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October 2019
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CFC-11

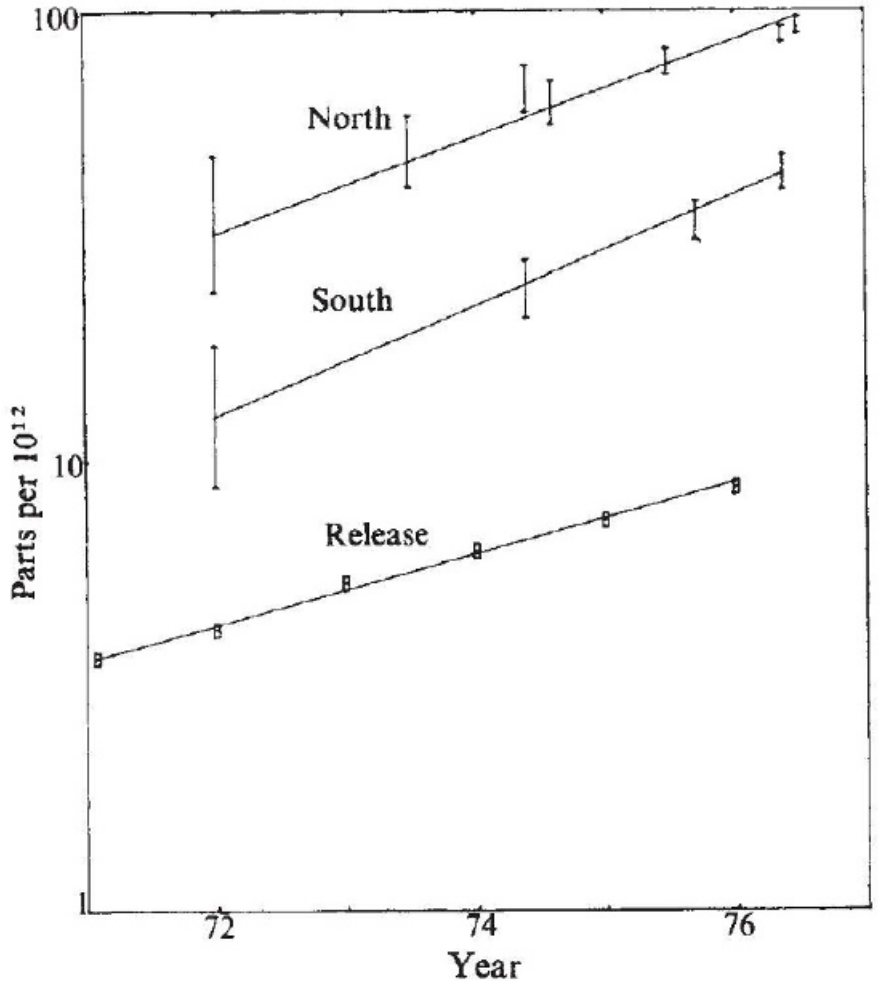
Is there illegal production?

