

Investigation of East Asian emissions of CFC-11 using atmospheric observations in Taiwan

Karina E. Adcock, Matthew J. Ashfold, Charles C-K Chou, Lauren J. Gooch, Norfazrin Mohd Hanif, Johannes C. Laube, David E. Oram, Chang-Feng Ou-Yang, Marios Panagi, William T. Sturges and Claire E. Reeves



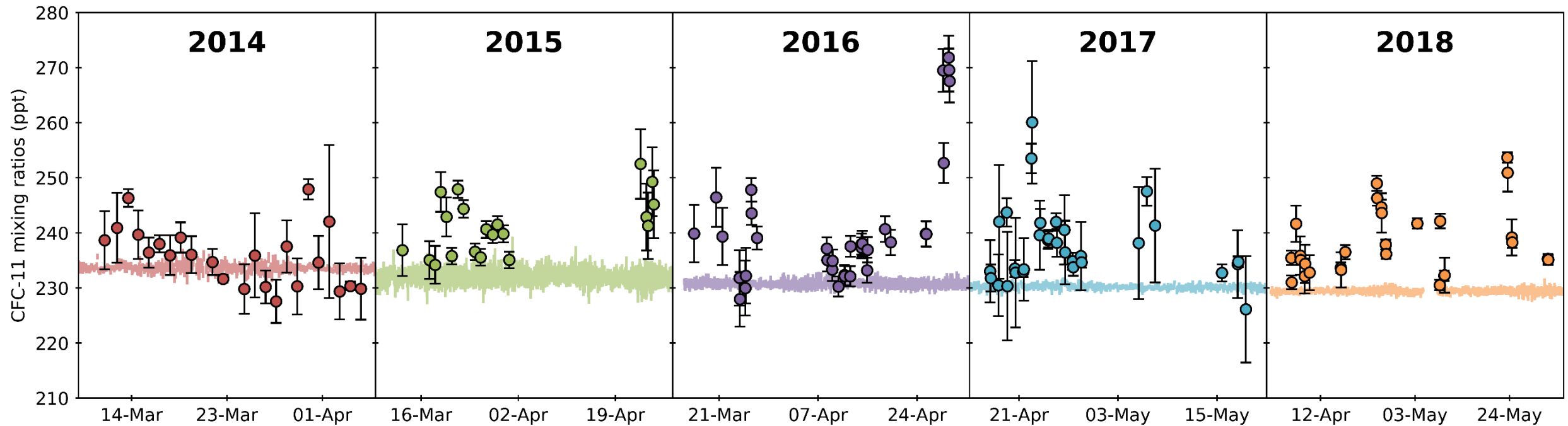
Methods – sample collection



Site	Year	Campaign period		No. of samples
		Start	End	
Cape Fuguei	2014	11-Mar-14	04-Apr-14	23
Hengchun	2015	12-Mar-15	25-Apr-15	20
Cape Fuguei	2016	16-Mar-16	29-Apr-16	33
Cape Fuguei	2017	17-Apr-17	18-May-17	31
Cape Fuguei	2018	05-Apr-18	01-Jun-18	28

