Aerosol Composition and Volatility in TTL - In situ Balloon Borne Measurements and sampling over Biak Indonesia -

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Outline

• Introduction and purpose

• Observation: Instruments and method

• Results
  Volatility of TTL aerosol over Biak, Indonesia observed in January of 2011, 2012 and 2013 and estimation of TTL aerosol constituents

• Sample return at Biak in 2015, and analyses

• Summary
Why do we observe aerosols?

- SOWER (Soundings of Ozone and Water in the Equatorial Region) have been trying to understand how do TTL processes control water vapor budget in stratosphere.

- One of key processes: cirrus and deep convective cloud.
- Any cloud needs aerosols as nuclei to form ice crystals and cloud droplets.

One symbolized question

Why such high super saturation (Rhi : 150%) appeared in TTL.

Aerosol cloud help to understand cirrus behavior in TTL.

Which kind of aerosol exist in TTL
How many particles exist in TTL.
How they are activate as nuclei in TTL.
Targets and observations

Aerosol composition, state and concentration in TTL by balloon borne observation

1. Volatility measurement using Thermo-Denueding Optical Particle Counter sonde (TD-OPC sonde)

2. Direct sampling using balloon borne impactor and elemental analyses using SEM-EDX
TD-OPC sonde : Thermo-Denuding Dual OPC

OPC : Optical Particle Counter
Flow rate : 3 liter/min
Size discrimination: D > 0.3, 0.4, 0.5, 0.8, 1.2, 2.0, 3.4, 5.0, 7.0, 11.4 µm
Integrated period: 4 sec
Height resolution: 20 m

GPS sonde (RS06G Meisei Co. Ltd)
Temp., humidity, height (GPS), wind (GPS)

3 kg rubber balloon
Parachute
Unwinder with 50 m line
TD-OPC

TD-OPC (100, 150, 200, 250, 300 °C)

Size distribution
in ambient condition

Size distribution
in heated condition
volatility v.s. denuder temp. for test particles in 1 atm

Thermo denuder
L = 50 cm,
ϕ= 5 or 8 mm,
sample flow rate
= 3 L/min
Residence time
≒ 0.1 or 0.25 sec

Residue number ratio (%)

Sulfuric acid solution : volatile completely
Ammonium sulfate : steep slope
Ammonium bi-sulfate : moderate slope
Sodium chloride : flat
Aerosol sampling and individual particle analyses in 2015

**Aerosol sampling sonde (ASS):** Two stage impactor with water proof arrangement
- Dimension: $80 \times 105 \times 130$ mm
- Weight: 3000g (Including case)
- Sampling rate: 1.6L/min at 1atm
- Nozzle dia.: 1.3mm, 0.5mm
- Cut off dia.: 1.4μm, 0.25μm
- Sample numbers: 16 samples
- Sampling duration: 3 minutes (variable)

Analyses: individual particle analyses in the laboratory
- Morphology by SEM
- Elemental composition by EDX

Cray mineral collected at 1100 m over Japan on April 13th, 2008
2011/1/4～1/13
1/ 7  OPC
1/10  TD-OPC (200)

2012/1/5～1/17
1/10  TD-OPC (200)
1/11  TD-OPC (150)
1/12  TD-OPC (100)

2013/1/4～1/14
1/ 9  TD-OPC (200)
1/10  TD-OPC (300)
1/11  TD-OPC (250)

2015/2/16～3/2
2/25  ASS
2/27  TD-OPC (200)
3/1   ASS

Fukuoka Univ.  OPC(size distribution and volatility)
Nagoya Univ.  Lidar (Nd:YAG 1064nm, 532nm, DPR)
HIVIS sonde
Hokkaido Univ.  CFH (H2O), ECC ozone sonde, Flash, Fine dew, etc
Aerosol concentration profiles over Biak, January 2011

- **Temperature (°C)**
- **Altitude (m)**
- **Number concentration of particles (particle / L)**

**Diagram Key**
- Dp > 0.26 μm
- Dp > 0.34 μm
- Dp > 0.43 μm
- Dp > 0.51 μm
- Dp > 0.6 μm
- Dp > 0.8 μm
- Dp > 1.41 μm
- Dp > 1.8 μm
- Dp > 4.72 μm
- Dp > 7.75 μm

**Legend**
- 0107
- 0110

**Regions**
- Strato.
- TTL
- CPT
- Tropo.
High and variable non-volatile constituent fraction in TTL

Ratio of residue to ambient aerosol in Jan., 2012 and 2013

0.3μm < Dp < 0.8μm

Number ratio of residue to ambient aerosol (%)
Cloud brings low volatile constituent to TTL, January 2013

Jan. 9th

Jan. 11th

Temp.

