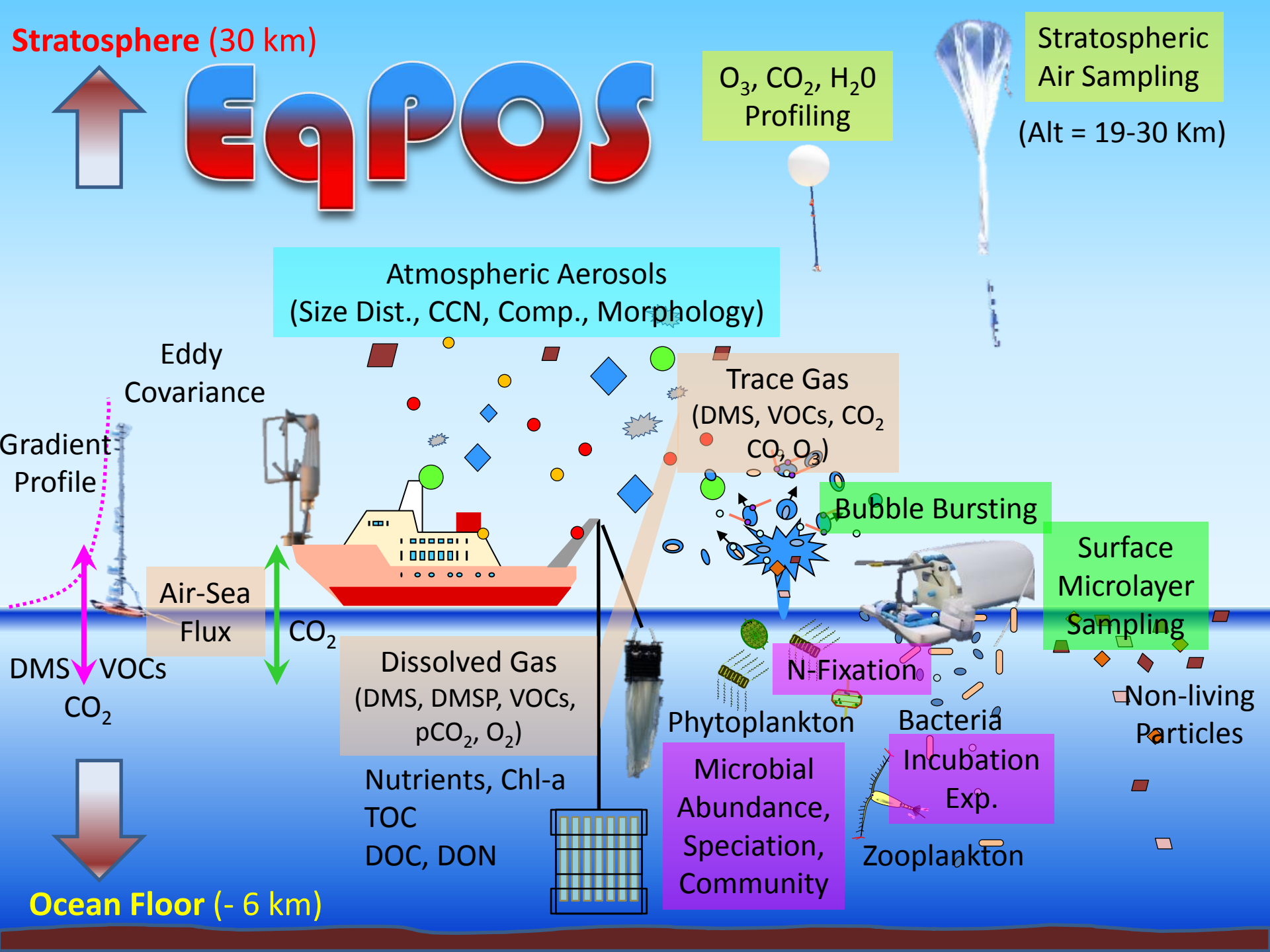
Ion relate with concentration of nucleation mode aerosols?

Miura Group
(Tokyo Univ. of Sic.)

Other Aerosol Data Coming Soon…

Categoly	Type	Instrument	Time Resolution	Note	Target
Aerosol	Size distribution	OPC(KC01D)	3 min	0.5-5 µm, 5 size bin	
		OPC(KC18)		0.3-0.5 µm, 5 size bin	
		SMPS3034		10-487 nm, 54 size bin	
	Chemical composition	Filter Sampler 1	12 hour	whole size	Ionic Spcies MSA Trace Metals Phosphorus (Org-P and Inorg-P)
		Filter Sampler 2	1 day	2 size fraction	
		Filter Sampler 3	3 day	(d < 2.5 µm, 2.5 µm < d)	
		Cacade Filter Impactor	6 or 12 days	0.06-12 µm, 12 size bin	
		Sampling by PILS	12 or 24 hours	Aerosol samples in liquids	
		Aerosol Time-Of-Flight Mass Spectrometer (ATOFMS)	Real-time	Single particle size-resolved mass spectrometry, d = 100 nm~3 µm	Org-N, Metals, Phosphorus, Oxy-Organics, Dust etc
		TEM Single Particle Observation	1-3 per day		Morphology, Elemental Composition
	Mass concentration	EC/OC analyzer	2 - 33hours	PM2.5	
		Nitrate Monitor	10 min		
		Sulfate Monitor	1 hour		
	Number concentration	Water-CPC	1 sec	Total concentradtion for d > 5 nm	CCN Activity
		CCN Counter	1 hour	SS = 0.1, 0.2, 0.3, 0.4, 0.6 (%)	
		Small Ion Concentration	4 min		


Omori and Tanimoto
(NIES)
EqPOS
Yuko Omori and Hiroshi Tanimoto
(National Institute for Environmental Studies)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(Alt = 19-30 Km)
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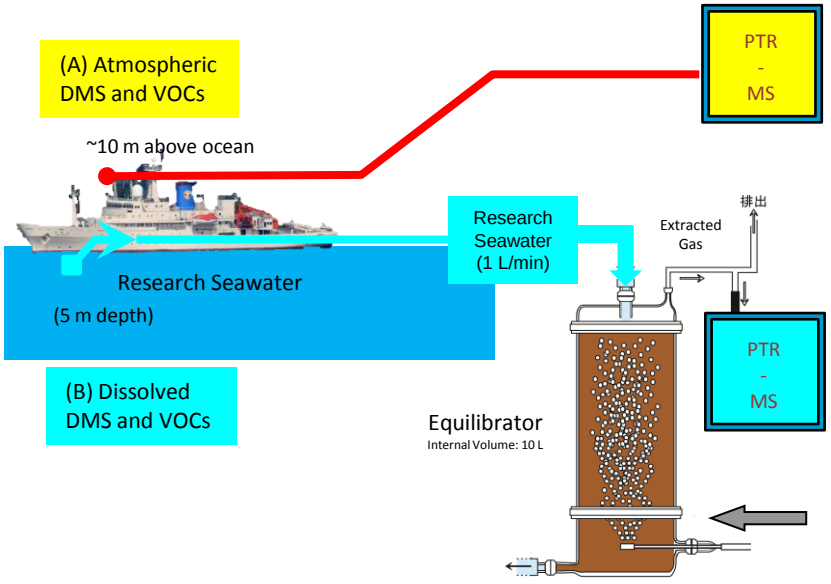
(DMS, DMSP, VOCs, pCO_2, O_2)
N-Fixation
Phytoplankton
Bacteria
Non-living Particles
Nutrients, Chl-a
TOC
DOC, DON
Microbial Abundance, Speciation, Community
Incubation Exp.
Zooplankton
Ocean Floor (- 6 km)

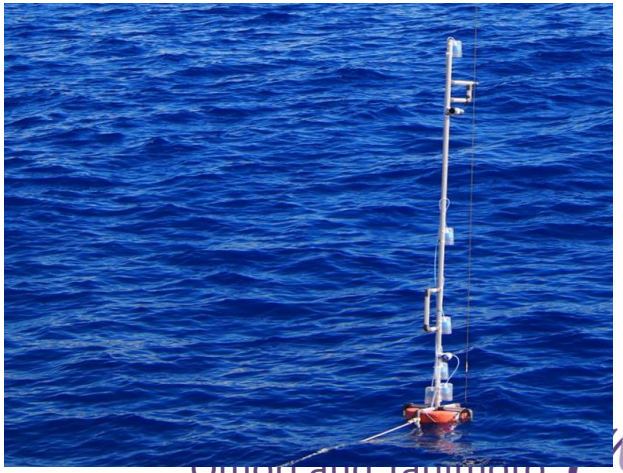
Subjects (NIES)

Omori and Tanimoto (NIES)

1. **Underway measurement for DMS and other VOC dissolved in surface seawater with equilibrator-inlet-PTR-MS (EI-PTR-MS)**

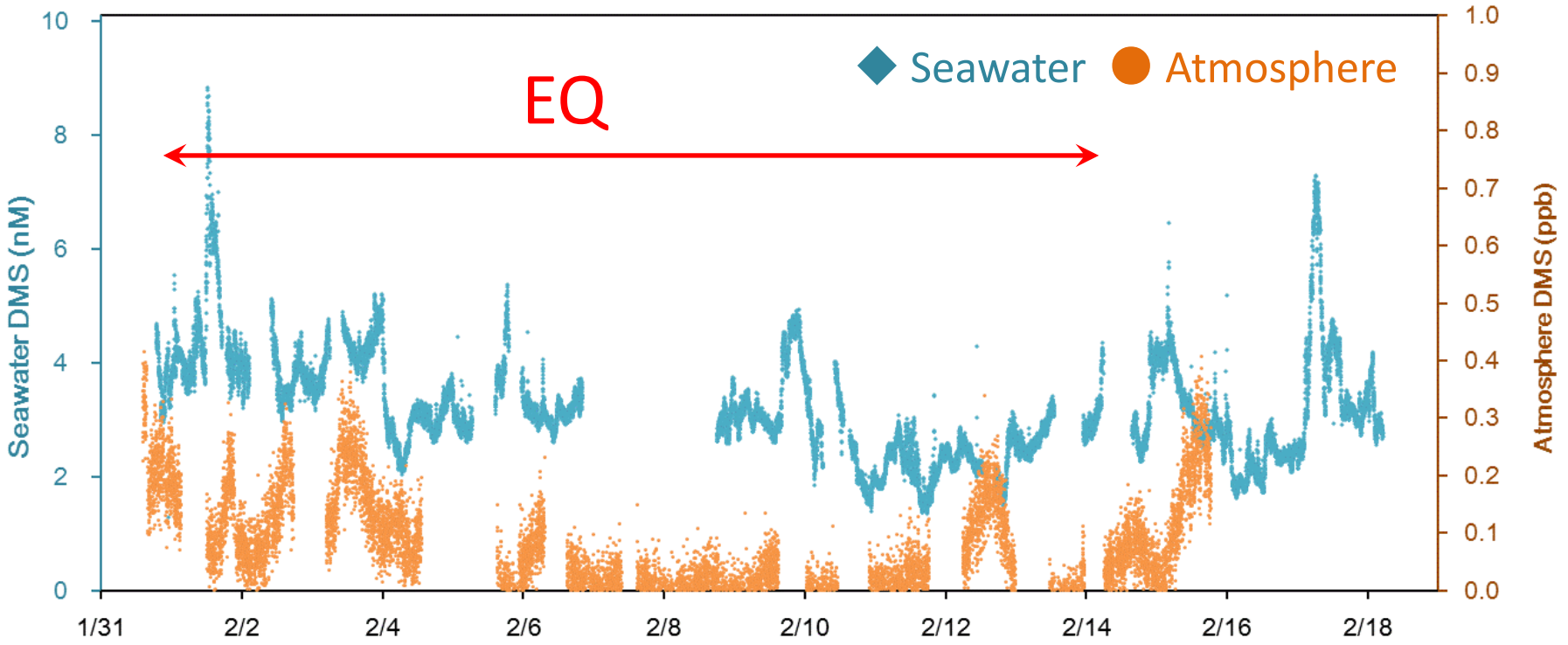


2. **DMS and other VOC flux measurement with "profiling buoy" system**



DMS distribution

Omori and Tanimoto (NIES)



DMS cocentration	Seawater (nM)	Atmosphere (ppb)
Min	1.3	0.00
Max	8.8	0.42
Ave (SD)	3.2 (1.0)	0.07(0.08)

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

Comparison with previous observations

DMS (nM) (SD)	Min-Max	Area	Ref
3.4 (0.9)	**1.4-10.1**	**10S-0N, 85-115W**	**this observation**
3.1		0-5N, 80-140 W	Andrea & Raemdonck (1983)
2.0 (0.70)	0.6-4.2	15N-10S, 145-165 W	Bates et al.(1993)
2.4	1.7-3.3	5.6-5.7S, 107 W	Turner et al. (1996)
1.58 (0.6)		Equatorial upwelling	Marandino et al. (2007)
0.95 (0.40)		Gyre	Marandino et al. (2007)
1.88		5-20N, 140W	Andrea & Raemdonck (1983)
2.22	0.94-4.06	Sargasso Sea, 25N	Andrea & Barnard (1984)

高時間分解能でのDMS測定によって、これまで観測されてこなかった
DMS濃度の局所的なピークを捉えることが出来たのかもしれない

Omori and Tanimoto
(NIES)

Calculation for sea-air DMS flux

$$\text{Flux} = k_{DMS} \times (DMS_{seawater} - DMS_{Air}) \fallingdotseq k_{DMS} \times (DMS_{seawater})$$

$$k_{DMS} = 0.31 \times U^2 \times (Sc_{DMS}/660)^{-0.5}$$ (Wanninkhof et al. 1992)

$$Sc_{DMS} = 2674.0 - 147.12t + 3.726t^2 - 0.038t^3$$ (Saltzman et al. 1993)

DMS : DMS concentration

k_{DMS} : exchange velocity of DMS

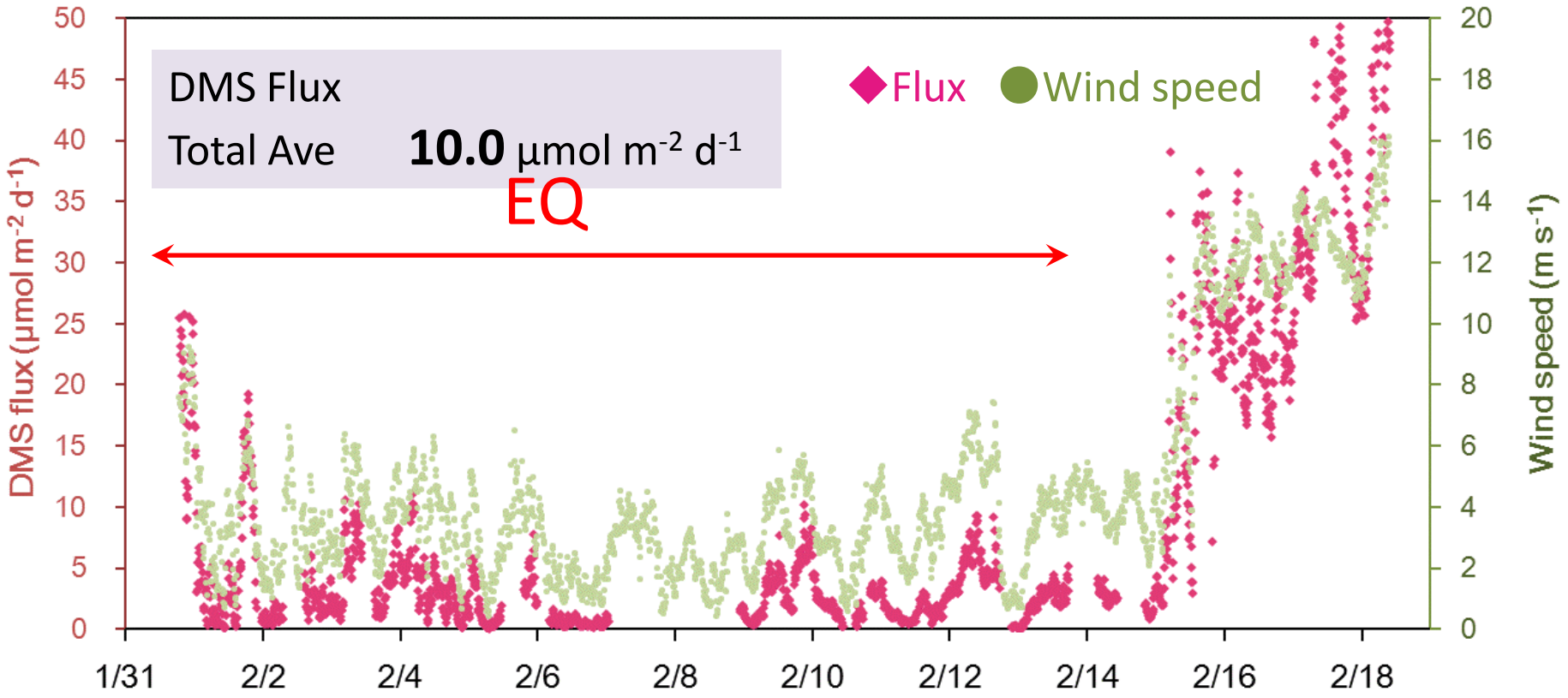
Sc_{DMS} : schmidt number of DMS

t : seawater temperature (℃)

U : wind speed (m s^{-1})

