Soundings of Ozone and Water in the Equatorial Region (SOWER) 1998-2015

SOWER/Pacific
Soundings of Ozone and Water in the Equatorial Region/Pacific Mission

http://sower.ees.hokudai.ac.jp/

Fumio Hasebe (Hokkaido Univ.), Masato Shiotani (Kyoto Univ.), **Masatomo Fujiwara (Hokkaido Univ.; fuji@ees.hokudai.ac.jp)**, Noriyuki Nishi (Fukuoka Univ.), Shin-Ya Ogino (JAMSTEC), Holger Vömel (NCAR), Samuel J. Oltmans (NOAA), Takashi Shibata (Nagoya Univ.), Suginori Iwasaki (NDA), Masahiko Hayashi (Fukuoka Univ.), Yoichi Inai (Hokkaido Univ.), Junko Suzuki (JAMSTEC), and Kazuyuki Miyazaki (JAMSTEC)

Introduction

- SOWER's scientific targets include:
  - Climatology and short-term/long-term variability of ozone and water vapor in the tropical troposphere and stratosphere over the tropical Pacific and South-east Asia
  - Satellite validation
  - Dehydration and transport processes in the Tropical Tropopause Layer (TTL)
- Observation campaigns have been made once or twice a year since 1998 by using balloon-borne instruments for ozone, water vapor, cloud and aerosol particles, etc.
- Recent focuses include "Match" measurements, RH-particle measurements, and collaboration with the Japanese balloon-borne cryogenic air sampling group, etc.
- Collaborated with other international projects, e.g., SHADOZ, EOS/Aura, ATTREX, CONTRAST, CAST, etc.

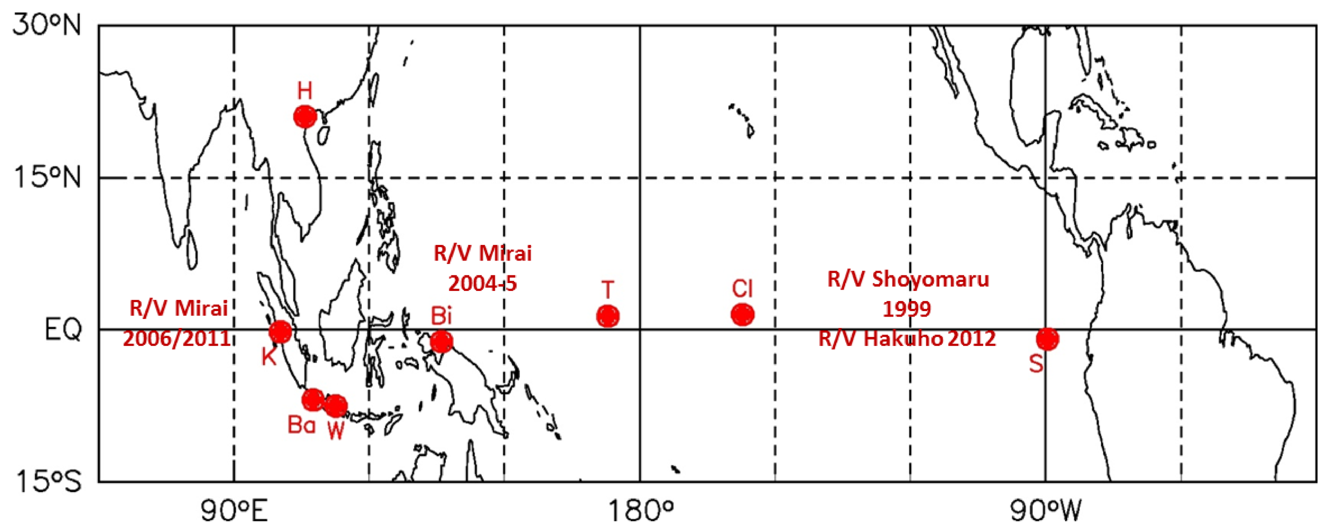

Figure 1: Stations where SOWER campaigns have been made. The research vessel (R/V) campaigns in which SOWER has participated are also shown.