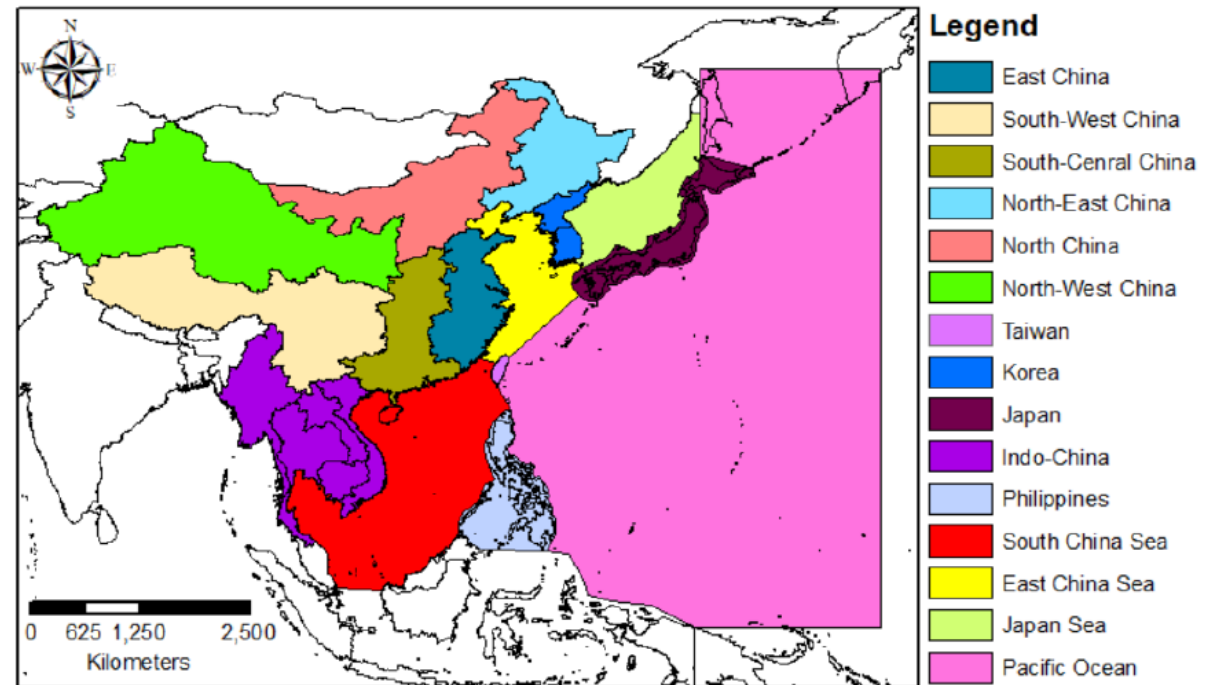
135
samples

CFC-11 mixing ratios in Taiwan

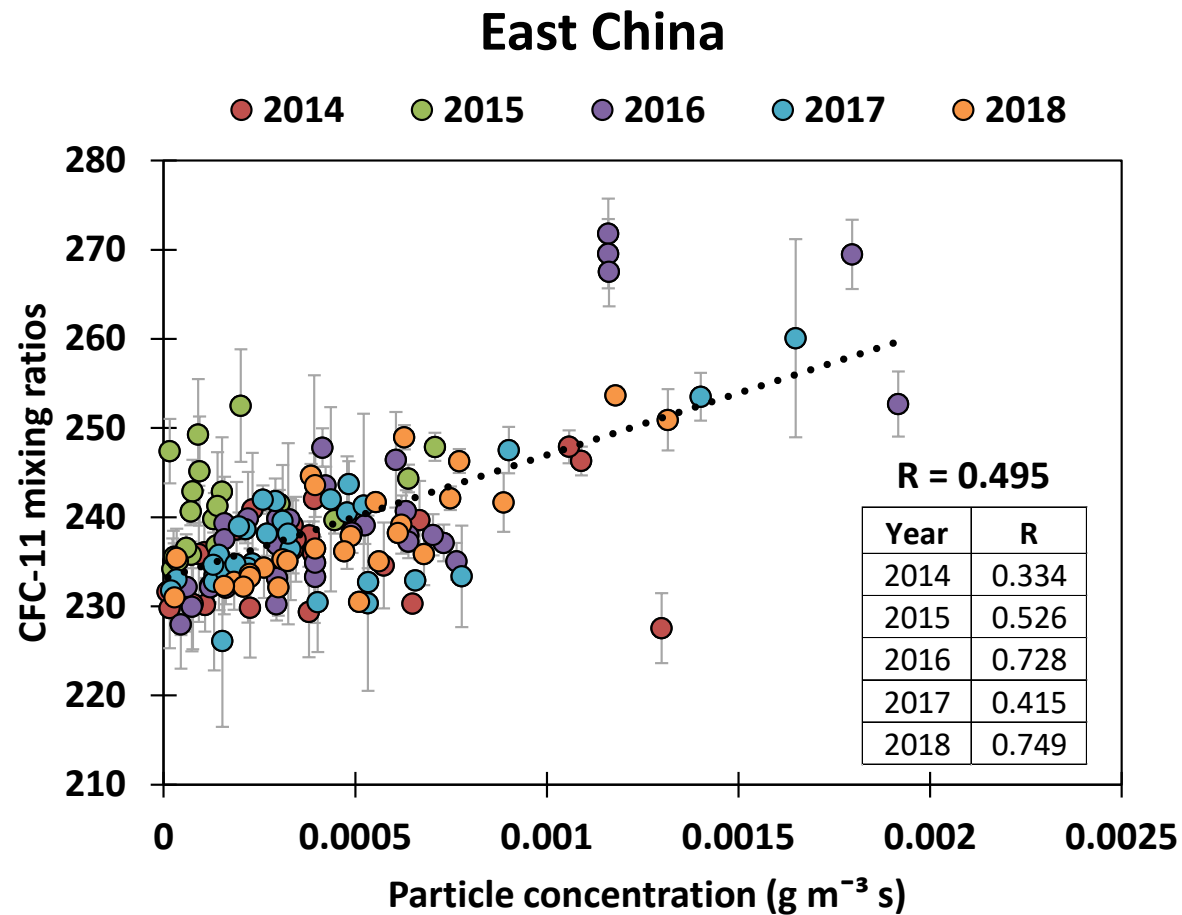


Identification of CFC-11 source regions

- UK Met Office's NAME (Numerical Atmospheric Modelling Environment) particle dispersion model
- 12-day backward trajectories
- 15 regions using shape files produced by ArcGIS, a geographic information system (GIS).
- The output is a mass density residence time ($\text{g m}^{-3} \text{ s}$) which is the sum of the particle concentration in each grid cell for each second.