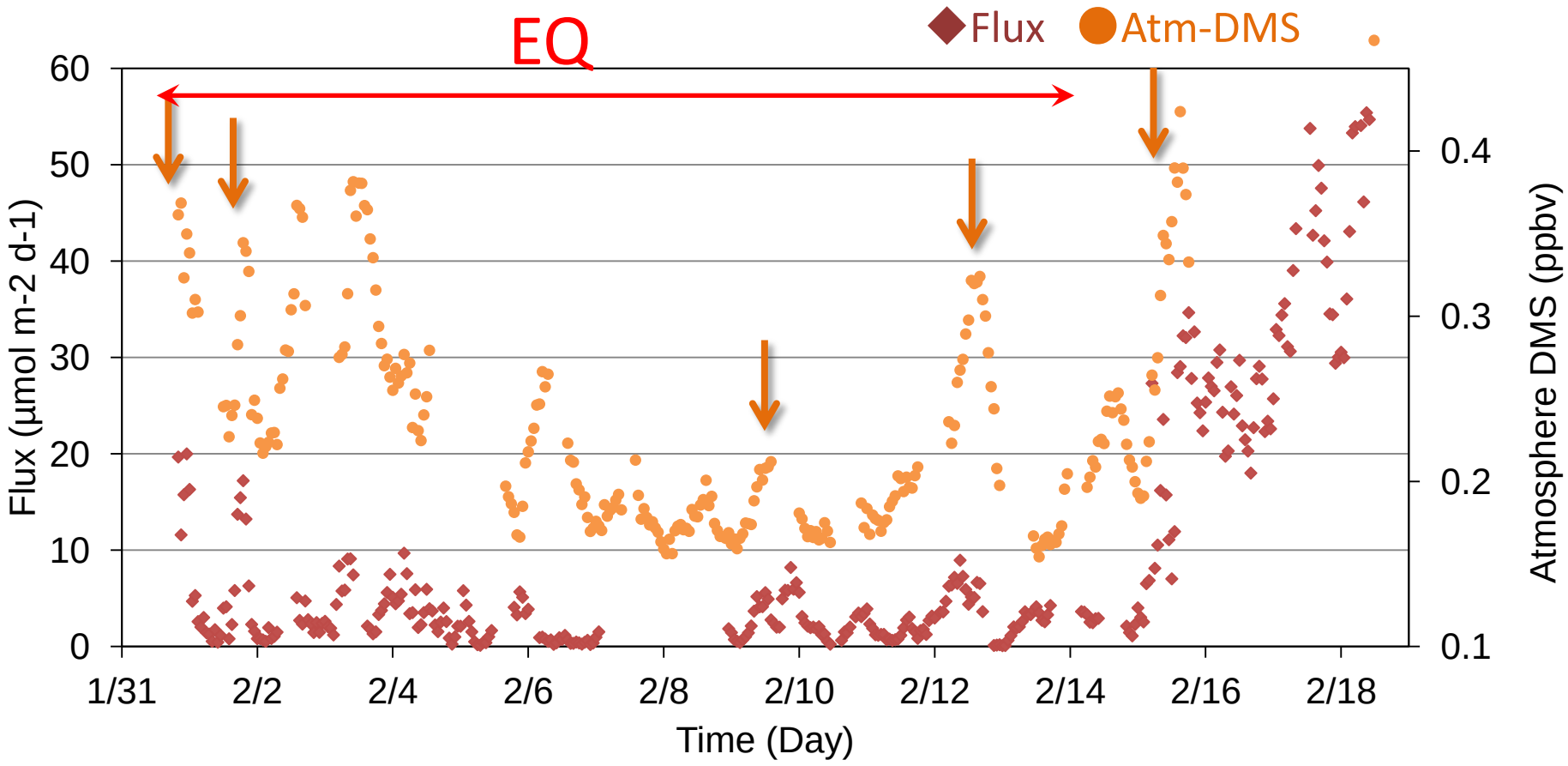
Omori and Tanimoto (NIES)

DMS flux and wind speed



Omori and Tanimoto (NIES)

DMS Flux vs. Atm-DMS



フラックスが大きい → 大気DMS濃度が増加する傾向を確認

今後、フラックスブイ観測との整合性を確認・エアロゾルなどのデータとも比較し、大気中の粒子形成とDMSの関係をみていきたい

2. “Profiling Buoy” observation

Subject of profiling buoy observation

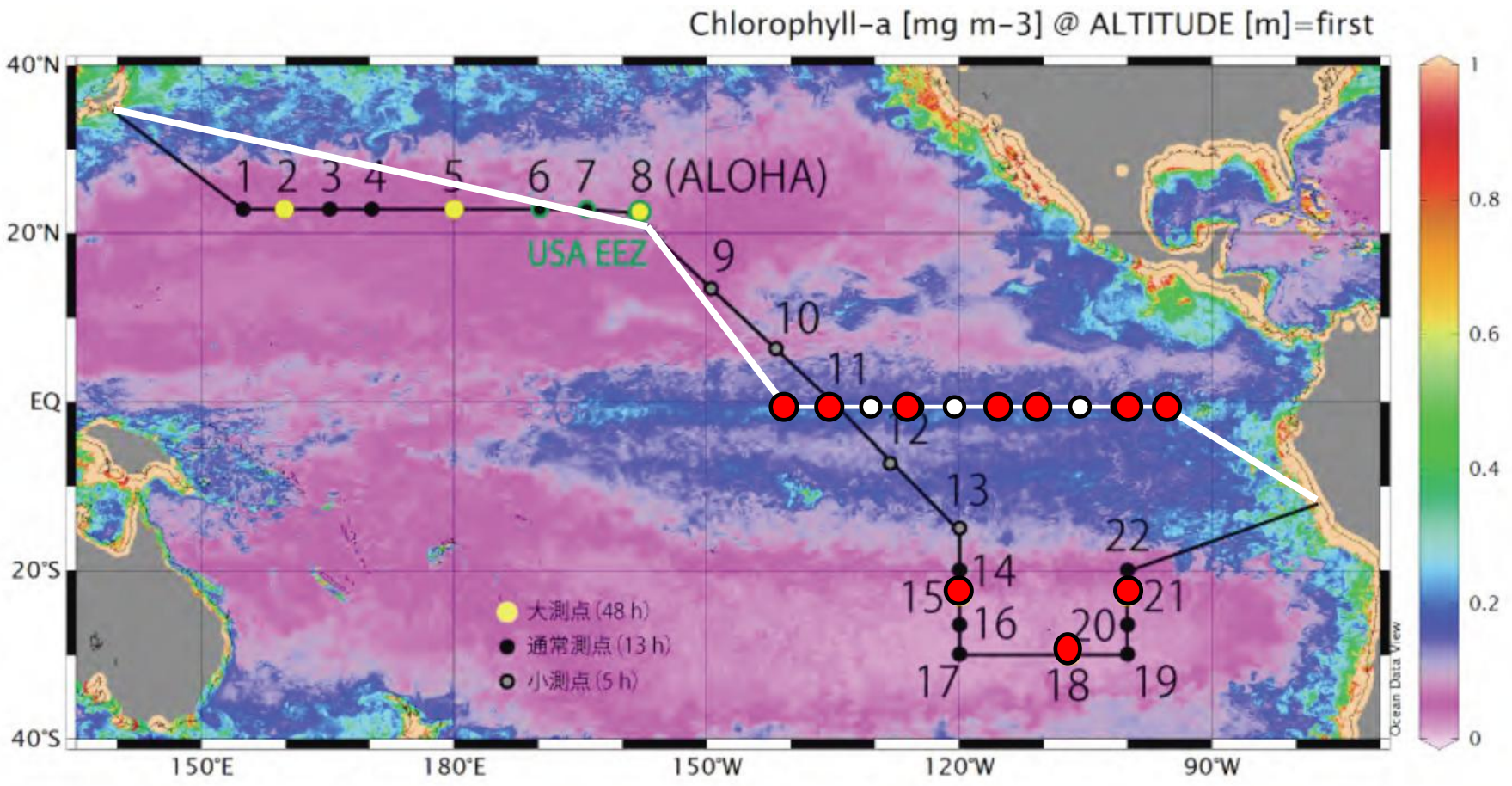
- Measurement of flux from of DMS and other VOC profiles
- Gas exchange velocity estimation

Omori and Tanimoto (NIES)

PTR-MS
(DMS, acetone)

Location of Flux Buoy Measurement

(●Flux Buoy)



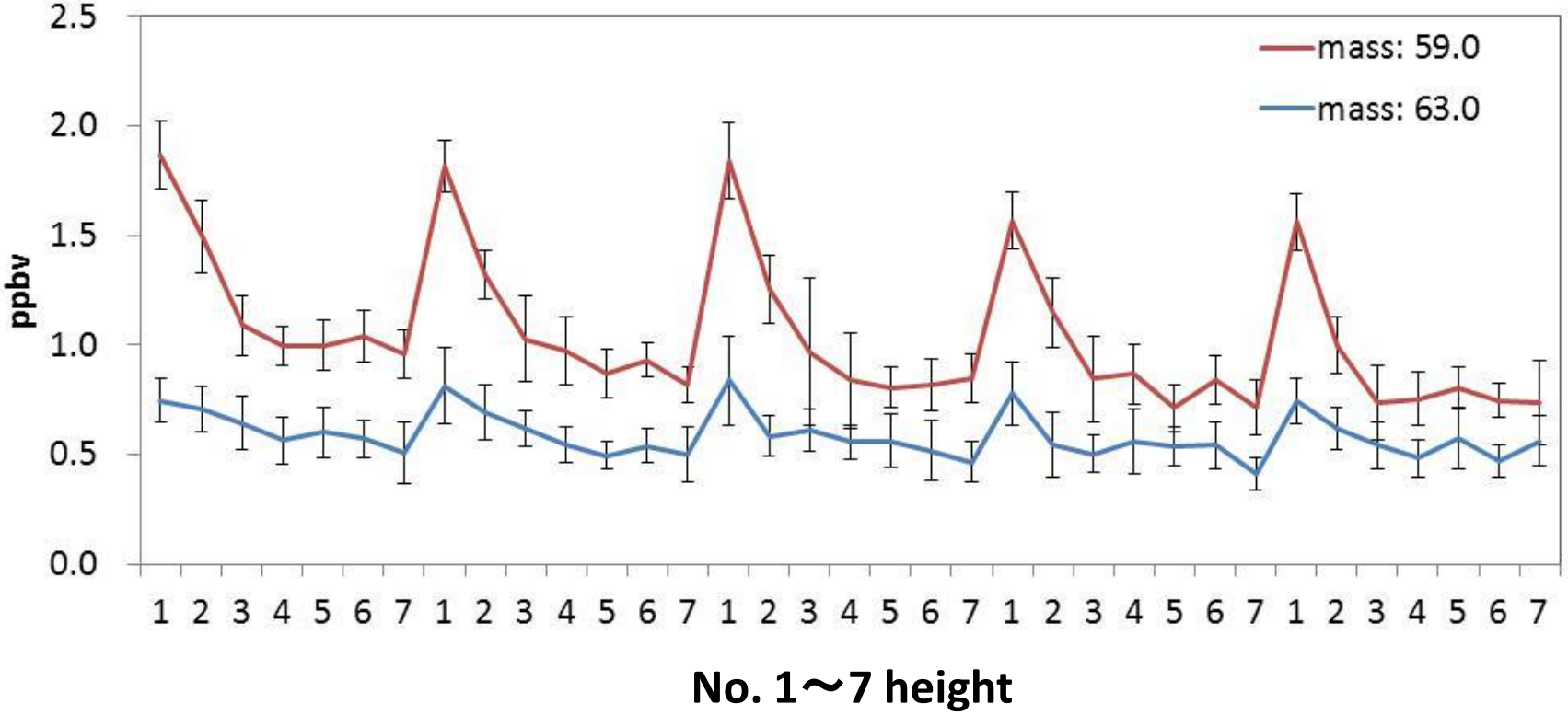
Omori and Tanimoto
(NIES)

DMS and acetone concentration

Each height from sea surface : 1.2, 5.0, 20, 53, 120, 258, 1400 (upper deck) cm

DMS(m/z = 63), Acetone(m/z = 59) (ppbv)

(average for 30 sec at each height)

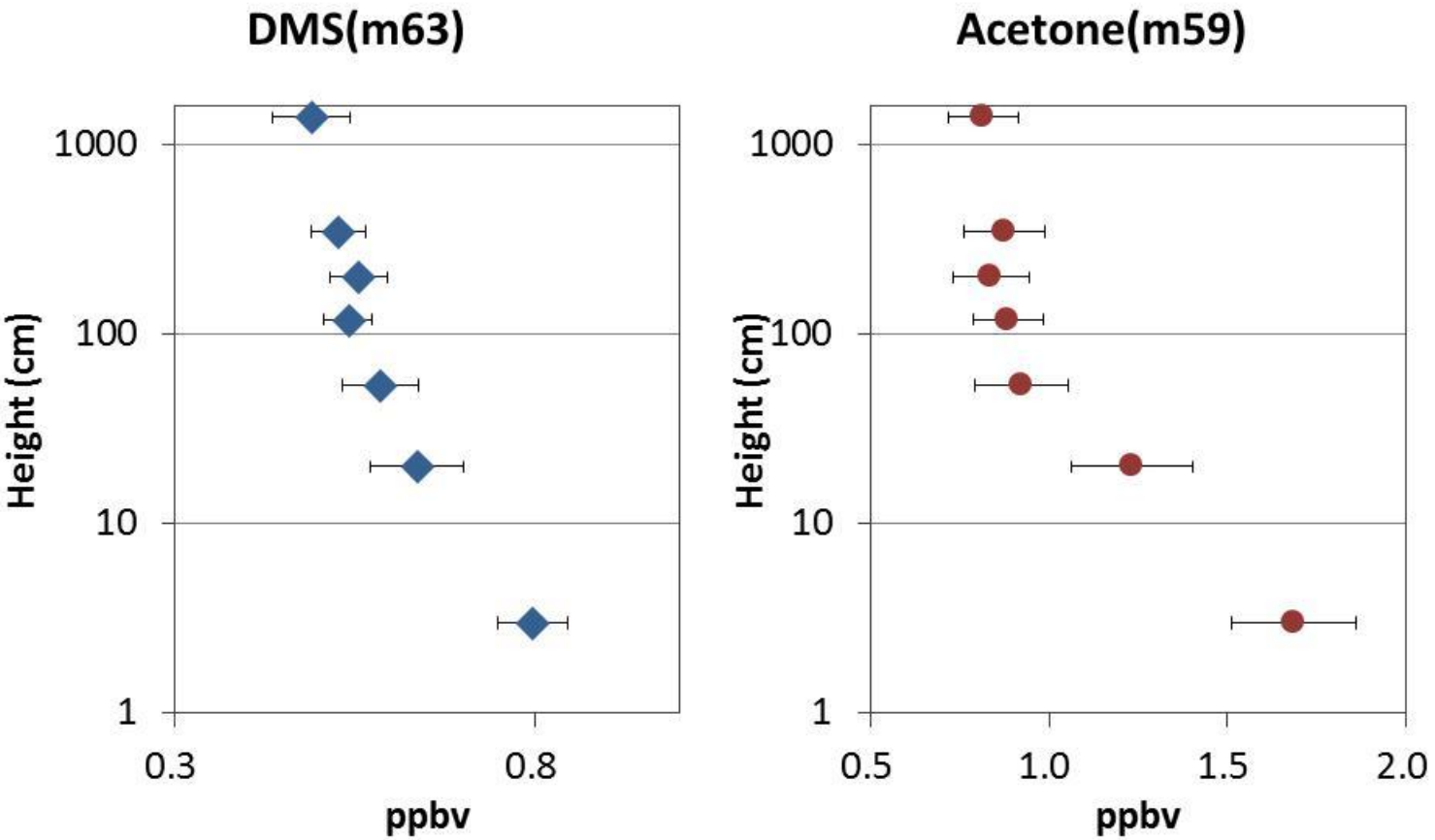


No. 1～7 height

Profiles of DMS and acetone

Omori and Tanimoto (NIES)

Average of 5 profiles (±SD)



Omori and Tanimoto
(NIES)

Future Work

- Comparison of flux observed by “flux buoy” and estimated from DMS air/sea concentrations.

  =>Factor controlling DMS flux

- Relationship with microorganisms and DMS concentration

  => Microbial structure/functional gene vs. DMS concentration.

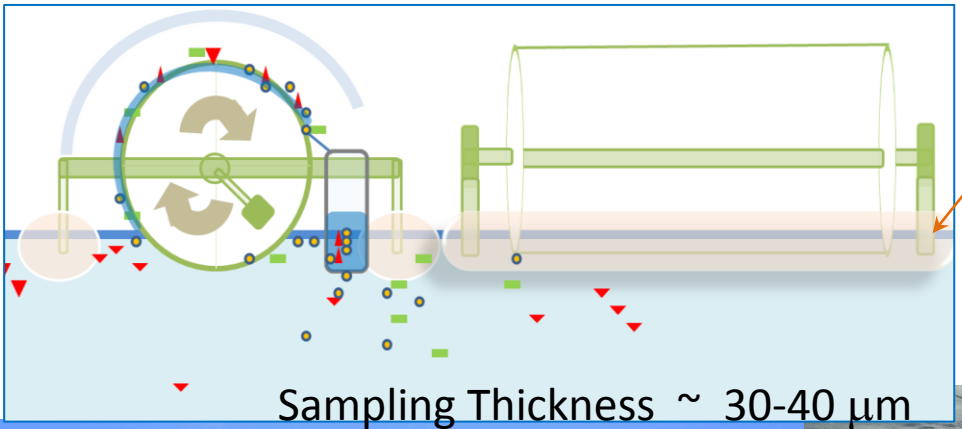
- Relationship with Atmospheric Aerosols

