

## Identifying the Global Sources and Impacts of new CFC-11 Emissions

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## **Ozone Depletion and Recovery**



## Discovery of increasing CFC-11 emissions



Fig. 2 | Global CFC-11 emission, reported production and implied release rate from CFC-11 banks. a, Production magnitudes reported

## Pinpointing emissions to China



# **CFC-11 Inverse Modelling with TOMCAT**

- INVICAT is 4D-var inverse model based on TOMCAT
- Horizontal resolution: 2.8° × 2.8°, 60 vertical levels up to 0.1 hPa. Covers 2008 – 2017.
- Stratospheric loss is **year-specific** and taken from TOMCAT full chemistry run
- Prior emissions: Homogeneous within 4 regions (East Asia, U.S., Europe, R.O.W), uncertainty = 250% per grid cell
- NOAA flask observations and AGAGE "GC-MD" in situ observations
- Observation uncertainty = **0.5 ppt + representation error**





### prior CFC11, all years



## **Results: Asia Dominates Emissions of CFC-11**

**CFC-11** surface site locations



Solution mostly dominated by large number of observations made at AGAGE sites – coverage of main emission regions is OK.



Example adjoint sensitivity for 1 month (Aug 2016). Red -> model is too high compared to observations, Blue -> model is too low compared to observations



Emissions decrease in central U.S. and Eastern Europe, but increase in East Asia, Western Europe and N.E. USA.



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# TOMCAT Model forward runs to test impact of emissions

## Model setup:

- Detailed stratospheric chemistry scheme. Specified aerosol SAD (3λ).
- Forced by ECMWF ERA-Interim winds and temperatures (no feedback).
- 1955 2080 (repeating 2000 meteorology)
- 2.8° × 2.8°. 32 levels: surface 60 km.

## Four simulations:

• R2000

- Forced by observed surface mixing ratios of long-lived ODSs (CFCs, HCFCs, solvents, CH<sub>3</sub>Cl...). VSLS constant after 2017.
- R2000\_NoVSLS
- R2000\_CFC11\_67
- R2000\_CFC11\_B

Constant 67 Gg/yr (WMO 2018) Based on 13 Gg/yr recent emissions, bank, 10-yr rampdown





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## Antarctic Ozone Recovery



## Future Antarctic Ozone Hole 2018-2080





- Renewed production of CFC-11 has been detected. Additional emissions of 13±5 Gg/yr. Around 6 Gg/yr ascribed to emissions from eastern China through regional modelling.
- Global model inversion (INVICAT) produces 9.9 Gg/yr increase in Asia and 11.7 Gg/yr globally. Asia is the main source of increase.
- Assumed 'scenario' of large, constant 67 Gg/yr emission gives ~10-year delay to recovery of Antarctic ozone. Smaller emissions have correspondingly smaller effect.





## **Extra Slides**





## Impact on Antarctic Ozone Hole