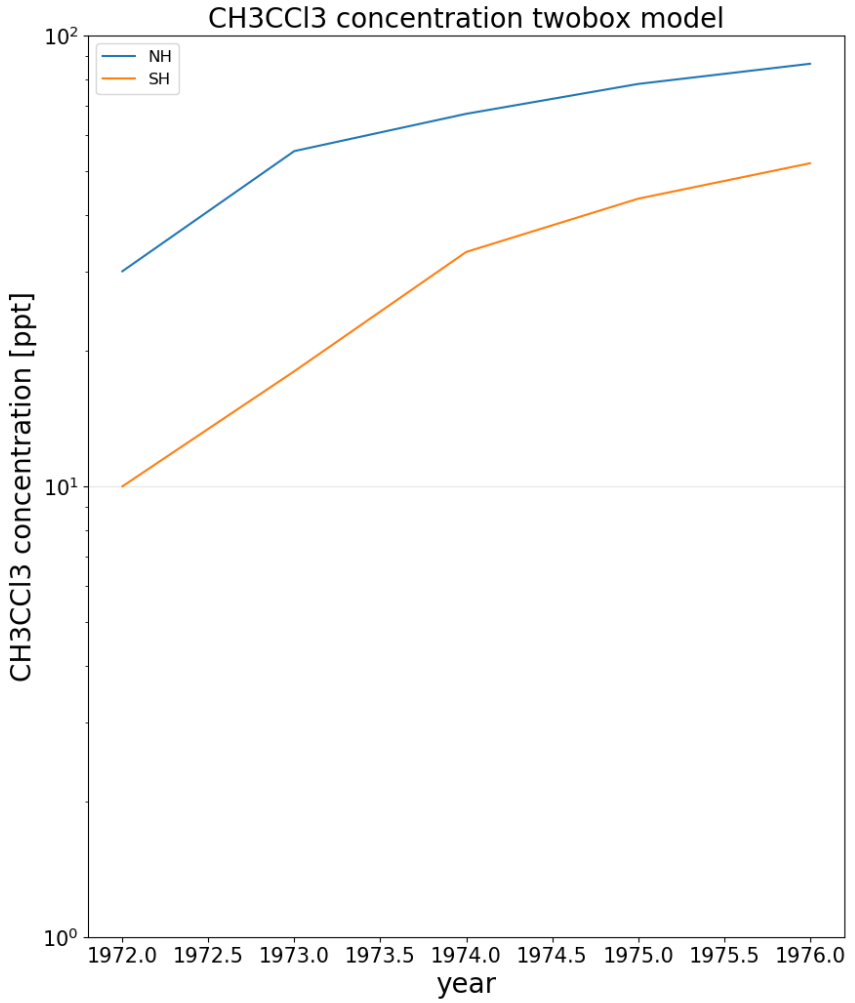
Presentation structure

- Lovelock on Ozone Depleting Substances
- Atmospheric box-models
- Inverse modelling
- Bottom up approach
- Missing emissions
- Discussion
- Take-home message

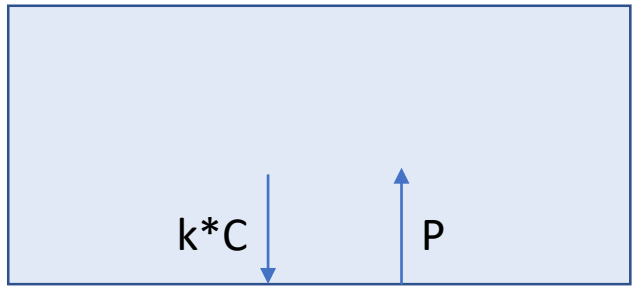
Lovelock two-box model

Fig. 1 Observed concentrations: parts per 10^{12} by volume of CH_3CCl_3 in the northern hemisphere (British Isles) and southern hemisphere (South Africa and Antarctica) during 1972–77. Cumulative releases (○) are in megatonnes.