Strat

TTL

Ambient

Temp.

Trop.

Altitude (m)

Altitude (m)

200 °C.

250 °C.

Number mixing ratio (particle/l)

Number mixing ratio (particle/l)

Number mixing ratio (particle/l)
Size distributions in ambient and heated conditions, Jan., 2012

Variation is small for $D_p < 0.8 \, \mu m$

- $1/10 \, A$
- $200^\circ C$
- $1/11 \, A$
- $150^\circ C$
- $1/12 \, A$
- $100^\circ C$

$\frac{dN}{d\log D} \, (/g)$

Diameter ($\mu m$)
High uniformity of size distribution of low volatile constituent in TTL and stratosphere, January 2013.
Sulfate solution or sulfuric acid internally / externally mixed with low volatility constituents for 0.3 < Dp < 0.8 μm.


Volatile vs. denuder temp.: Composition estimation

Graph showing the number ratio of residue to ambient aerosol (%) against denuder temperature (°C) for different altitudes and compositions.
Aerosol sampling and individual particle analyses in 2015

Aerosol sampling sonde (ASS): Two stage impactor with water proof arrangement
- Dimension: 80 × 105 × 130 mm
- Weight: 650g
- Sampling rate: 1.6L/min
- Nozzle dia.: 1.3mm, 0.5mm
- Cut off dia.: 1.4μm, 0.25μm
- Sample numbers: 16 samples
- Sampling duration: 3 minutes

Analyses: individual particle analyses in the laboratory
- Morphology by SEM
- Elemental composition by EDX

Cray mineral collected at 1100 m over Japan on April 13th, 2008
Aerosol sampling and individual particle analyses in 2015

- 3000 g balloon
- cutter
- parachute
- Unwinder (50 m)

2015/2/25

- 8:03:11 Launching
- 10.1km Start of sampling
- 8:30:15
- 9:09:12 End of sampling
- 9:33:20

2015/3/1

- 8:06:24 Launching
- 8:34:11 Start of
- 9:19:29 End of sampling
- 9:48:52

Launch

- Unwinder (50 m)
- Iridium bui
- Radio sonde
- Unwinder

3000 g balloon
cutter
parachute
Unwinder (50 m)
sampler

8:03:11 Launching
8:30:15
10.1km Start of sampling

End of sampling
9:33:20
23.1km

9:09:12
12.8km

24.9km

9:48:52

9:19:29
End of sampling
24.8km
1. Volatility of TTL aerosol was observed by balloon borne thermo-denuding OPC at Biak in January of 2011, 2012 and 2013 and show as following,

- Major constituent of TTL aerosol is sulfate and low volatile constituent are commonly included as minor, whose origin is both in troposphere (sea salts?) and stratosphere (organic carbon? Meteorite?).
  
a) Mixing ratios of residue aerosol in TTL is lower than those in stratosphere
b) Number ratios of residue to ambient aerosol is variable and around 10 %, which is higher than those in stratosphere and just below TTL level.
c) Ratio of low volatile constituent is higher in larger size (primary mode?) than those in smaller size.

- Concentrations of ambient aerosol and residue at 100 to 300 °C, for Dp>0.3μm, range 100-1000#/liter and 10-100#/liter, respectively. Number concentrations of residue are comparable with those of cirrus in TTL.

2. Aerosol samples were recovered from TTL, upper free troposphere, and lower stratosphere using small rubber balloon in February and March, 2015. (Analyses of those sample will be performed as soon as possible)
Thank you for your attentions