10 years of observation for greenhouse gases by commercial airliner in the CONTRAIL project

CONTRAIL
Comprehensive Observation Network for Trace gases by Airliner
この飛行機は上空の
CO_2濃度を観測しています。
In-Flight Observation of Atmospheric CO_2.

Y. Sawa[1], T. Machida[2], H. Matsueda[1], Y. Niwa[1], T. Umezawa[2], K. Tsuboi[1], K. Katsumata[2], H. Eto[3], D. Goto[4], S. Morimoto[5], S. Aoki[5]

1. Meteorological Research Institute, 2. National Institute for Environmental Studies
3. Japan Airlines, 4. National Institute of Polar Research, 5. Tohoku University

Outline

1. What is "CONTRAIL"
2. Equipment
   - ASE, MSE, CME
3. Results: seasonal CO_2 distributions
4. Inter-annual variations of CO_2
5. Summary
   - Accessibility of the data

1. What is "CONTRAIL"

- **Comprehensive Observation Network for TRace gases by AirLiner**
- **NIES, MRI, JAL, JAMCO, JAL foundation**
  1. **Flask samplings :**
     Australia-Narita since 1993 (from former JAL project),
     Paris-Haneda since 2012
  2. **in-situ CO_2 observations in wide regions since 2005**

2. Equipment

ASE: Flask sampling for several greenhouse gases

Machida et al., 2008, JTEC
Matsueda et al., 2008, Pap. Meteorol. Geophys.

- get 12 air samples during the flight (once/twice a month)
- mixing ratios of CO_2, CH_4, N_2O, SF_6, CO, and H_2
  - Isotope analysis of CO_2, CH_4 by NIES or Tohoku Univ. (Umezawa et al., 2012, ACP)
- Long record more than 20 years between Australia and Japan (Matsueda et al., 2015, GRL)
- Can be installed on only 777-200ER
- Not used in the regular flights to Europe, nor Australia (May, 2017)

In case we can not use 777-200ER…

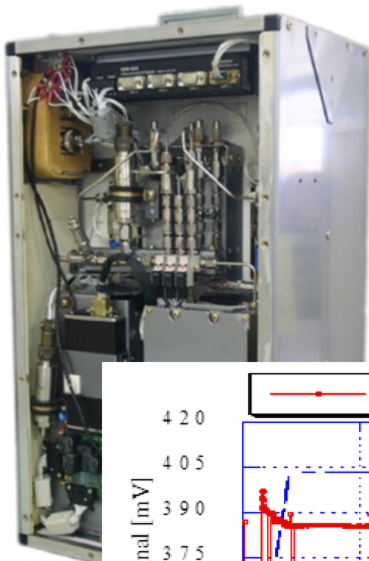
Manual Sampling Equipment

Under special support and permission by JAL, JCAB, …

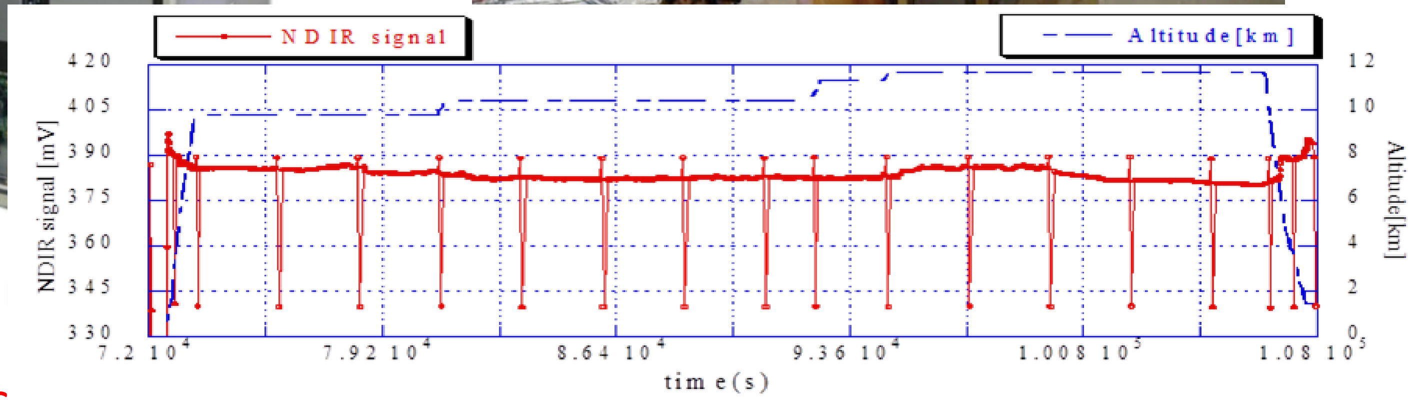
- fill the data gap due to changes of aircraft assignment
- sampled by one of 4 researchers (CDG) or JAL personnel (SYD)
- use air-outlet nozzle in the cockpit on 777-300s
- CDG-HND since Apr. 2014, SYD-NRT from Nov. 2015 to Mar. 2017

- Tough work; 12 samplings during a 12 hours flight, and 3 hours stay in CDG airport
- My one-day trips to CDG: in Jan., Aug., and Oct. 2017.

