Inverse analysis of fire-induced carbon emission from Equatorial Asia in 2015 with CONTRAIL and NIES-VOS data

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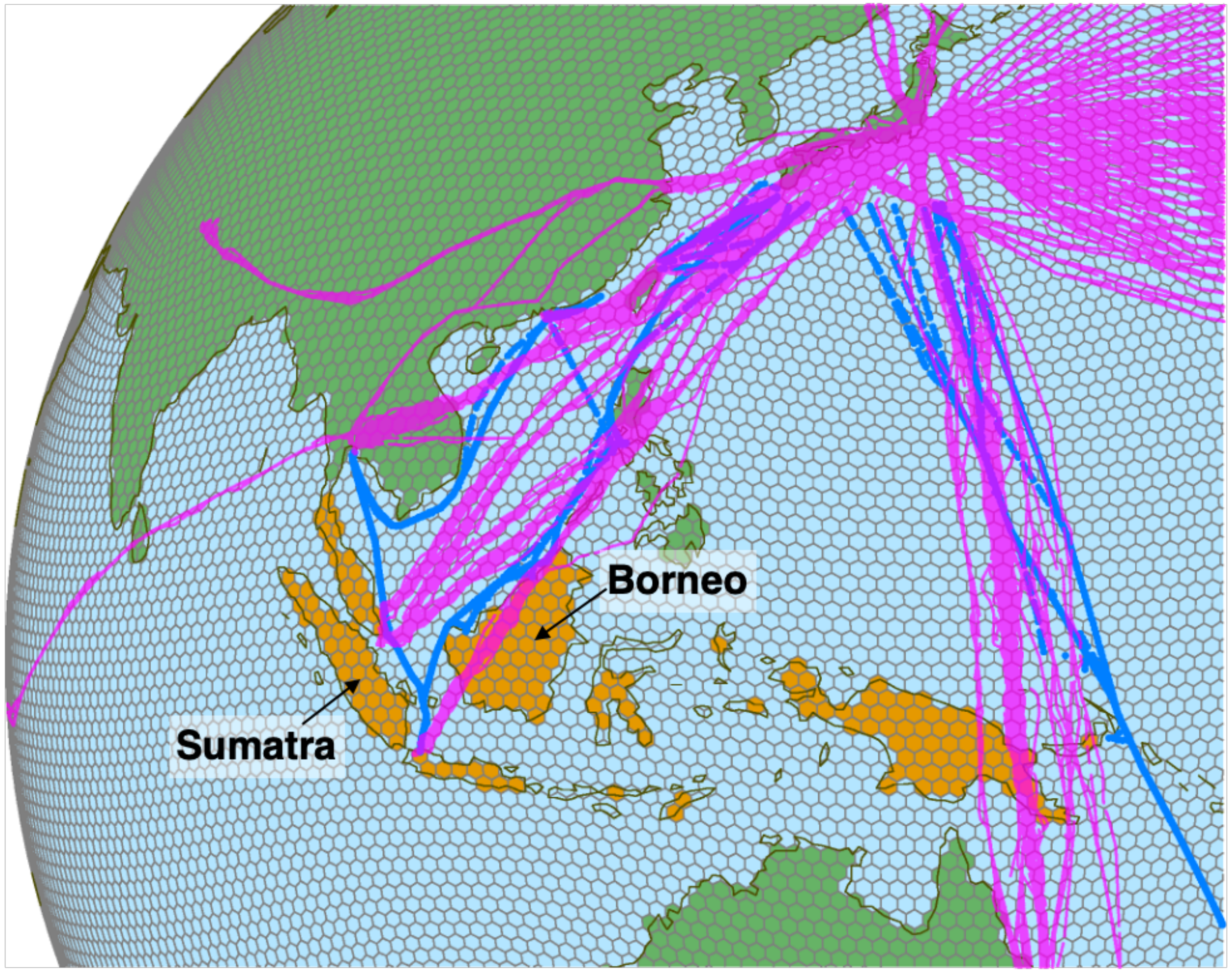
Outline

- We performed the inverse analysis for carbon fluxes in Equatorial Asia during the historic El Niño of 2015.
- We extensively used the CONTRAIL aircraft data in the inverse analysis. Furthermore, with the help of NIES VOS observations, we validated the estimated fluxes.

1. Fires in 2015
2. Aircraft data: CONTRAIL
3. Ship data: NIES VOS
4. Inversion system: NISMON-CO_2
5. Results
6. Summary