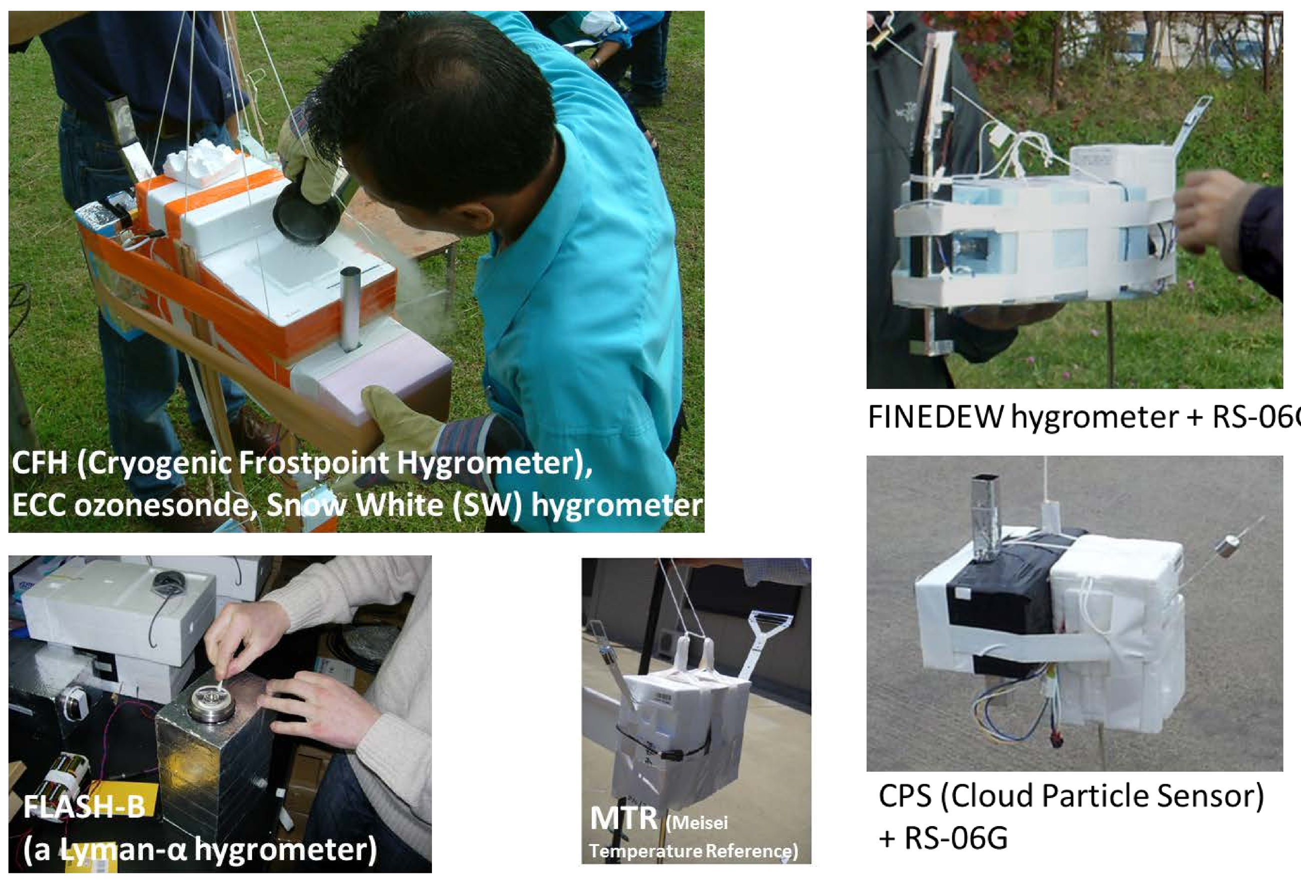

Figure 2: SOWER's main measurement tools: Special sensors on meteorological balloon-borne radiosondes. The lidar systems for particle measurements are also being operated.