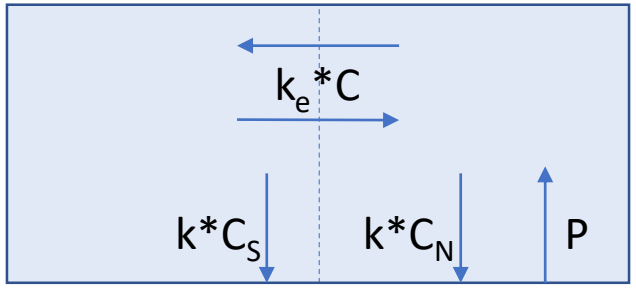
Atmospheric box models



$$C^{n+1} = C^n + \left(P^{n+1/2} - k * C^n\right) * \mathrm{dt}$$

$$k = \frac{1}{\tau}$$

- Input: lifetime, emissions and initial concentration



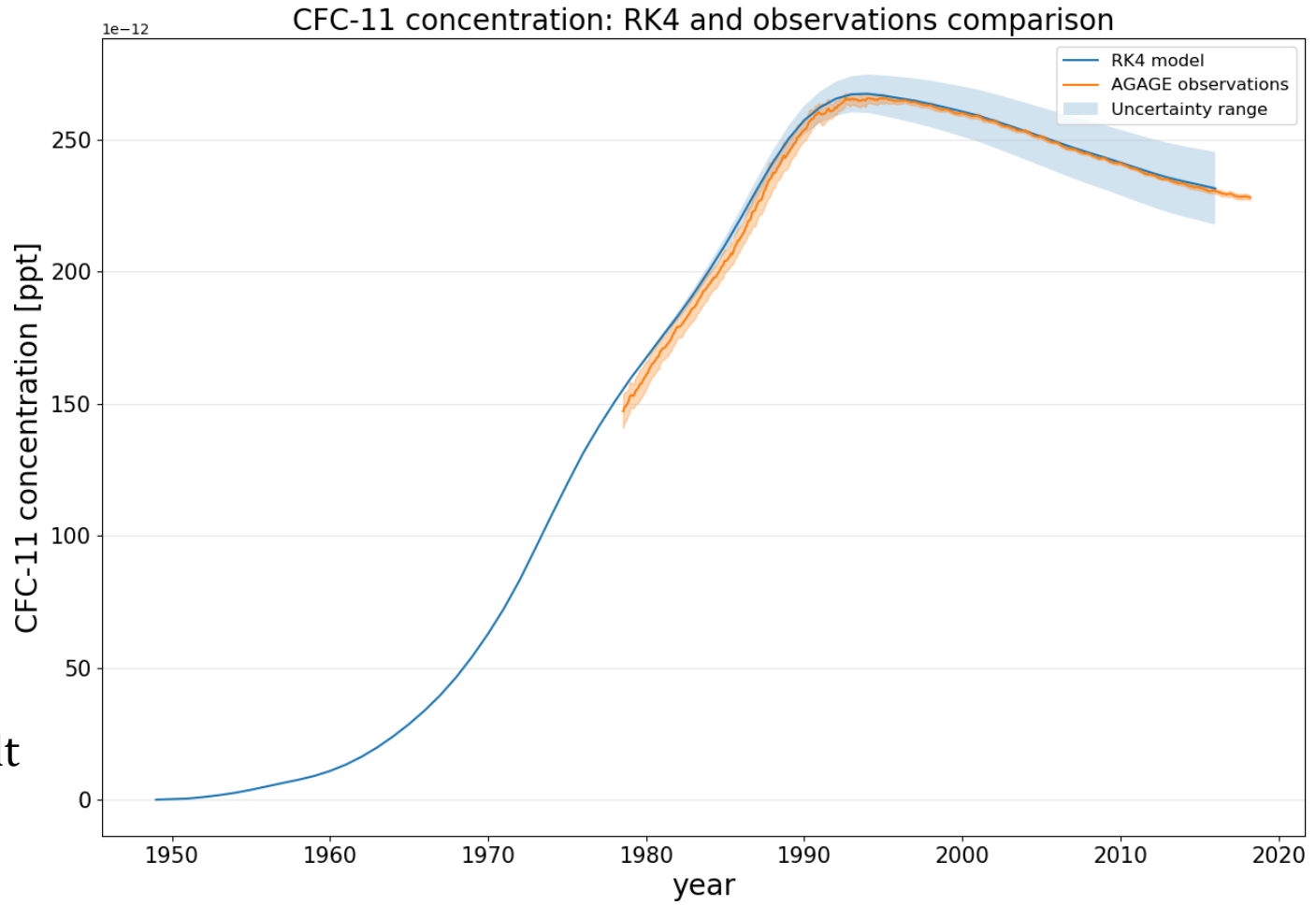
$$C_{NH}^{n+1} = C_{NH}^n + \left(P^{n+1/2} - k * C_{NH}^n - k_e * C_{NH}^n + k_e * C_{SH}^n\right) * dt$$

$$C_{SH}^{n+1} = C_{SH}^n + \left(-k * C_{SH}^n - k_e * C_{SH}^n + k_e * C_{NH}^n\right) * dt$$

Global CFC-11 Concentrations

- Emission data from inverse 12-Box model assesments (*WMO 2014, WMO 2018)*.
- Most likely range lifetime (τ): 43 – 67 years *(SPARC 2013).*