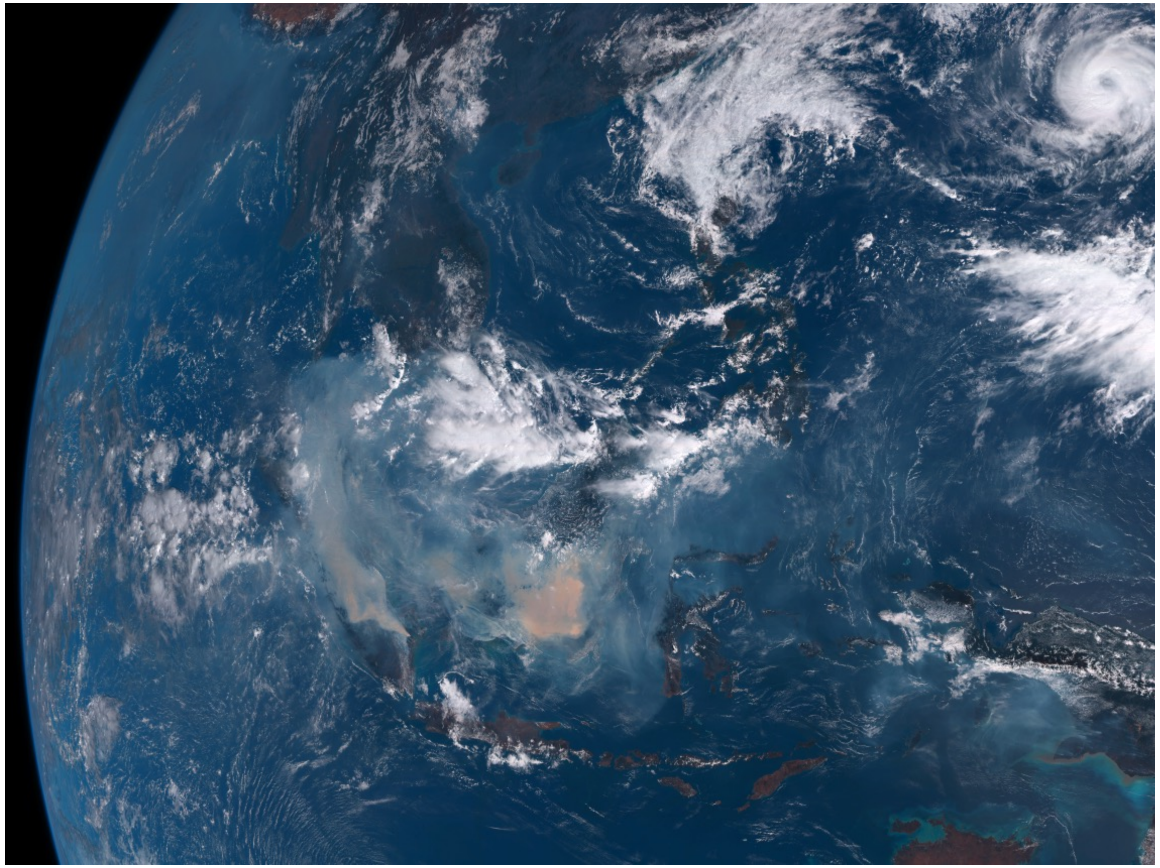


How much was carbon emitted from the devastating fires in 2015?

Previous studies

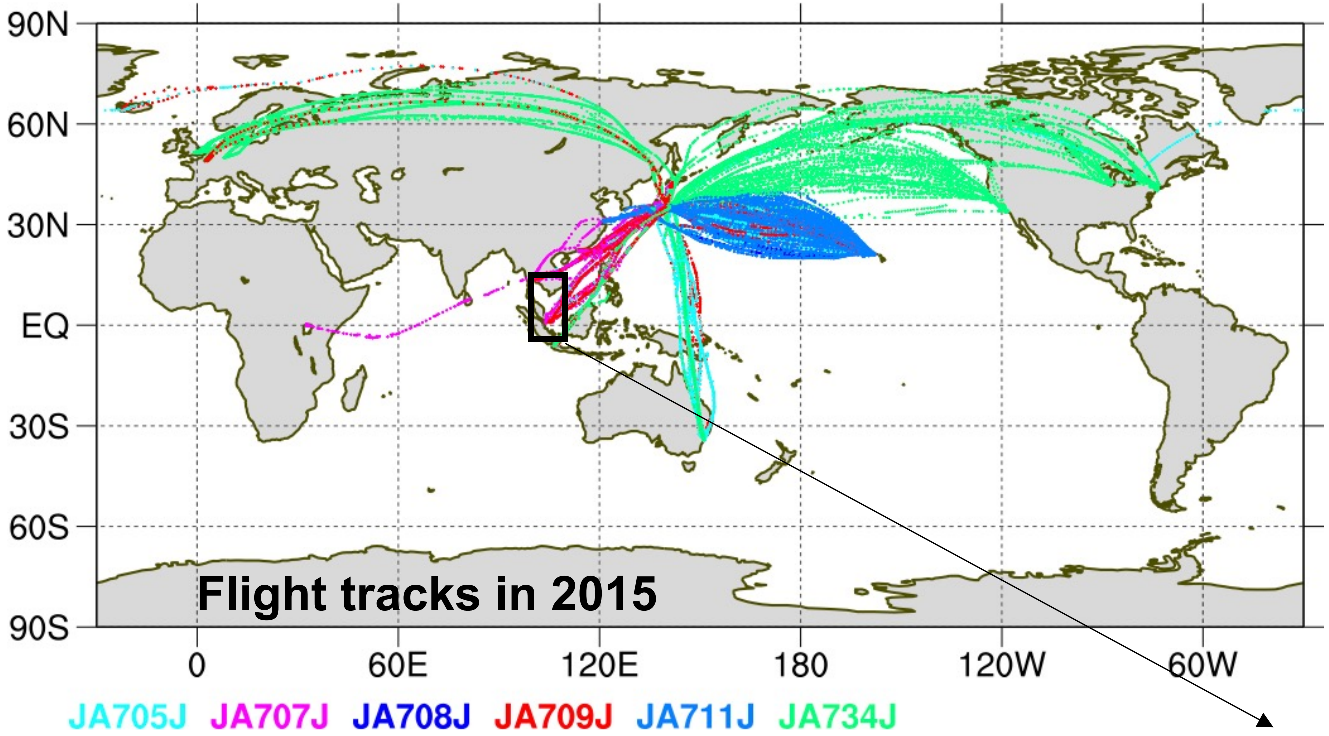
- Huijnen et al., Sci. Rep., (2016)
  - **MOPITT-CO** + local obs. for emission factor
- Field et al., PNAS, (2016)
  - **Multiple satellites CO**, **Aerosol**
- Yin et al., GRL, (2016)
  - **MOPITT-CO**
- Heymann et al., GRL, (2017)
  - **OCO-2 CO2**