Results I. Decadal Variations of Water Vapor in the Tropical Lower Stratosphere

- Water vapor variations in the tropical lower stratosphere were investigated on seasonal, quasi-biennial oscillation (QBO), and decadal time scales using balloon-borne cryogenic frost point hygrometer data taken from various campaigns. **[Fujiwara et al., JGR, 2010]**

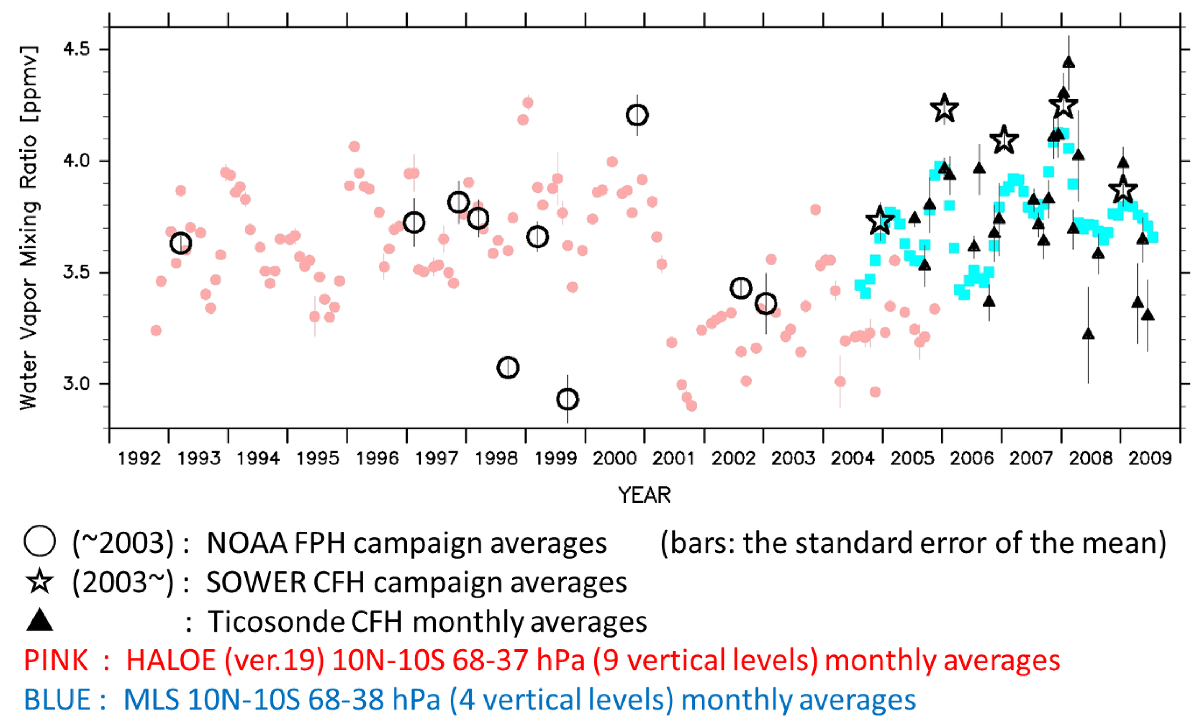

Figure 3: Time series of cryogenic frost point hygrometer data averaged in a lower stratospheric layer (68-37 hPa, 19-23 km), together with two satellite datasets (the Halogen Occultation Experiment (HALOE) and Aura Microwave Limb Sounder (MLS)), showing the existence of decadal variations: The mixing ratios were higher and increasing in the 1990s, lower in the early 2000s, and probably slightly higher again or recovering after 2004.