CME: High frequent CO_2 observation



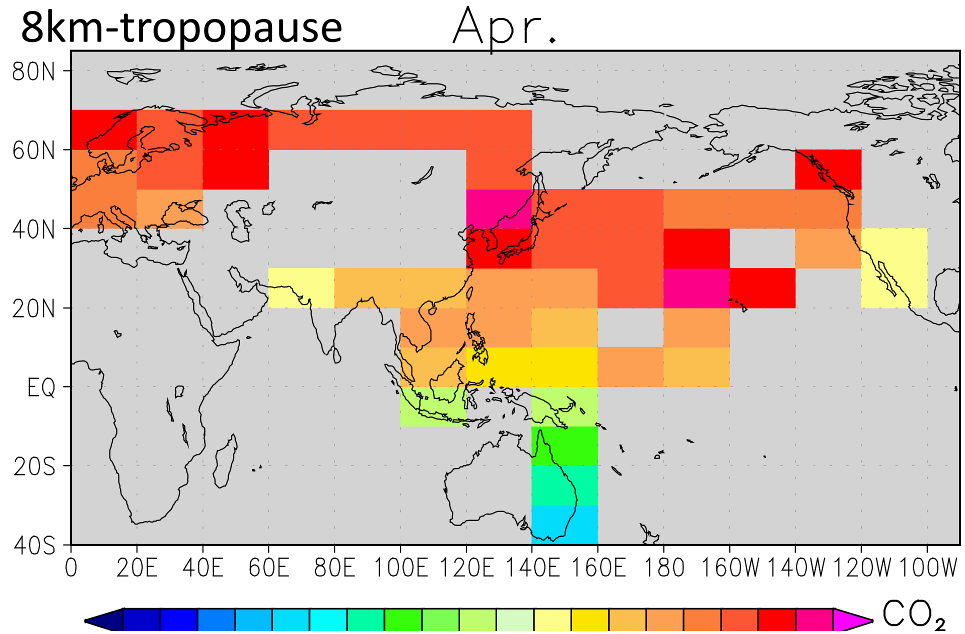
Machida et al., 2008



in-situ CO_2 measu

- high resolutions
  - 10 sec average during ascending/descending ~ 100 m in vertical
  - 1 min average during the cruising flight ~ 10 km in horizontal
- 1-2 month operation (usually on 3 aircraft simultaneously)
- real time control by aviation information (ARINC)
- onboard calibrations; high accuracy ±0.2 ppm
- Several modifications, update/amend FAA/STC (2008, 2011, 2014, 2015, 2017)

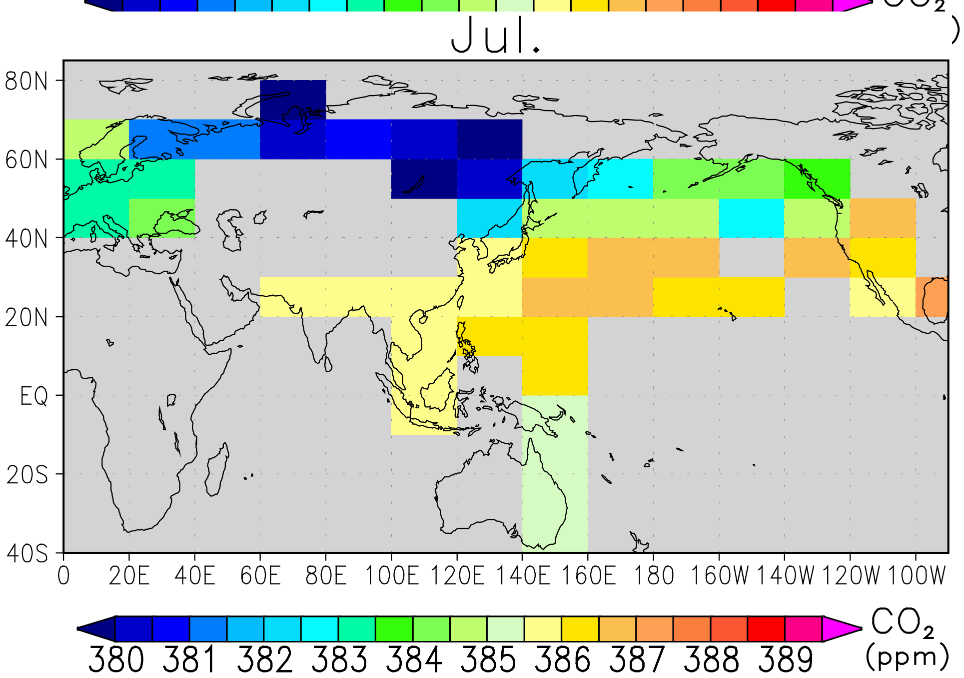
3. Results: seasonal CO_2 distributions

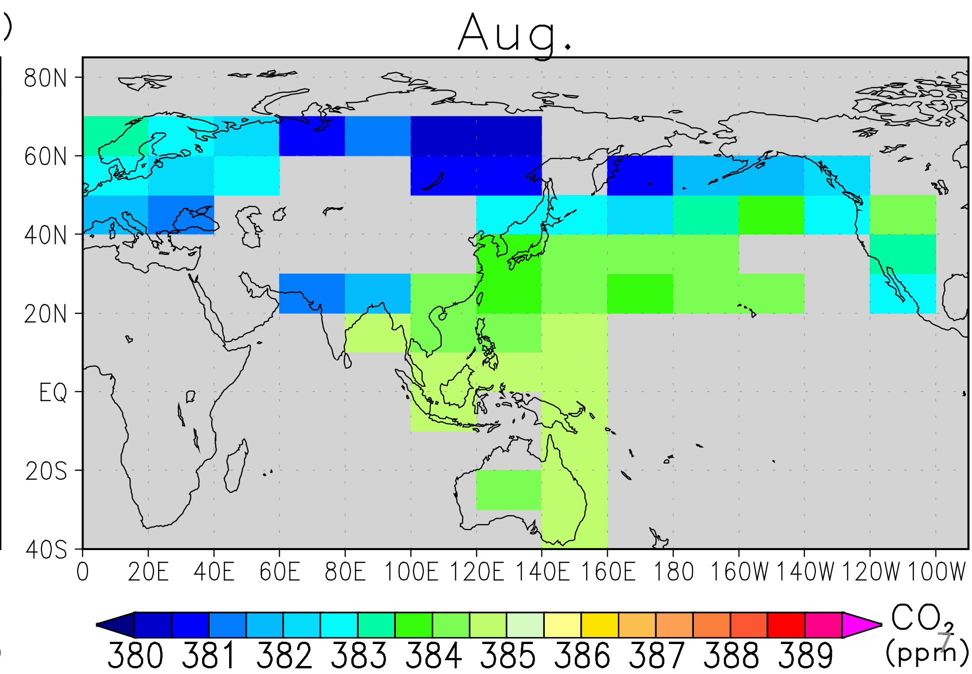


- with larger amount of CO_2 data (8 million data from 14000 flights)