Every study used satellite data; furthermore, most of those used carbon monoxide (CO), as a proxy of fire-induced CO_2. Also, their estimates have a significantly large range. (~200 – 500 Tg C)



taken by Himawari-8 on 21 Oct 2015

Worldwide aircraft observation network of CONTRAIL

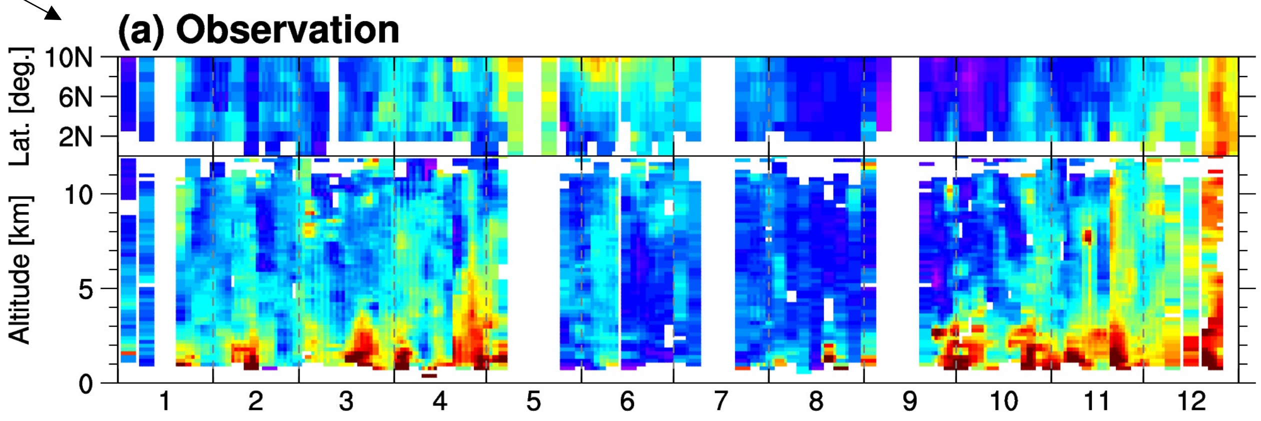


Machida et al., (2008)
Sawa et al. (2012) etc.

In this study, we used in-situ continuous measurement data of CO_2 by CME.

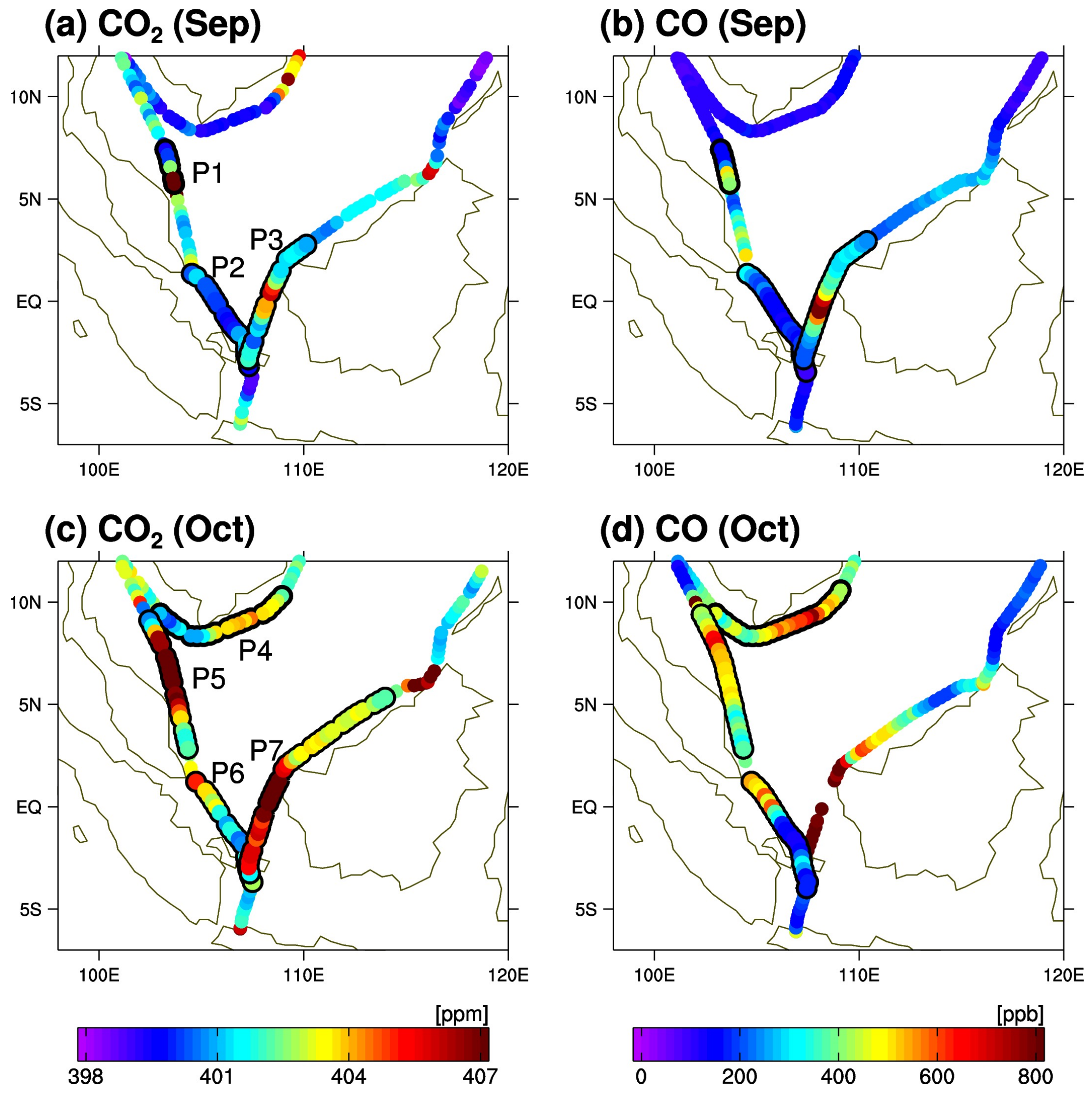
In 2015, CONTRAIL aircraft flied to Singapore very often, which elucidated detail temporal variations of atmospheric CO_2 in Equatorial Asia.