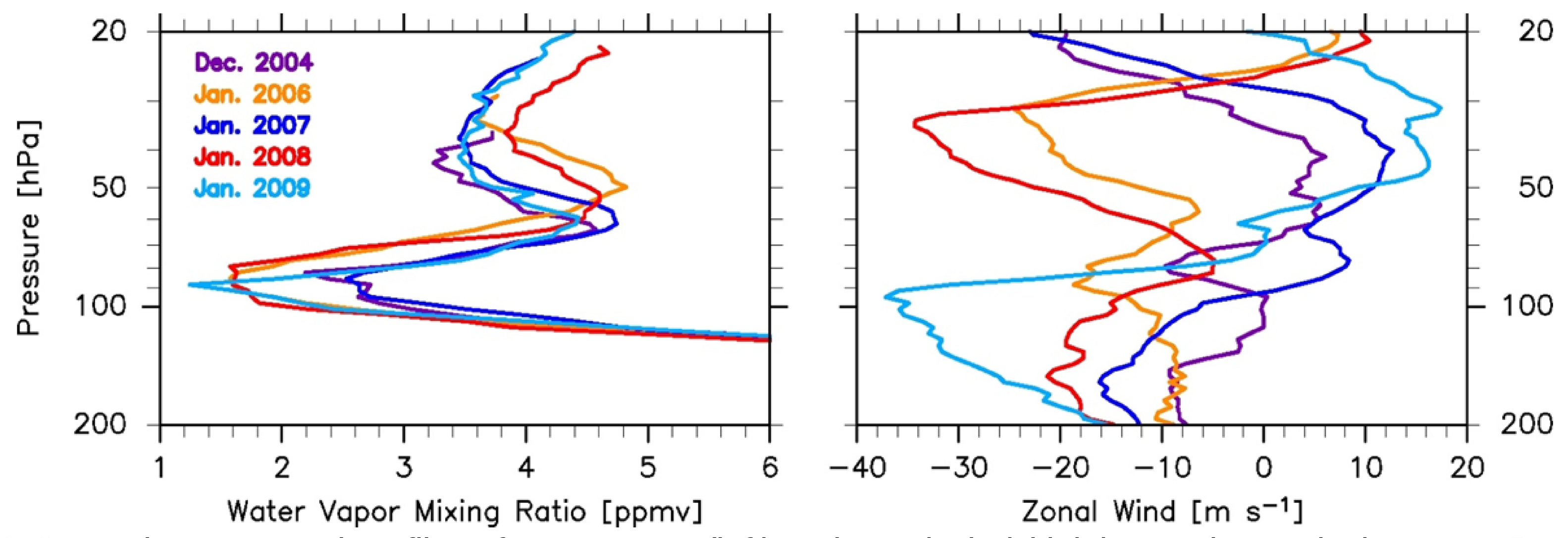

Figure 4: Campaign-averaged profiles of water vapor (left) and zonal wind (right) over the tropical western Pacific every year between Dec. 2004 and Jan. 2009. Two effects of the QBO on the water vapor profile can be observed. (1) Vertical displacements (1-1.5 km) associated with the QBO meridional circulation anomalies (i.e., downward displacement during the eastward wind phase, and upward displacement during the westward wind phase). (2) Concentration variations (~0.5 ppmv) associated with the QBO tropopause temperature variations (e.g., Dec. 2004: higher at 90 hPa → Jul-Aug. 2005: higher at 60 hPa → Jan. 2006: higher at 40 hPa → . . .), i.e., QBO-related water vapor anomalies created at the tropopause propagate upward by the Brewer-Dobson circulation.

Reference

- Please visit the SOWER website (*http://sower.ees.hokudai.ac.jp/*) for a full reference list.

Results II. "Match" Analysis for TTL Dehydration

- We aimed at making the first direct "Match" measurements of Lagrangian changes of water vapor in air parcels in the TTL, by making multipoint, coordinated sounding campaigns in the tropical western Pacific in northern winter season. **[Inai et al., ACP, 2013]**
- "Match" is to measure (and analyze) the same air parcel twice or more to quantify the Lagrangian water vapor changes by using balloon measurements and trajectory calculations