- wide distributions of CO_2 in the upper troposphere

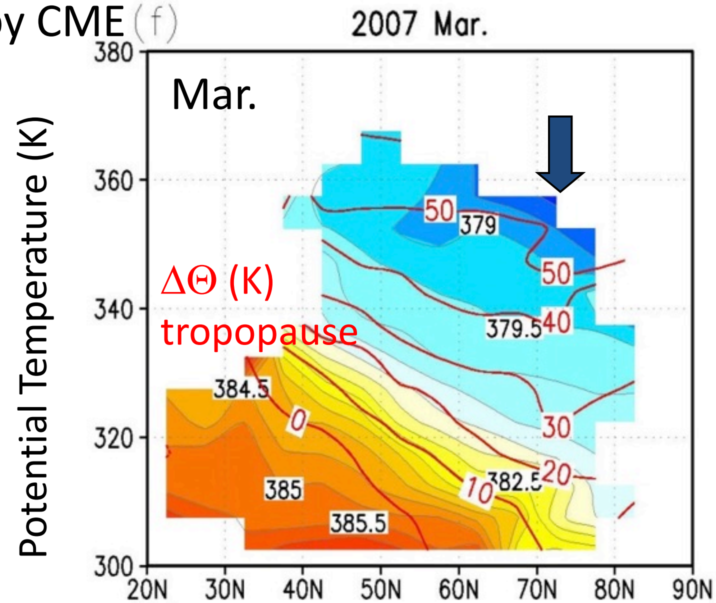
Sawa et al., 2012, JGR

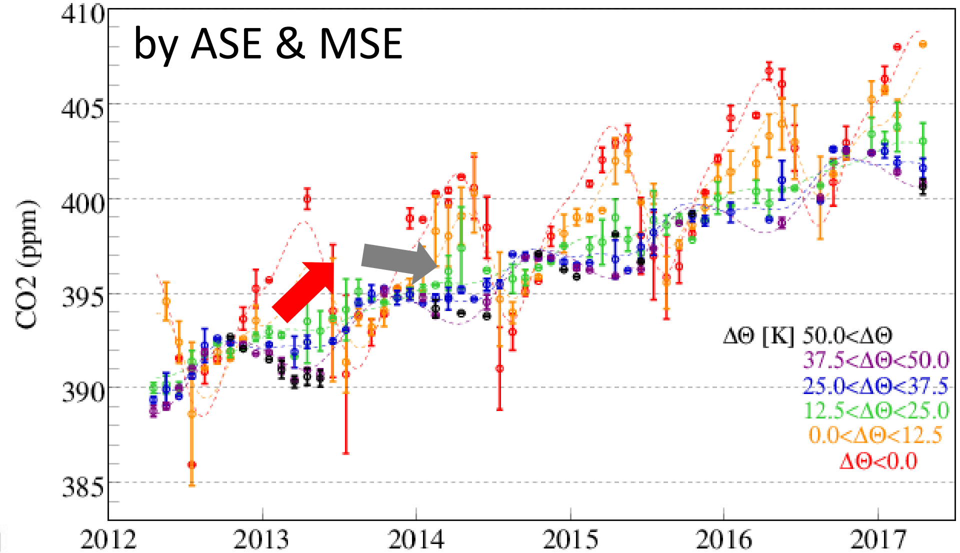




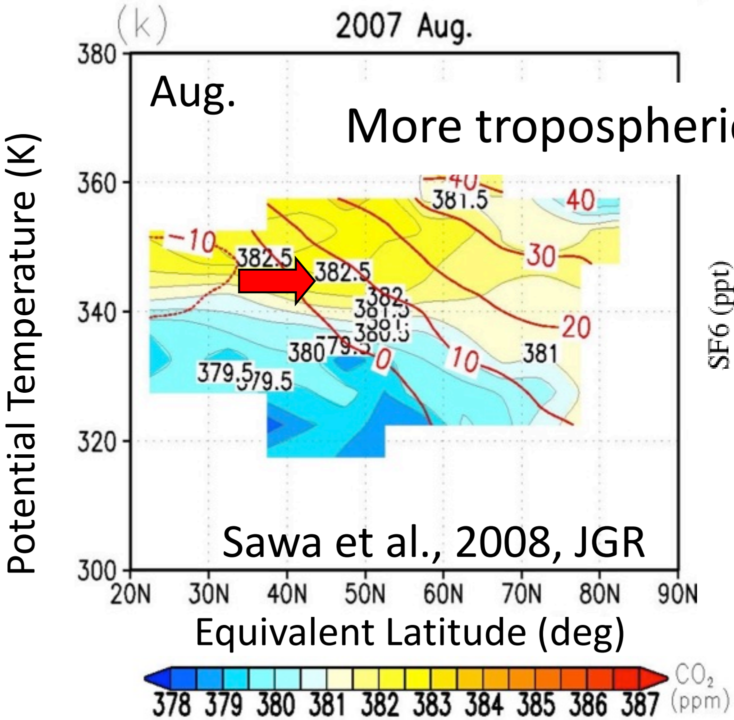
Distributions in the Upper Troposphere/Lower Stratosphere