CO_2 observed over Singapore



Please visit http://www.cger.nies.go.jp/contrail/

Coincident CO_2 and CO elevations observed by cargo-ship

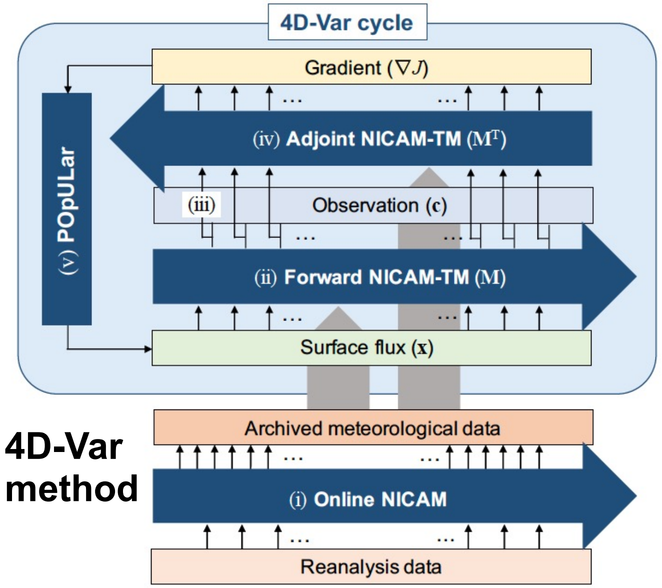


Fujitrans World

NIES Volunteer Observing Ship (VOS) Programme
(Tohjima et al., 2005; Terao et al., 2011; Nakaoka et al., 2013; Nara et al., 2011, 2014, 2017)

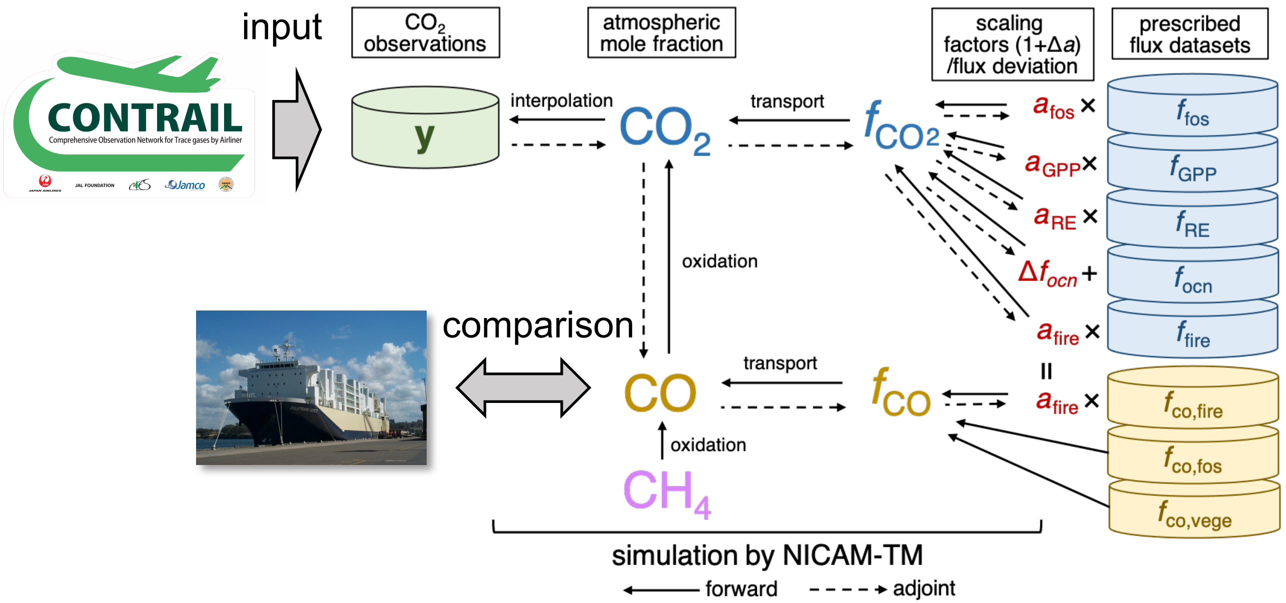
NIES VOS observations in both September and October 2015 captured coincident elevations of CO_2 and CO mole fractions in the east of the Malay Peninsula and west of Borneo.

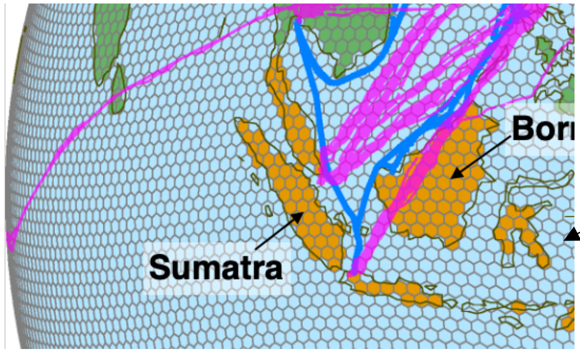
Inversion system NISMON-CO_2



NICAM-based Inversion Simulation for Monitoring CO_2 (NISMON-CO_2)
(Niwa et al., 2017a,b)

A CO function is newly implemented in the inversion system to use CO as a proxy of fire-induced emissions.