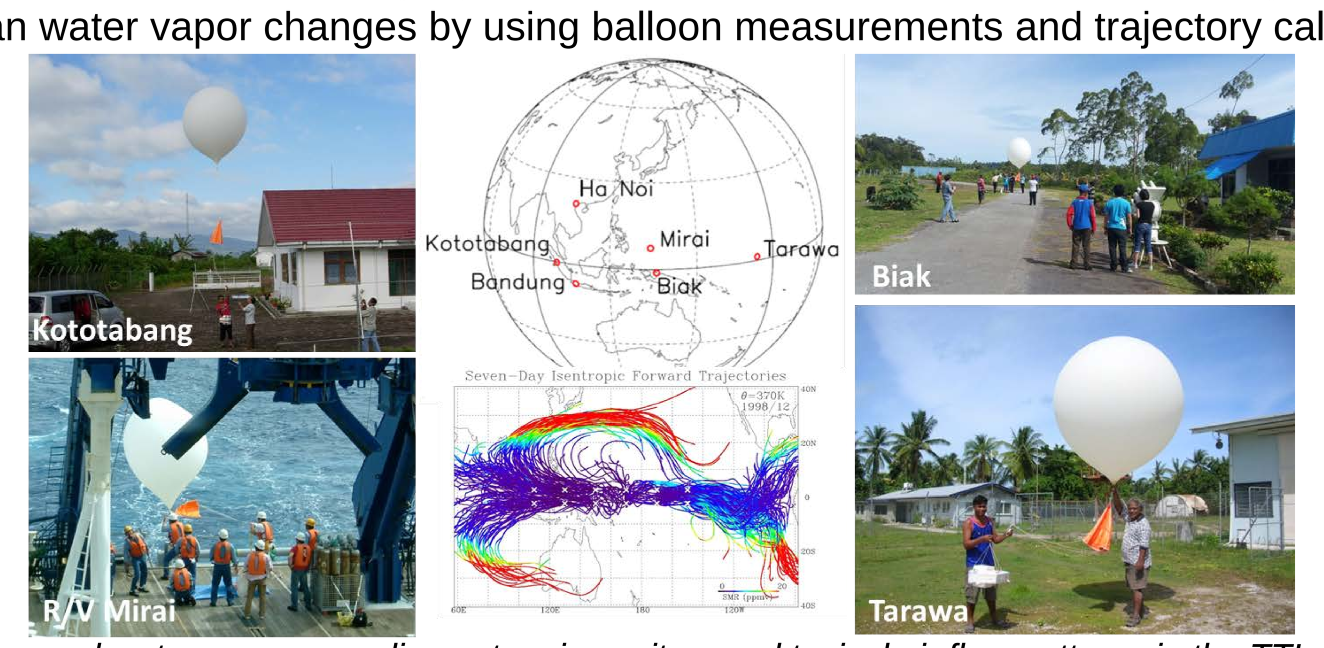

Figure 5. Ozone and water vapor soundings at various sites, and typical air flow patterns in the TTL in northern winter over the tropical Pacific.

Table 1. The number of water vapor soundings (using CFH or Snow White) during the 5 SOWER "Match"campaigns. All soundings were made with ECC ozonesonde.

Site	Dec.2004	Jan.2006	Jan.2007	Jan.2008	Jan.2009
Bandung	4 (CFH)	-	-	-	-
Biak	3 (SW)	12 (SW), 9 (CFH)	6 (CFH)	7 (CFH)	4 (CFH)
Hanoi	8 (SW)	15 (SW)	6 (CFH)	5 (CFH)	4 (CFH)
Kototabang	-	10 (SW)	5 (CFH)	4 (CFH)	-
R/V *Mirai*	15 (SW)	-	-	-	-
Tarawa	10 (SW)	11 (SW) , 2 (CFH)	5 (CFH)	-	-