CO_2 by CME

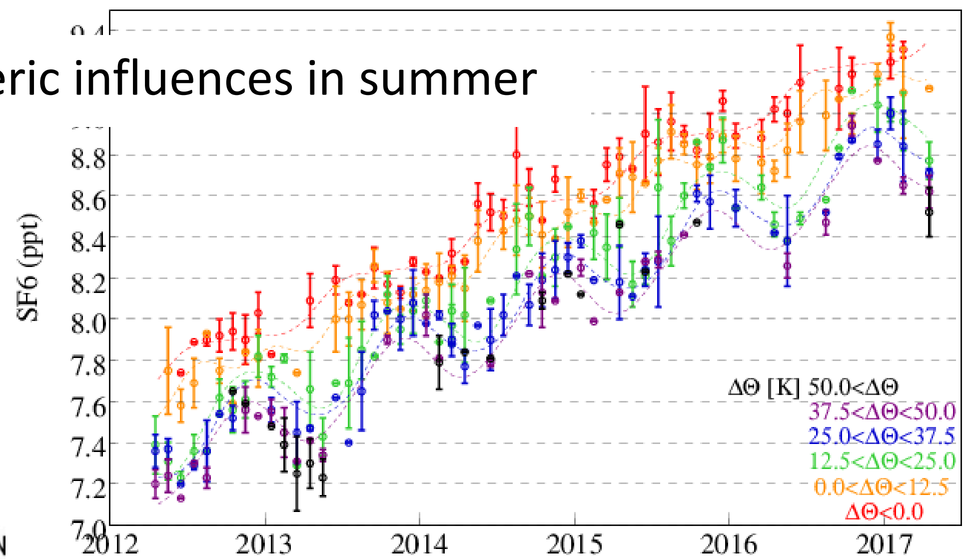




More tropospheric influences in summer



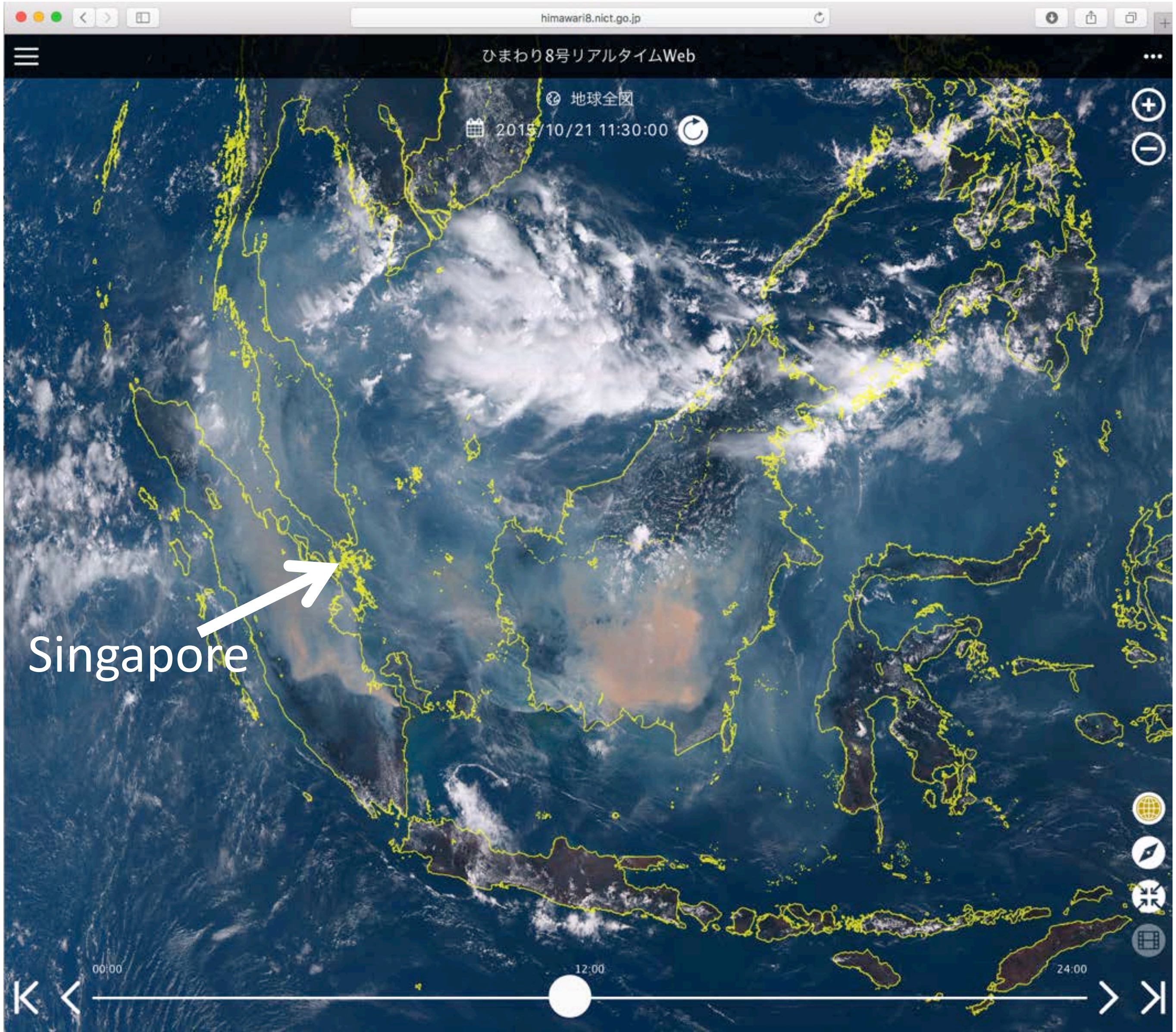
Sawa et al., 2008, JGR



Updated from Sawa et al., 2015, GRL

4. Inter-annual variations of CO_2

Intensive Biomass Burnings in Indonesia in 2015



Oct. 21, 2015

Visible image from Himawari-8 (GMS)