Characterization of Sea Surface Microlayer

Sea-Surface Microlayer (SML) Sampling

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

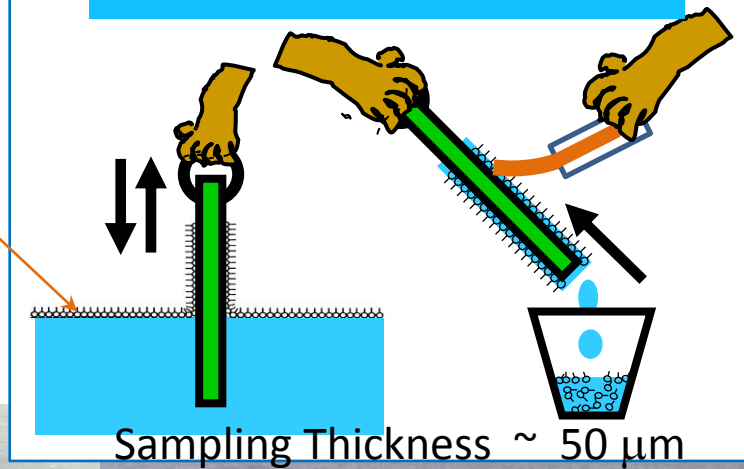
Rotating Drum Method



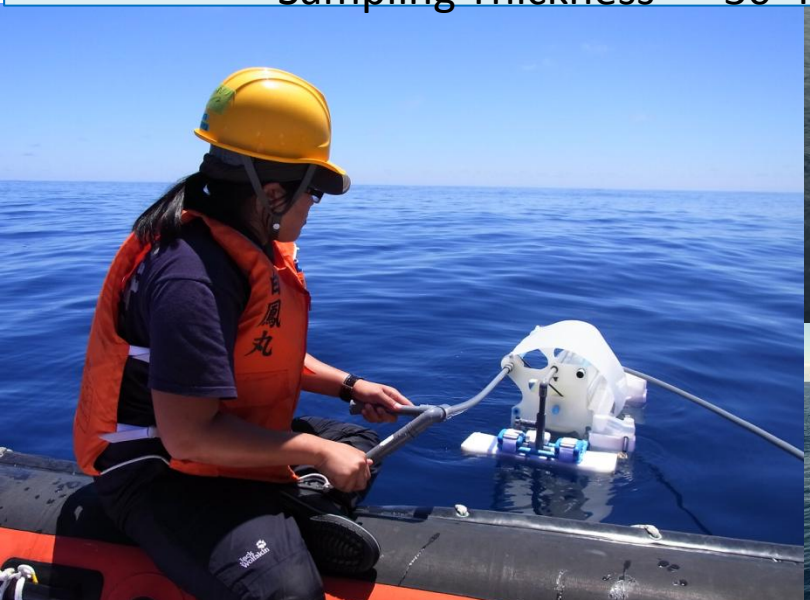
Sampling Thickness ~ 30-40 μm

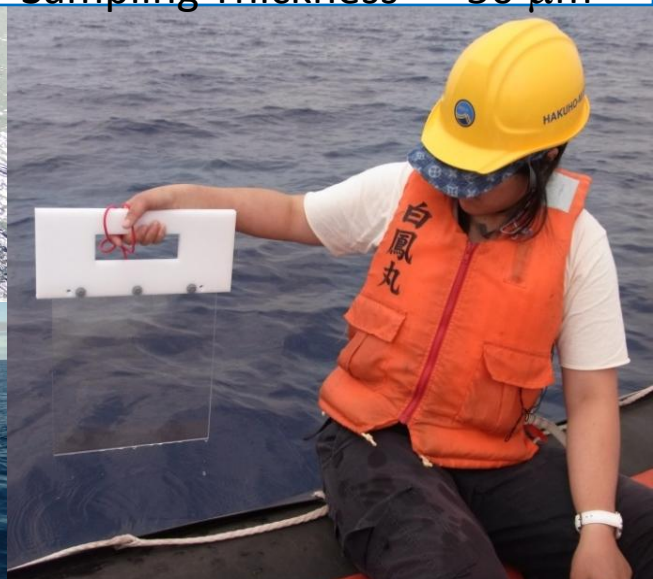
SML

Glass Plate Method

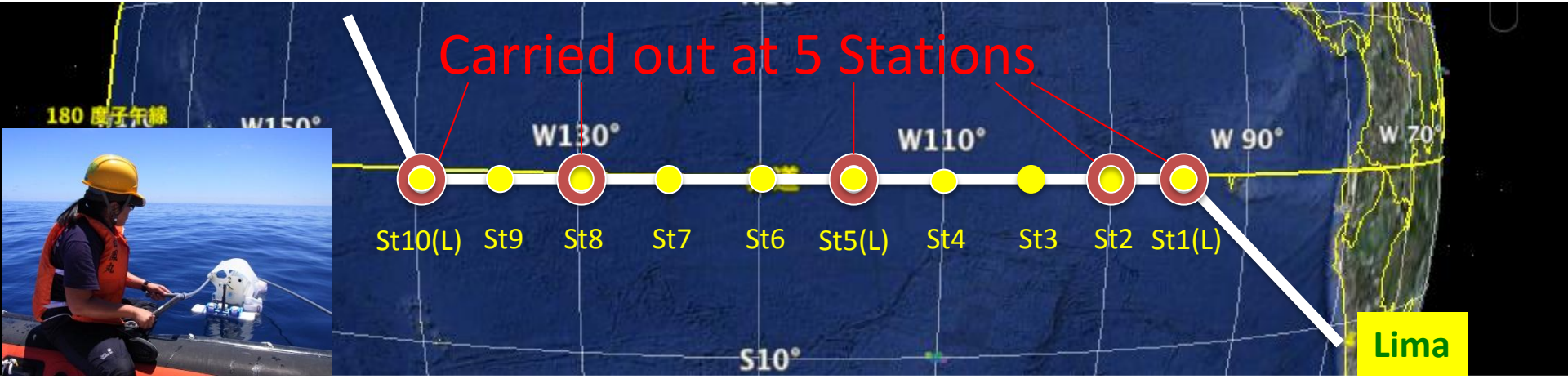


Sampling Thickness ~ 50 μm





Sea-Surface Microlayer (SML) Sampling



Further Analysis

SML Seawater

Sub-Surface Seawater
(Reference)

1

2

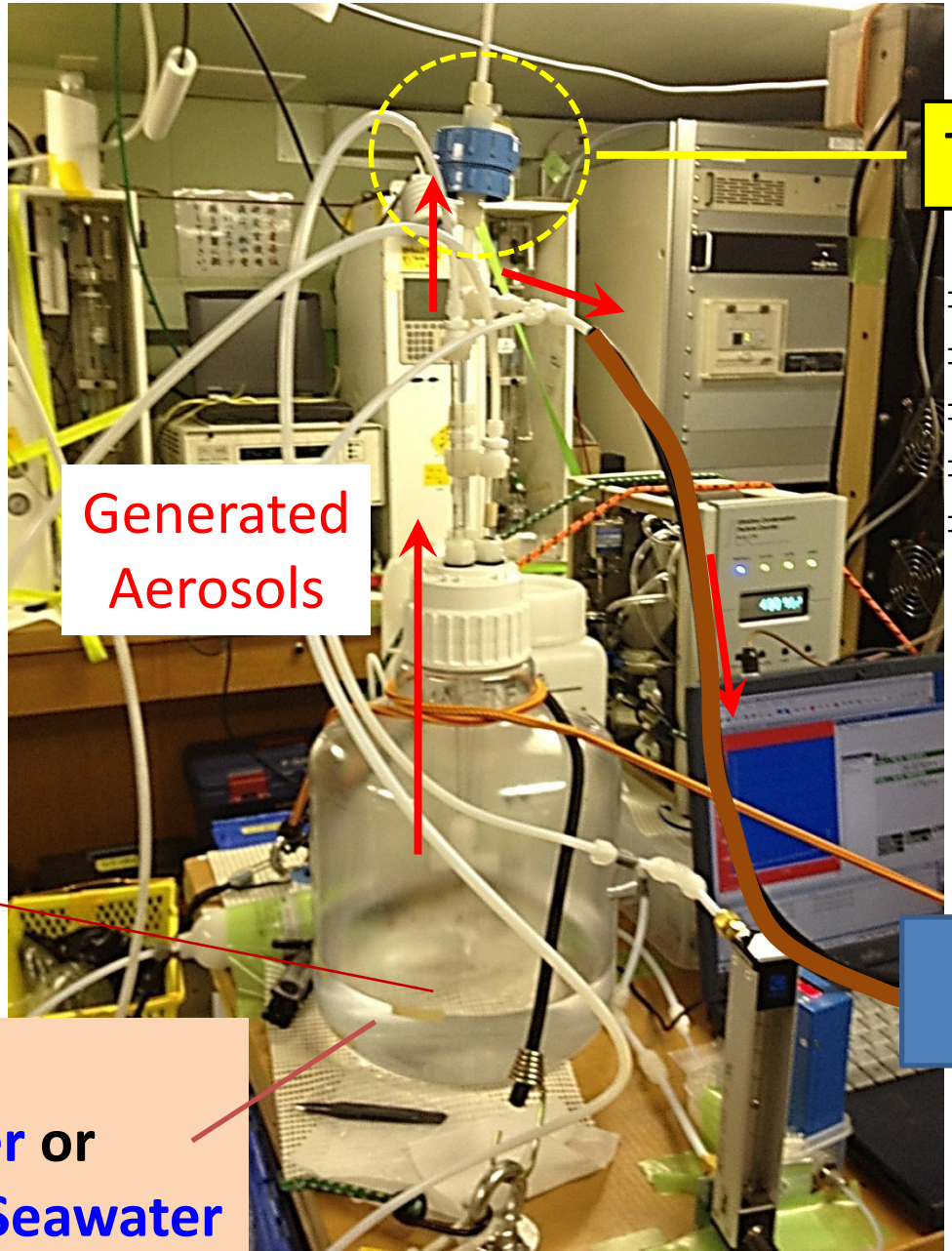
Chemical Analysis

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

Generated Aerosols

Laboratory
Air Bubble Bursting

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

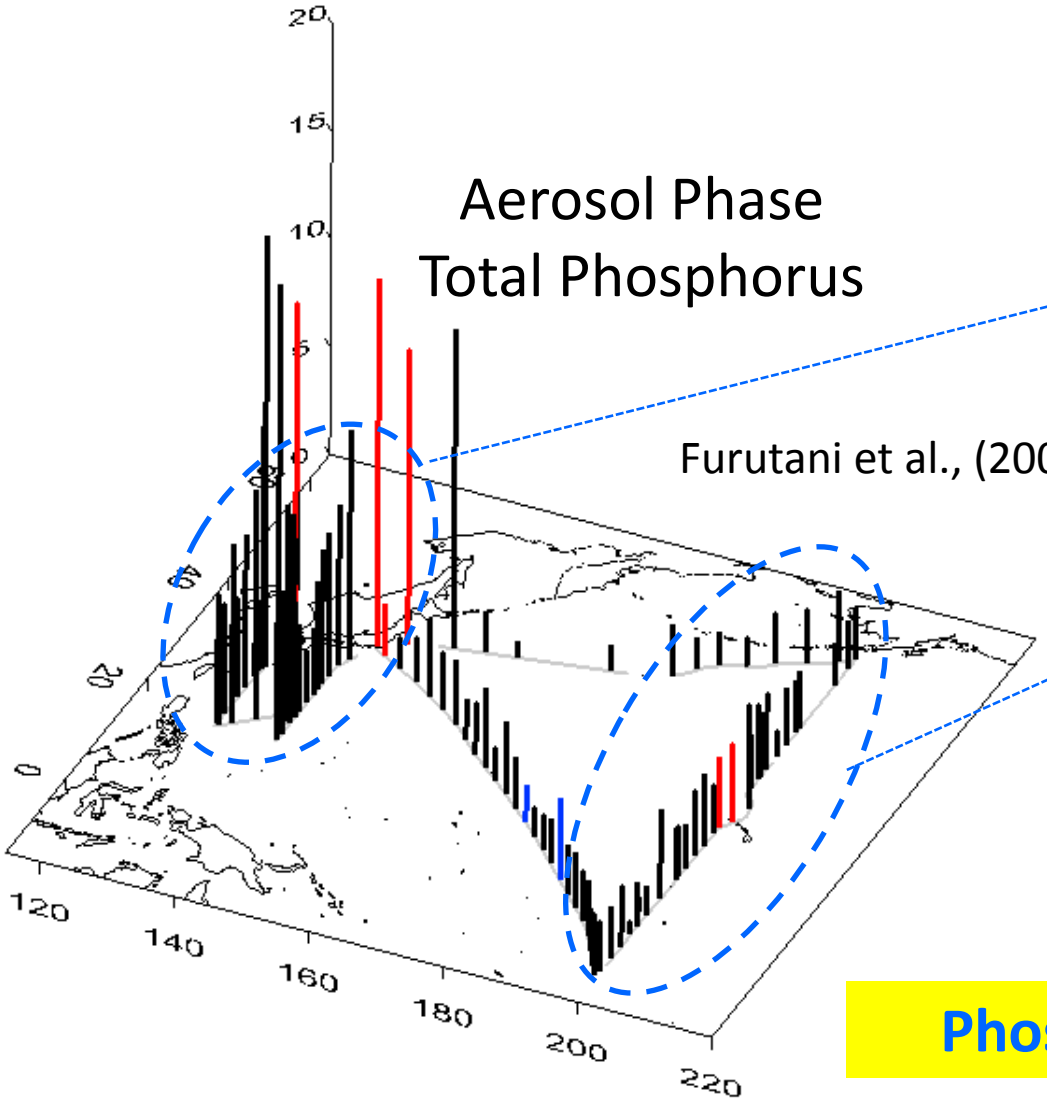
Pump

Sample:

SML Seawater or

Sub-Surface Seawater

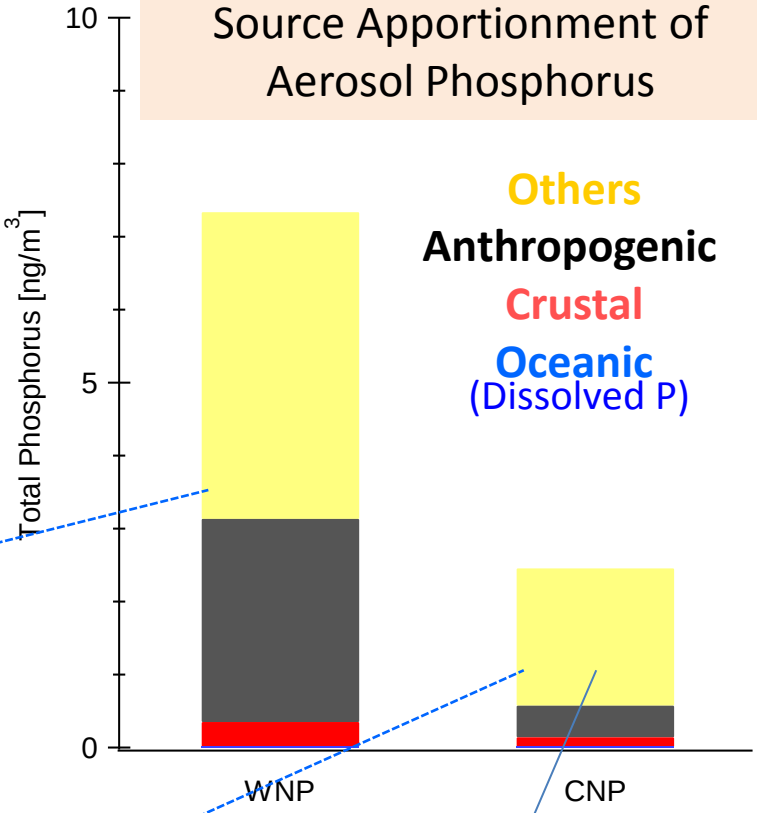
Missing Source of Atmospheric P in open ocean



Aerosol Phase
Total Phosphorus

Furutani et al., (2009)

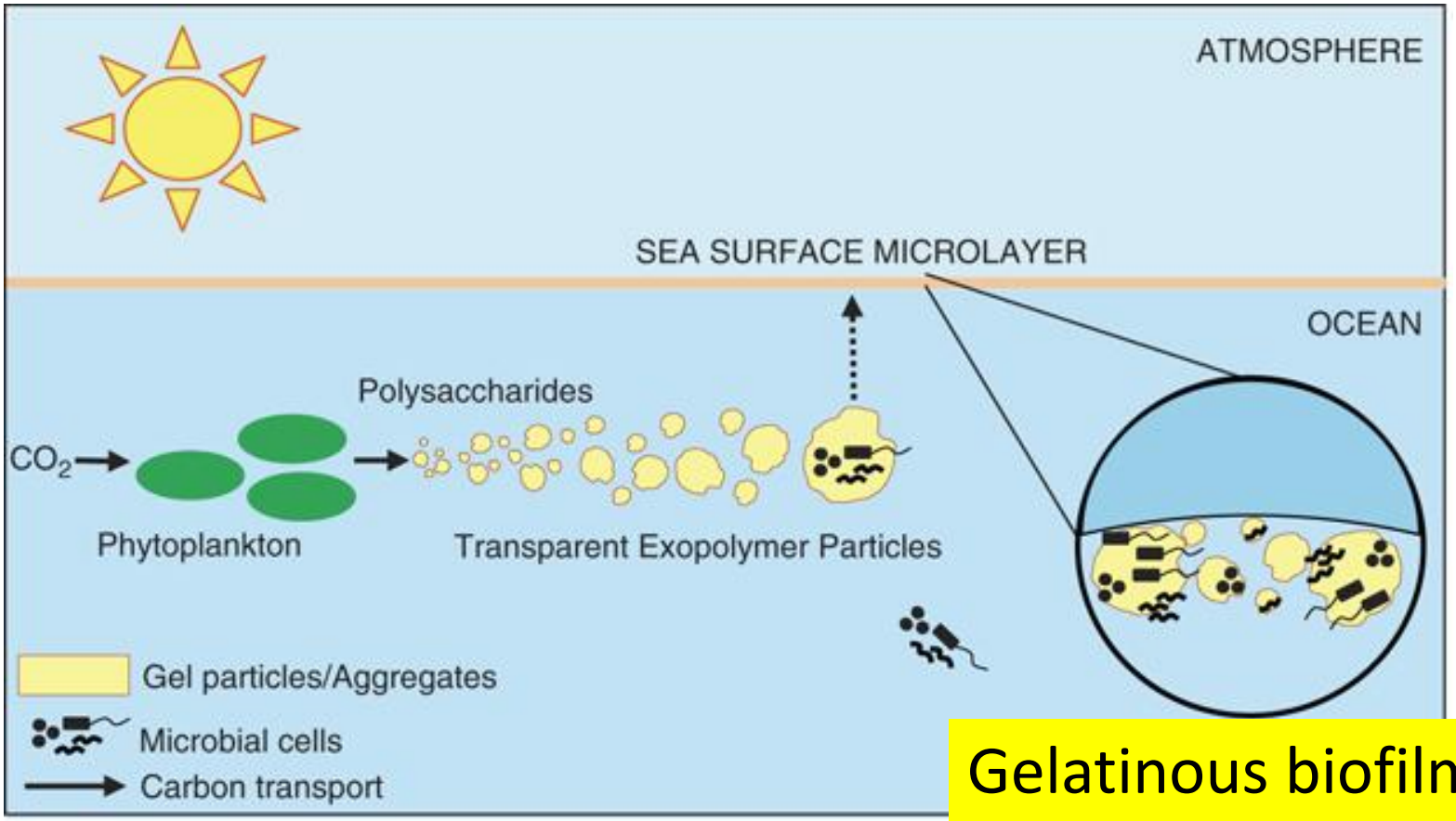
Source Apportionment of Aerosol Phosphorus



Unaccounted source other than ***dissolved oceanic P***

Phosphorus is enriched in SML?