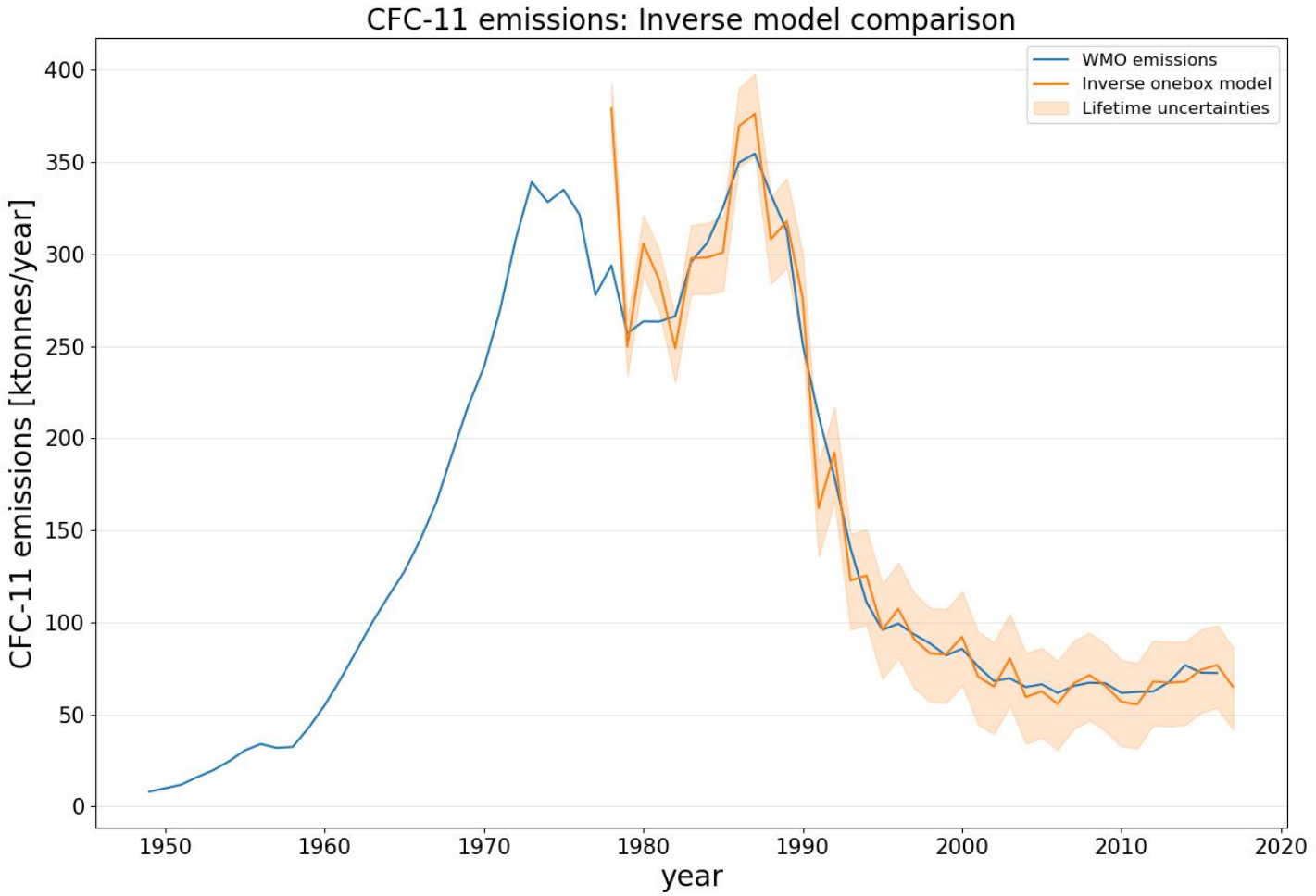
$$C^{n+1} = C^n + \left(P^{n+1/2} - k * C^n\right) * \mathrm{dt}$$