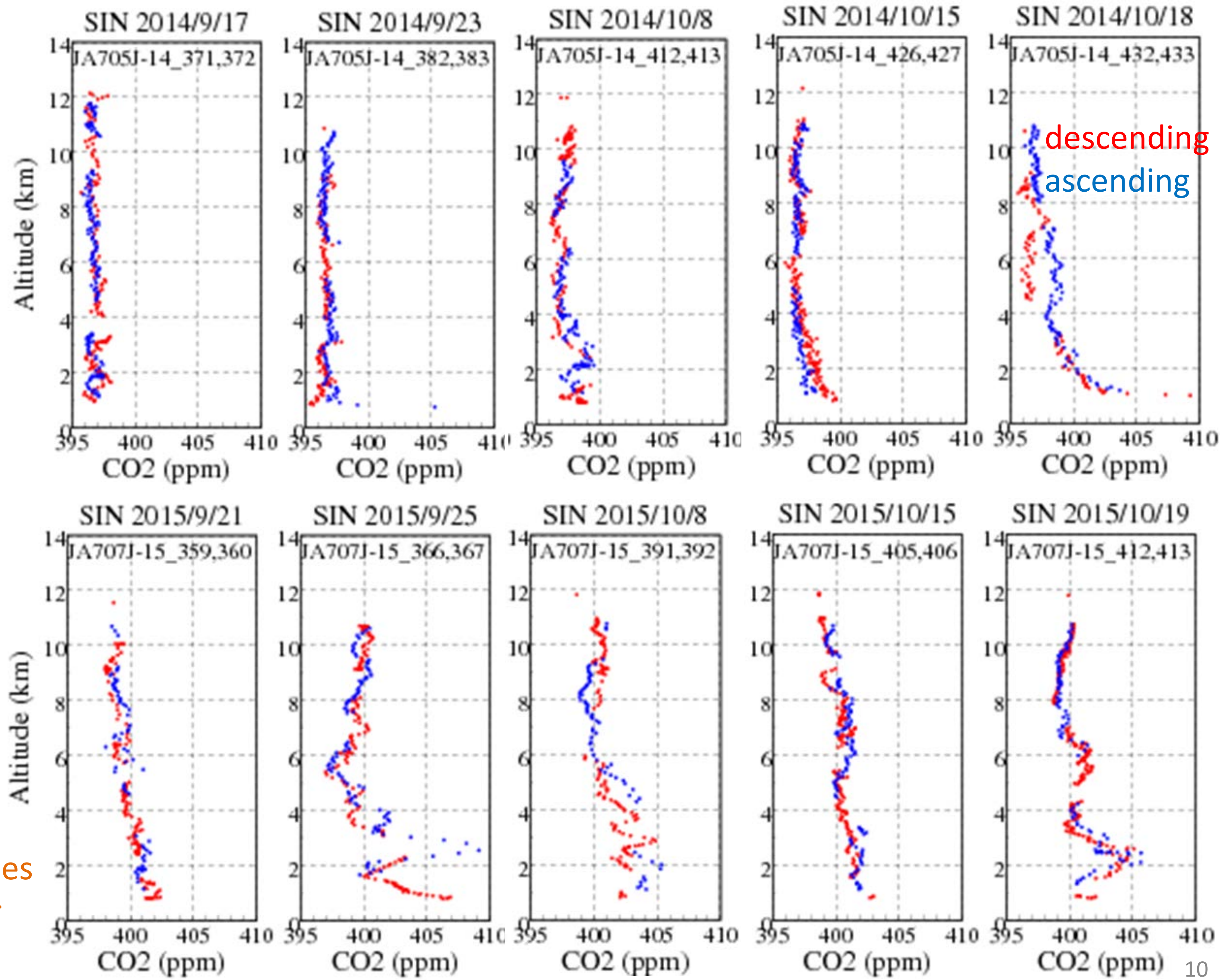
Luckily, we have many CME flights to SIN both in 2014 and 2015

Vertical profiles of CO_2 over Singapore in Sep.-Oct.

Smaller vertical gradient in 2014

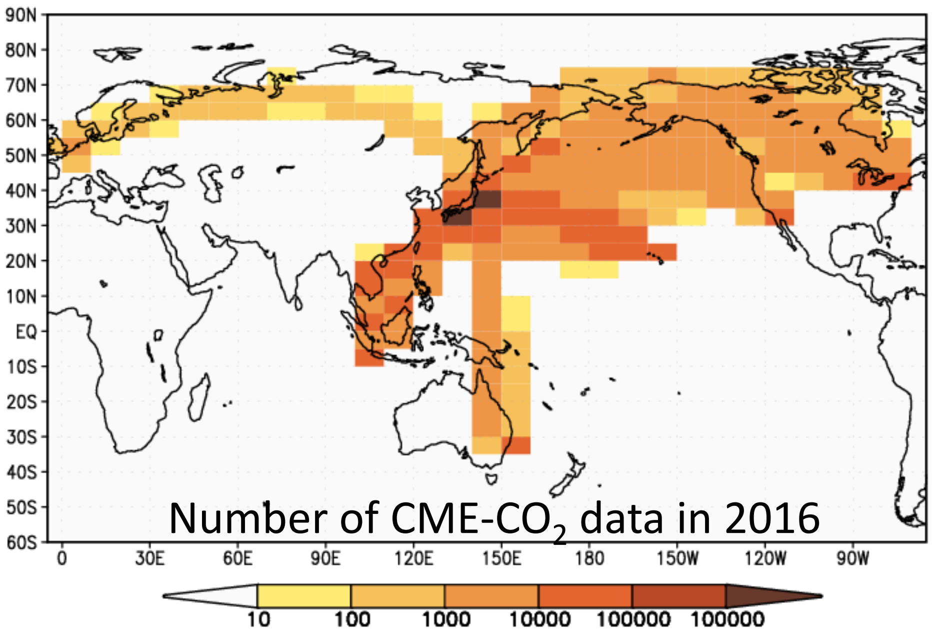
Higher CO_2 at lower altitudes in 2015

larger increases ~ 3 ppm/year

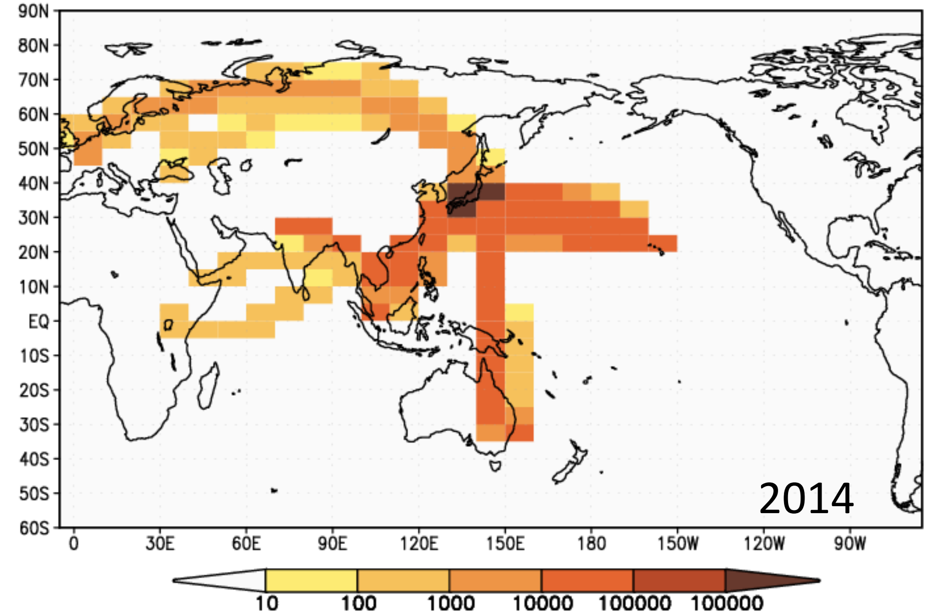


Can we detect inter-annual variations ?