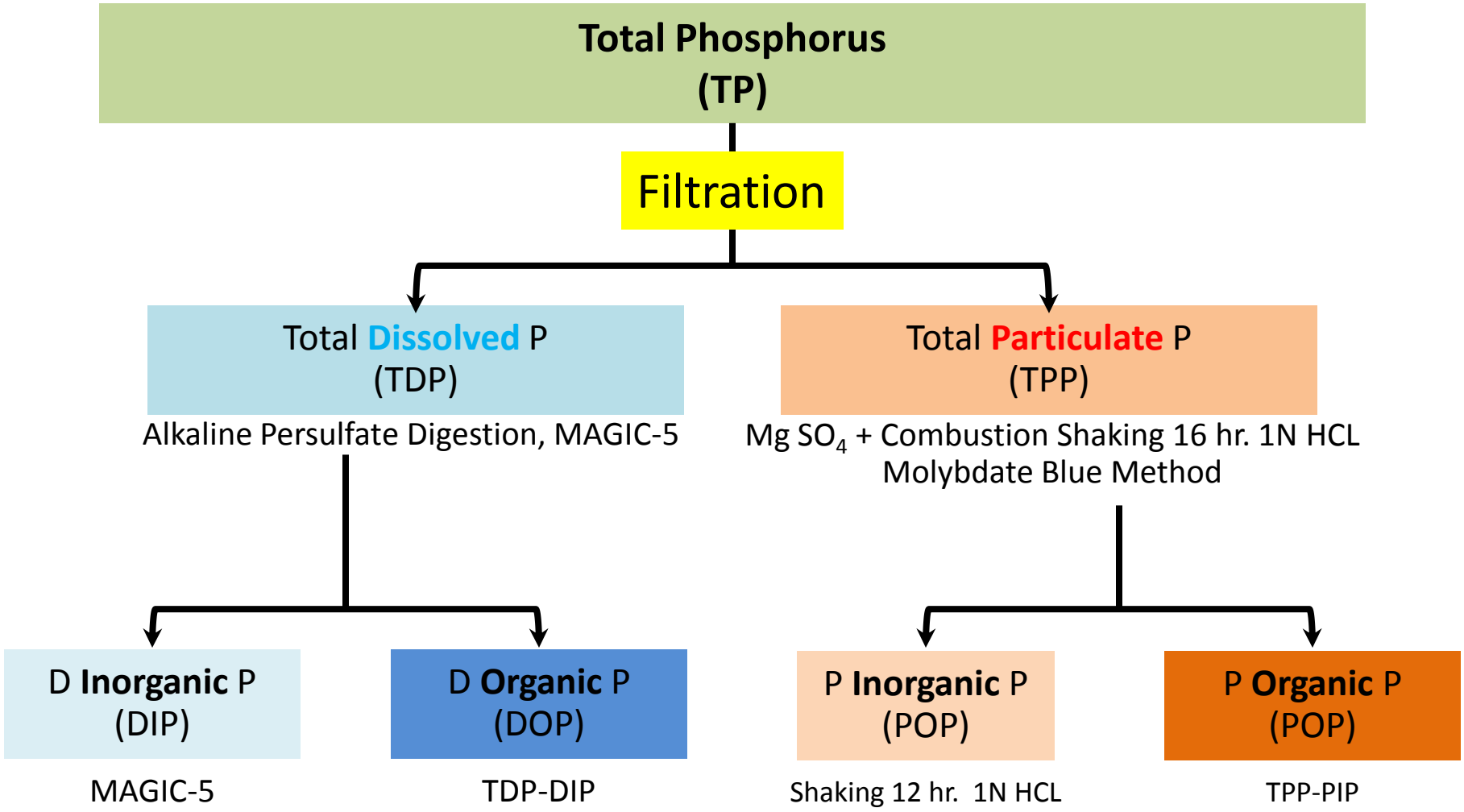
Surface Microlayer: Gelatinous biofilm?



Particulate P << Dissolved P in bulk seawater
Particulate P may be enriched in SML?

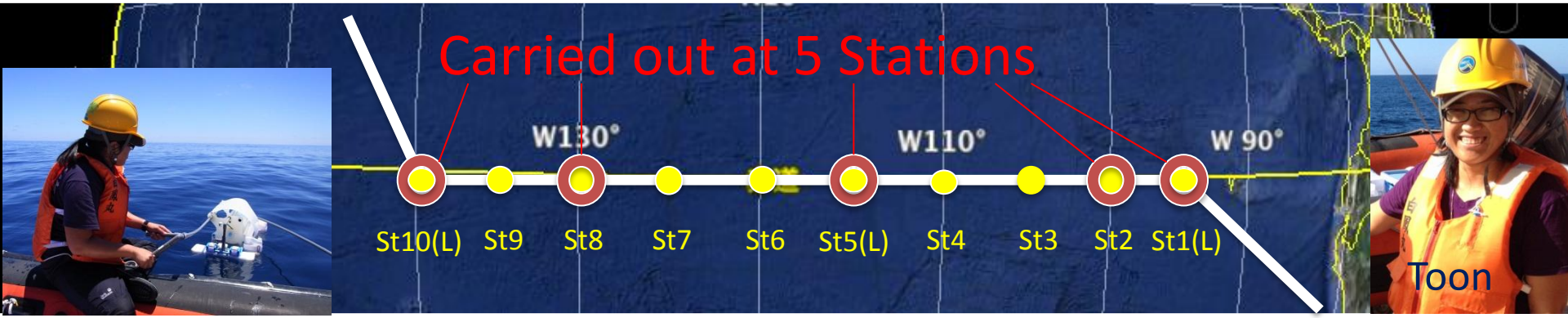
Cunliffe and Murrell (2009)

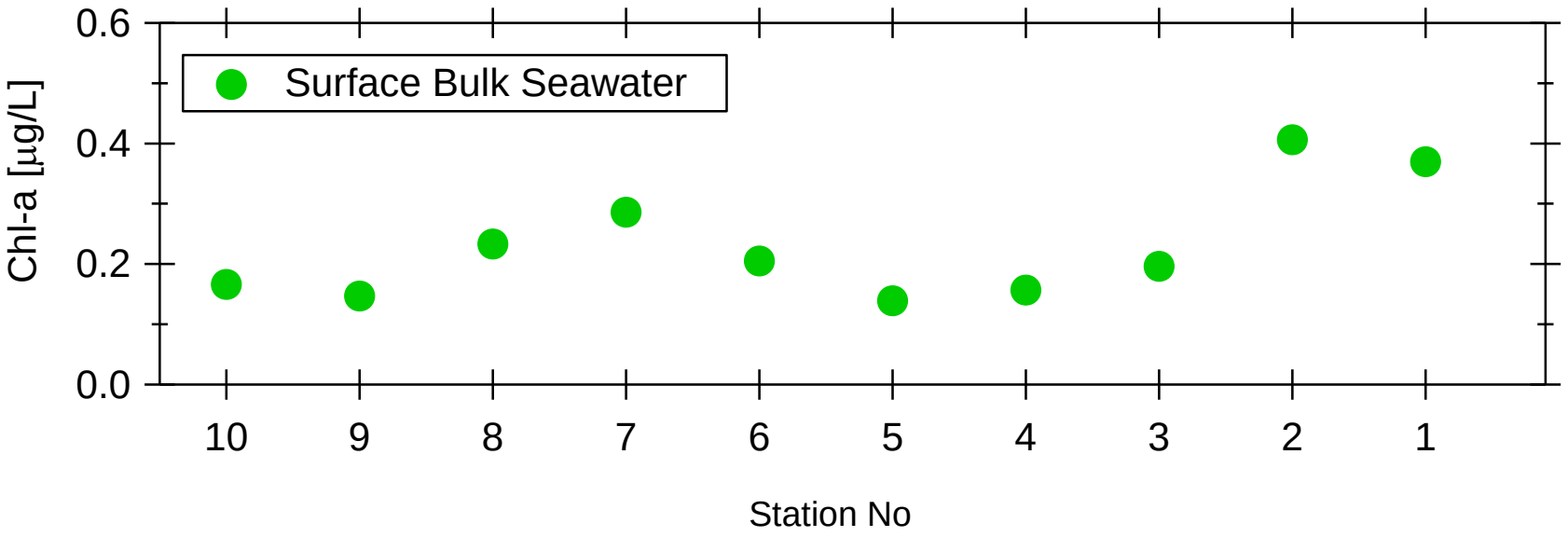
Chemical Fractionation of Phosphorus



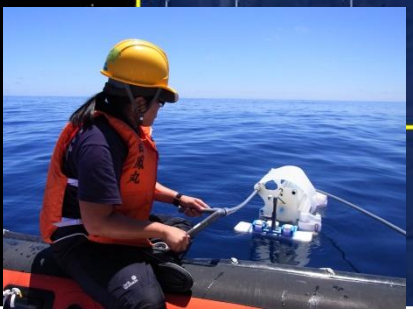
Grasshoff *et al*. (1999), Moutin *et al.* (2005) and Chen *et al.* (2006)

TDP Sea-Surface Microlayer (SML) Sampling

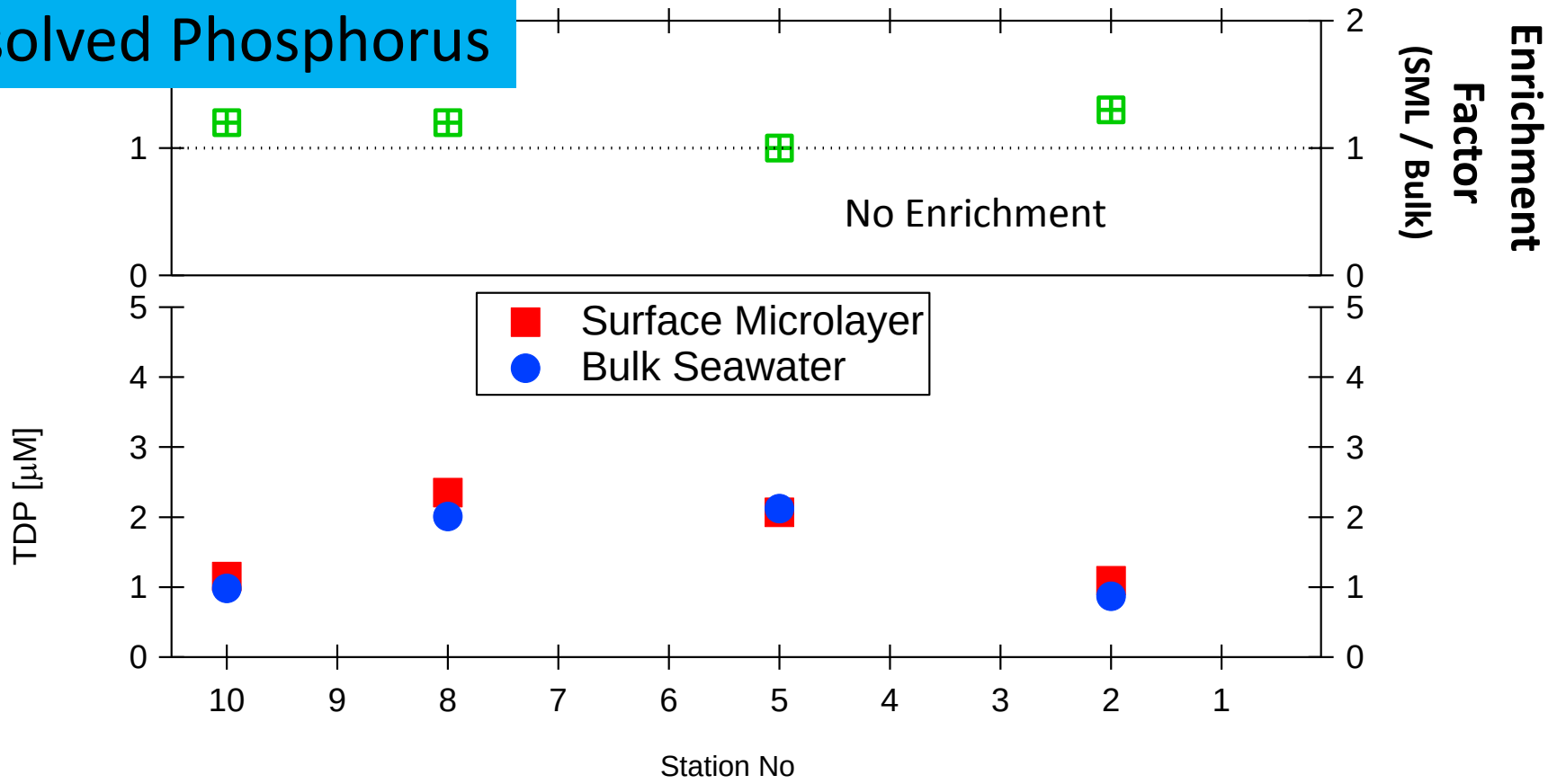




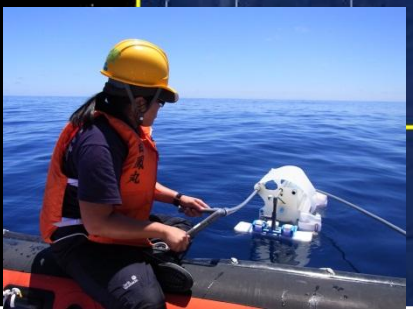
TDP Sea-Surface Microlayer (SML)



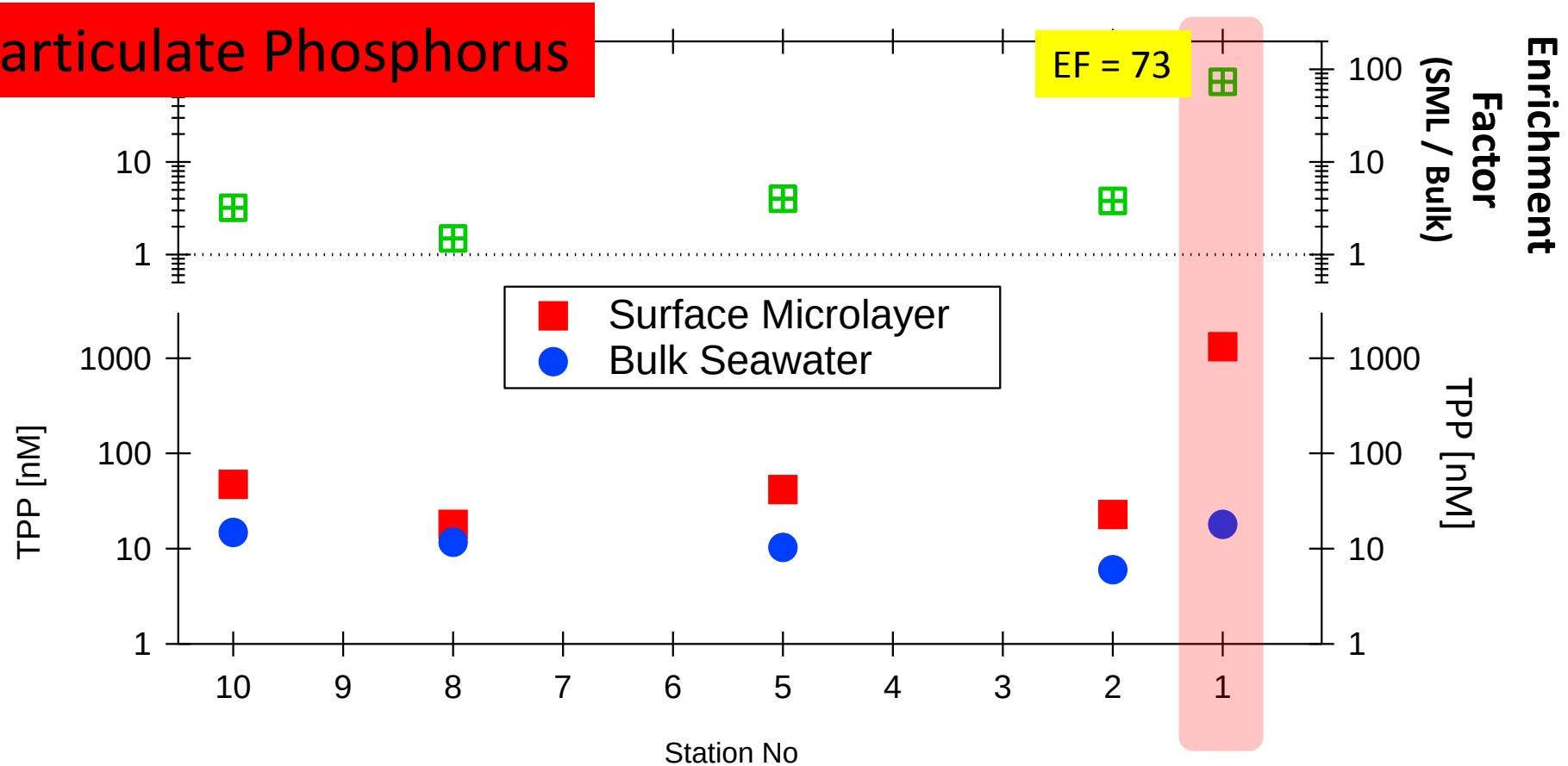
Dissolved Phosphorus



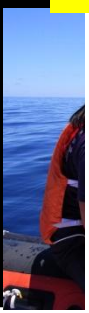
TDP Sea-Surface Microlayer (SML)