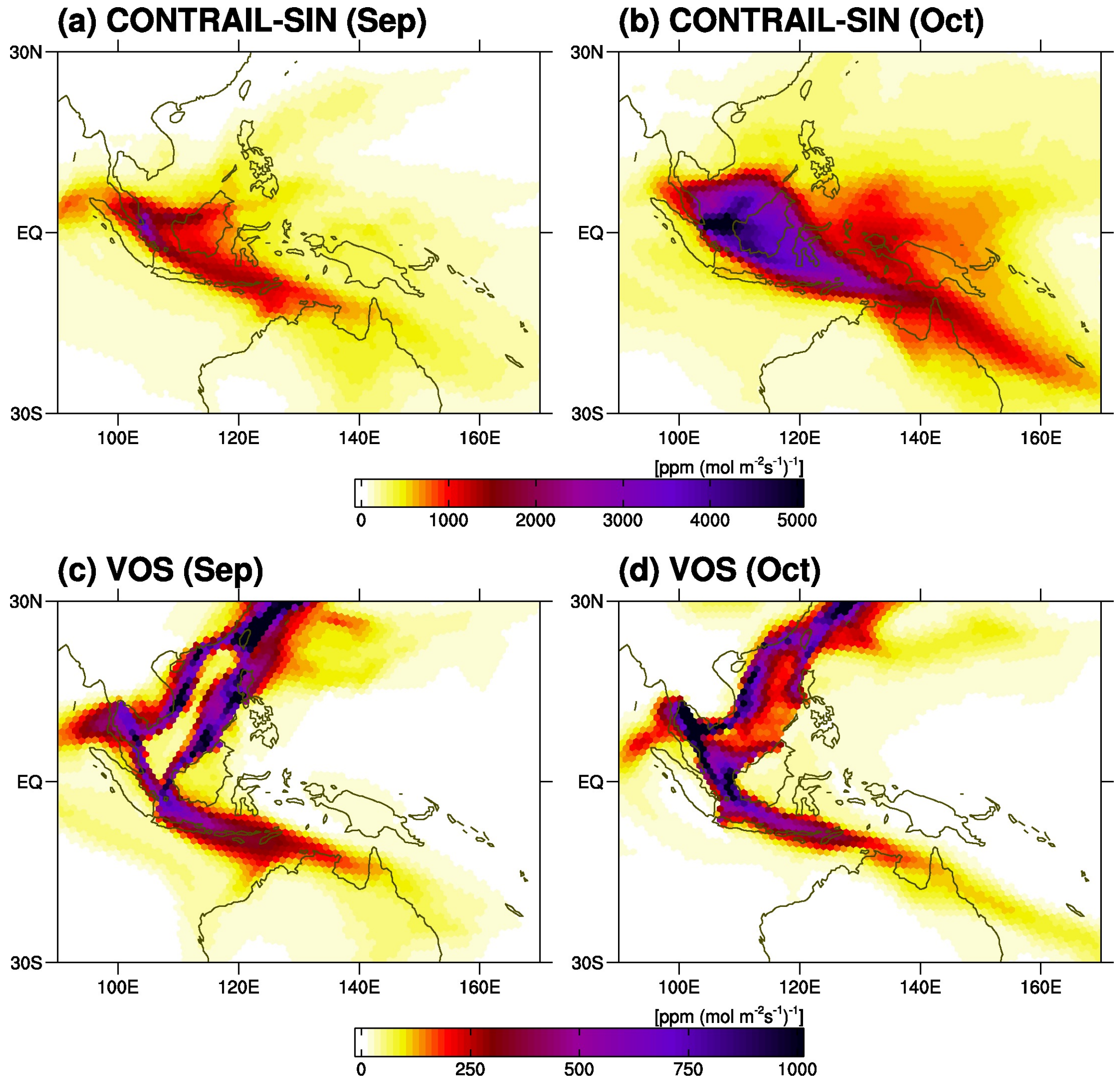




NICAM's grid
(icosahedral grid ~112km)
(Satoh et al., 2008)

An inverse analysis was performed with CO_2 data of CONTRAIL and flux scaling factors were separately optimized. The optimized scaling factor of the biomass burning component was applied to that of CO and the simulated CO mole fractions were compared with the NIES VOS observations.

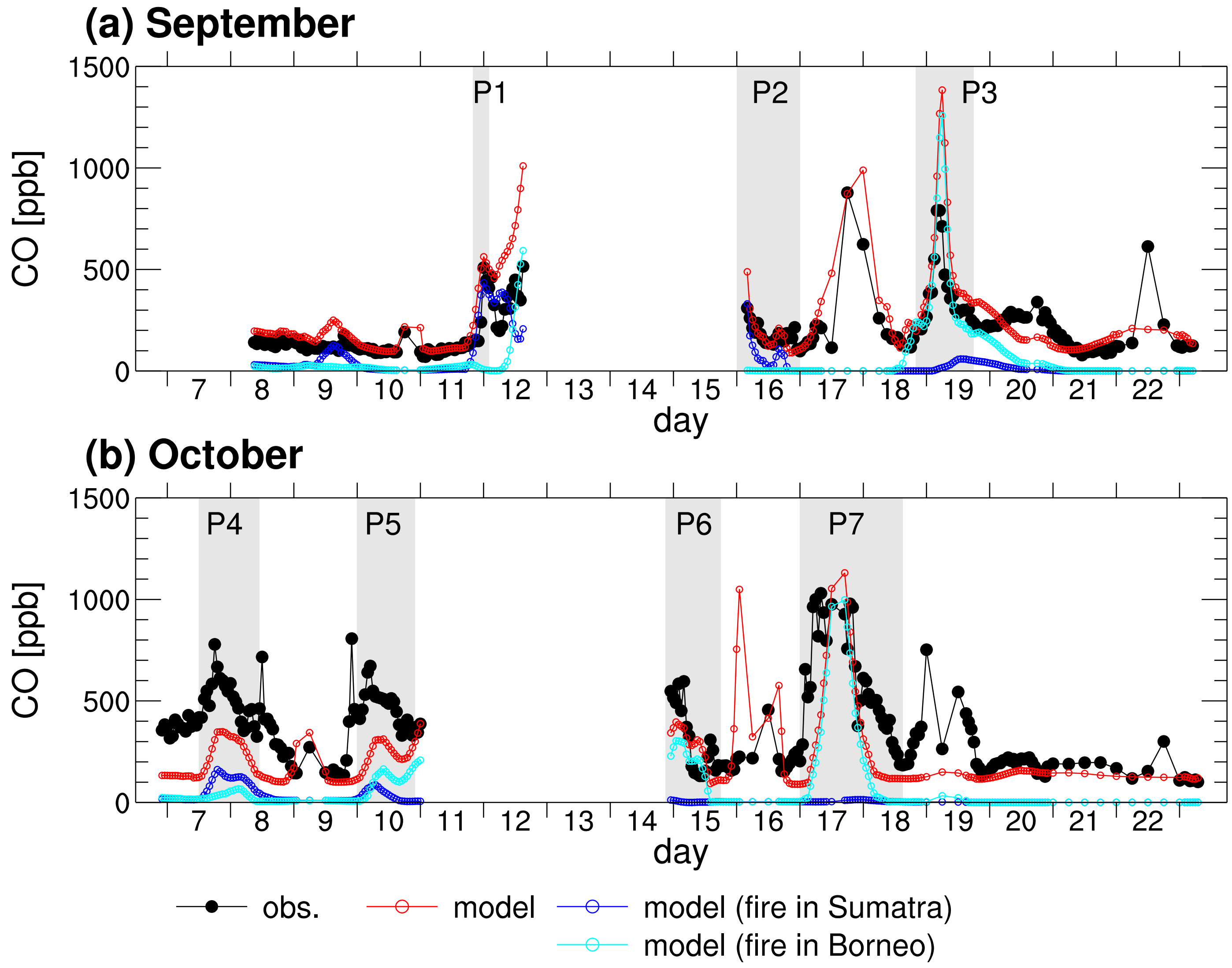
How did the observations see surface fluxes?