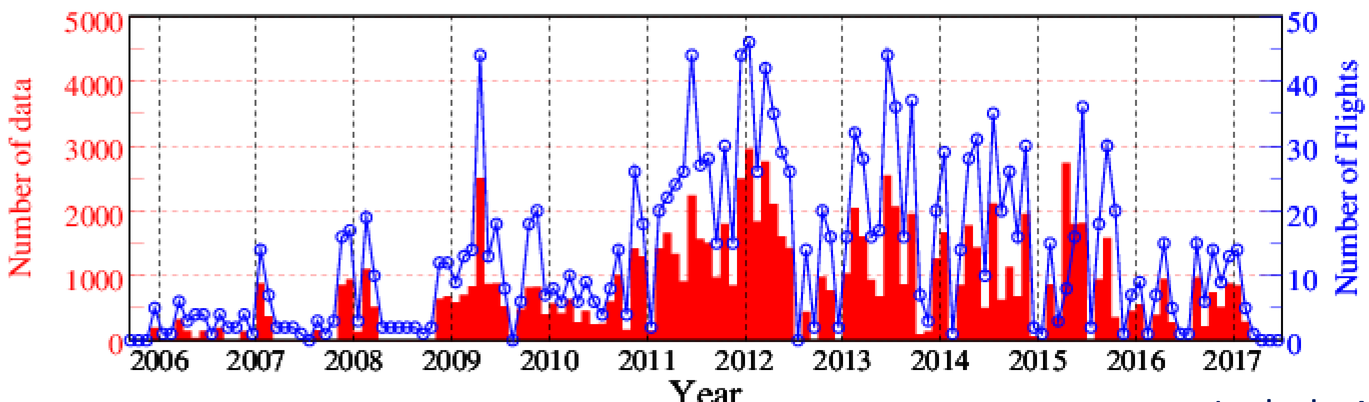
Our observation largely depends on aircraft assignment
<-> surface stations, satellites



Number of CME-CO_2 data in 2016



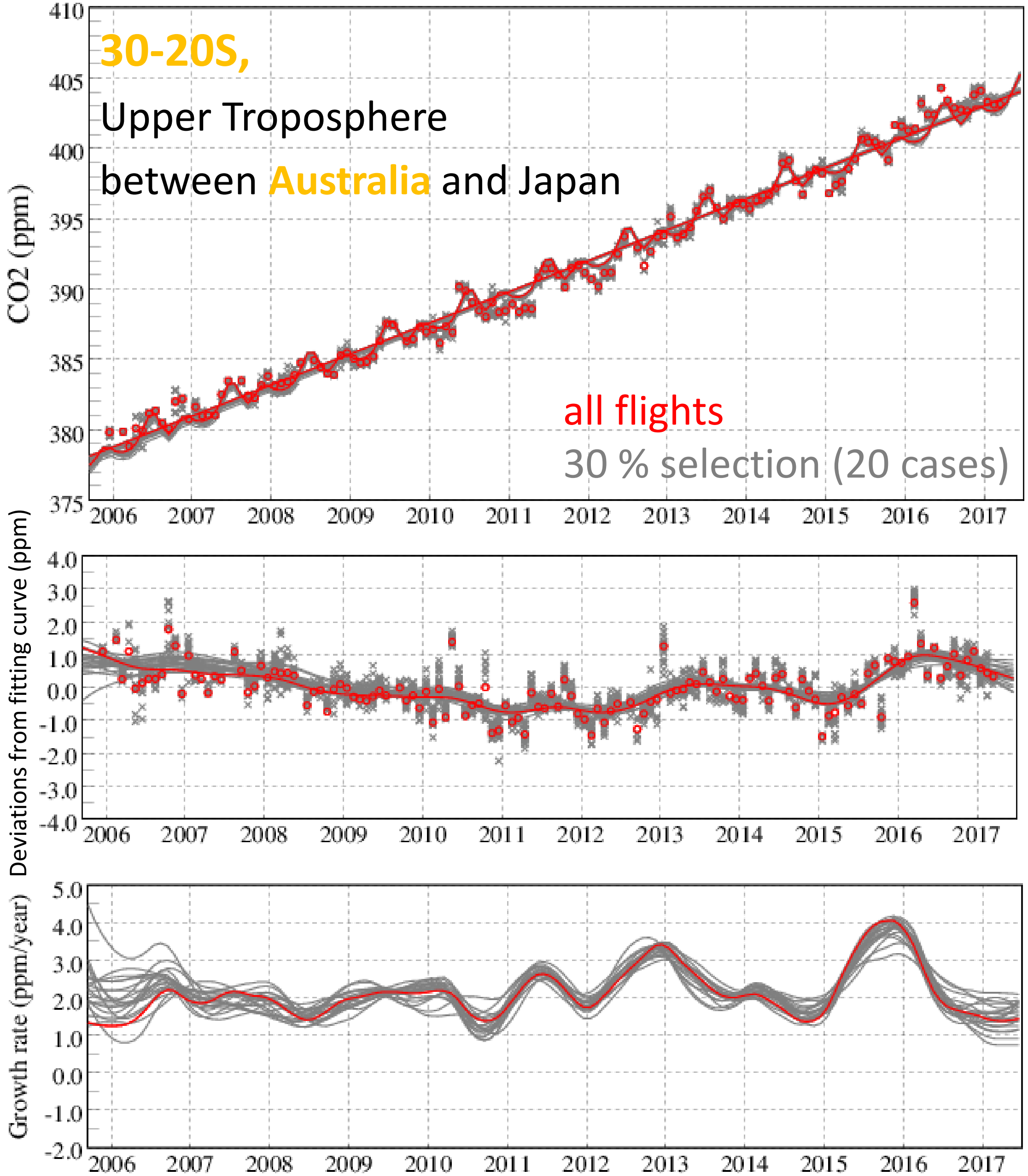
Example for number of data in 30S-20S from flights between Australia and Japan