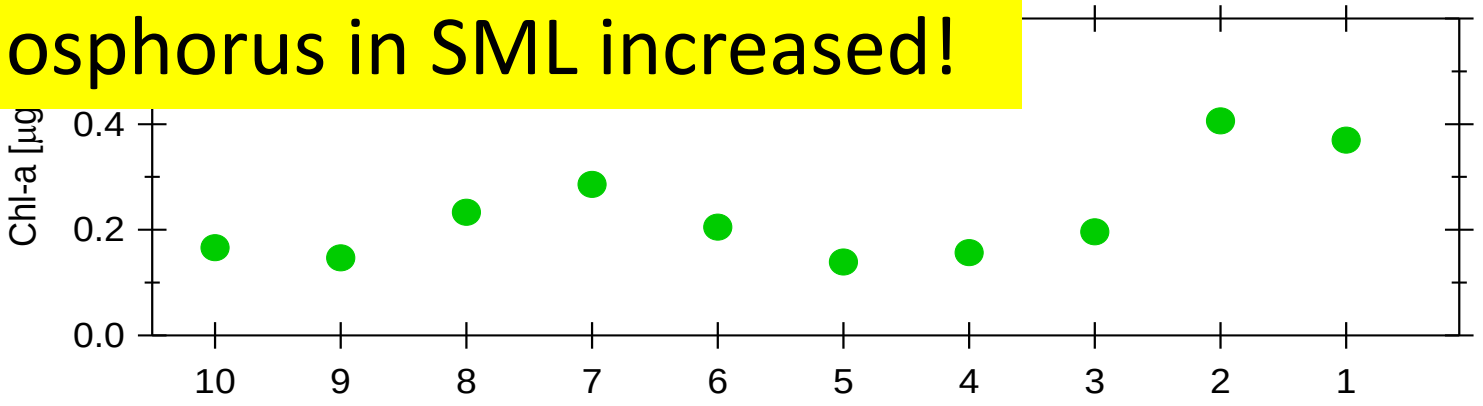


Particulate Phosphorus

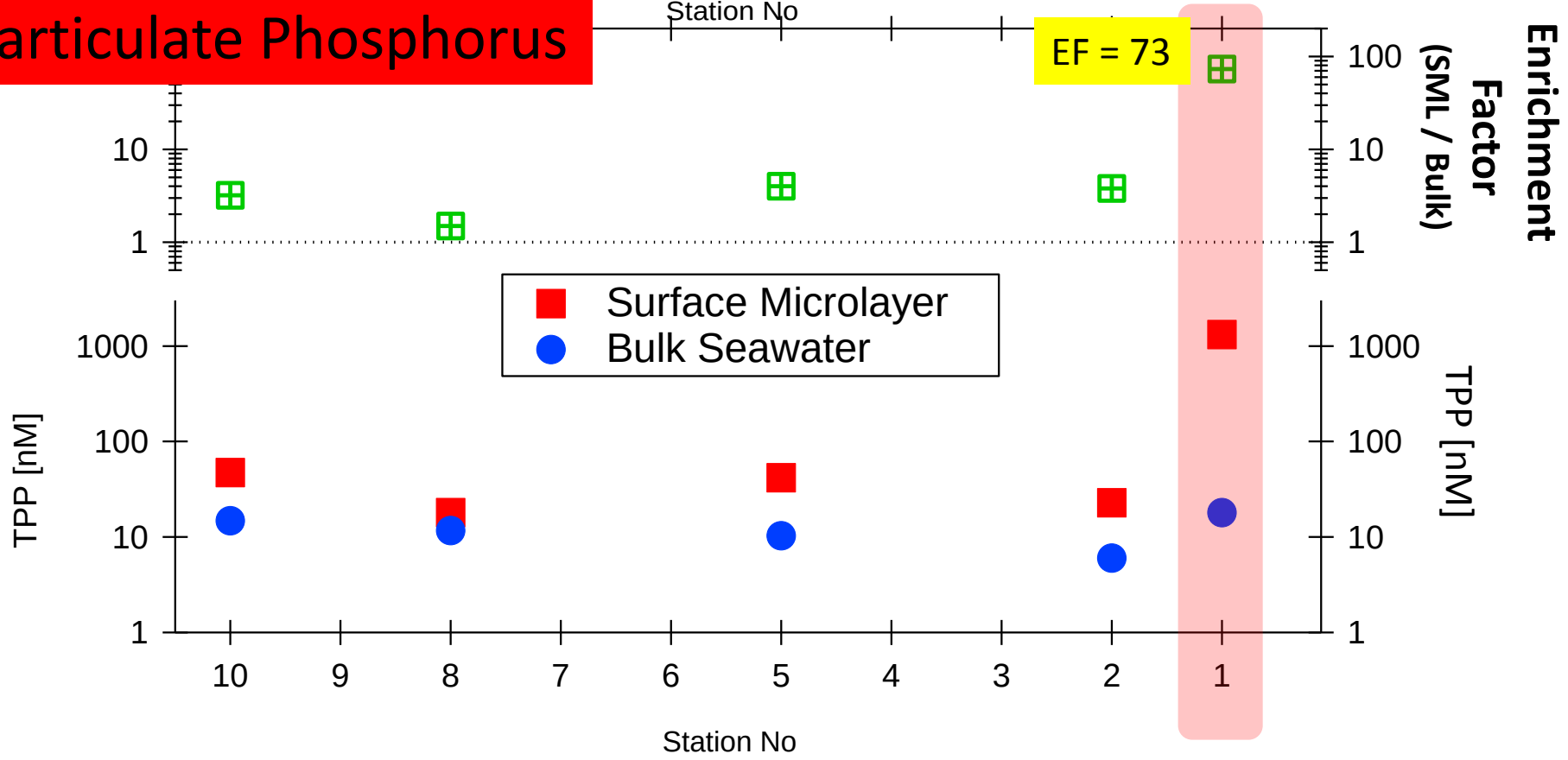


Looks like Only Particulate Phosphorus in SML increased!

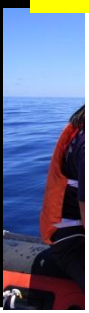


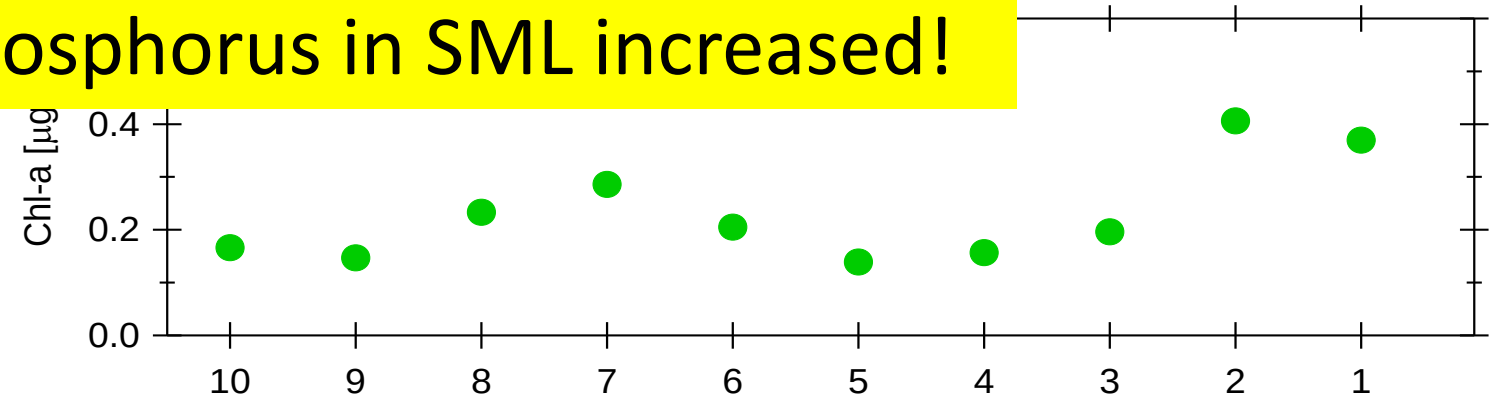


Particulate Phosphorus

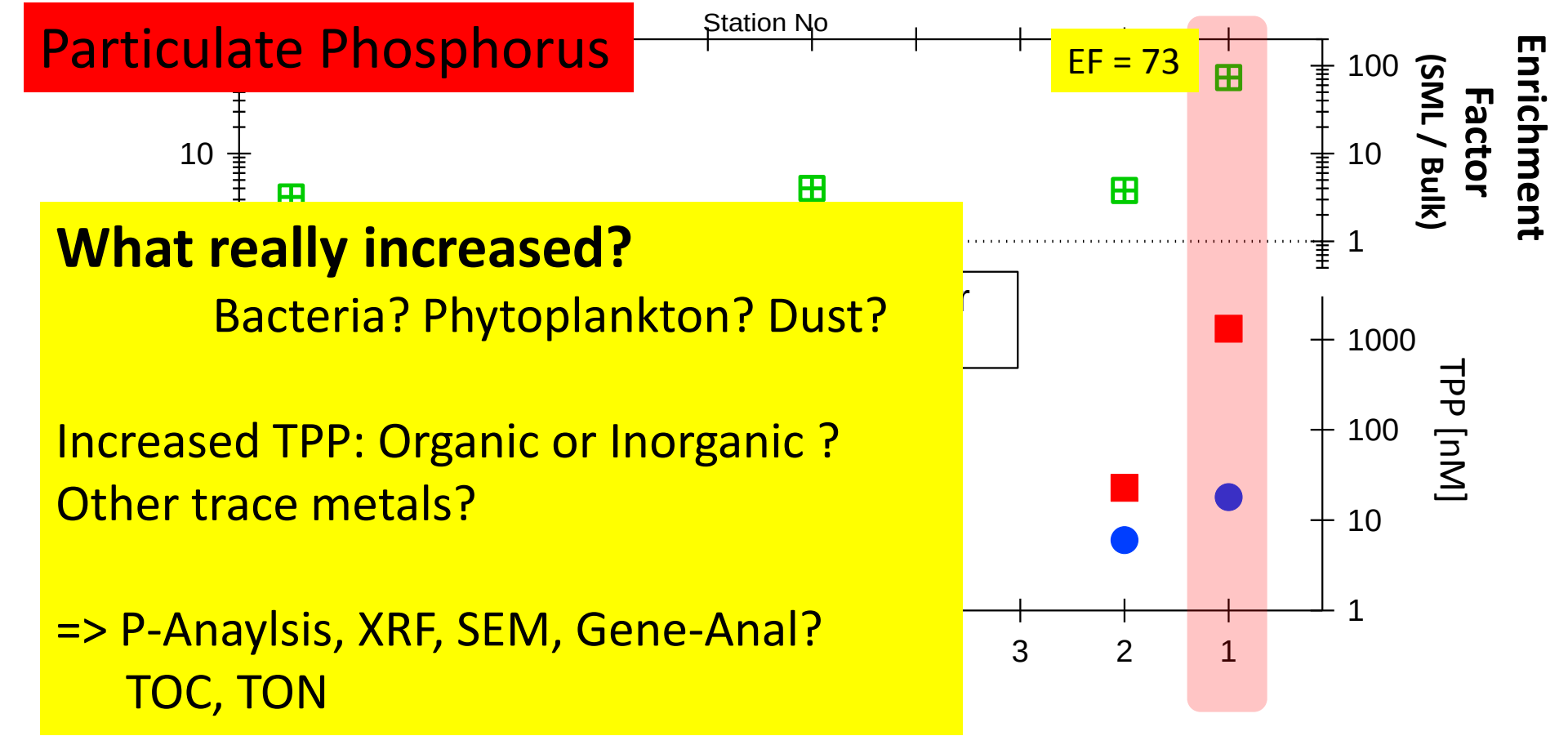


Looks like Only Particulate Phosphorus in SML increased!





Particulate Phosphorus



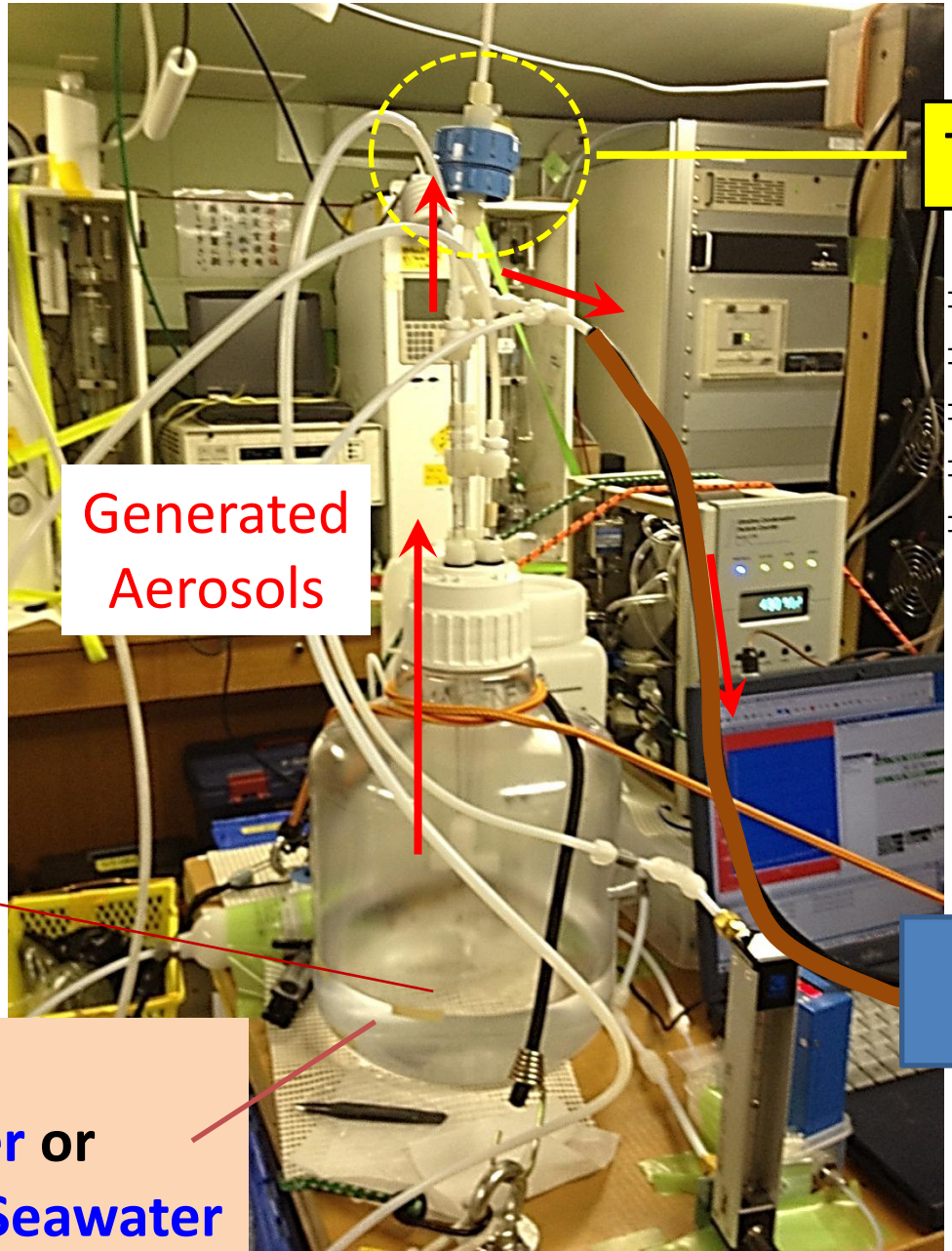
What really increased?

Bacteria? Phytoplankton? Dust?

Increased TPP: Organic or Inorganic ?
Other trace metals?

=> P-Anaylsis, XRF, SEM, Gene-Anal?
TOC, TON

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

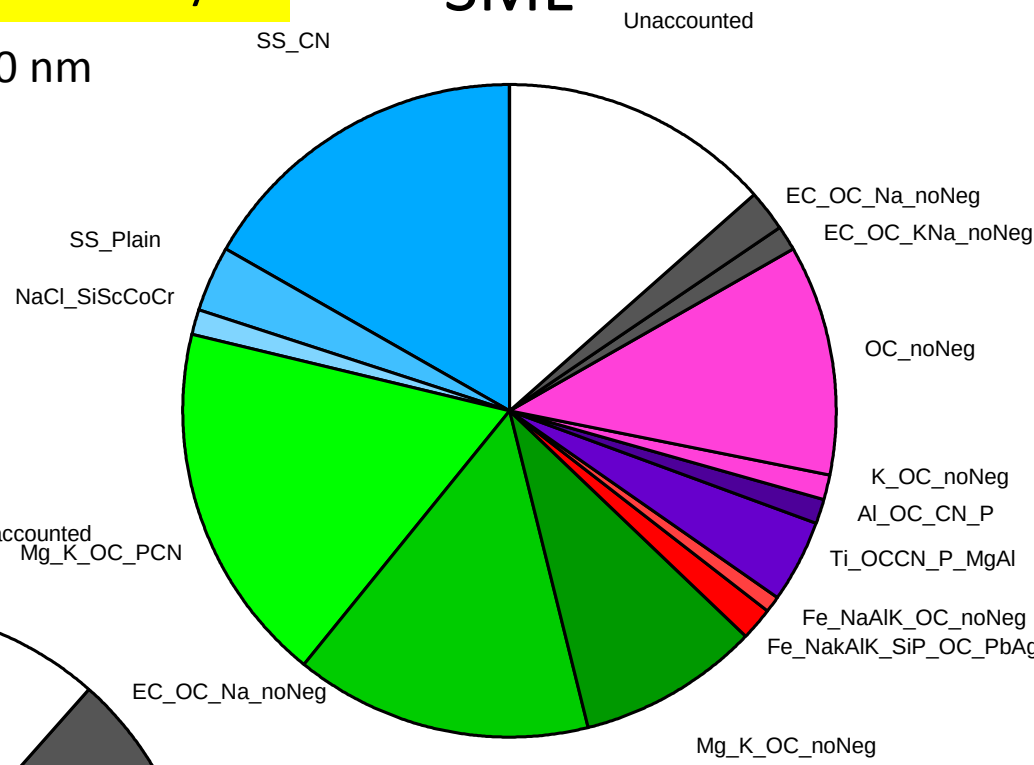
Sub-Surface Seawater

Single Particle Mass Analysis

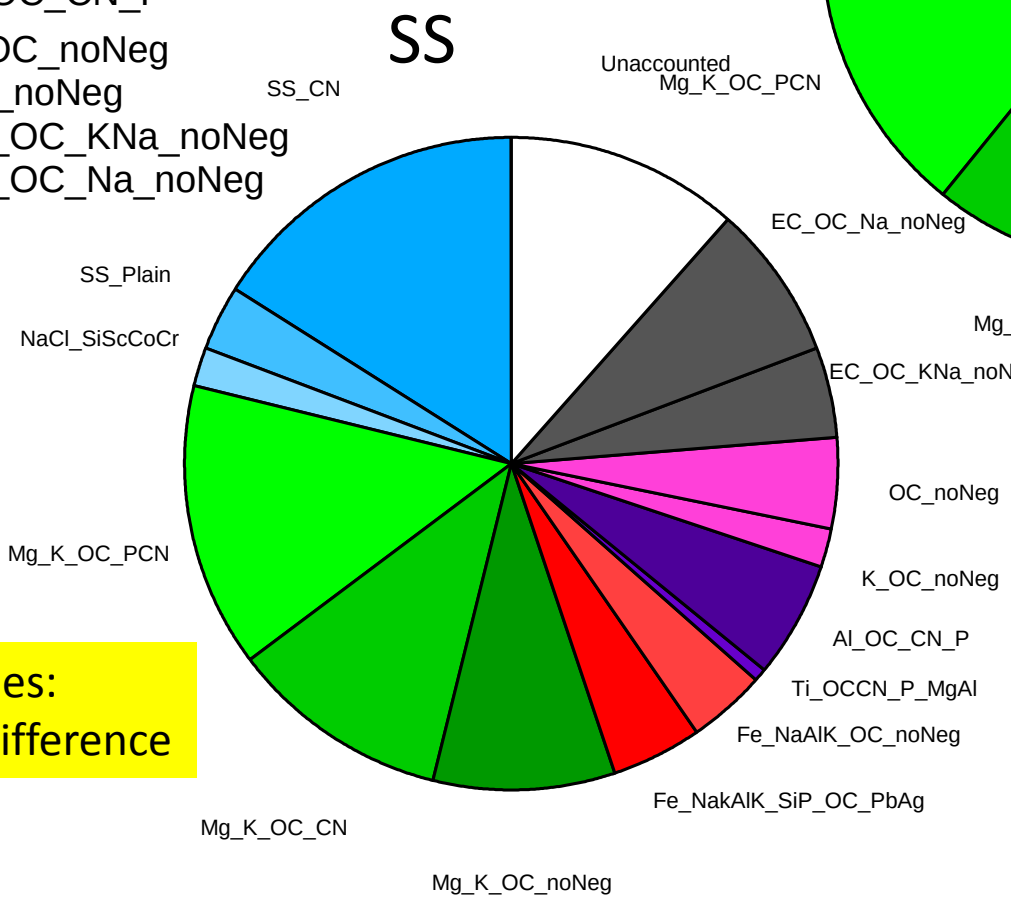
D = 100 – 3000 nm

- Unaccounted
- SS_CN
- SS_Plain
- NaCl_SiScCoCr
- Mg_K_OC_PCN
- Mg_K_OC_CN
- Mg_K_OC_noNeg
- Fe_NakAlK_SiP_OC_PbAg
- Fe_NaAlK_OC_noNeg
- Ti_OCCN_P_MgAl
- Al_OC_CN_P
- K_OC_noNeg
- OC_noNeg
- EC_OC_KNa_noNeg
- EC_OC_Na_noNeg