Inverse modelling

- Rewriting of one-box Euler forward model

$$P^{n+1/2} = \frac{C^{n+1} - C^n}{dt} + k * C^n$$



Bottom-up estimates: Sectoral breakdown

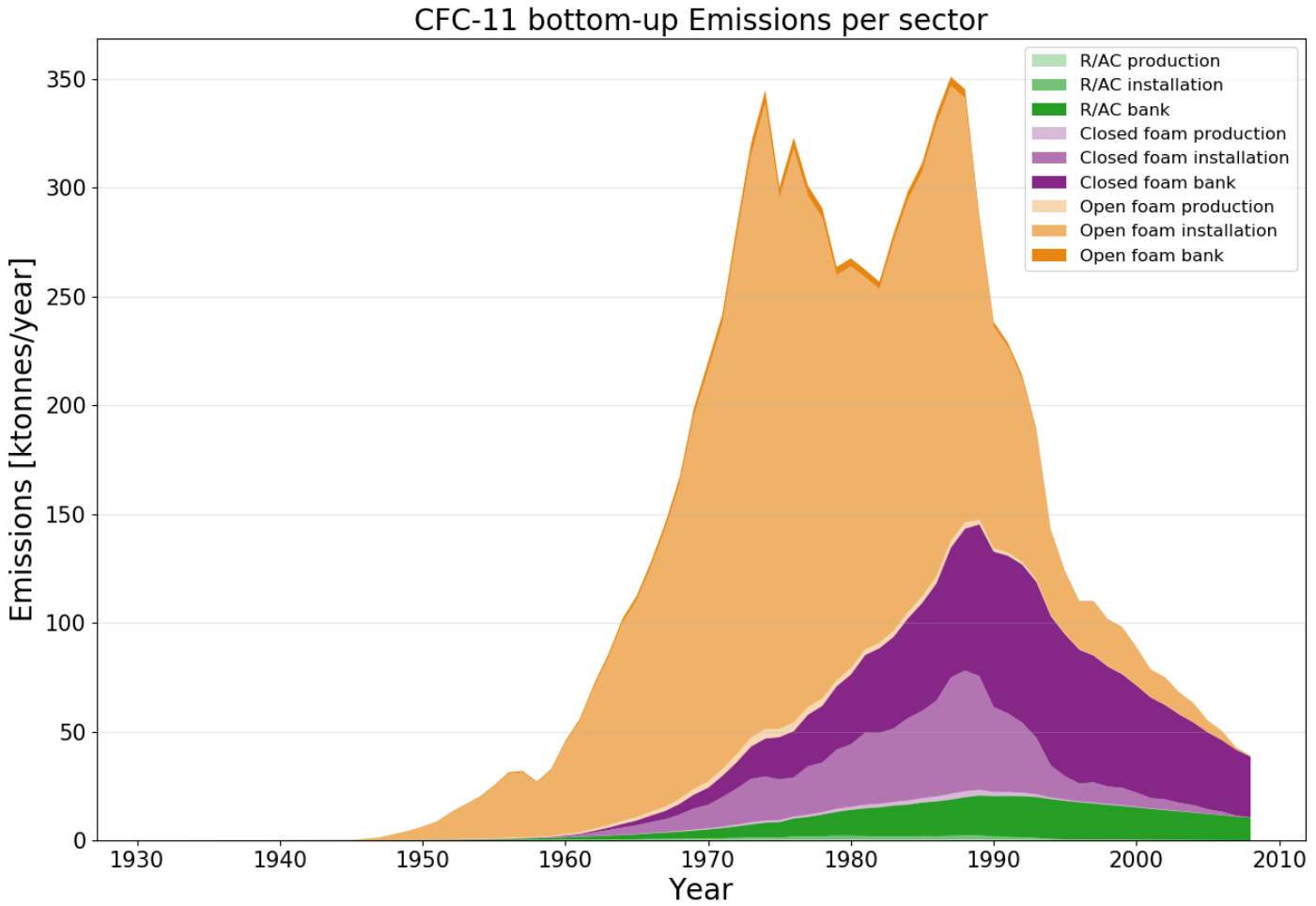
	Sectoral Breakdown CFC-11	**Emissions from:**		
		Production & distribution	Installation	Bank
Refrigerators and Airconditioning (R/AC)	10%	1.5%	5%	2 – 10%
Closed Cell Foam	50%	1.5%	30%	4 – 10%
Open Cell Foam & others	40%	1.5%	98%	70 – 98%