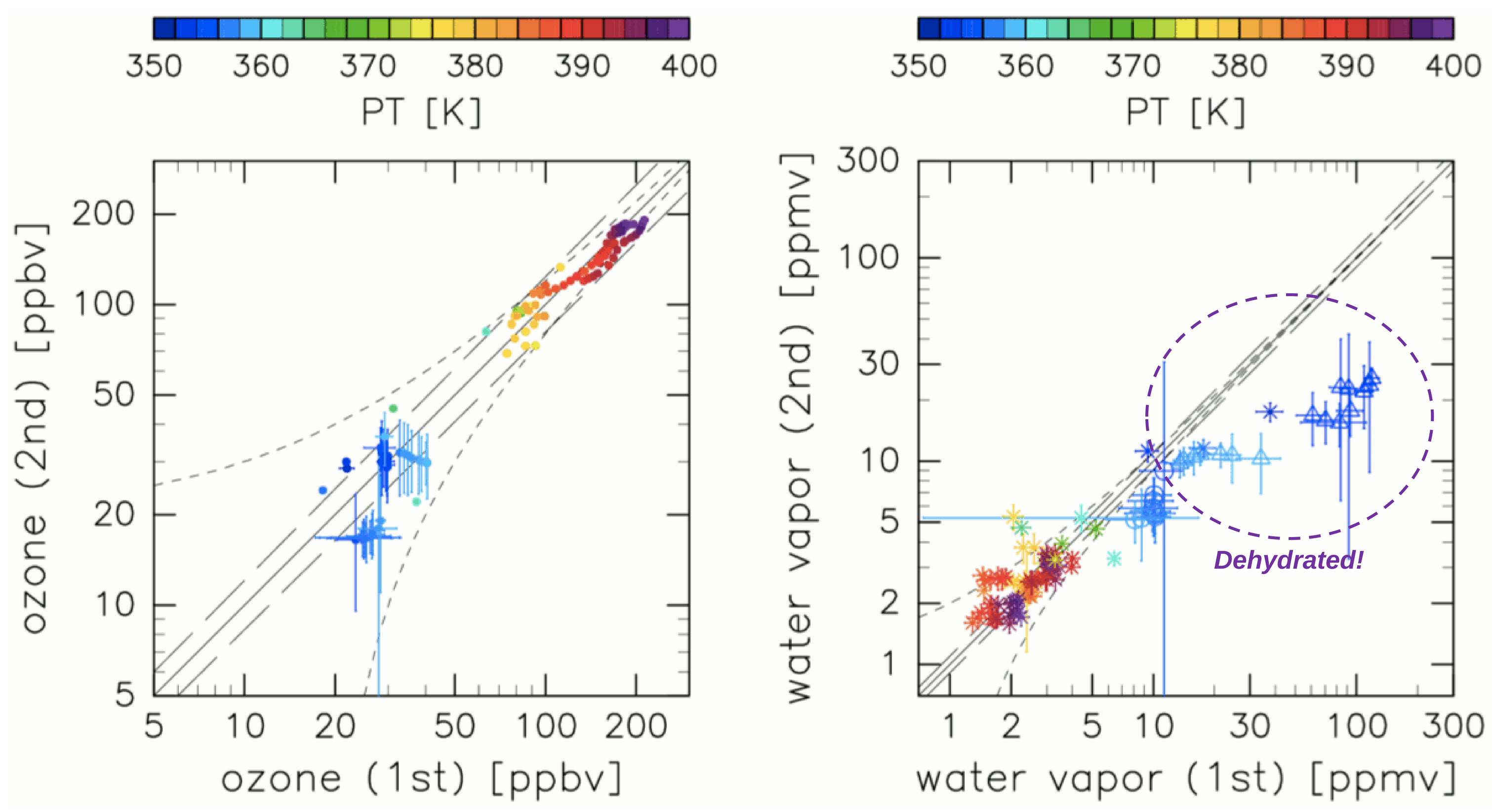

Figure 6: Scatter plots showing the first versus the second observed values of ozone (left) and water vapor (right) mixing ratios for matches identified after applying all of the screening procedures. Colors indicate different potential temperature levels (e.g., 350 K~13 km, 370 K~16 km, 400 K~19 km). Significant dehydration occurs below 365 K (see dotted circle in right). Water vapor broadly unchanged above 365 K (for 5-day trajectories; dehydration around CPT may take much longer time). This is the first direct evidence of TTL dehydration in horizontal advection.