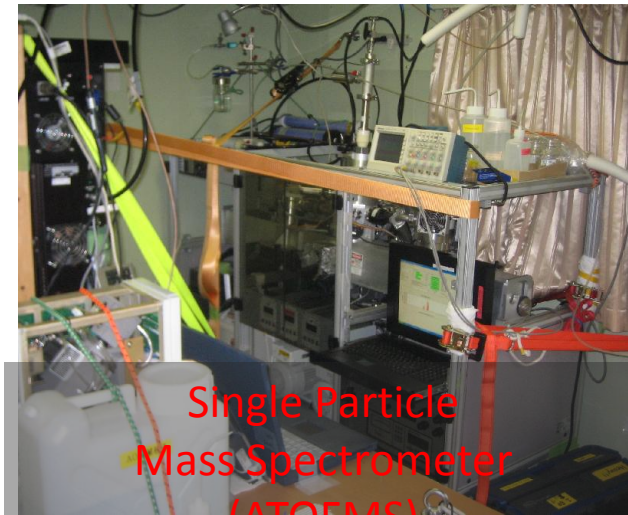
SML



SS



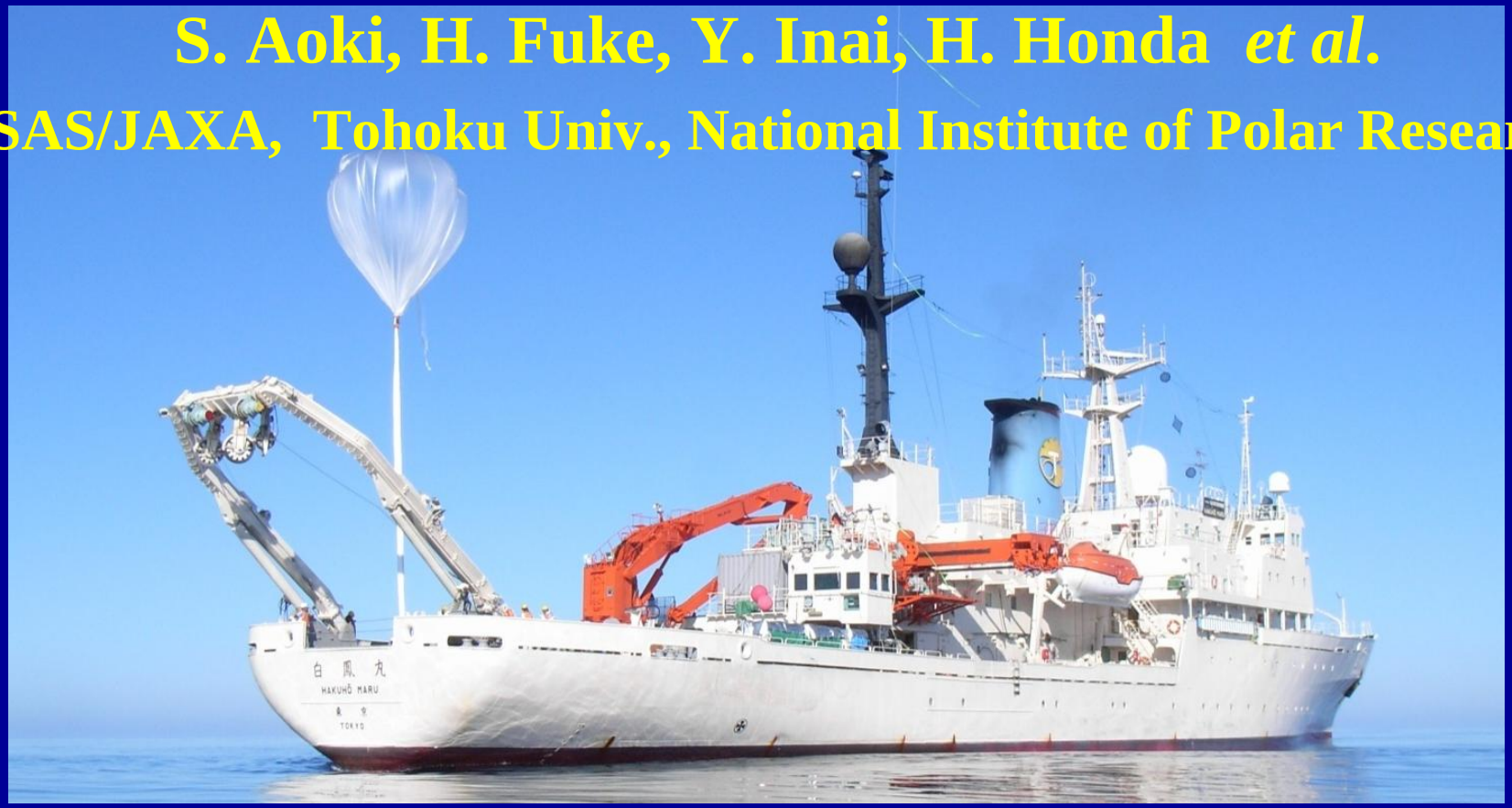
Filter Samples:
Not much difference



Balloon Launch and Flight Operation from R/V "*Hakuho-Maru*" for Stratospheric Air Sampling over the Equator of Eastern Pacific

S. Aoki, H. Fuke, Y. Inai, H. Honda *et al.*

ISAS/JAXA, Tohoku Univ., National Institute of Polar Research



Sampling of Stratospheric Atmosphere

- Since 1985, stratospheric air sampling has been carried out repeatedly, over Japan (Sanriku, Taiki), Sweden (Kiruna), and Antarctica (Syowa).

Antarctica (2004)

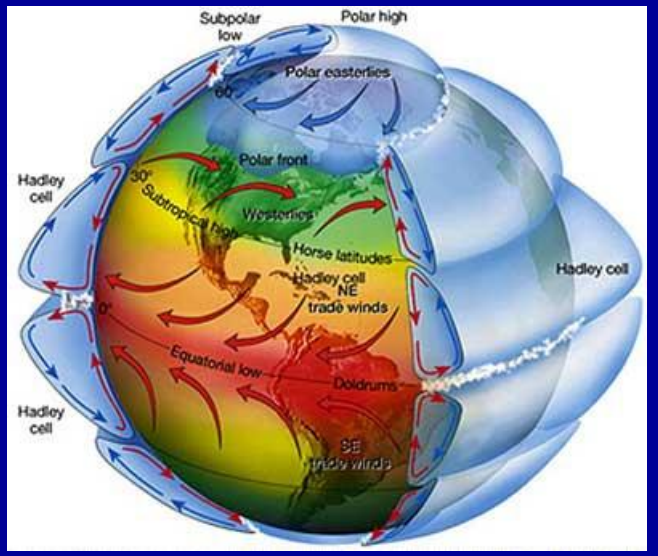
Sanriku (2007)

Taiki (2010)

Antarctica (2008)

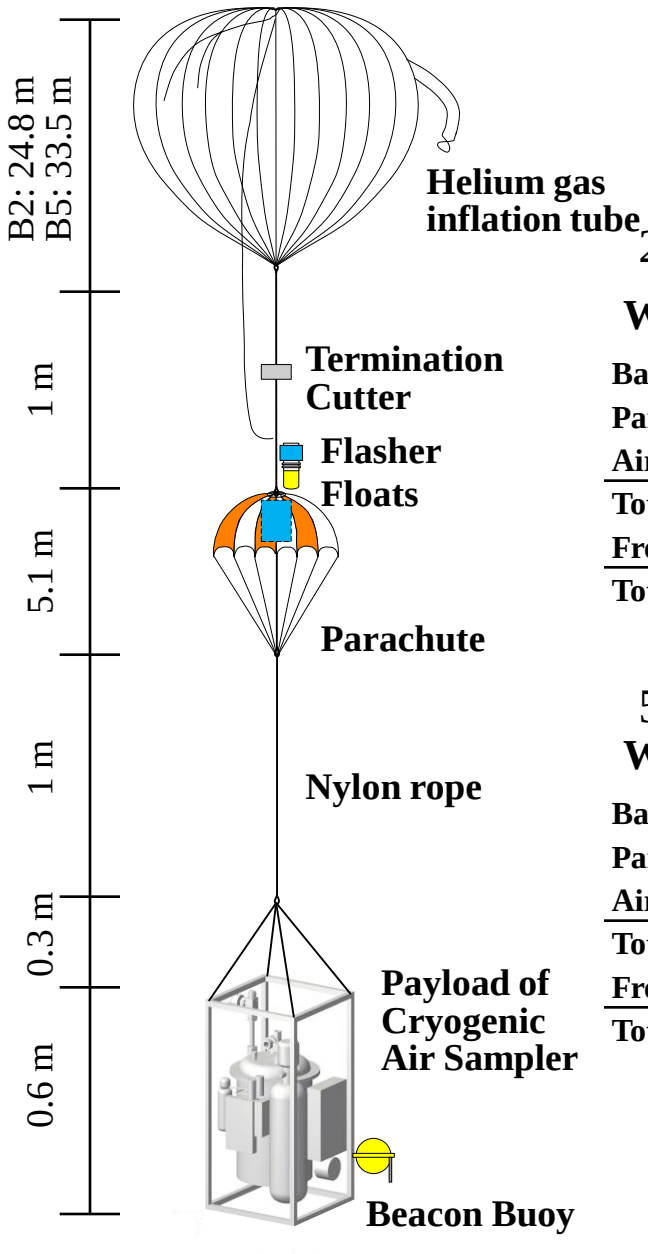
Sampling of Stratospheric Atmosphere

- Since 1985, stratospheric air sampling has been carried out repeatedly, over Japan (Sanriku, Taiki), Sweden (Kiruna), and Antarctica (Syowa).
- It primarily aims to elucidate the stratospheric transport / chemical processes by direct and long-term sporadic air sampling.
- Concentration of various compounds and isotopes including green-house gases have been monitored;
  - CO_2, CH_4, N_2O, SF_6, etc.
  - $\delta^{15}N$ of N_2, $\delta^{18}O$ of O_2, CO, H_2, Ar, etc.
- Gravitational separation of major components has been found in their stratospheric vertical distributions.



- It is essential to sample the air **“<u>over the equator</u>”** to investigate the transport process of greenhouse gases from the troposphere to the stratosphere.
- Air sampling had never been carried out over the equator. (**“<u>data gap</u>”**)

Flight Train Configuration



2000 m³ Balloon

Weight of B2 System

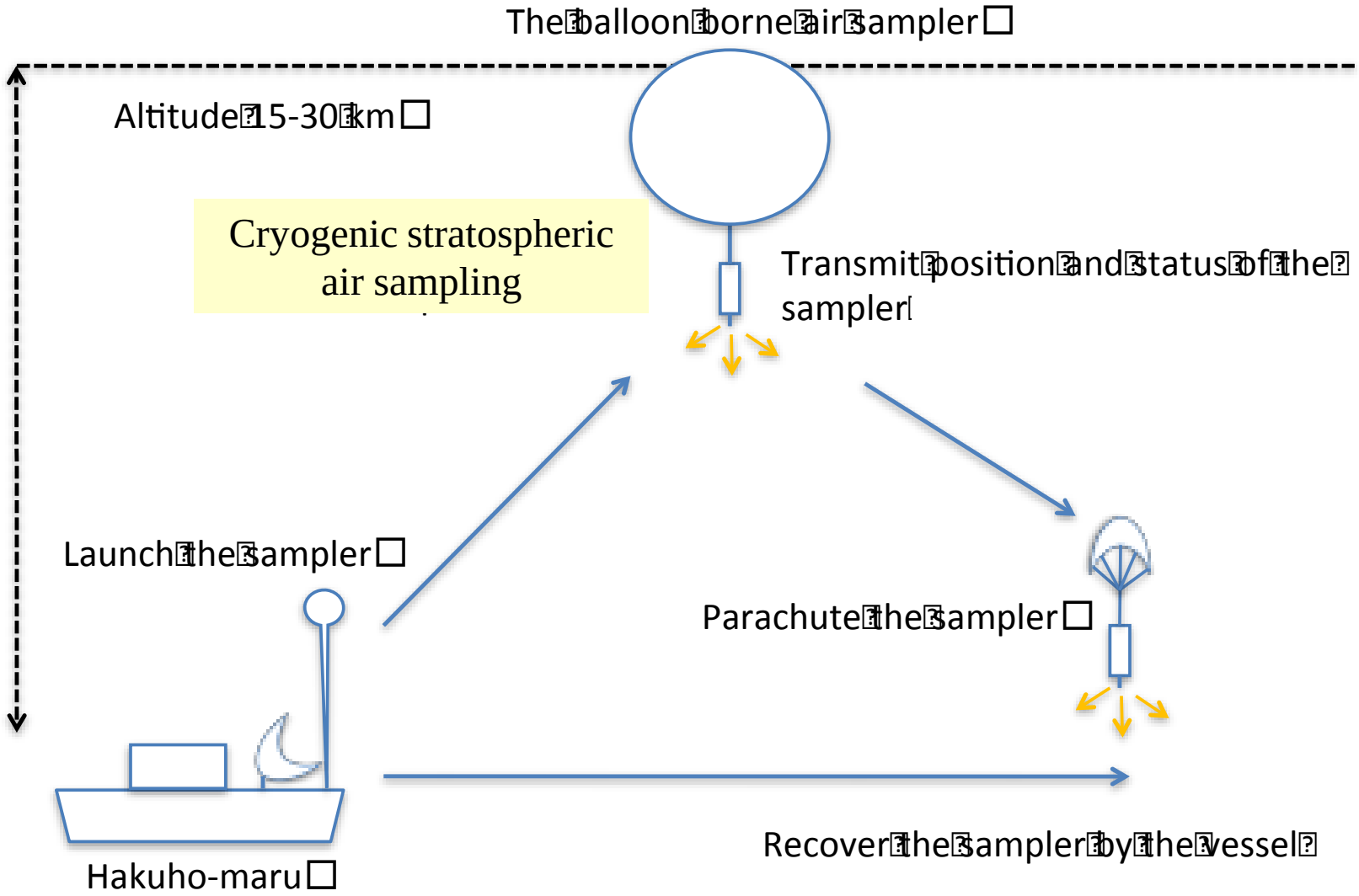
Balloon	21.5 kg
Parachute etc.	4.1 kg
Air Sampler	22.0 kg
Total Weight	47.6 kg
Free Lift (20%)	9.5 kg
Total Buoyancy	57.2 kg

5000 m³ Balloon

Weight of B5 System

Balloon	37.1 kg
Parachute etc.	4.1 kg
Air Sampler	22.0 kg
Total Weight	63.2 kg
Free Lift (18%)	11.4 kg
Total Buoyancy	74.5 kg

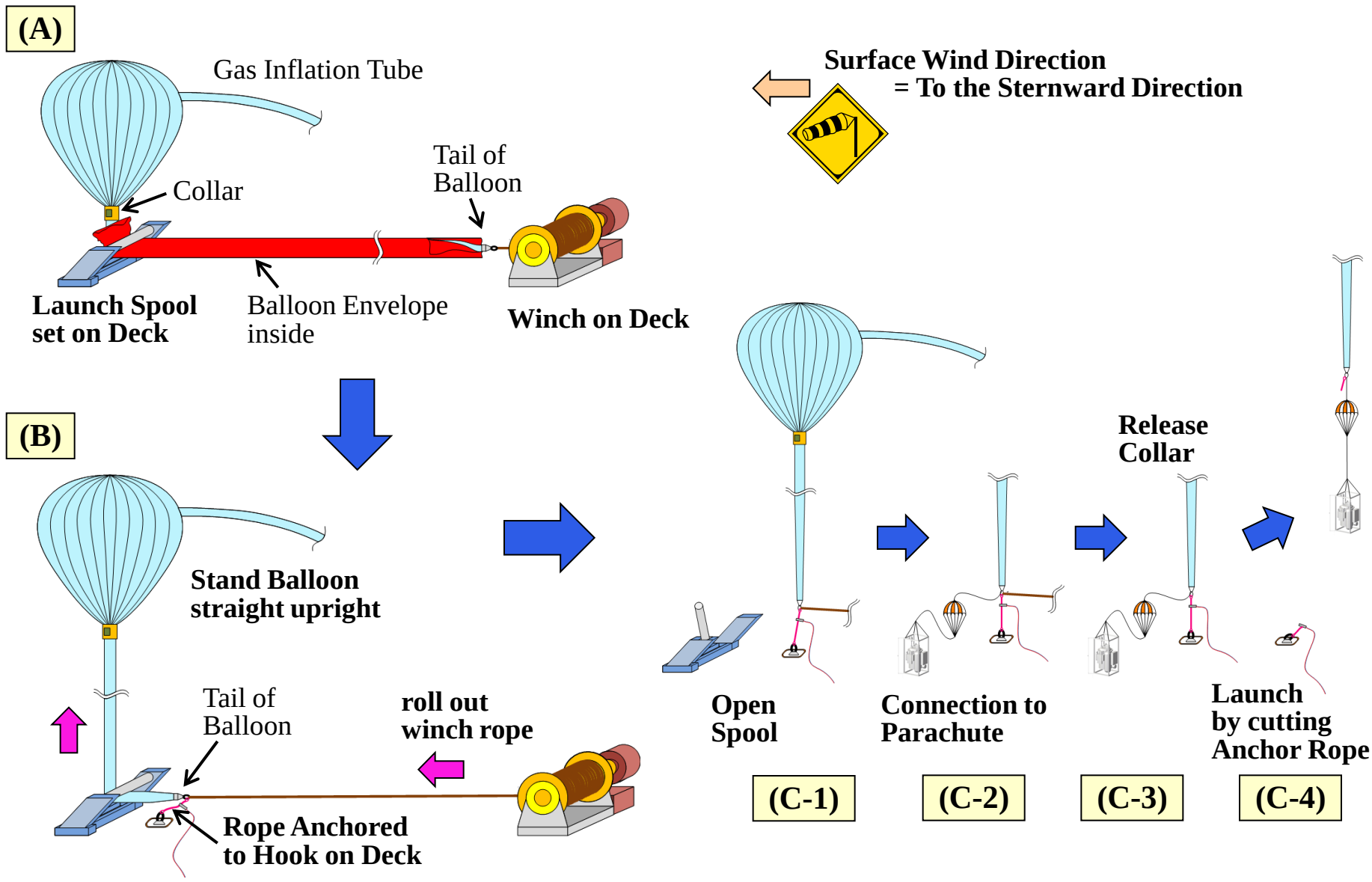
Flight Sequence



Technical Challenges for Launch

- Narrow deck; The open space of vessel deck is limited to only 20 m^{L}, 7 m^{W}.
- Many equipments are located: such as a big crane C-frame, poles, and antennas.
- Minimum cargo; It is important to utilize existing equipments on vessel as much as possible.
- Limited number of people; “a few scientists + crews” (no staff from ISAS balloon office).