From TEAP Report (2019)

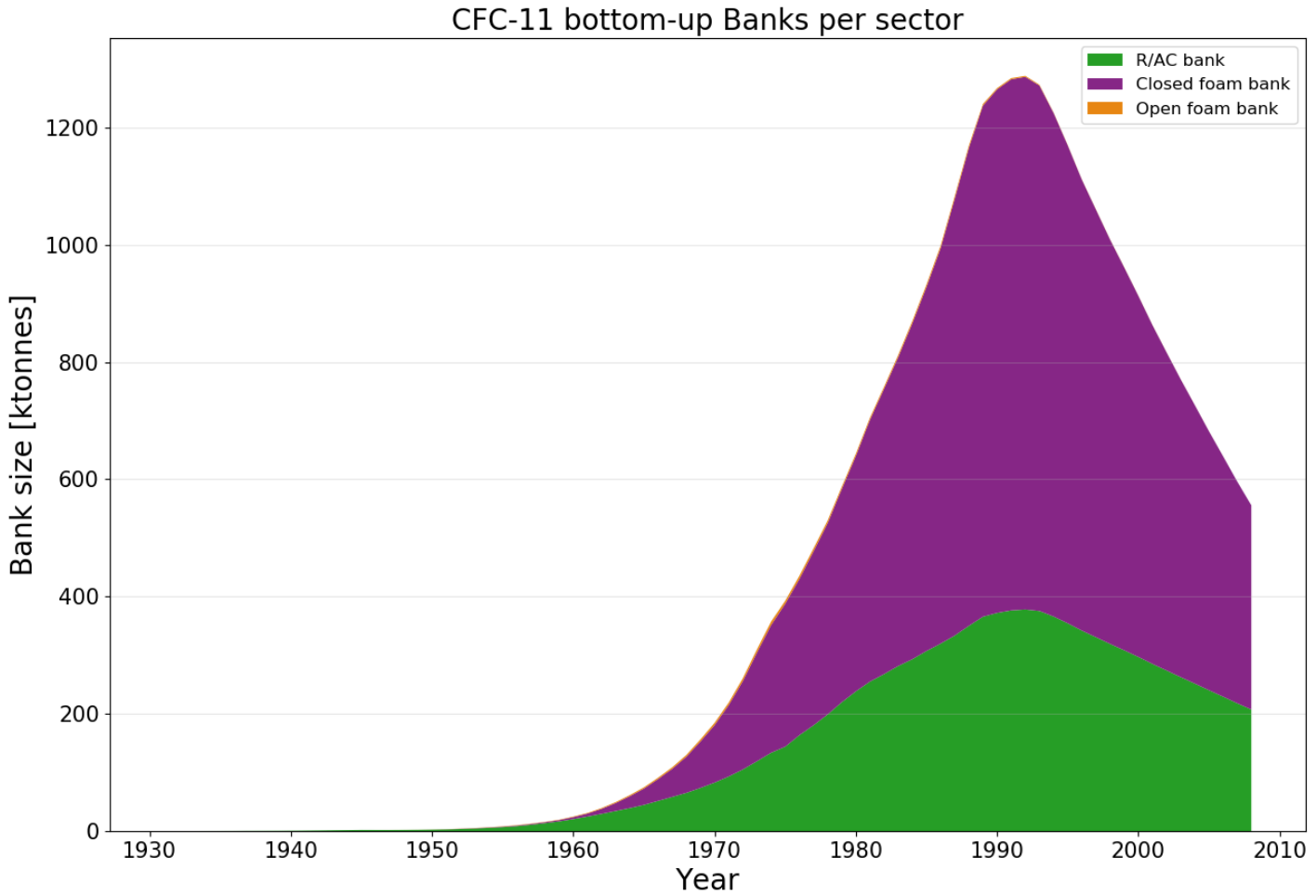
- When not emitted during production or installation, CFC-11 stored in bank.