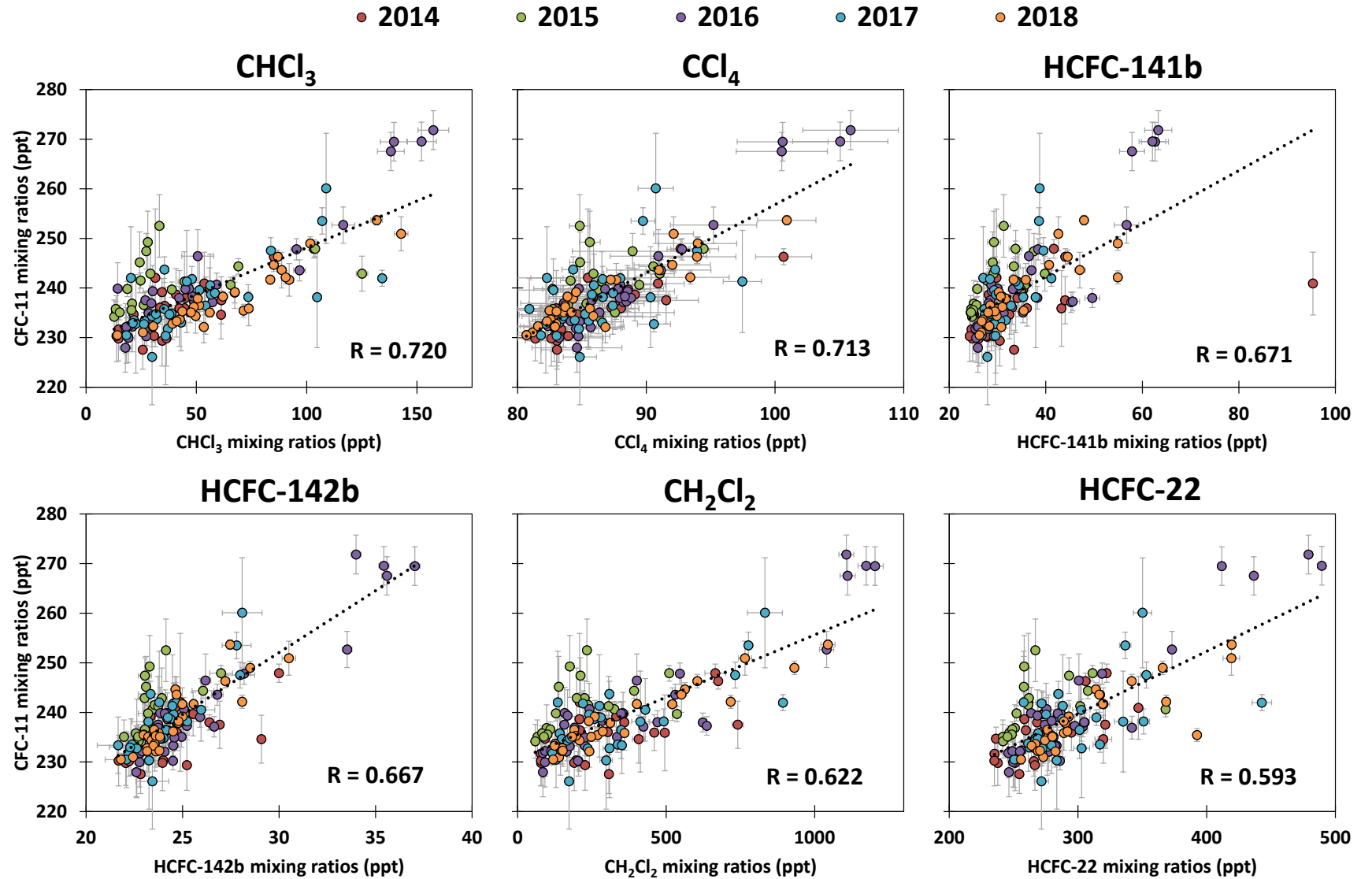


Identification of CFC-11 source regions



- Best correlation with East China, $R = 0.495$
- Other regions $R < 0.3$
- Major industrial area
- Rigby et al., 2019, “Increase in CFC-11 emissions from eastern China based on atmospheric observations”

Correlations of CFC-11 with other trace gases



Estimation of CFC-11 emissions from China

Emissions of CFC-11

Slope

Emissions of X

Molecular weight of CFC-11

Molecular weight of halocarbon X

$$E_{CFC-11} = S E_x \frac{M_{CFC-11}}{M_x}$$

Estimation of CFC-11 emissions from China

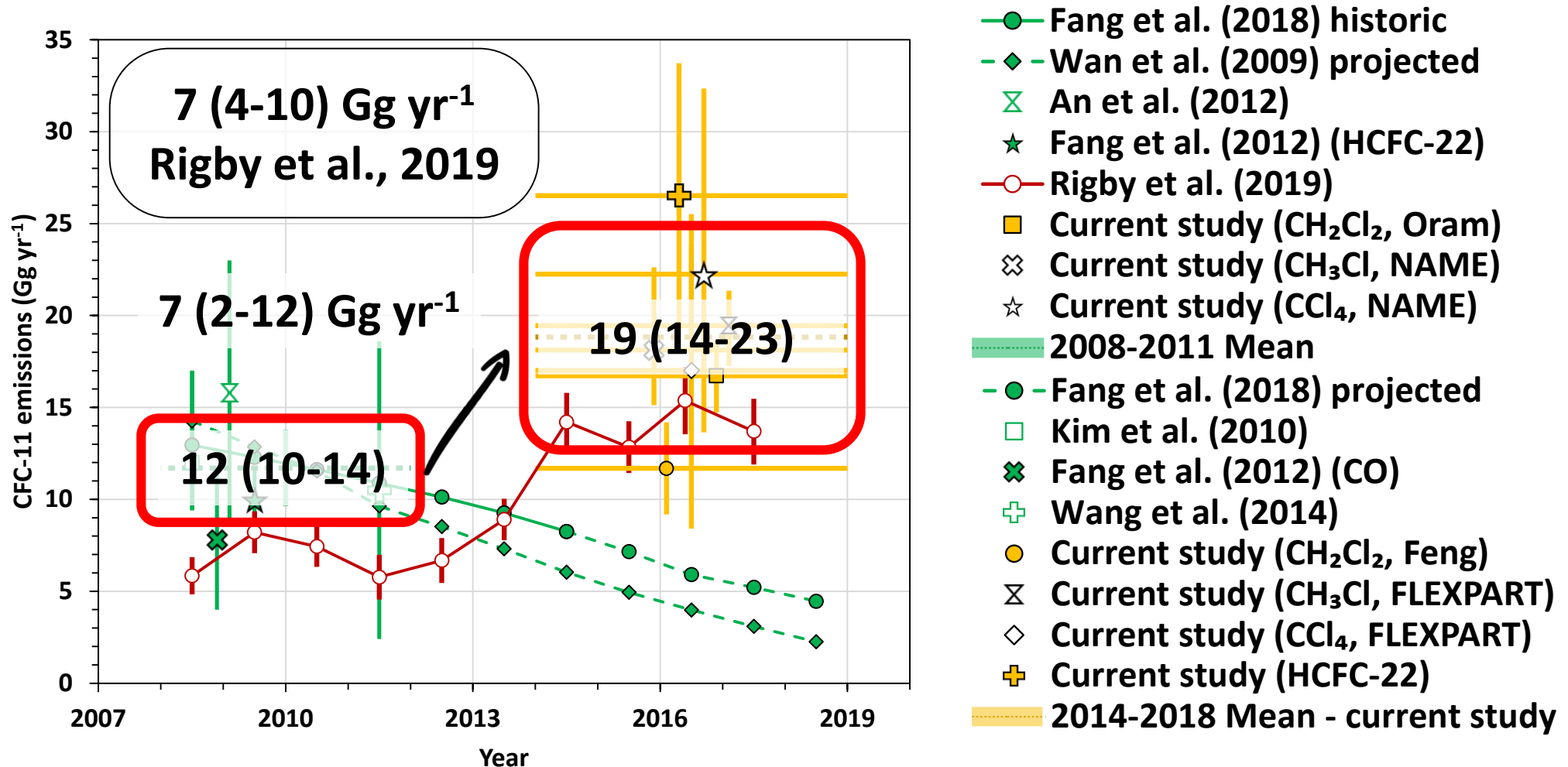
Compound	Location of Emissions	Years of Emissions	Emissions (Gg yr ⁻¹)	Reference	Method
CH ₂ Cl ₂	China	2016	318 (254-384)	Feng et al, 2018	Bottom-up emissions based on a survey of known consumption and emission factors in industrial sub-sectors
CH ₂ Cl ₂	China	2015	455(410-501)	Oram et al., 2017	Bottom-up emissions based on chlorocarbon production and sales information
CHCl ₃	East China	2015	88 (80-95)	Fang et al, 2019 (FLEXPART)	Using atmospheric observations from Gosan, South Korea, and two atmospheric inversion models, NAME and FLEXPART
CHCl ₃	East China	2015	82 (70-101)	Fang et al, 2019 (NAME)	
CCl ₄	East China	2009-2016	13 (7-19)	Lunt et al, 2018 (FLEXPART)	Using atmospheric observations from Gosan, South Korea and Hateruma, Japan and two atmospheric inversion models, NAME and FLEXPART
CCl ₄	East China	2009-2016	17 (11-24)	Lunt et al, 2018 (NAME)	
HCFC-22	China	2016	134 (100-167)	Li et al, 2016	Using an emission-factor based bottom-up method