8km - tropopause

Include ASE/MSE flights

Check robustness by sub-sampling method



Use all available flights

-> linear trend,
climatological seasonal changes,
anomaly, growth rates

Use 30 % of all flights by random selections

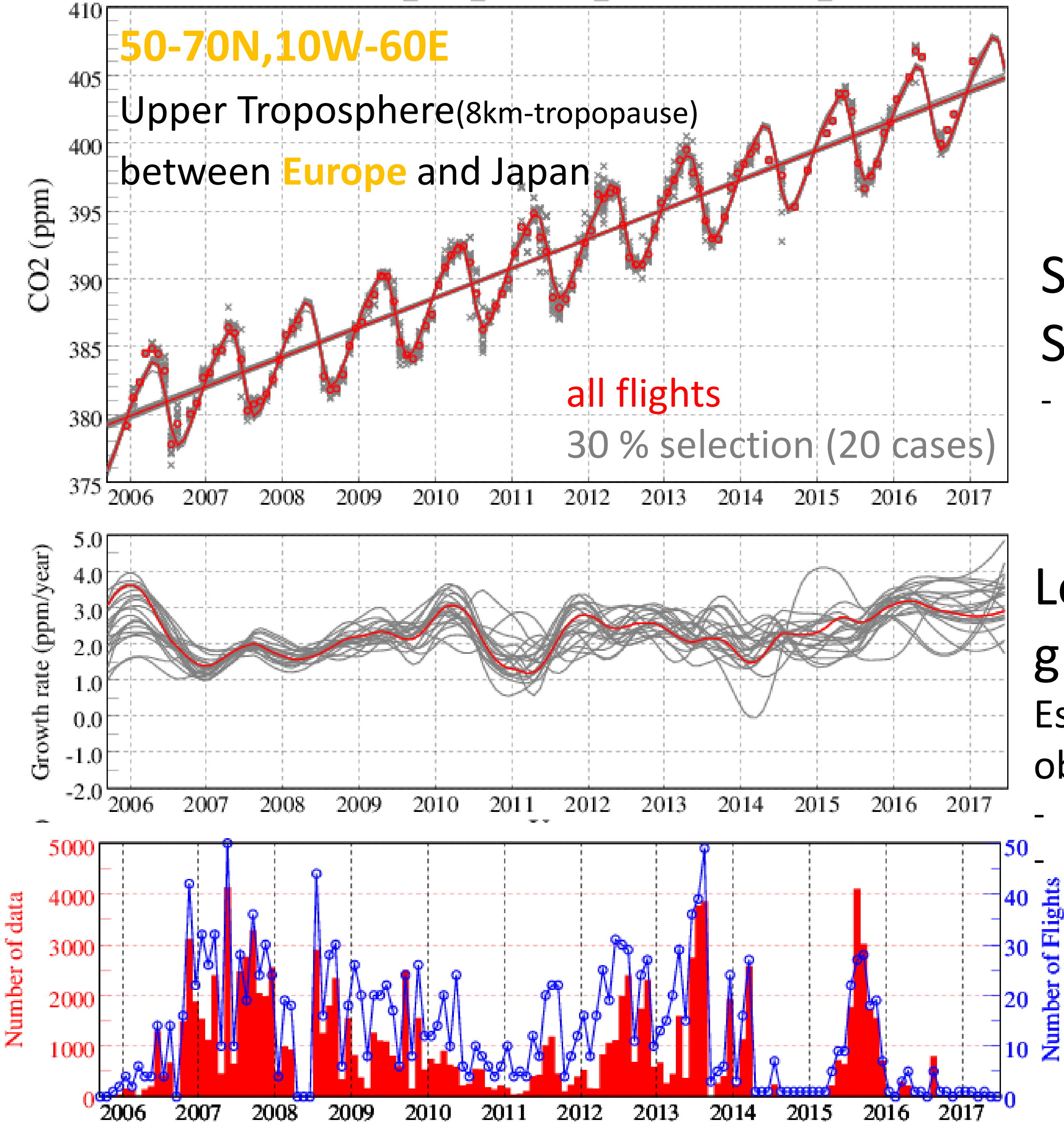
-> linear trend,
climatological seasonal changes,
anomaly, growth rates

X 20 cases

Similar growth rates

- High representativeness in the region
- may be trustworthy

Results over Eurasian continent ?