Bottom-up estimates: Emissions

- Since 21th century emissions predominantly from closed foam and R/AC banks

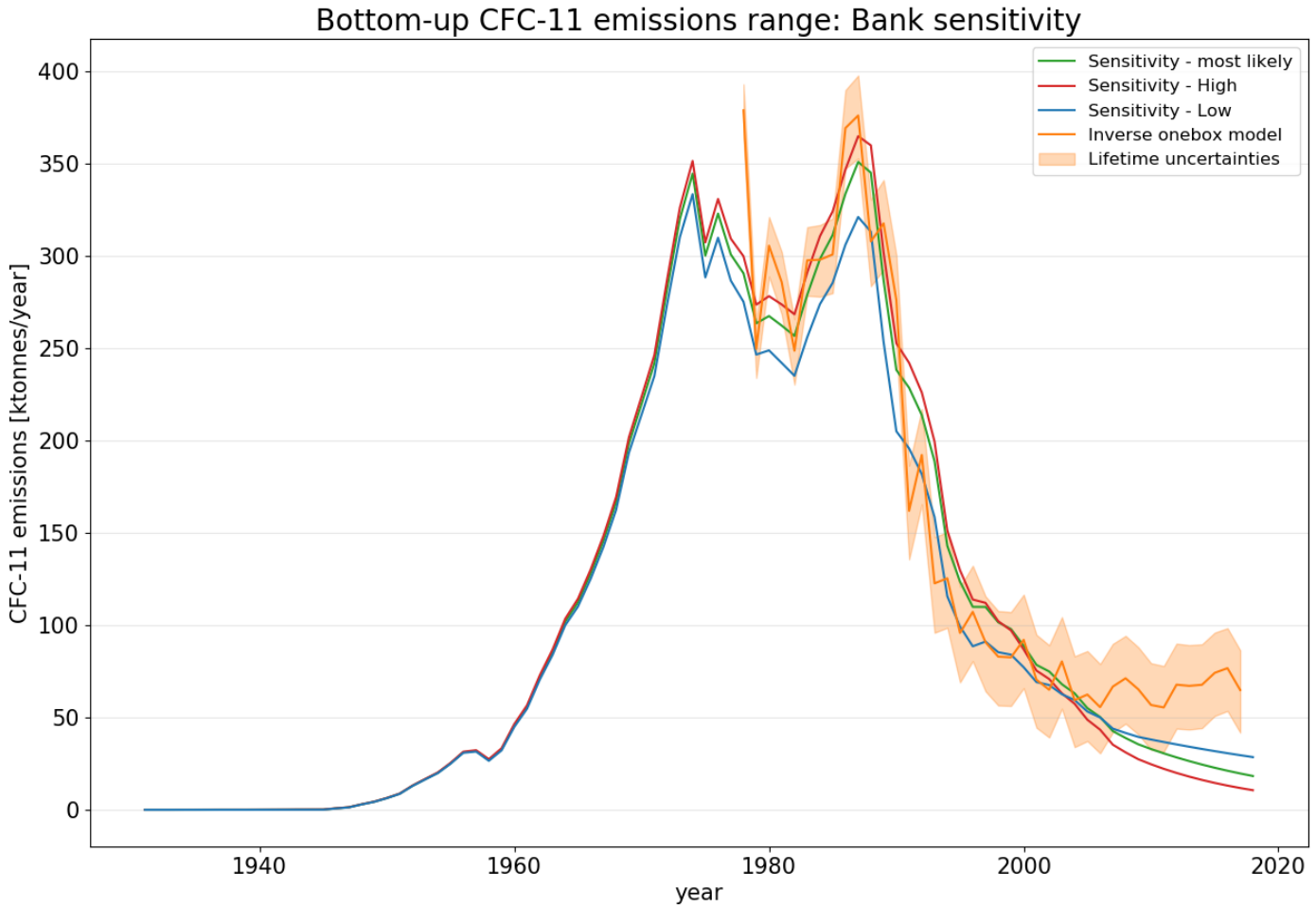


Bottom-up estimates: Banks



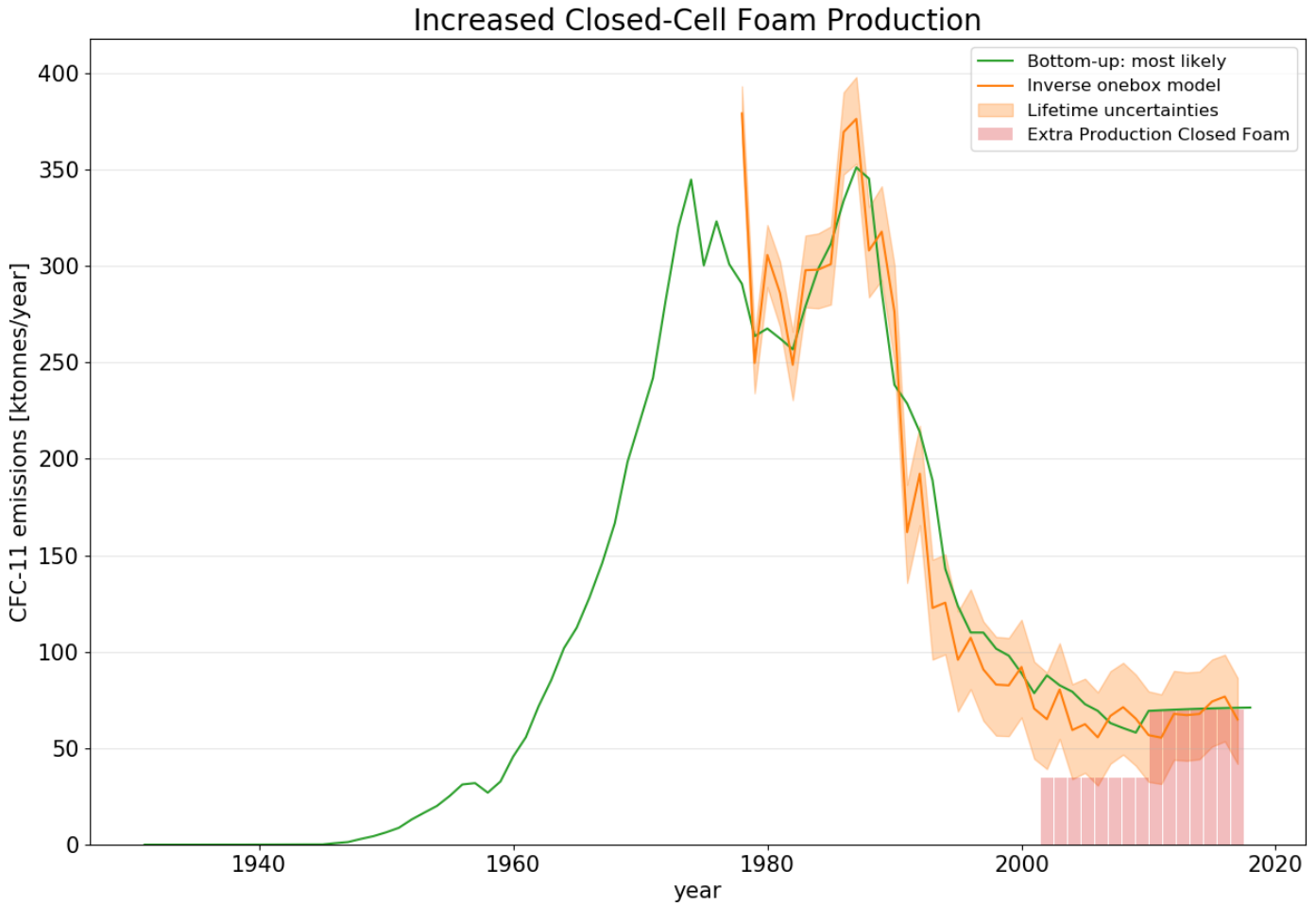
Missing emissions

- All scenarios unable to explain top-down emissions from 2007 onwards.



Missing emissions

- 35 ktonnes/year from 2002 to 2009
- 70 ktonnes/year from 2009 to 2018



Discussion

- Not very reliable observations for period 1930-1970
- How reliable are reported production data?
- Onebox model unable to point out location of unreported emissions.

Take-home message

- The onebox model closely approximates observed CFC-11 concentrations.
- Top-down and bottom-up approaches agree very well for the period 1980-2000.
- Strong evidence for new CFC-11 production in the 21th century.