Newly Modified Static Launch Method



Launch from "*Hakuho-Maru*"

Payload Recovery by "*Hakuho-Maru*"

All Four Flights Successfully Done !!

EqPOS

Stratospheric Air Sampling Balloon
(4 Launches)
Alt = 19-30 km

O_3, CO_2, H_2O Sonde
(6 Launches)
Alt = 0-30 km

St10
2/14
2/10
2/7
St5
2/4
2/2
St1
1/29
Callao (Peru)

Google ea

Chemical Analysis for Stratospheric Air

CO_2
CH_4
N_2O
SF_6
CO
H_2
Ar

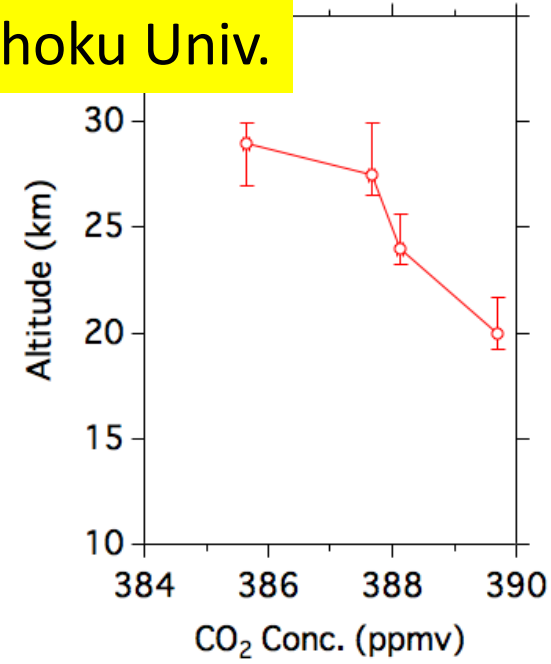
$\delta^{15}N$ of N_2
$\delta^{18}O$ of O_2
D/H of CH_4

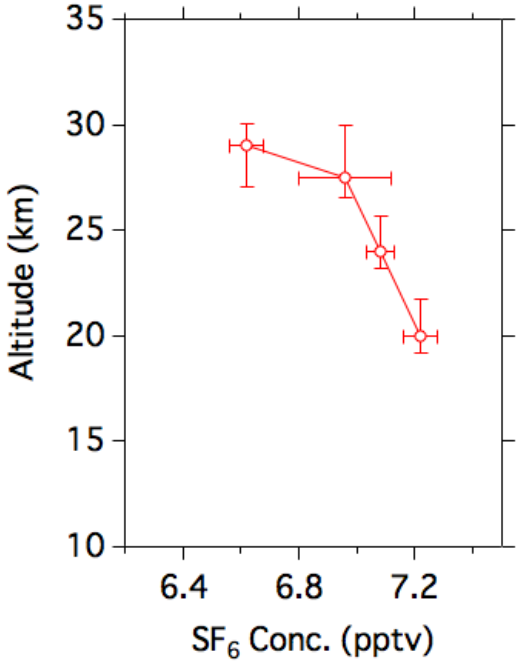
etc.

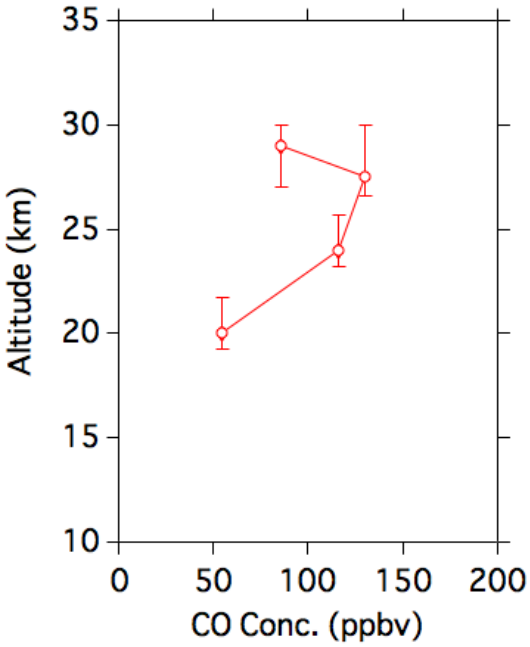
Aoki Group
Tohoku Univ.

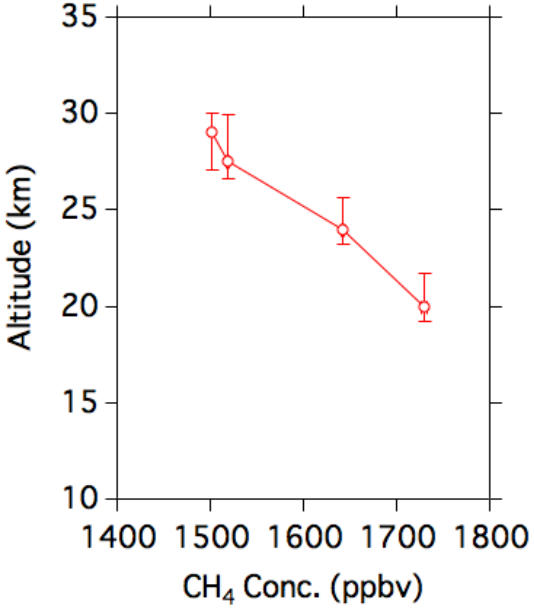
Aoki Group
Tohoku Univ.

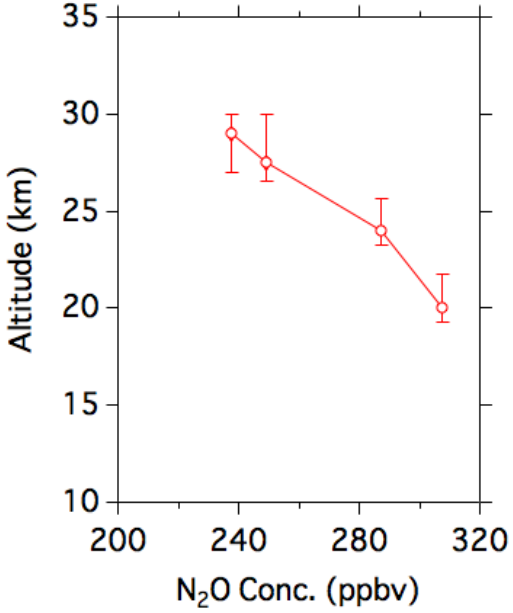
Preliminary results 2012.03.27

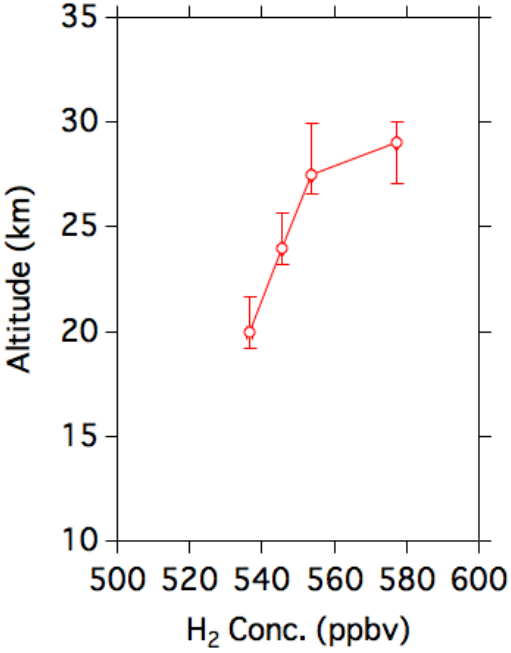






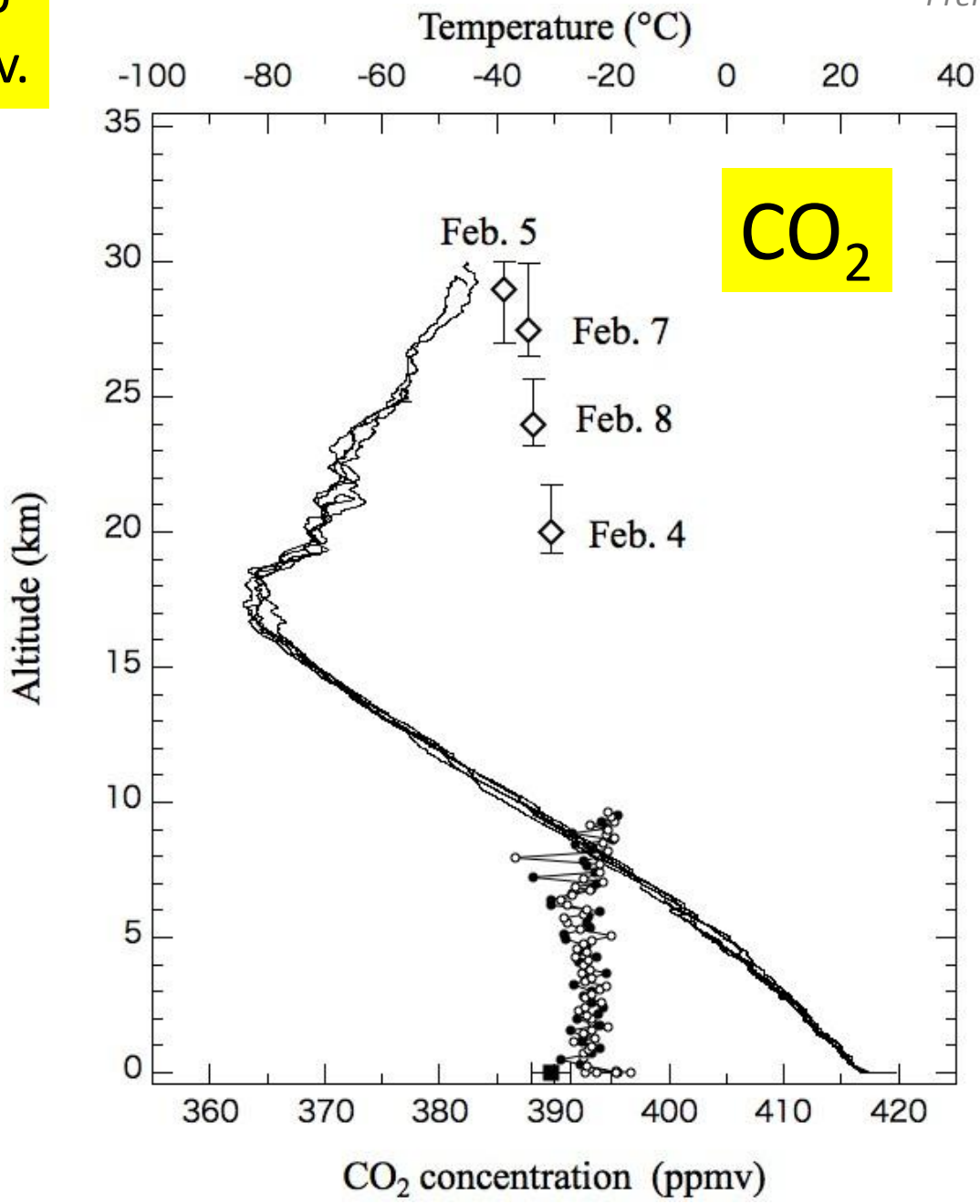






Aoki Group
Tohoku Univ.

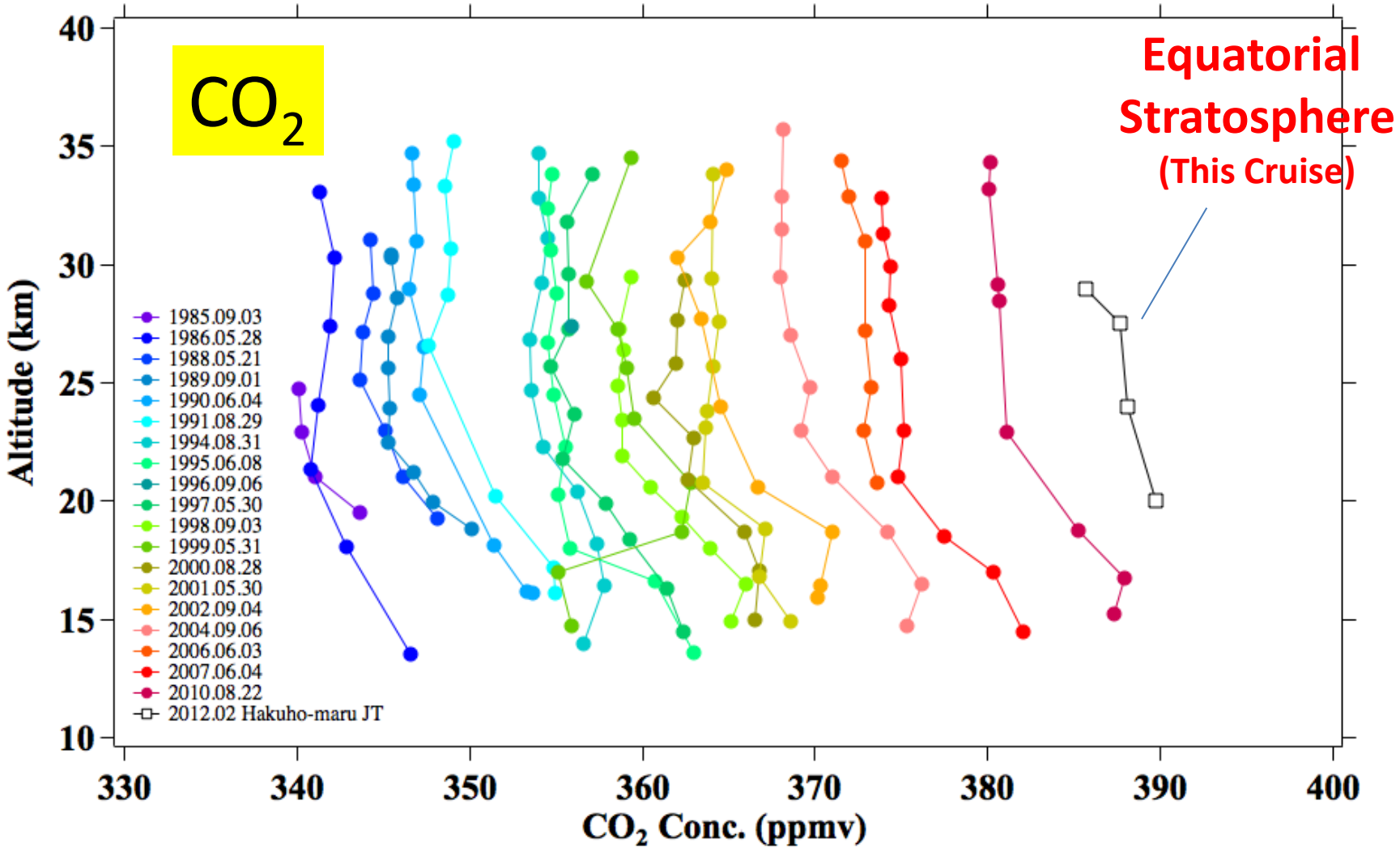
Preliminary results 2012.07.15



CO_2

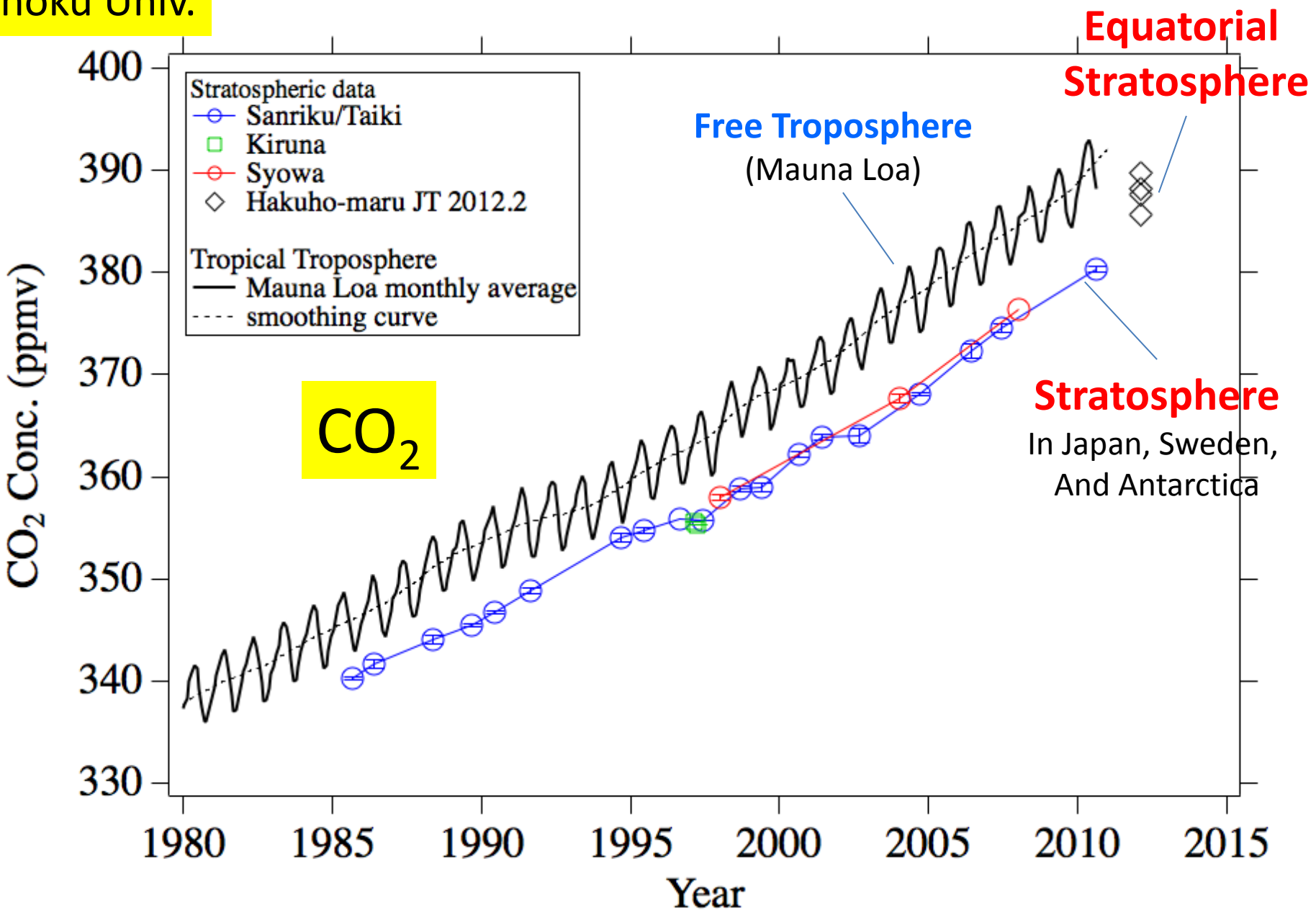
Aoki Group
Tohoku Univ.