Sensitivity of surface CO_2 flux against the observations (e.g., footprints) of CONTRAIL over Singapore (upper) and NIES VOS (lower) for September (left) and October (right) 2015.

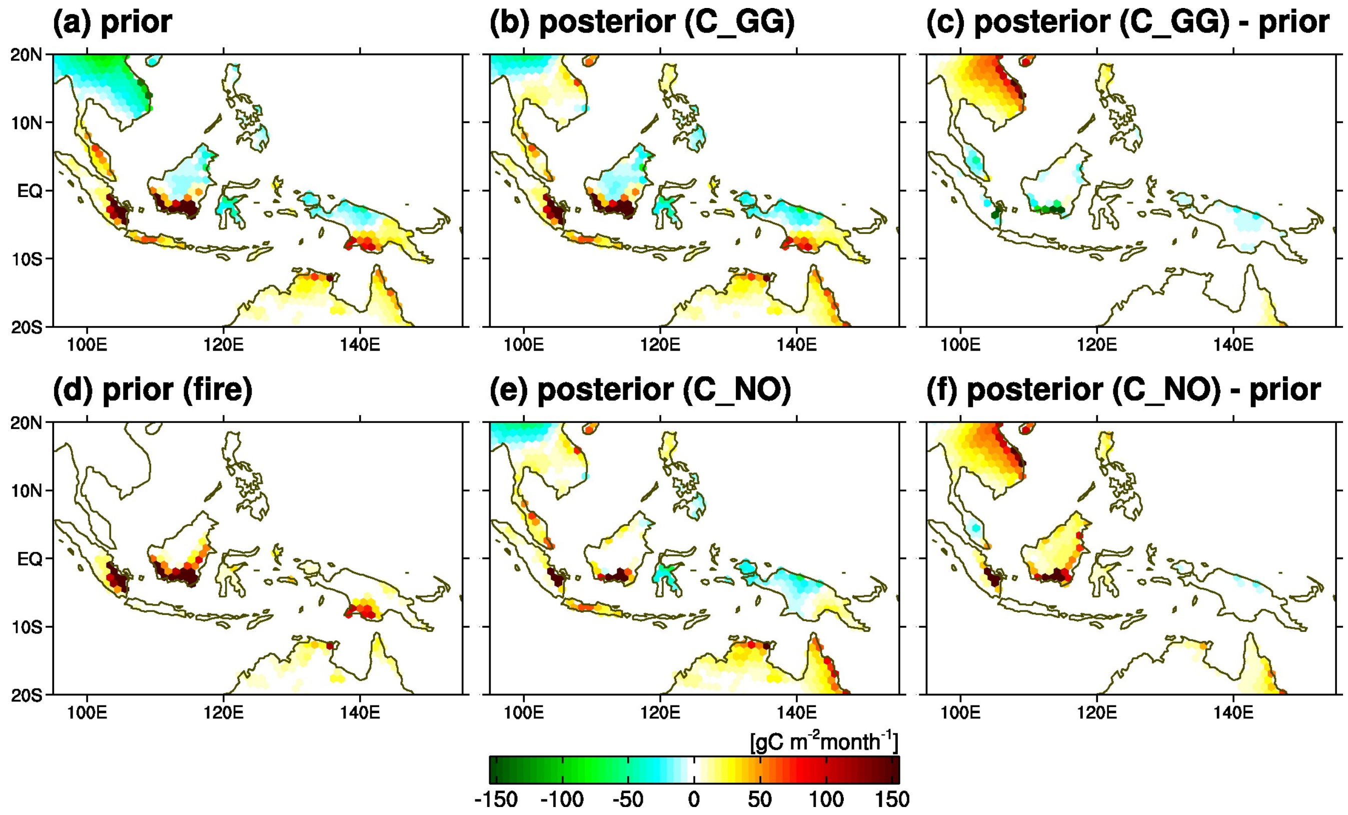
The calculated footprints indicate that the CONTRAIL observations could provide significant constraints on flux estimates for Equatorial Asia, especially Borneo. Compared to CONTRAIL, the NIES VOS footprints are restricted to the ocean because the observations were made within the marine boundary layer. Nevertheless, there are some sensitivities of the NIES VOS observations on the coasts of the islands.

Clear biomass burning signals in the CO data of NIES VOS



Time series of CO mole fractions obtained by the in situ NIES VOS measurement (black) for September (a) and October (b) and corresponding simulation results by NICAM-TM with prior CO emission data (red). Model simulations only from fire emissions in Sumatra and Borneo are also denoted by blue and cyan colours, respectively.