Similar linear trend,

Seasonal phase, amplitude

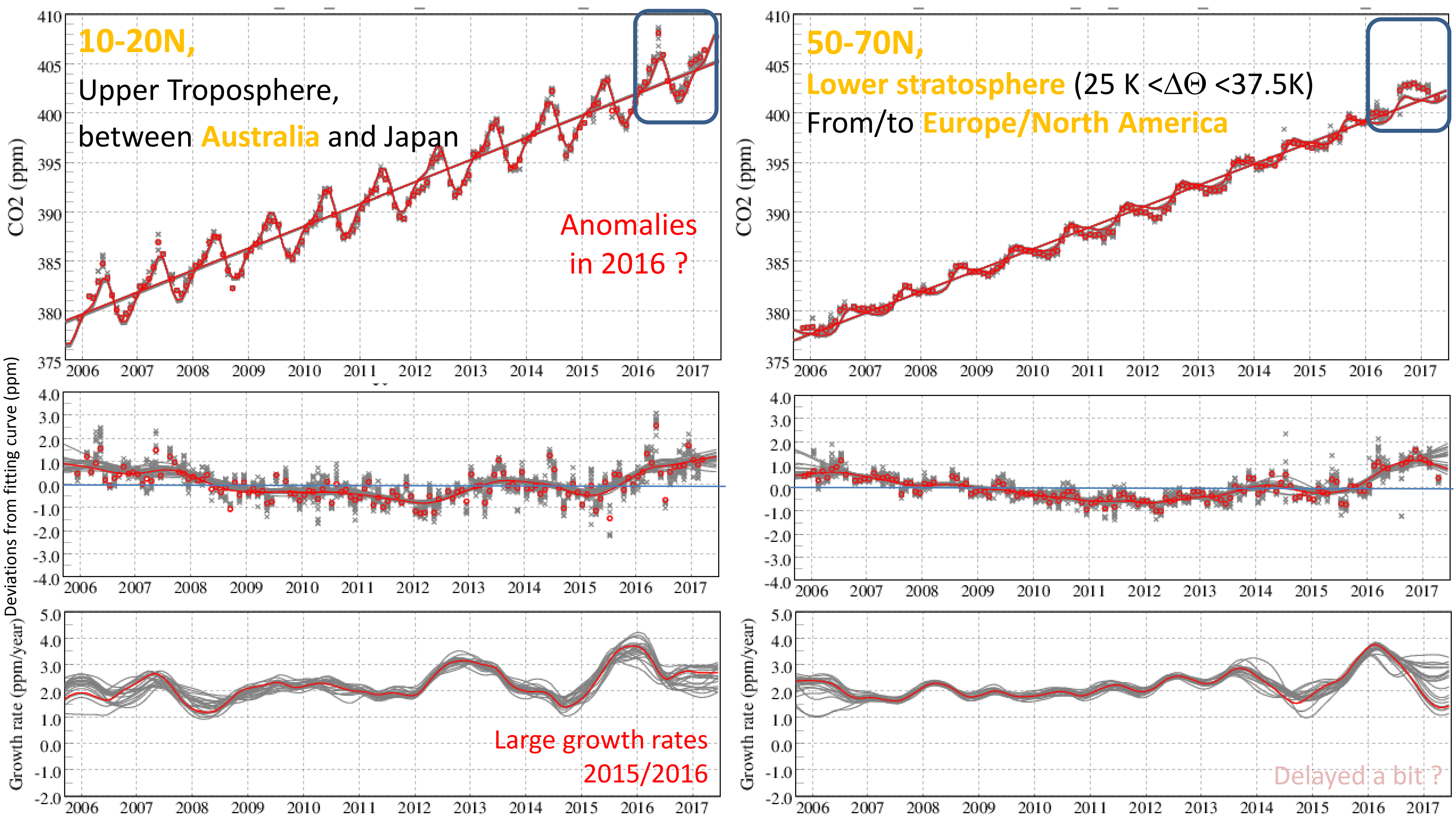
- Based on 10 years observations

Less reliable for changes in growth rates

Especially after 2014 with less observations

- Need more observations
- for regions with large variabilities

Effect from ENSO in 2015/2016 ?



Large anomalies in 2016 in western Pacific

- Highest growth rates in these 10 years

Still need to check for data in 2015-2016

- CME stabilities, Standard gases
- End effects, Dependencies on flight routes, ΔΘ analysis
- Sub-sampling limitations with less data period/region

5. Summary

- Observations for greenhouse gases by airliner
- Flask samplings since 1993 over the western Pacific
- In-situ CO_2 observations over the past 10 years since 2005
  - More than 8 million CO_2 data from about 14000 flights
  - Spatial distributions and seasonal changes of CO_2 in wide regions
- Large anomalies of CO_2 in 2016
  - May reflect ENSO in 2015/2016
  - Also need to check robustness of the trend analysis for end-effect, instrumentations such as standard gases

Accessibility of the data

CONTRAIL NIES

- **Please visit CONTRAIL WEB (http://www.cger.nies.go.jp/contrail/index.html)**
- **Available according to the CONTRAIL data protocol**
  - **Already provided to GOSAT, OCO-2 team, ...**
- **Flask CO_2 data(~Dec. 2015) are available at WDCGG/ObsPack**
- **Just submitted updated CME data(~2010) to ObsPack**
- **Plan to open the data at NIES server.**
- **Contact PIs for recent data, other flask data, or details**

Acknowledgements

- many engineers in the Japan Airlines and JAMCO Tokyo
- Dr. Katsumata, Ms. Matsuura, and Sandanbata (NIES) for sample analysis
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- Support for sampling over Siberia by GRENE Arctic Climate Change Research Project, and Arctic Challenge for Sustainability

the CONTRAIL logo on the Boeing 777-200ER (JA705J and JA707J).

環境省
Ministry of the Environment

GRENE-Arctic

ArCS
Arctic Challenge for Sustainability

CONTRAIL data has been used in many works

1. GOSAT or other remote sensing validation
- CO_2 by TANSO-SWIR (Araki et al., 2010, etc.)
- CH_4 by TANSO-SWIR (Inoue et al., 2014)
- CH_4 by TANSO-TIR (Saito et al., 2012)
- TCCON (Wunch et al., 2010, etc.)
- AIRS, IASI (Crevoisier et al., 2004; 2010)
- TES (Kulawik et al., 2010)

2. Flux estimate with CONTRAIL data
- Impact on India (Niwa et al., 2012)
- Impact on China (Jiang et al., 2014)

3. Simulated CO_2 validation
- Assimilation system (Engelen et al., 2005)
- Latitudinal CO_2 distribution (Nassar et al., 2010)
- South Asia (Patra et al., 2011)
- Latitudinal gradient (Miyazaki et al, 2009)
- Time series over western Pacific (Feng et al., 2011)
- Multi model comparison (Niwa et al., 2011; Houweling et al., 2015)

4. Collaborative works with other programs
- IAGOS (Volz-Thomas et al., 2009), CARIBIC (Schuck et al., 2012), Tohoku Univ. (Ishijima et al., 2010, Umezawa et al., 2012)

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