Preliminary results 2012.07.15



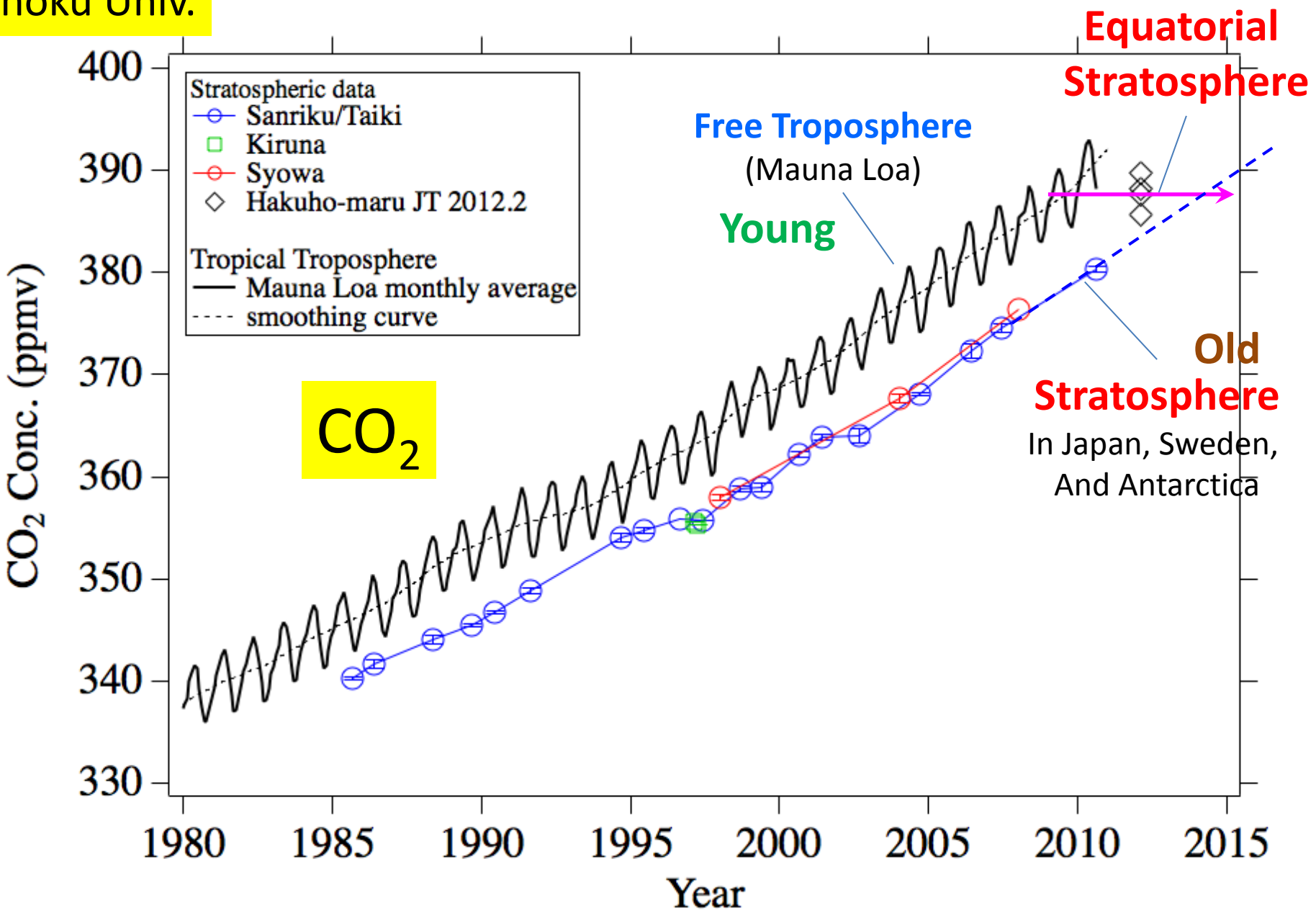
Aoki Group
Tohoku Univ.

Preliminary results 2012.07.15



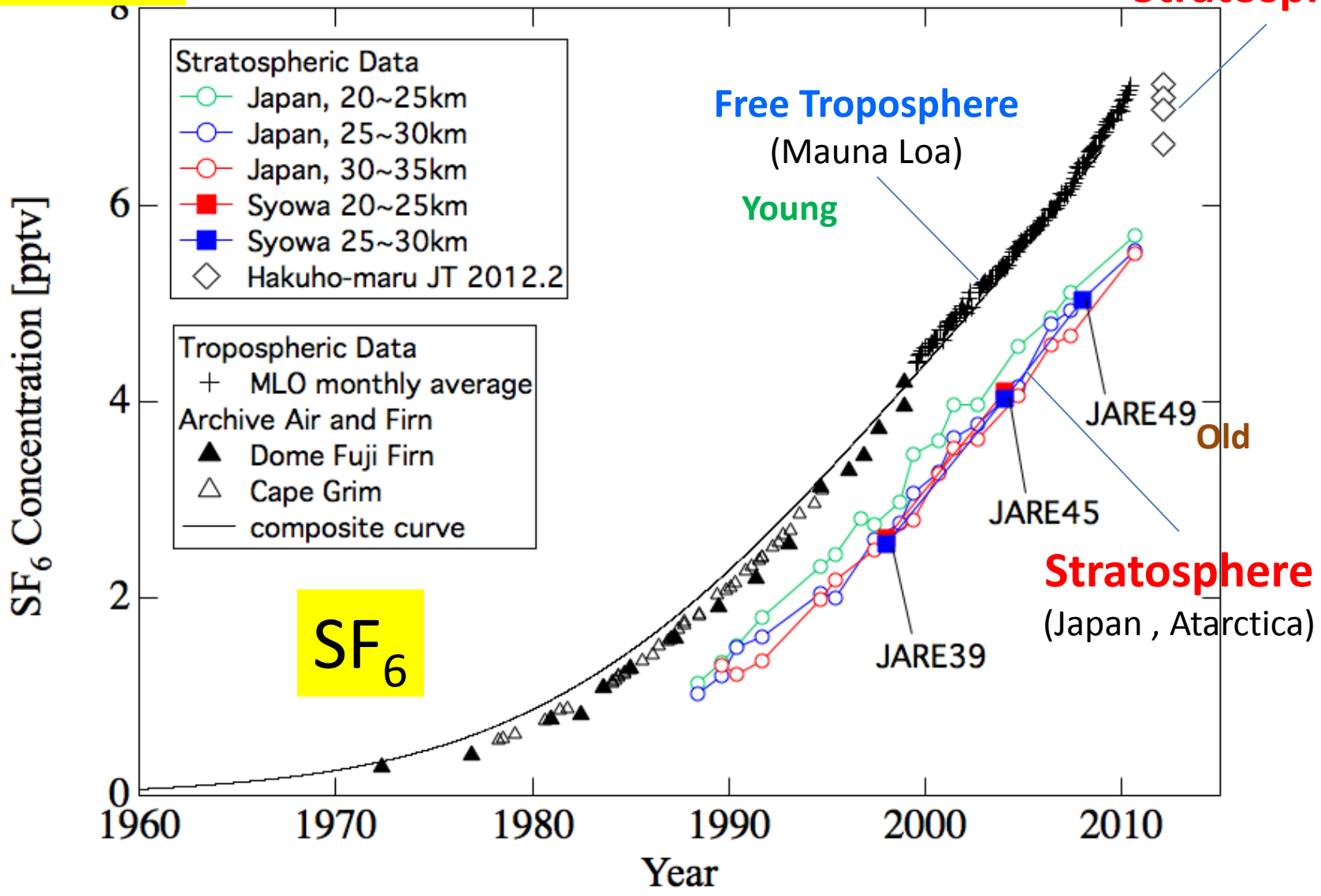
Aoki Group
Tohoku Univ.

Preliminary results 2012.07.15



Aoki Group
Tohoku Univ.

Preliminary results 2012.07.15



Chemical Analysis for Stratospheric Air

CO_2
CH_4
N_2O
SF_6
CO
H_2
Ar

$\delta^{15}N$ of N_2
$\delta^{18}O$ of O_2
D/H of CH_4

etc.

Aoki Group
Tohoku Univ.

Summary of rubber-balloon soundings

(Total 6 Launches)

CO_2, O_3, H_2O
T, RH, GPS

Altitude = Surface to 30 km

Launch time (LT)	Longitude	Sensors
09:12, Feb. 2, 2012	95.501degW	T, RH, GPS
10:56, Feb. 3, 2012	100.035degW	H2O, O3, T, RH, GPS
17:30, Feb. 5, 2012	110.009degW	CO2, T, RH, GPS
17:14, Feb. 6, 2012	115.000degW	CO2, T, RH, GPS
13:37, Feb. 7, 2012	115.021degW	H2O, O3, T, RH, GPS
17:29, Feb. 7, 2012	115.010degW	CO2, T, RH, GPS

Just before a launch

Preparation for a balloon

Aoki Group
Tohoku Univ.

Instruments for soundings

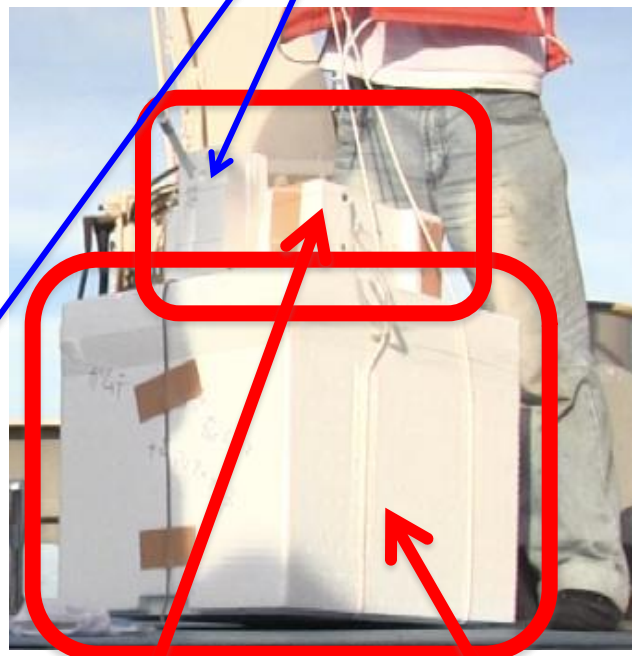
Cryogenic Frostpoint Hygrometer (CFH)

uncertainty: < 9%
vertical resolution: < 100m

Electrochemical Concentration Cells (ECC) ozonesonde

uncertainty: ~10%
vertical resolution: ~100m

Radiosonde



CO2 sonde

uncertainty: a few ppmv(?)
vertical resolution: ~240m

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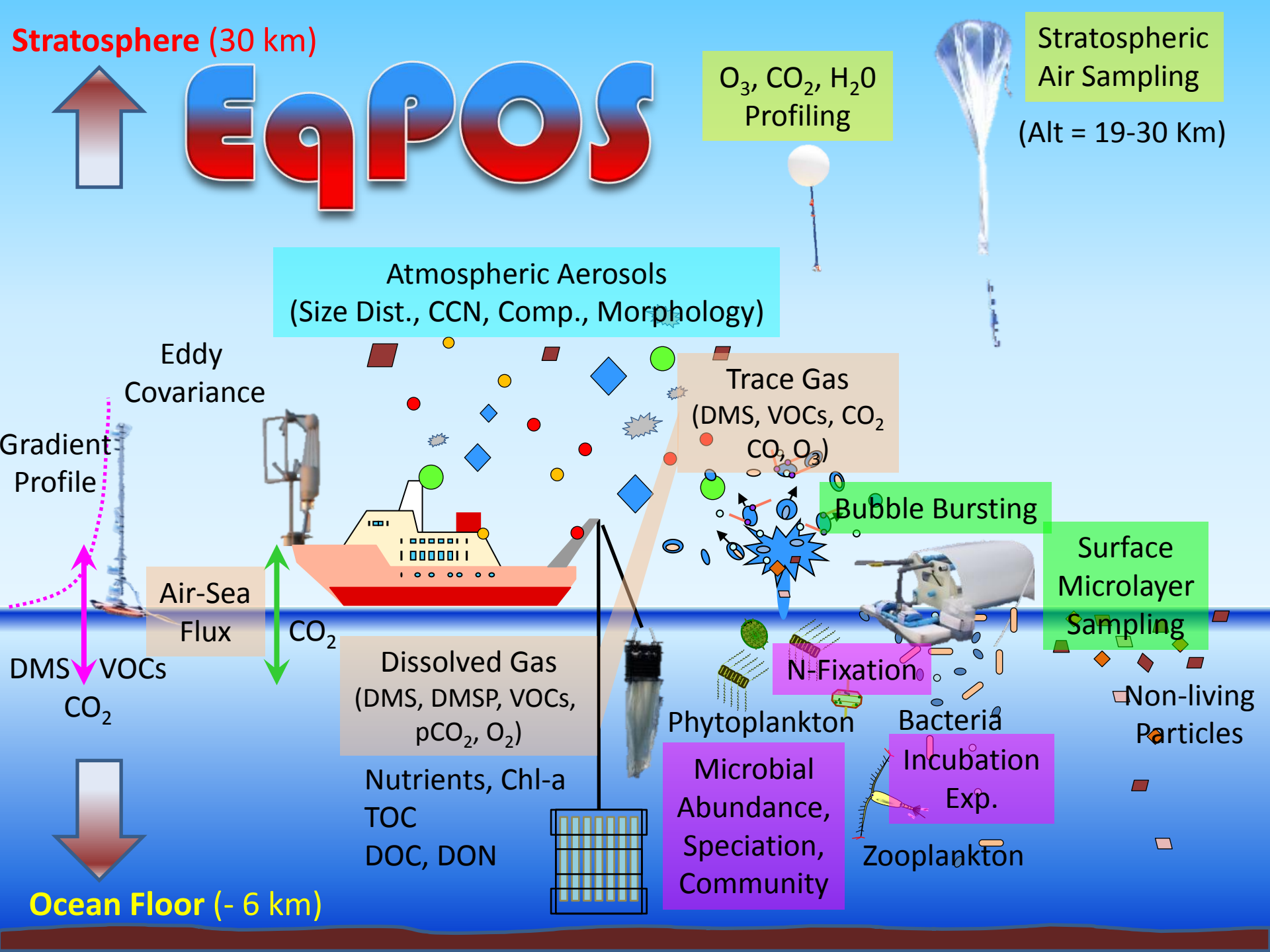

Stratosphere (30 km)
EqPOS
O_3, CO_2, H_2O Profiling
Stratospheric Air Sampling
(Alt = 19-30 Km)
Atmospheric Aerosols
(Size Dist., CCN, Comp., Morphology)
Eddy Covariance
Gradient Profile
Trace Gas
(DMS, VOCs, CO_2 CO, O_3)
Bubble Bursting
Surface Microlayer Sampling
Air-Sea Flux
CO_2
DMS VOCs
CO_2
Dissolved Gas
(DMS, DMSP, VOCs, pCO_2, O_2)
N-Fixation
Phytoplankton
Bacteria
Non-living Particles
Nutrients, Chl-a
TOC
DOC, DON
Microbial Abundance, Speciation, Community
Incubation Exp.
Zooplankton
Ocean Floor (- 6 km)

EqPOS

Equatorial Pacific Ocean and Stratospheric/Tropospheric Atmosphere Study

Summary (Preliminary Results)

- EqPOS was mainly influenced by SH (South Pacific Ocean) air mass.

- Particulate matter seems to be enriched in SML, but only St. 1 among 5 stations.
- Continuous and simultaneous sewater-DMS and atmospheric DMS were successfully conducted with 30 sec time resolution with EI-PTR-MS.
- Patch-like high seawawter-DMS in tropical /EQ Pacific Ocean
- Emission from ocean seems to incrase atmospheric DMS
- Stratospheric large balloons were all successfully launched from R/V Hakuho and recovered for the first time.
- Nicely overlaps with TORERO campaign in time and space, and scientific research topics.
- Marine biogeochemical /biogeochemical information would be interesting.

Ocean Floor (~ 6 km)

Acknowledgement

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

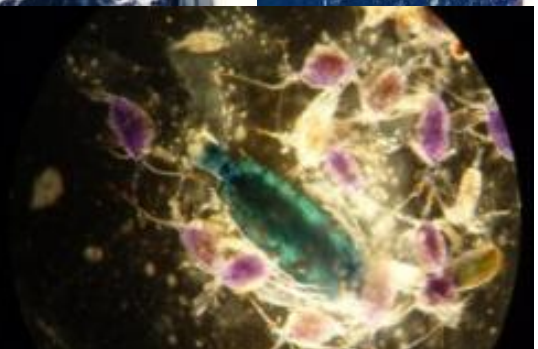
EqPOS

Equatorial Pacific Ocean and Stratospheric/Tropospheric Atmosphere Study

EqPOS

Jan 29, 2012 – Feb 19, 2012 (22 days)

Equatorial **P**acific **O**cean and **S**tratospheric/Tropospheric Atmosphere Study



Sky, Ocean, and In-Between

Thank you for your attention!

AORI

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