CO_2 fluxes estimated by CONTRAIL



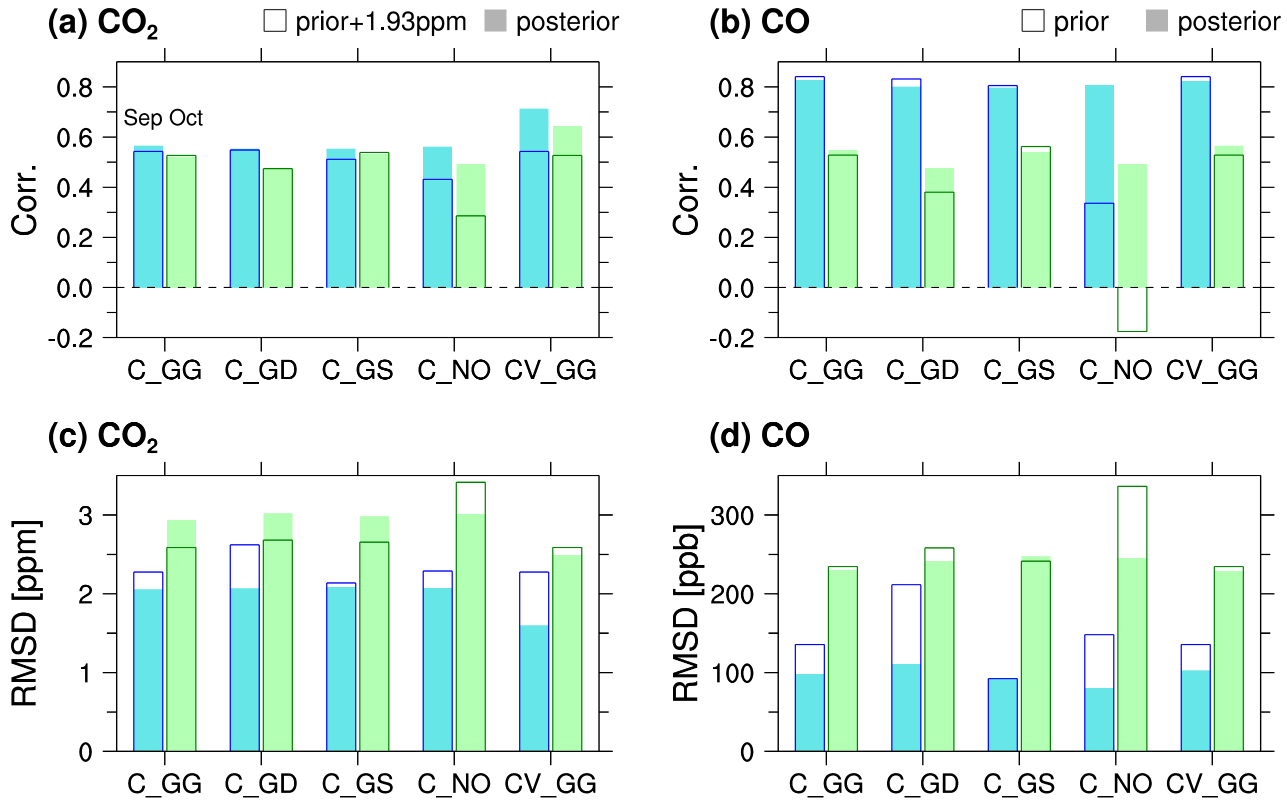
Prior (a) and posterior (b: C_GG, e: C_NO) surface CO_2 flux distributions averaged for September 2015. Differences between prior and posterior fluxes (c,f) and prior fire emissions (d) are also shown. Note that the prior estimate of (a) was used both for C_GG and C_NO, while the prior fire estimate of (d) was used only for C_GG.

Total net flux and fire emission of carbon from Equatorial Asia for September–October 2015

	Total net flux [Tg C]	Fire emission [Tg C]
Prior (GG)	357	299
Prior (GD)	360	301
Prior (GS)	355	296
Prior (NO)	59	0
C_GG	324	277
C_GD	304	256
C_GS	320	265
C_NO	211	122
CV_GG	322	273

C_: CONTRAIL, CV_: CONTRAIL & NIES VOS
GG: (GFED+GFAS)/2, GD: GFED, GS: GFAS
NO: without biomass burning priors

Better consistency with the NIES VOS data



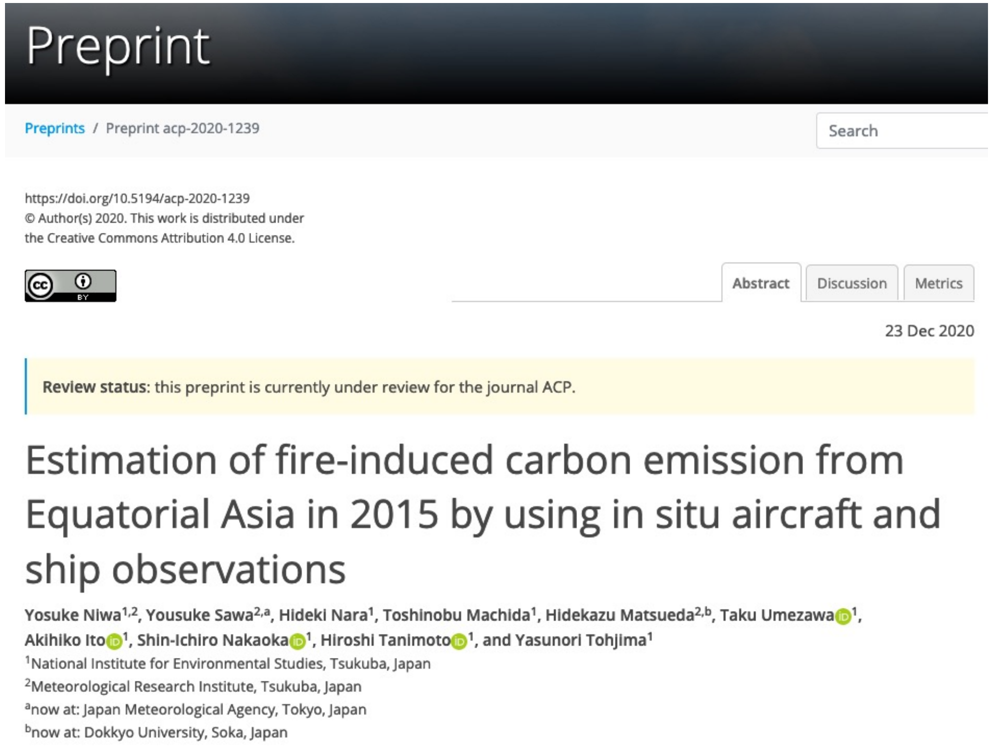
Correlation coefficient (upper panels) and root-mean-square-difference (RMSD) (lower panels) between the observed and simulated NIES VOS CO_2 (left) and CO (right) mole fractions.