Results III. Ozone Variability at Hanoi, Vietnam – Tropical-Midlatitude Connections

- Regular ozonesonde soundings have been made at Hanoi (21N, 106E), Vietnam in collaboration with the AMO/NHMS and the SHADOZ project since 2004. Seasonal and subseasonal variations in the ozone mixing ratio have been investigated by using continuous 7-year Hanoi ozonesonde data. **[Ogino et al., JGR, 2013]**
- Large seasonal variations were found in the UTLS region (10–18 km) and in the lower troposphere (around 3 km).
- UTLS: A minimum in winter and a maximum in spring to summer were found. They are caused by the seasonal change in horizontal transport. Low ozone comes from equatorial troposphere in winter by the anticyclonic flow, and high ozone from the midlatitude stratosphere in summer due to Rossby wave breakings (UT) and the Tibetan High (LS).
- Lower troposphere: A spring maximum around 3 km was found. This is caused by biomass burning and tropopause foldings.

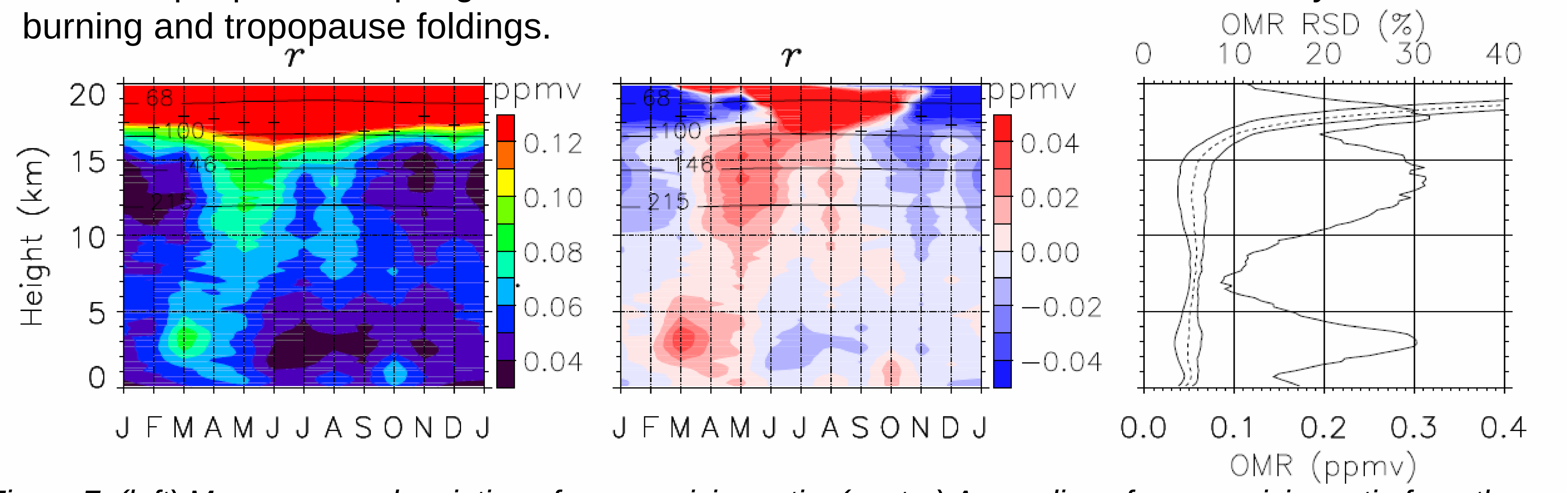

Figure 7: (left) Mean seasonal variation of ozone mixing ratio. (center) Anomalies of ozone mixing ratio from the annual mean at each height. (right) Vertical profiles of annual mean ozone mixing ratio (thick dashed line), standard deviation of mean seasonal variation (thin solid line), and standard deviation normalized by the annual mean at each height (thick solid line). Plus marks in left and center panels indicate cold point tropopauses.

Recent Activities and Near Future Plans

- February-March 2015: Balloon-borne cryogenic air samplings at Biak, Indonesia.
- 2015-2016: Summer monsoon campaign at Hanoi, and winter-time campaign in the tropical western Pacific.
- 2017-2019: Collaboration with the Year of the Maritime Continent (**YMC**) project in the Indonesian maritime continent and South-east Asia (see *http://www.jamstec.go.jp/ymc/*)

Acknowledgments

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