CFC-11 emissions from China

Compound	Location and Years of Emissions	CFC-11 emissions (Gg yr ⁻¹)	CFC-11 emissions (Gg yr ⁻¹)							
			0	5	10	15	20	25	30	
CH ₂ Cl ₂ Feng et al. (2018)	China 2016	12 (9-14)								
CH ₂ Cl ₂ Oram et al. (2017)	China 2015	17 (15-19)								
CHCl ₃ FLEXPART, Fang et al. (2019)	Eastern China 2015	19 (17-21)								
CHCl ₃ NAME, Fang et al. (2019)	Eastern China 2015	18 (15-22)								
CCl ₄ FLEXPART, Lunt et al. (2018)	Eastern China 2009-2016	17 (9-25)								
CCl ₄ NAME, Lunt et al. (2018)	Eastern China 2009-2016	22 (14-31)								
HCFC-22 Li et al. (2016)	China 2016	27 (20-33)								

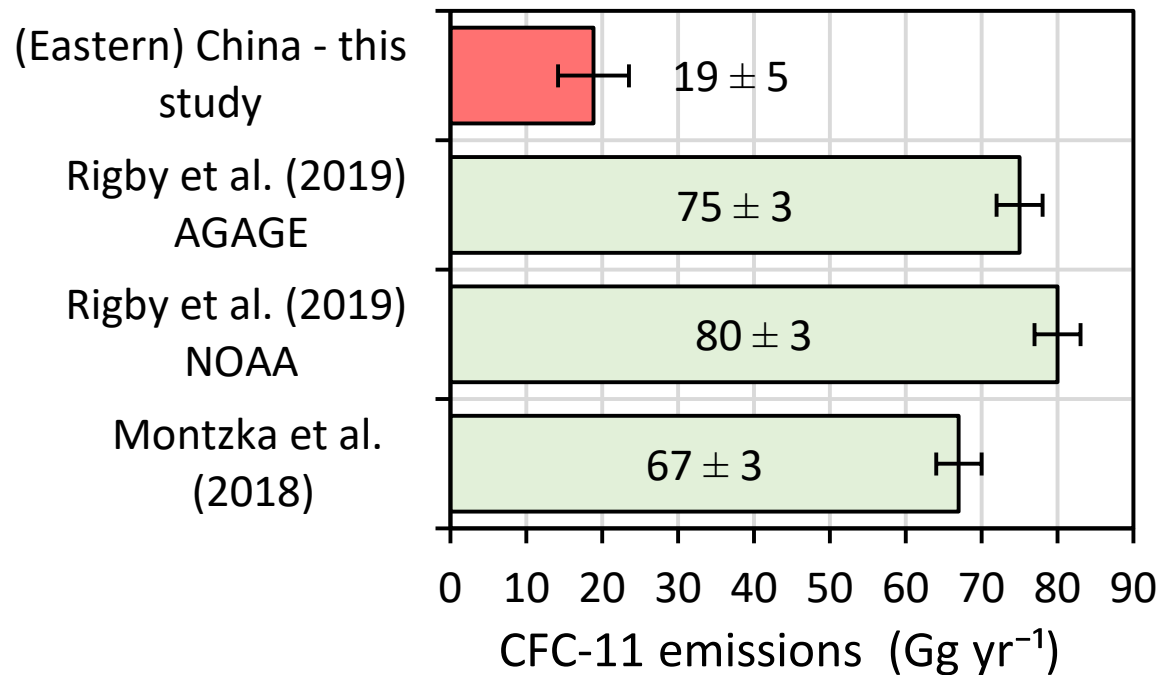
19 (14-23) Gg yr⁻¹

Changes in CFC-11 emissions from China

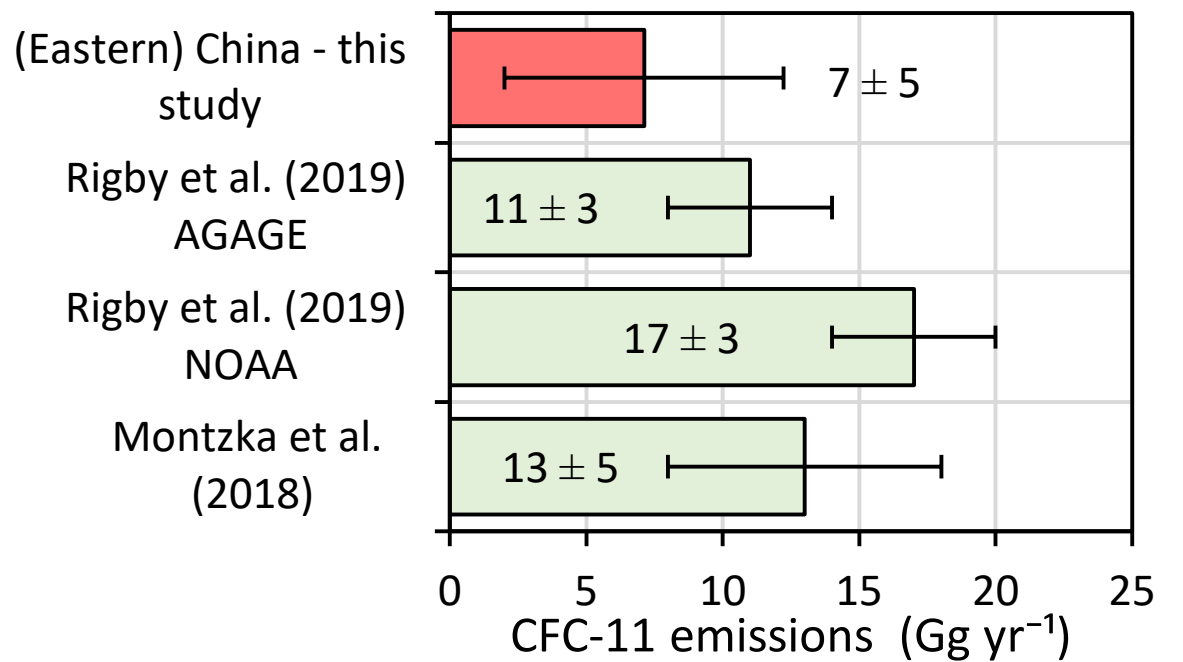


Comparison to global emissions

Total CFC-11 emissions



Increase in CFC-11 emissions



Summary