Comparing the posterior results with the prior ones, we found better consistency with the NIES VOS observation, which is true for both CO_2 and CO.

Note that the NIES VOS data are independent of the inversions except for CV_GG.

Summary

- We performed the inverse analysis for carbon fluxes in Equatorial Asia during the historic El Niño of 2015.
- We extensively used the CONTRAIL aircraft data in the inverse analysis. Furthermore, with the help of NIES VOS observations, especially its CO data, we demonstrated the validity of our inverse analysis and the fact that the aircraft data could constrain flux estimates efficiently. It is essential for Equatorial Asia because there are insufficient ground-based observations in the region.
- We estimated the fire-induced carbon flux to be 273 Tg C for September–October. This number accounts for 75% of the annual fire emission and 45% of the annual net carbon flux in Equatorial Asia, demonstrating that fire emissions are a major driving force of the carbon flux in the region.



Preprint

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Abstract Discussion Metrics

23 Dec 2020

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Estimation of fire-induced carbon emission from Equatorial Asia in 2015 by using in situ aircraft and ship observations

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under review for ACP

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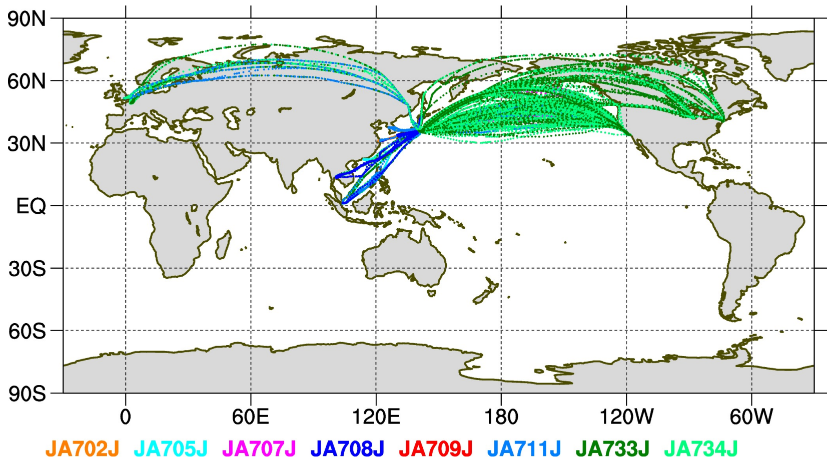
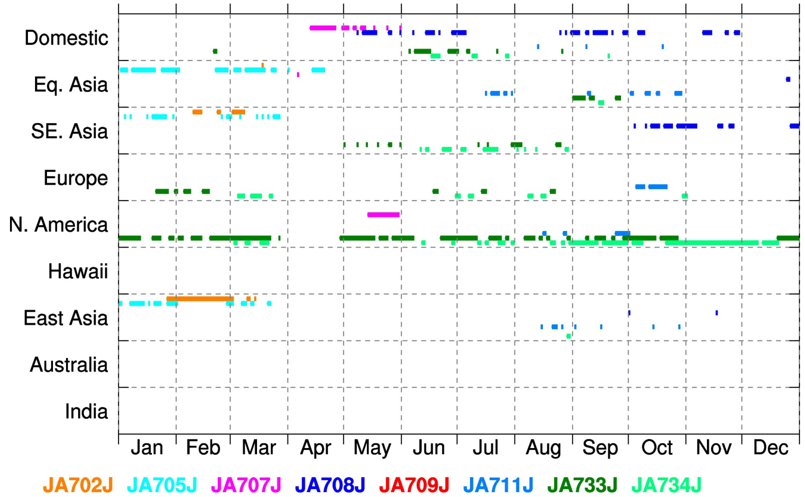
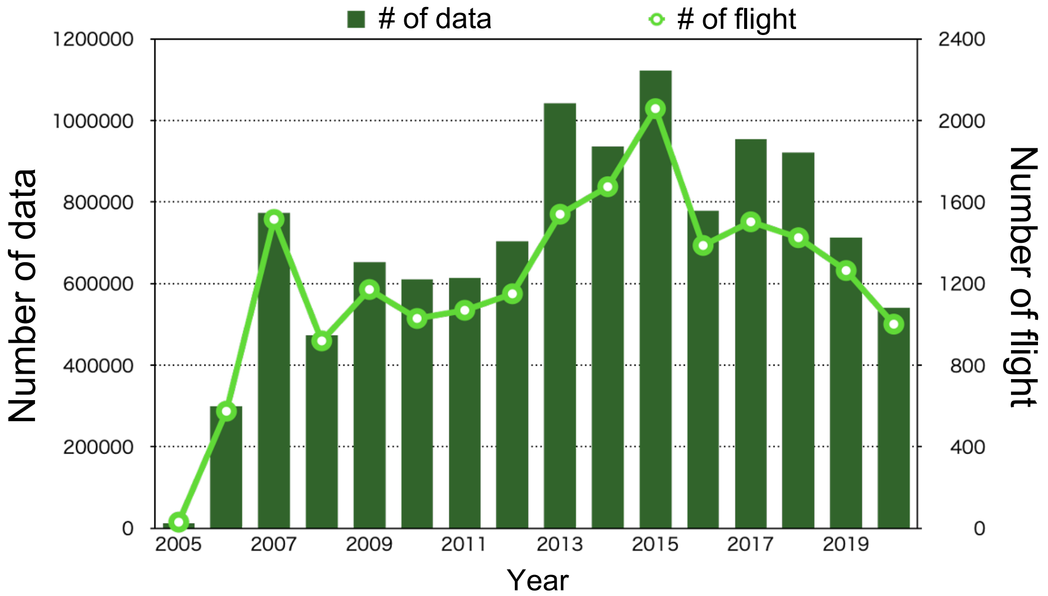
What happend in CONTRAIL for 2020?



Flight map of CME for 2020



Destinations of CME for 2020



Even now, the CONTRAIL observation is ongoing!

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The CONTRAIL CME data (CO_2) are available with doi:10.17595/20180208.001.